# THE UNIVERSITY OF ZAMBIA

## SCHOOL OF ENGINEERING

## 2020/2022 ACADEMIC YEAR

1. AEA 4131: Farm Structures
2. CEE 2219: Statics and Intro to Strength of Materials
3. CEE 3311: Fluid Mechanics
4. CEE 5222: Design in Structural Steel
5. EEE 2019: Principles of Electrical and Electronic Engineering
6. EEE 2019: Principles of Electrical and Electronic Engineering
7. EEE 3112: Electrical Engineering Practice
8. EEE 3132: Computer Engineering
9. EEE 3352: Electromachanics and Electrical Machines
10. EEE 4242: Electrical Instrumentation
11. EEE 4352: Electrical Machines I
12. EEE 4362: Electrical Power Systems I
13. EEE 4670: Electronic Engineering III
14. EEE 5240: Dynamic Systems and Control Engineering
15. ENG 2159: Mechanical and Electrical Workshop Technology
16. ENG 3165: Fluid Mechanics and Thermodynamics
17. ENG 4129: Engineering Management and Society I
18. ENG 5129: Engineering Management II
19. MAT 2110: Engineering Mathematics I
20. MAT 3110: Engineering Mathematics II
21. MEC 2009: Engineering Drawing I
22. MEC 2309: Properties of Engineering Materials I
23. MEC 3102:Production Engineering I, Electricity and Electronics II
24. MEC 3352: Strength of Materials II
25. MEC 3705: Dynamics
26. MEC 4055: Machine Design I (Paper II)
27. MEC 4402: Thermodynamics II and Heat Engines
28. MEC 5855: Automobile Engineering

THE UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

2020/2021 ACADEMIC YEAR SUPPLEMENTARY AND DEFFERED FINAL EXAMINATIONS

FEBRUARY, 2022

AEN 4131 FARM STRUCTURES

**DURATION:** **THREE (3) HOURS**

**INSTRUCTIONS:**

ANSWER: FIVE QUESTIONS

**INFORMATION**

1. THE EXAMINATION PAPER CONTAINS **SIX (6)** QUESTIONS
2. ALL QUESTIONS CARRY **20 MARKS**
3. THE MARKS FOR EACH QUESTION ARE GIVEN IN THE BRACKETS

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**QUESTION 1**

a) Timber is used as a building material in numerous situations. List any THREE factors that make wood a common building material. **(6)**

b) Defects in timber make it unsuitable for certain purposes. Defects are classified according to the time of their manifestation either as natural or those which arise due to poor handling and seasoning. Below is a list of categories of defects that arise from poor handling and seasoning. For each category, mention TWO defects.

i). Defects in timber which has not been converted. **(2)**

ii). Defects due to poor seasoning. **(2)**

iii). Defects due to poor conversion (sawing). **(2)**

c) Use the textural triangle given in Fig. Q1 to determine the texture of the soil with the following particle compositions.

10% sand, 15% clay and 75% silt **(4)**

d) What major problem would one anticipate if one intended to use this soil for making adobe blocks? **(4)**

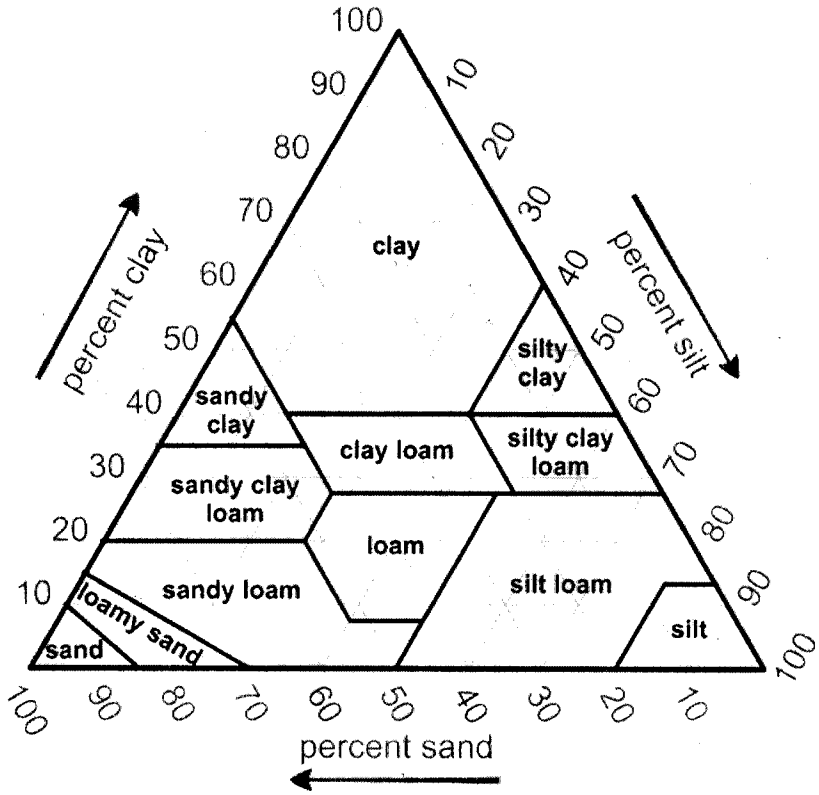


**Fig. Q1**

## QUESTION 2

a) Other than the rate of curing, the effect of temperature, quality of aggregates and placement methods, mention two aspects that greatly affect the strength of concrete. **(2)**

b) A farmer is building a 10 cm thick maize shed concrete slab with a flow plan area of 300 $m^2$. The farmer has already built the foundation walls and has already backfilled the foundation. You are told to approximate the cost of building the slab. You feel for a maize shed slab a nominal mix of 1:3:5 is ideal.

Properties of the aggregate you intend to buy are as follows:
Moisture content of sand: 2%
Moisture content of stones: 1%
Bulk density of the sand: 1400 $kg/m^3$
Bulk density of the stones: 1600 $kg/m^3$

Take the decrease in volume to be 34% and wastage to be 6%

The strength of the concrete is such that the water-cement ratio is 0.6.

Determine:

i) The number of bags of cement to be bought. **(3)**

ii) The number of tonnes of sand to be bought. **(3)**

iii) The number of tonnes of stones to be bought. **(3)**

iv) The number of 200L drums of water to be bought. **(6)**

v) The cost of constructing the slab given the following:
Stones cost K150.00/tonne.
Sand costs K130.00/tonne.
Cement costs K160.00/50kg (37L) bag of cement.
Labour costs are charged per completed slab as K3,500.00.
Water is drawn from the neighbouring farm at a cost of K30.00 per 200L drum. **(3)**

## QUESTION 3

a) Farm structures are in static equilibrium because they do not exhibit linear or rotary motion. List conditions that should be met for a structure to be in static equilibrium. **(2)**

b) The beam shown in Fig. Q3, has a pin support at A and a (roller) smooth support at B. Determine:

i) The reaction forces at the supports A and B. **(3)**

ii) Draw the shear force diagram (SFD) and bending moment diagram (BMD). **(11)**

iii) Give the value of the maximum shear force and state its location. **(2)**

iv) Give the value of the maximum bending moment and state its location. **(2)**

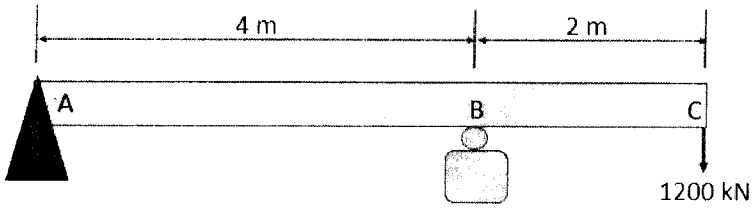


**Fig. Q3**

## QUESTION 4

a) The environment in agricultural buildings affects animal comfort and health and ultimately production. It also influences the quality and longevity of stored products. Mention any FOUR factors that influence the quality of the environment in Agricultural buildings. **(4)**

b) You are required to raise the temperature of 81 $m^3$ of air from 10°C and 80% relative humidity (RH) to a final temperature of 32°C. Using the Psychrometric chart provided at the end of the question paper (Fig. Q4), determine:

i) The heat required to raise the temperature. **(5)**

ii) The relative humidity at the final temperature of 32°C. **(5)**

c) Ventilation is important in farm buildings such as pig houses. Give any THREE functions of ventilation in a pig house? **(6)**

**QUESTION 5**

a) The goal of animal housing design is to produce an environment in which animals are easily handled, fed and can produce without stress or injury. Mention FOUR environmental factors that affect animal production. For each factor give ONE example. **(8)**

b) Crops can be categorised as durable, semi-perishable and perishable. Mention ONE example crop for each category. **(3)**

c) Write short notes on how the following factors affect maize storage:
   i). Temperature **(3)**
   ii). Relative humidity **(3)**
   iii). Insects and rodents **(3)**

**QUESTION 6**

A farmer is planning to start running a pig unit with 20 sows. The farmer practices the following in rearing his pigs:

It takes an average of 15 days from weaning to the day a sow is successfully mated. The gestating sow is taken to the farrowing pen 7days before farrowing. After farrowing, piglets are weaned at 8weeks but remain in the pen till they are 12 weeks. On average, 7 piglets per litter survive to 12 weeks and beyond. After the weaners are removed from the farrowing pens, they take 5 months to grow and fatten. Then, the pigs are sold immediately. Apart from the farrowing pens which house 1 sow per pen, the size of the farmer's other pens is such that a pen can house 8 gestating sows or 10 growing/fattening pigs. After any pen is made empty, it is given 7 days for cleaning purposes before it is reoccupied. You are given that a year has 365 days and a month comprises 30 days.

*In the calculation stages, use numbers that are up to 2 decimal places. For final answers, whole numbers without decimal places should be given.*

Determine the following with respect to the farmer's pig unit:

a) The number of farrowings per sow per year. **(5)**

b) The number of farrowing pens the farmer is expected to have. **(5)**

c) The number of dry sow/gestating sow pens. **(5)**

d) The number of growing/fattening pens. **(5)**

## SOME USEFUL EQUATIONS

$$\tau_{allowable} \geq \tau_{Max} = \frac{4V_{Max}}{3A} = \frac{16V_{Max}}{3\pi d^2}$$

$$I = \frac{1}{12}bd^3$$

$$\sigma_{Max} = \frac{Mc}{I}$$

$$q = m(h_y - h_x)$$

$$Q = AU\Delta T$$

$$\tau_{allowable} \geq \tau_{Max} = \frac{3V_{Max}}{2A} = \frac{3V_{Max}}{2bd}$$

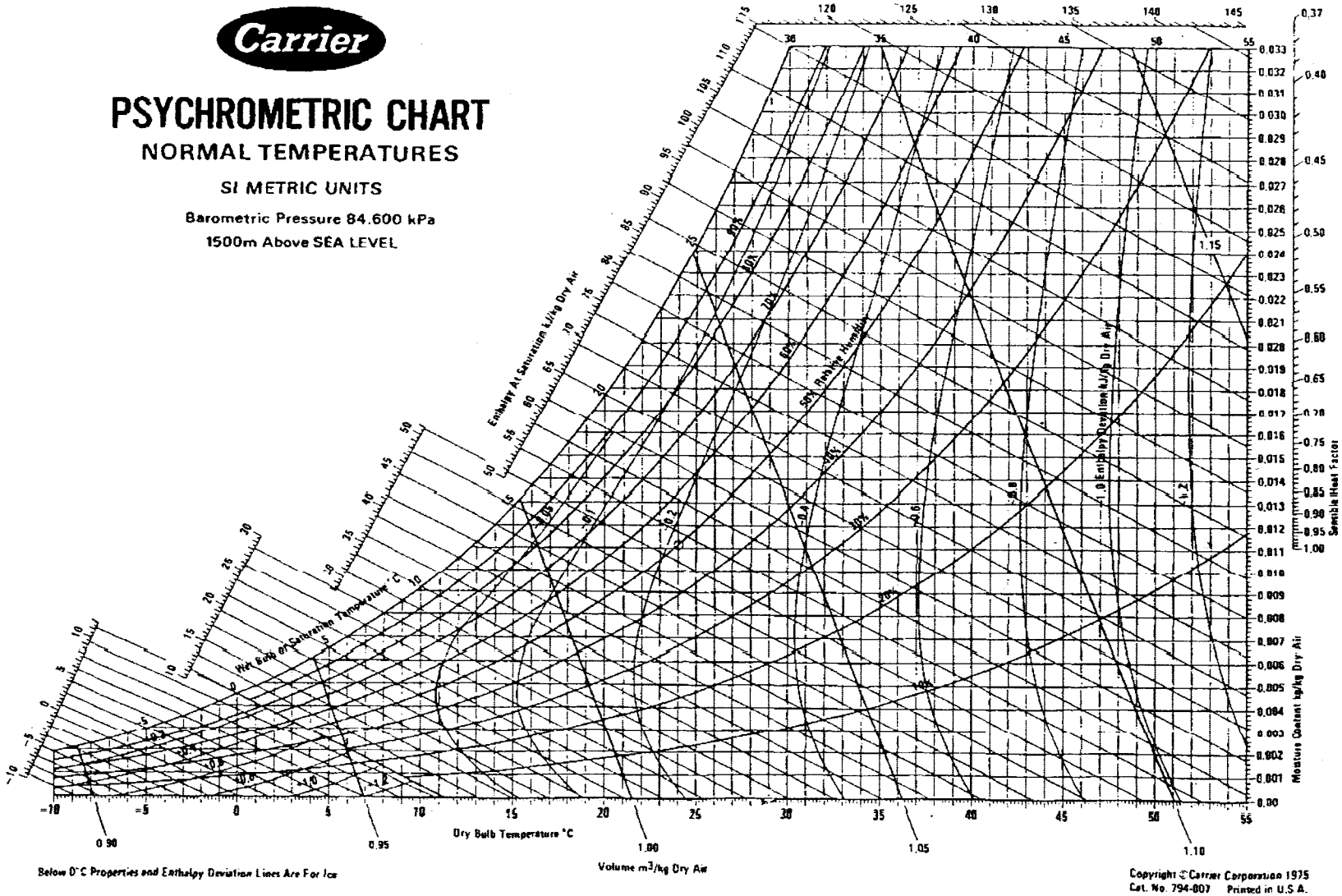
Carrier
PSYCHROMETRIC CHART
NORMAL TEMPERATURES
SI METRIC UNITS
Barometric Pressure 84.600 kPa
1500m Above SEA LEVEL
Dry Bulb Temperature °C
Wet Bulb or Saturation Temperature °C
Enthalpy At Saturation kJ/kg Dry Air
Moisture Content kg/kg Dry Air
Sensible Heat Factor
Volume m³/kg Dry Air
Below 0°C Properties and Enthalpy Deviation Lines Are For Ice
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Fig. Q4

# UNIVERSITY OF ZAMBIA

## SCHOOL OF ENGINEERING

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

**CEE 2219 – STATICS AND INTRO TO STRENGTH OF MATERIALS**

# FINAL EXAMINATION

**TUESDAY, 22 ND NOVEMBER 2022; 14:00 – 17:00 HRS** **DURATION: 3 Hours**

## INSTRUCTIONS FOR CANDIDATES

- The Exam has a total of 7 questions, Section A has only one (1) question which is compulsory. Section B has a total of 6 questions, answer any four (4) questions.
- All questions carry equal marks (20%). The numbers in the square brackets are the marks for each sub question.
- The Exam is closed book.
- Additional marks will be gained showing all your working and drawing proper sketches and FBDs where necessary.
- Candidates must ensure that their computer numbers are clearly written on each answer booklets

All the best, be of good cheer

## SECTION A:

### QUESTION 1:

a) What is the formula for the value of the normal stress(s) when the state of plane stress for an element exhibits maximum in plane shear stress. [2]

b) The state of stress of an element is as shown in the Fig. 1.

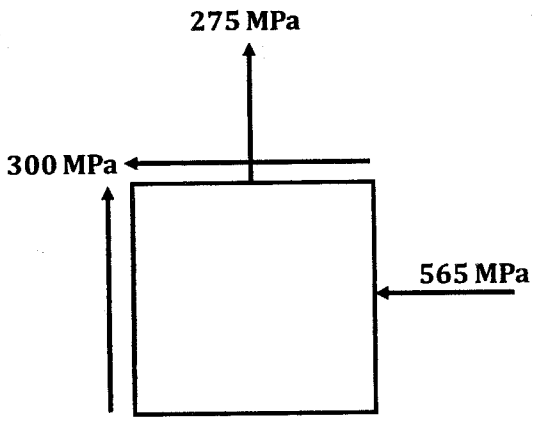



**Fig. 1**

i. Determine the average normal stress and the radius of the Mohr circle? [1+1]

ii. Draw the Mohr circle for this state of stress? [4]

iii. Determine the values of the principal stresses? [3]

iv. Determine the orientation of the principal planes? [3]

v. Determine and draw the state of stress for an element in fig. 1 rotated $40^0$ counterclockwise? [6]

## SECTION B:

### QUESTION 2:

Determine the resultant moment about point A and about point B caused by the three forces acting on the structural system shown in Fig. 2, take joint A as Fixed. [5+5]

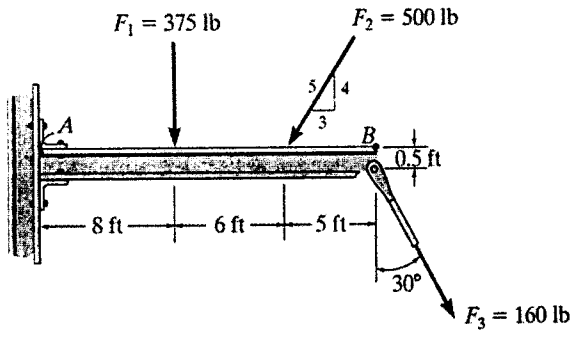



**Fig. 2**

Force F =400 N acts perpendicular to the inclined plane ABC as shown in Fig. 3. Determine the moment produced by F about point A. Express the result as a Cartesian vector form. [10]

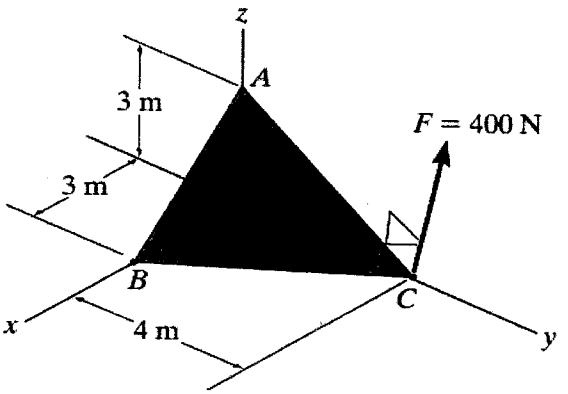



**Fig. 3**

## QUESTION 3:

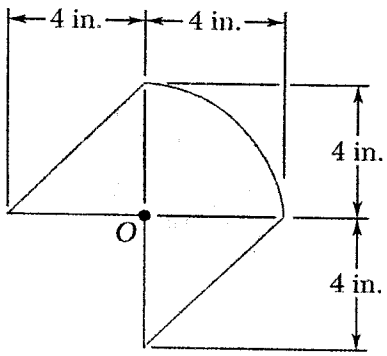
a) State the Parallel Axis Theorem? [3]

b) Fig. 4 (a) shows a shape made up of 2 triangles and a quarter circle as shown. Given that the moment of inertia and centroid for the quarter circle about the x-axis as shown in Fig. 4 (b) are $I_x = \frac{1}{16}\pi r^4$ and $y_c = \frac{4r}{3\pi}$. Determine

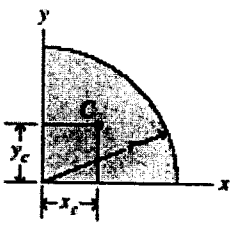
i. The location of the centroidal x – axis ($\bar{y}$) referenced from the horizontal axis passing through O in Fig 4 (a)? [5]

ii. The centroidal moment of inertia ($\bar{I}_x$) for the shaded area in Fig 4 (a)? [7]

iii. The radius of gyration about centroidal x – axis? [5]




**(a)**




**(b)**

**Fig. 4**

## QUESTION 4:

a) A 180-lb farmer tries to restrain the cow from escaping by wrapping the rope two turns around the tree trunk as shown in Fig.5. If the cow exerts a force of 300-lb on the rope, determine if the farmer can successfully restrain the cow. The coefficient of static friction between the rope and the tree trunk is $\mu_s = 0.15$, and between the farmer's shoes and the ground is $\mu_s' = 0.3$. [7]

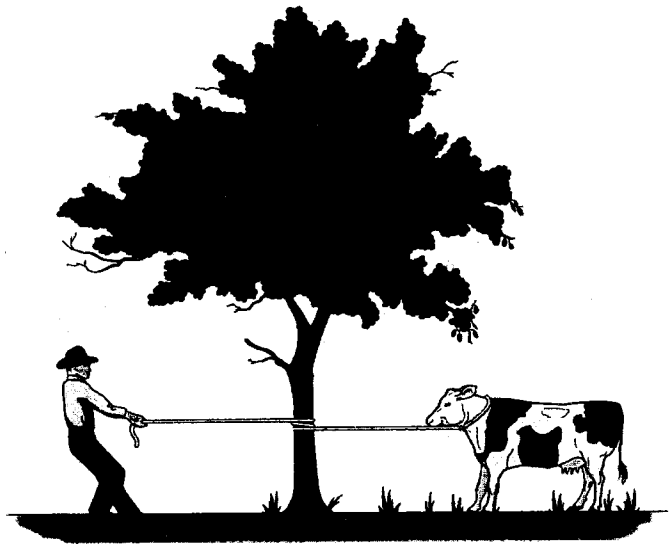


**Fig.5**

b) A stadium roof truss is loaded as shown in Fig. 6 below. Determine the force in members AE, FG and FJ. [4+4+5]

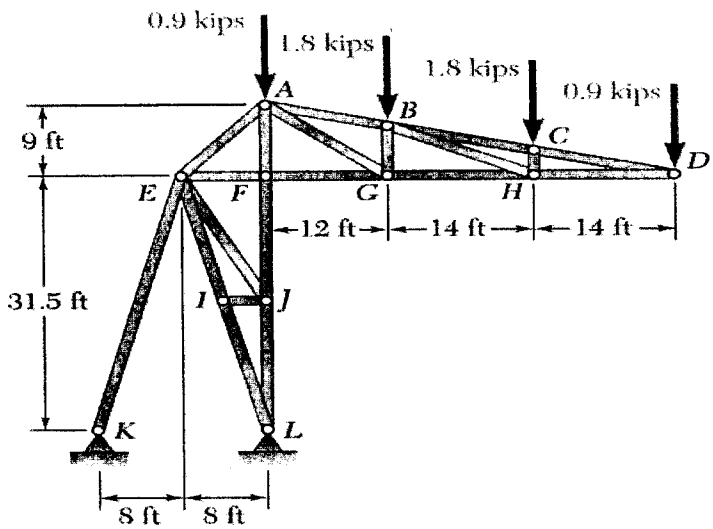



**Fig. 6**

**QUESTION 5:**

a) What is the difference between the normal stress and the shear stress? [2]

b) Define the terms 'Stiffness' and 'Elasticity' of a material? [2+2]

c) A rigid bar ABC is hinged at A and attached to a brass bar BD at B and a steel bar CE at C as shown in Fig. 7. The temperature of the steel bar is increased by $30^0C$ and that of the brass bar is lowered by $40^0C$. Taking $E_b = 95\ GPa; \alpha_b = 22 \times 10^{-6}/^0C;\ E_s = 205\ GPa; \alpha_s = 11.8 \times 10^{-6}/^0C$, determine

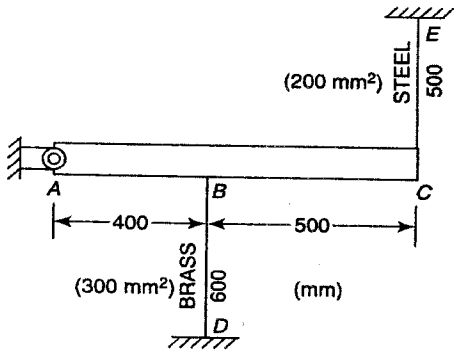



**Fig. 7**

a) Determine the normal stress in the steel bar and in the brass bar. [3+3]

b) Determine the vertical deflection of point C. [8]

**QUESTION 6:**

a) Write the formula for the thermal strain? [2]

b) Define the 'Malleability' of the material? [2]

c) A partly rectangular tapered steel bar ABCD with a constant thickness of 50 mm and is firmly fixed at A as shown in Fig. 8. Its width varies from 50 mm at A to 200 mm at C and then it maintains a constant width of 200 mm from C to D. The bar is loaded at B with 545 KN and at D with 260 KN. Taking E = 200 GPa.

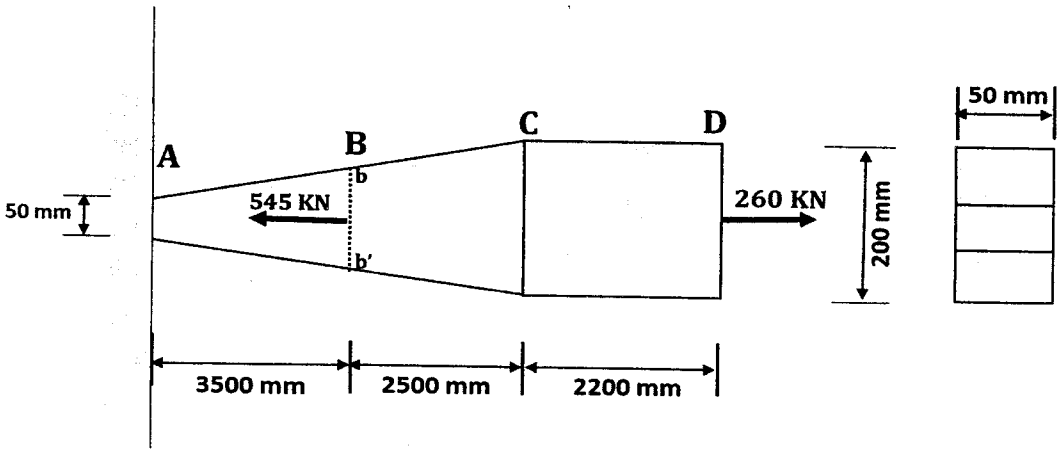



**Fig. 8**

i. Determine the force acting in the section AB? [4]

ii. Determine the total axial deformation of the bar as a result of the loading. [12]

**QUESTION 7:**

a) For the following, answer **True** or **False.** [4]

i. Negative internal moment in the simply supported beam tends to sag the beam.

ii. When a portion of a beam is loaded by a triangular distributed load, the shear force in that potion is governed by a quadratic equation.

iii. Shear force in the beam is an internal force directed along the length of the beam.

iv. When a simply supported beam is loaded with moments only, the SFD is 0 (just x-axis.)

b) The beam AB is loaded with a 40 KN/m distributed load, a 20 KN point load and a 150 KN.m couple as shown in the Fig. 9.

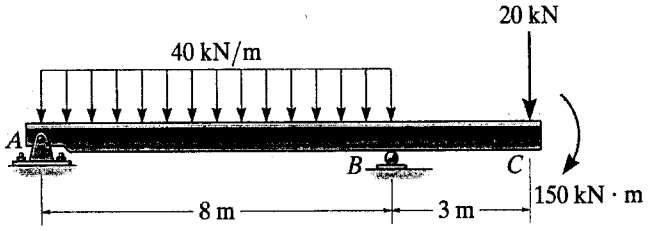



**Fig. 9**

i. Determine the vertical reaction at A and B? [1+1]

ii. Draw the shear force diagram? [7]

iii. Draw the bending moment diagram? [7]

## END OF EXAM!

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## USEFUL FORMULAE

Equilibrium, forces, moments,

$$\mathbf{F}_R = \Sigma\mathbf{F} = \Sigma F_x\mathbf{i} + \Sigma F_y\mathbf{j} + \Sigma F_z\mathbf{k}; \quad \cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1; \quad A = \sqrt{A_x^2 + A_y^2 + A_z^2}$$

$$\cos\alpha = \frac{A_x}{A} \quad \cos\beta = \frac{A_y}{A} \quad \cos\gamma = \frac{A_z}{A}; \qquad \bar{P}\bullet\bar{Q} = PQ\cos\theta = P_xQ_x + P_yQ_y + P_zQ_z \qquad \theta = \cos^{-1}\left(\frac{\mathbf{A}\cdot\mathbf{B}}{AB}\right) \quad 0° \le \theta \le 180°$$

$$\zeta + (M_R)_o = \Sigma Fd; \qquad (M_R)_o = F_1d_1 - F_2d_2 + F_3d_3 \qquad \Sigma F_x = 0; \Sigma F_y = 0;$$

$$M_0 = Fd; \; \boldsymbol{C} = \boldsymbol{A} \times \boldsymbol{B} = (AB\sin\theta)\,\boldsymbol{u_c}; \quad \mathbf{A}\times\mathbf{B} = (A_yB_z - A_zB_y)\mathbf{i} - (A_xB_z - A_zB_x)\mathbf{j} + (A_xB_y - A_yB_x)\mathbf{k} \quad \Sigma M = 0;$$

Friction

$$M = \mu Lr; \; F_k = \mu_k N; M = rWtan(\theta + \varphi_s); M' = rWtan(\theta - \varphi_s); \; F_{max} = \mu_s N; M'' = rWtan(\varphi_s - \theta); T_2 = T_1e^{\mu\beta};$$

Centroids and Moment of Inertia

$$\bar{x} = \frac{\int \tilde{x}\,dA}{\int dA}; \; \bar{y} = \frac{\int \tilde{y}\,dA}{\int dA}; I_x = \int y^2\,dA; I_y = \int x^2\,dA; \; I_{xy} = \int xy\,dA; I_a - Ad^2 = \bar{I}_c; I = k_x^2A;$$

$$J_o = \int r^2\,dA; \bar{y} = \frac{\Sigma\bar{y}_nA_n}{\Sigma A_n}; \; \bar{x} = \frac{\Sigma\tilde{x}_nA_n}{\Sigma A_n} \qquad I_u = \frac{I_x + I_y}{2} + \frac{I_x - I_y}{2}\cos 2\theta - I_{xy}\sin 2\theta \qquad \tan 2\theta_p = \frac{-I_{xy}}{(I_x - I_y)/2} \qquad R = \sqrt{\left(\frac{I_x - I_y}{2}\right)^2 + I_{xy}^2}$$

$$I_v = \frac{I_x + I_y}{2} - \frac{I_x - I_y}{2}\cos 2\theta + I_{xy}\sin 2\theta$$

$$(I_u - a)^2 + I_{uv}^2 = R^2 \qquad I_{uv} = \frac{I_x - I_y}{2}\sin 2\theta + I_{xy}\cos 2\theta \qquad I_{max\,min} = \frac{I_x + I_y}{2} \pm \sqrt{\left(\frac{I_x - I_y}{2}\right)^2 + I_{xy}^2}$$

Stress and Strain

$$\sigma = \frac{P}{A} \quad \epsilon = \frac{\delta}{L} \quad \delta = \frac{PL}{AE} \quad \delta = \sum_i \frac{P_iL_i}{A_iE_i} \qquad P = -AE\alpha(\Delta T) \quad \delta_T = \alpha(\Delta T)L \qquad \Delta = \frac{4PL}{\pi EdD} \qquad \Delta = \frac{P}{ktE}\log_e\frac{B}{b}$$

Combined stress and strain

$$\sigma_{x'} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta \qquad \sigma_{y'} = \frac{\sigma_x + \sigma_y}{2} - \frac{\sigma_x - \sigma_y}{2}\cos 2\theta - \tau_{xy}\sin 2\theta \qquad \tan 2\theta_s = \frac{-(\sigma_x - \sigma_y)/2}{\tau_{xy}}$$

$$\tau_{x'y'} = -\frac{\sigma_x - \sigma_y}{2}\sin 2\theta + \tau_{xy}\cos 2\theta \qquad \tan 2\theta_p = \frac{\tau_{xy}}{(\sigma_x - \sigma_y)/2} \qquad \sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \qquad \tau_{max\,in\,plane} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

**THE UNIVERSITY OF ZAMBIA**
**SCHOOL OF ENGINEERING**

**DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING**

**2022 ACADEMIC YEAR**

**DEFERRED EXAMINATIONS**

**CEE 3311 – FLUID MECHANICS**

**NSTRUCTIONS**

1. Attempt any FIVE questions.
2. All questions carry equal marks (20%). Marks for sub-questions are indicated at the end of each su question.
3. If you fail to answer part of a question, assume a value and use it in the subsequent calculations
4. Make sure the computer number is clearly indicated on all the booklets together with the questio attempted.

**TIME: THREE (3) HOURS** **CLOSED BOOK TES**

**Question 1**

a) Name the terms in the Bernoulli Equation. (3 marks)
b) Briefly explain what would happen when a ship on the Zambezi River enters the Indian Ocean whose water has a specific gravity of 1.2. (4 marks)
c) How does one choose a control volume? (3 marks)
d) The control surface may be in motion through space relative to an absolute frame of reference. In wha situation is this acceptable? (3 marks)
e) Briefly explain what happens to the buoyant force when a floating body is lowered slightly into the water. (4 marks)
f) Briefly explain the difference in the Reynolds Number between groundwater flow and fully turbulent pi flow. (3 marks)

**Question 2**

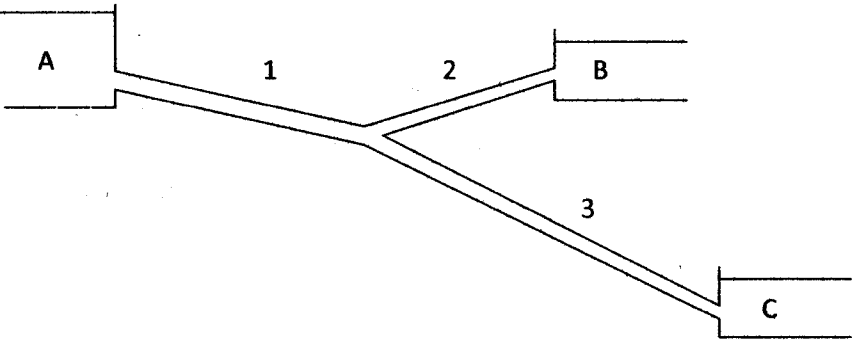
a) State 2 properties of a perfect gas. (3 marks)
b) Why does surface tension manifest itself only in liquids at an interface, usually a liquid-gas interface. (3 marks)
c) Name the type of acceleration which takes place when a pipeline changes its diameter from 30cm to 2 cm. (3 marks)
d) What circumstance (s) reduces the Energy Equation to a form identical with the Bernoulli Equation? (4 marks)
e) . Why is the control volume approach also called the Eulerian approach. (3 marks)
f) State when flow work is done. (4 marks)

## Question 3

a) State the three basic relations that must be satisfied in any pipe network. (3 marks)
b) Briefly discuss how age of a pipe affects the friction factor. (4 marks)
c) A rectangular channel 9m wide carries 7.6m$^3$/s when flowing 1.0m deep.
   i. What is the specific energy? (5 marks)
   ii. Is the flow subcritical or critical?? (8 marks)

## Question 4

Given that, in Figure below, pipe 1 is 1,800m of 45cm diameter, pipe 2 is 450m of 30cm diameter, and pip 3 is 1,350m of 20cm diameter, all asphalt-dipped cast iron, e=0.12mm. The elevations of the water surfac on reservoirs A and C are 75m and 48m, respectively, and the discharge $Q_2$ of water into reservoir B is 0.093 m$^3$/s. Find the surface elevation of reservoir B using two trials. Use kinematic viscosity of 1.13 x 10$^{-}$ m$^2$/s. (20 mark




## Question 5

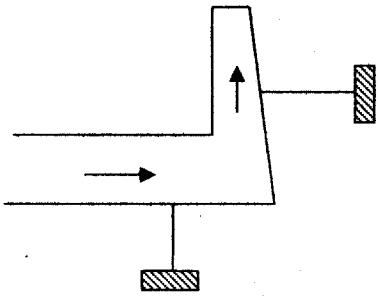
a) Give the reason for referring open channel flow as gravity flow. (3 marks)
b) State two applications of the hydraulic jump. (4 marks)
c) Using the equations below, prove that the streamlines and equipotential lines are everywhere perpendicular to each other.
   $d\varphi = -vdx + udy$
   $d\emptyset = -udx - vdy$ (4 marks)
d) A piece of wood of specific gravity 0.651 is 80mm square and 1.5m long. How many newtons of lead weighing 110kN/m$^3$ must be fastened at one end of the stick so that it will float upright with 0.3m out o water? (9 marks)

## Question 6

a) Distinguish between drag and lift in external flows. (2 marks)
b) What is the usual definition of the thickness of the boundary layer? (4 marks)
c) A pipe carrying oil of specific gravity 0.877 changes in size from 150mm at section E to 450mm at section R. Section E is 3.66m lower than R, and the pressures are 91.0kPa and 60.3kPa, respectively If the discharge is 0.146m$^3$/s, determine
   i. the lost head (11 mark
   ii. the direction of flow? (3 marks)

**Question 7**

Water flows through a horizontal pipe bend and exits into the atmosphere. The bend reduces diameter fro 8cm to 4cm. The flow rate is $0.01 m^3/s$. Calculate the force in each of the rods holding the pipe bend in position. Neglect body forces and viscous effects. (20 marks



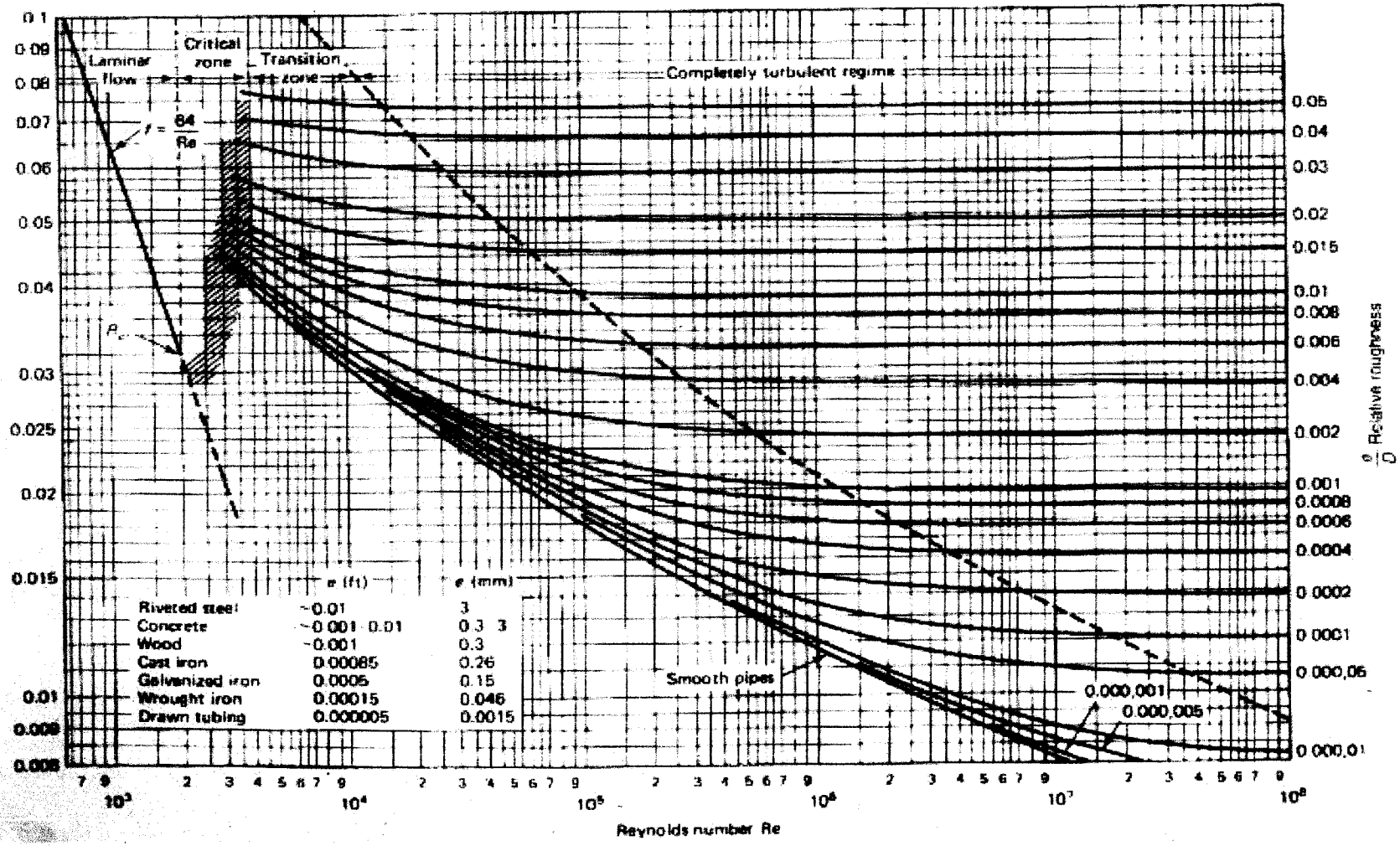
HINTS

$$Re = \frac{vD}{\upsilon}$$

$$\frac{dN_{sys}}{dt} = \frac{d}{dt}\int_{CV} \eta\rho dV + \int_{CS} \eta\rho(\vec{v}\vec{dA})$$

Turbulent flow, Type 2 $$V = -2\sqrt{\frac{2gDh_L}{L}}\, log\left(\frac{^e/_D}{3.7} + \frac{2.51v}{D}\sqrt{\frac{L}{2gDh_L}}\right)$$

END OF EXAMINATION


Laminar flow
Critical zone
Transition zone
Completely turbulent regime
$f = \frac{64}{Re}$
$R_c$
Smooth pipes
0.000,001
0.000,005
Reynolds number Re
$\frac{e}{D}$ Relative roughness
e (ft) e (mm)
Riveted steel ~0.01 3
Concrete ~0.001 0.01 0.3 3
Wood ~0.001 0.3
Cast iron 0.00085 0.26
Galvanized iron 0.0005 0.15
Wrought iron 0.00015 0.046
Drawn tubing 0.000005 0.0015

**THE UNIVERSITY OF ZAMBIA**

**SCHOOL OF ENGINEERING**

**CIVIL AND ENVIRONMENTAL ENGINEERING DEPARTMENT**

**UNIVERSITY EXAM**

**2022 ACADEMIC YEAR**

**CEE 5222**

**DESIGN IN SRTUCTURAL STEEL.**

TIME: **THREE** HOURS

INSTRUCTIONS TO CANDIDATE

(a) Candidates must ensure that their ID numbers are clearly written on each answer booklet used and that the number of answered questions is entered in the space provided on the front of the booklet.
(b) Answer ALL **FIVE** questions.
(c) Mathematical gadgets and drawing instruments are allowed.

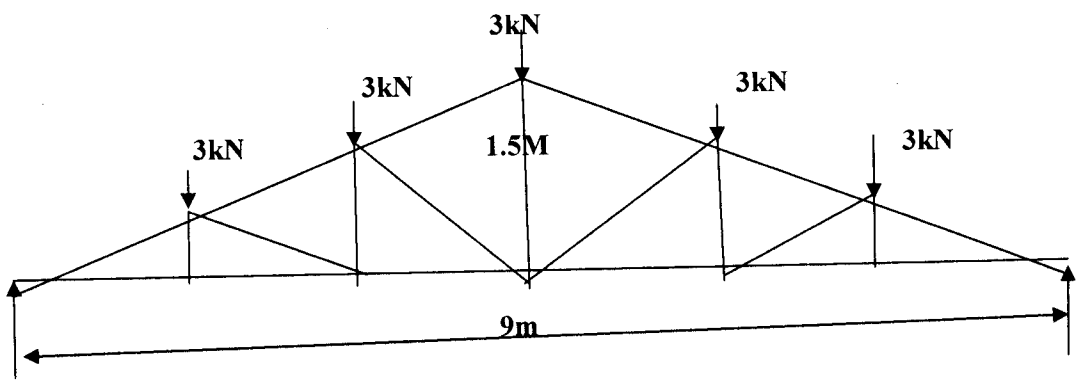
**MAXIMUN SUM OF MARKS: 100** **(OPEN BOOK)**

**Study the picture and drawings of a double storey house.**

## QUESTION ONE

## TRUSS DESIGN

Given that roofing truss is simply supported at both ends and has a total design load of 15kN design the top rail compressed member in Equal angles bars. **(20 marks)**



## QUESTION TWO

## SLAB DESIGN -PROFILE METAL DECKING

The slab is constructed using profile metal decking of maximum span of 3m and grade concrete of 35MPa and is required to have a fire resistance of 2 hours. Design the composite slab, to provide thickness of concrete, type of mesh, and thickness of steel gauge decking, if the total imposed load is 7.2kN/$m^2$.

**(20 marks)**

## QUESTION THREE

## BEAM DESIGN

Design Beam 5 grade 275 in universal beam UB, given that, the loadings from the slab given that imposed loads are totaling 7.2kN/$m^2$ and dead loads including self-weight of slab is 24kN/$m^3$. Beam 5 is fixed on both ends.

**(20 marks)**

## QUESTION FOUR

## COLUMN DESIGN

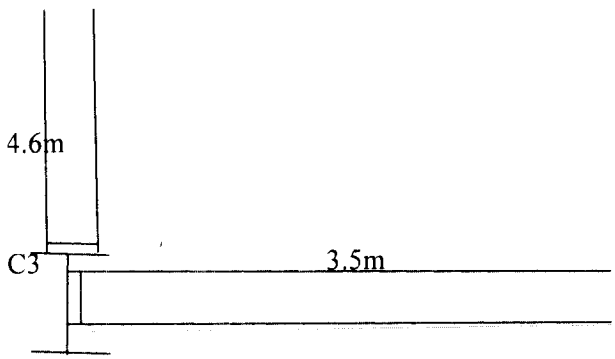
Calculate moments in Beam 6 grade 275, which is fixed on both ends, and Design the structural steel UC Column C3 of height 3.3meters between slabs, given that loadings from the slab given that imposed loads and 7.2kN/$m^2$ and dead loads including self-weight of slab is 24kN/$m^3$. Assume beam 3 has weight of 23kg/meter. **(20 marks)**

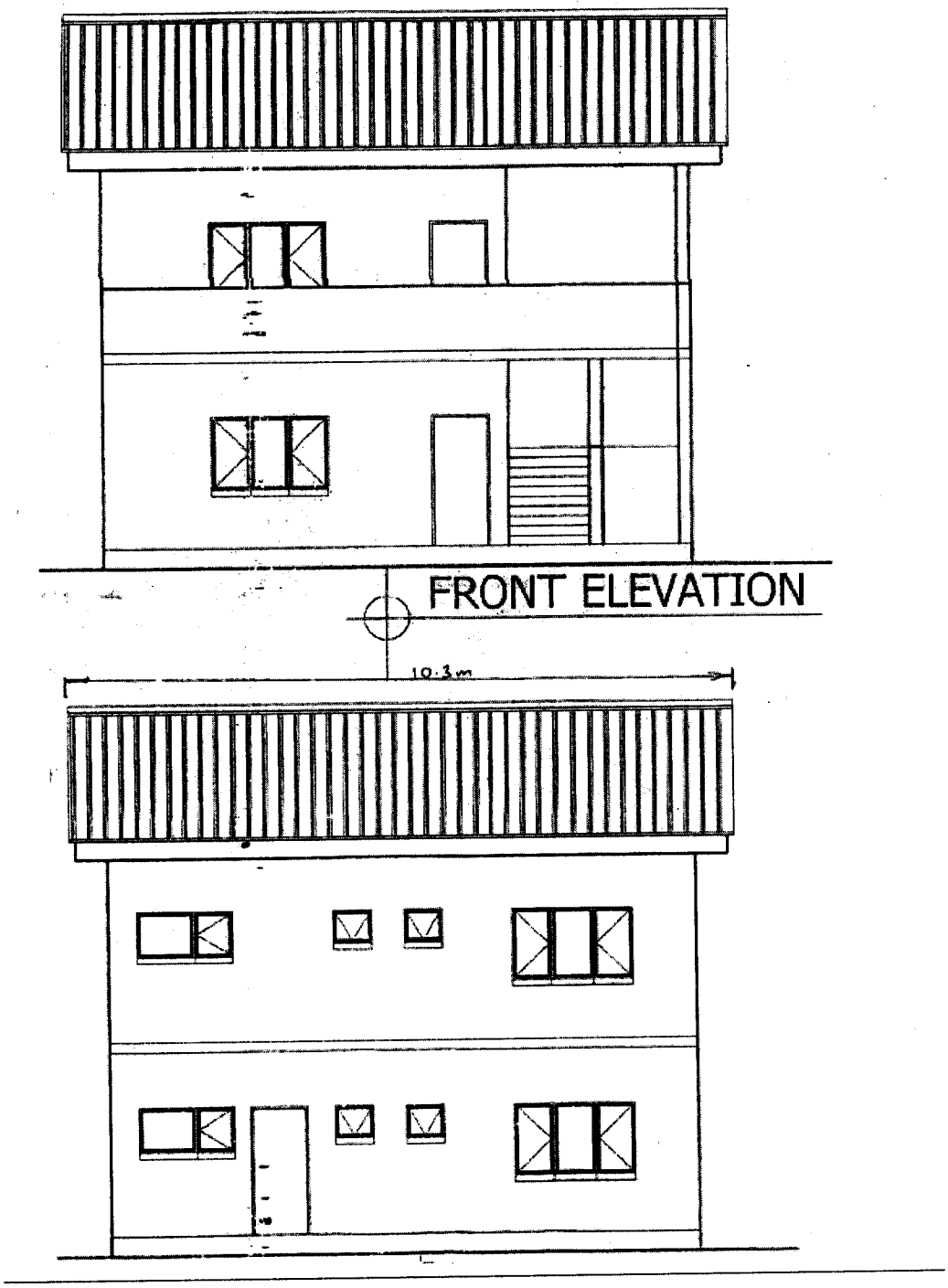
## QUESTION FIVE

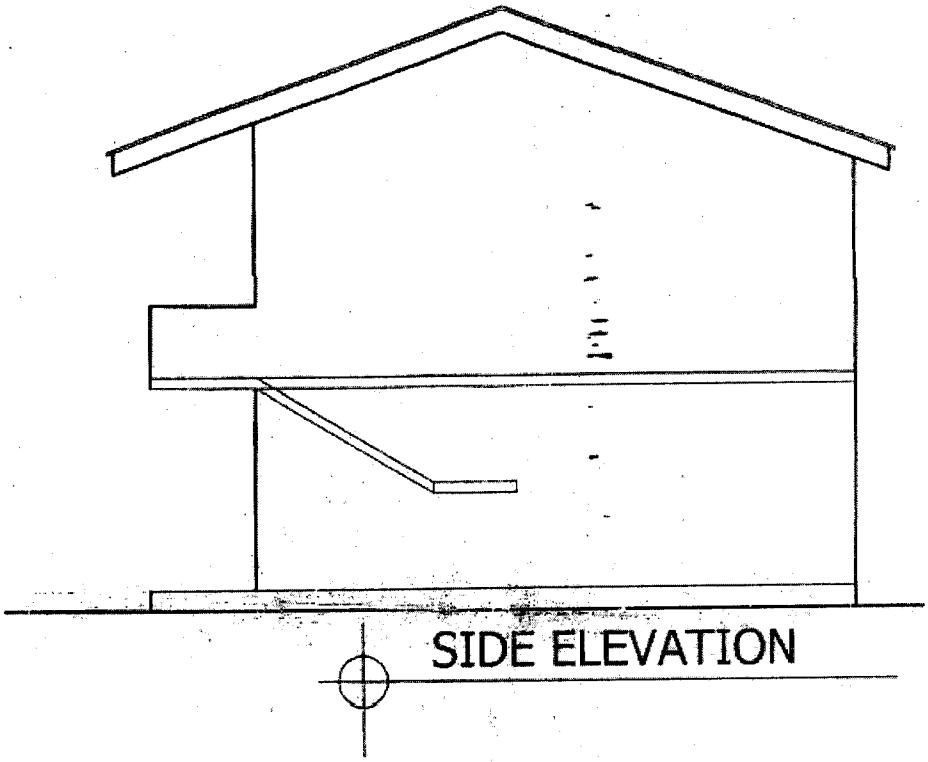
## JOIST DESIGN

The joint between beam 5 and column C3 is a fixed joint made up of M12 Bolts of grade 4.6. Calculate the number of bolts required on this joint using the shear force in the joint.

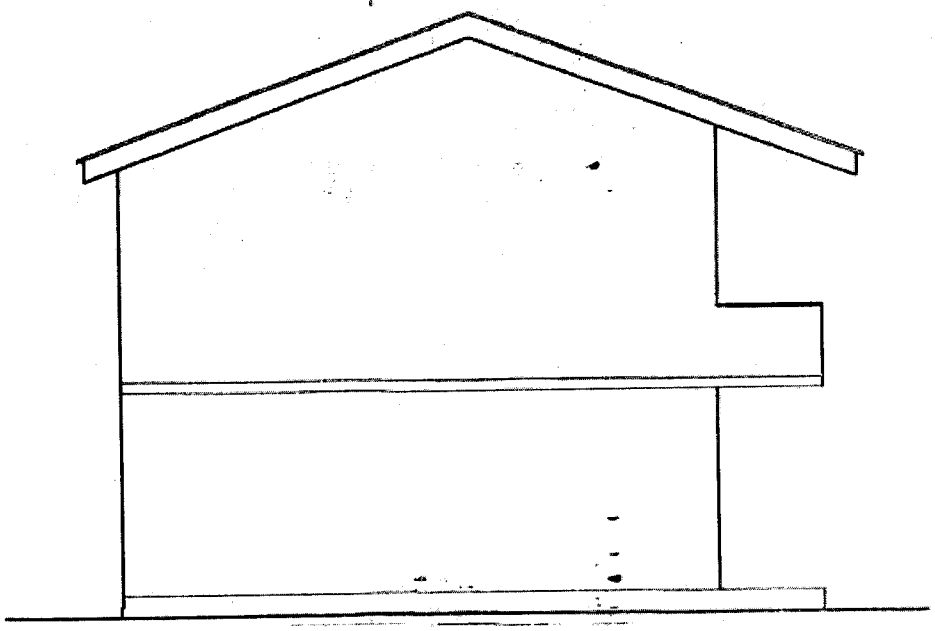
**(20 marks)**



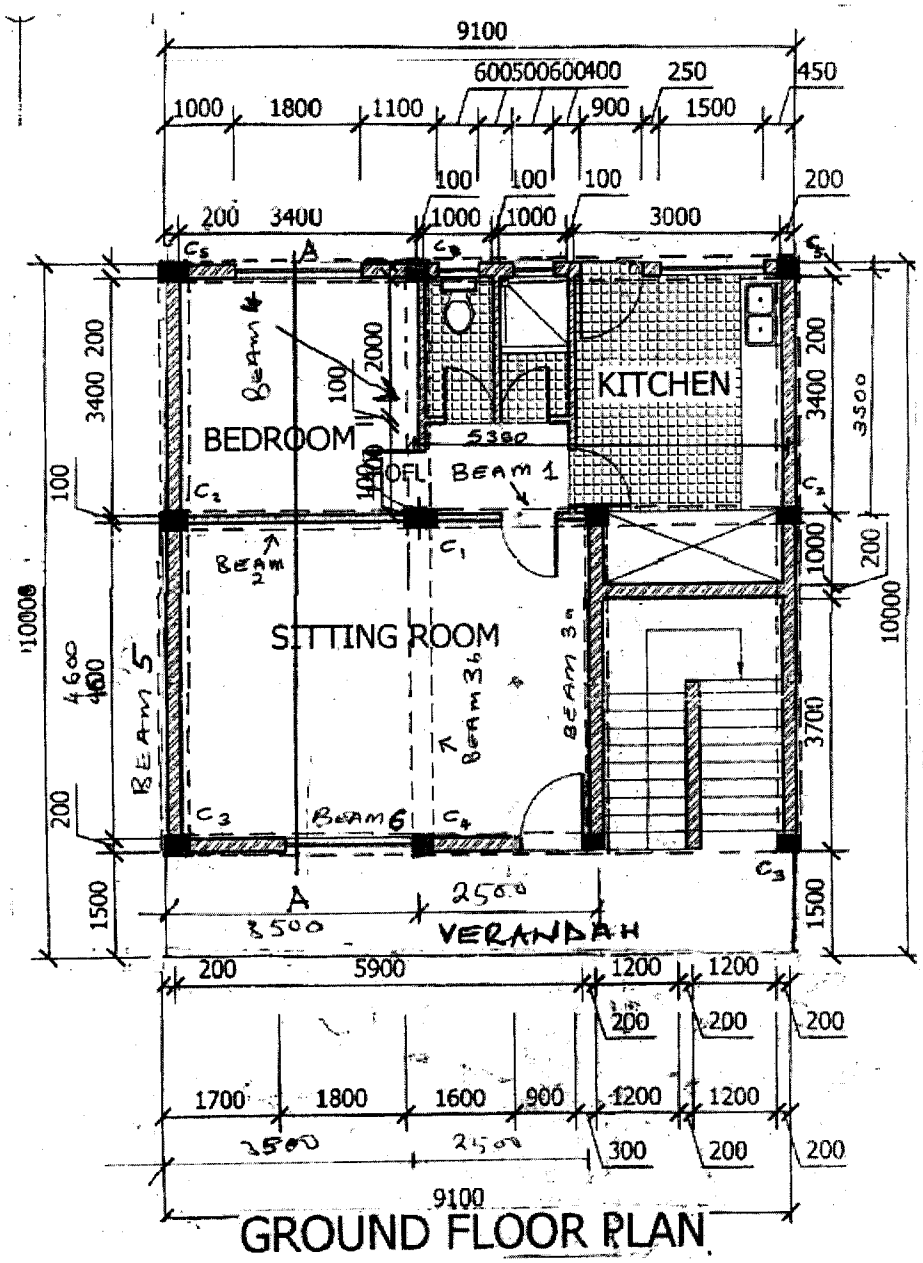

FRONT ELEVATION
10.3m

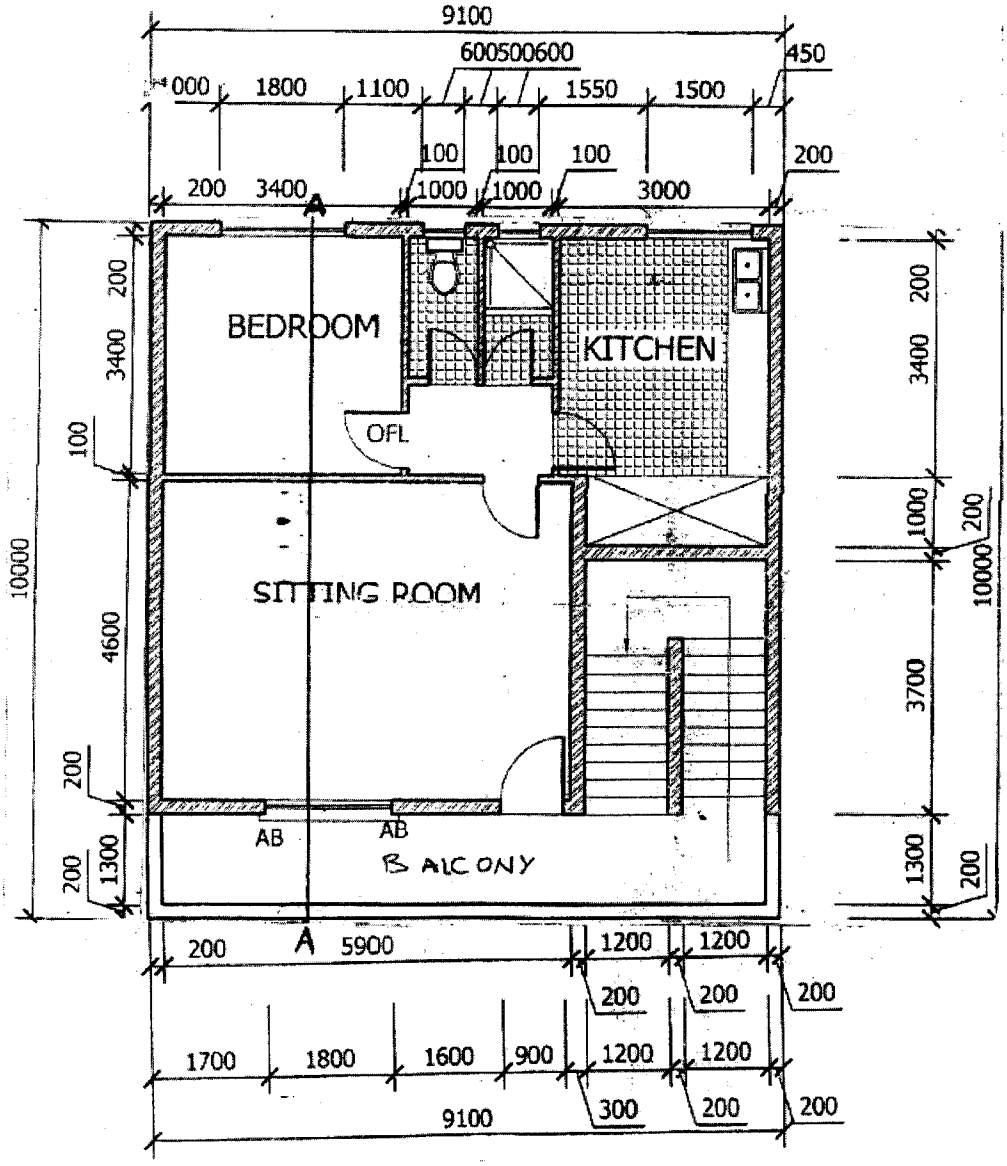


SIDE ELEVATION



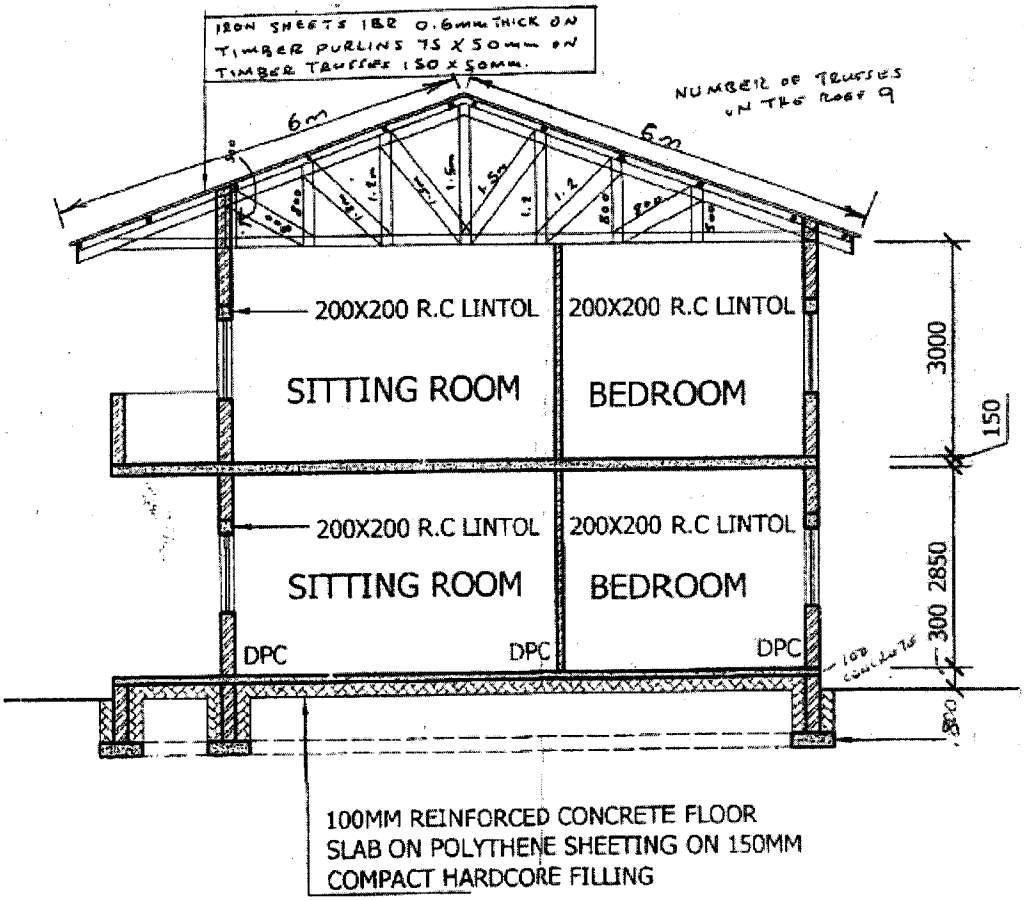
SIDE ELEVATION


9100
600500600400
250
450
1000
1800
1100
900
1500
100
100
100
200
200
3400
1000
1000
3000
BEDROOM
KITCHEN
SITTING ROOM
VERANDAH
BEAM 1
BEAM 2
BEAM 3a
BEAM 3b
BEAM 5
BEAM 6
5390
2500
3500
5900
1200
1700
1800
1600
2500
300
10000
4600
3700
1500
GROUND FLOOR PLAN




FIRST FLOOR PLAN

## ROOF CONSTRUCTION




SECTION A-A

# THE UNIVERSITY OF ZAMBIA

## SCHOOL OF ENGINEERING

## DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATIONS

FINAL EXAM – 2021/2022 ACADEMIC YEAR
15 DECEMBER, 2022

# EEE 2019

# PRINCIPLES OF ELECTRICAL AND ELECTRONIC ENGINEERING

| | |
|---|---|
| TIME | THREE HOURS |
| INSTRUCTIONS | There are SEVEN QUESTIONS each having 20 MARKS, ANSWER ANY FIVE; TOTAL 100 MARKS. |
| ADDITIONAL INSTRUCTIONS | Where not stated, resistances are in ohms. |

## QUESTION 1

**a)** Determine the potential difference $V_{AB}$ in the circuit of Figure Q1(a). **[10 Marks]**

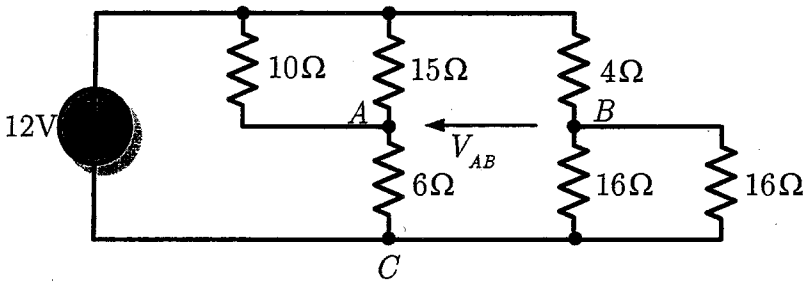



**Figure Q1(a)**

**b)** A circuit, ***ABCD*** is arranged as follows: Resistances between terminals *A-B*, *B-C*, *C-D*, *D-A*, and *B-D* are 10Ω, 20Ω, 15Ω, 5Ω and 40Ω respectively. A 20V source of negligible internal resistance is connected between terminals *A* and *C*. Determine the current in each resistor. **[10 Marks]**

**[Total 20 Marks]**

## QUESTION 2

**a)** With your knowledge of nodal analysis find the current $i_x$ in the circuit of Figure Q2(a). **[10 Marks]**

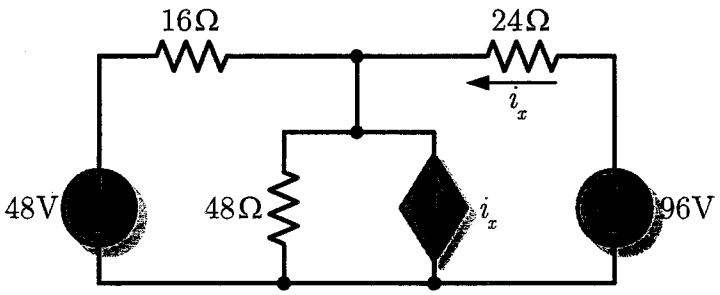



**Figure Q2(a)**

**b)** By means of delta to wye ($\Delta \rightarrow Y$) transformation, find the current supplied by the battery in the circuit of Figure Q2(b). **[10 Marks]**

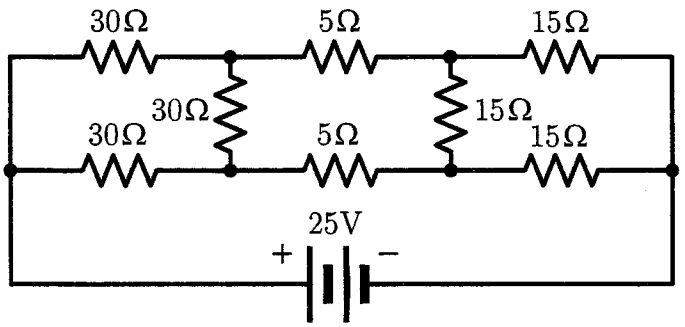



**Figure Q2(b)**

**[Total 20 Marks]**

## QUESTION 3

**a)** Find $I_0$ in the circuit shown in Figure Q3(a) using the principle of superposition. **[10 Marks]**

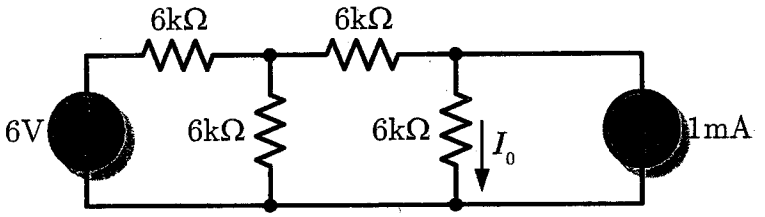



**Figure Q3(a)**

**b)** Determine the Norton equivalent at the terminals $a$-$b$ for the circuit in Figure Q3(b). **[10 Marks]**

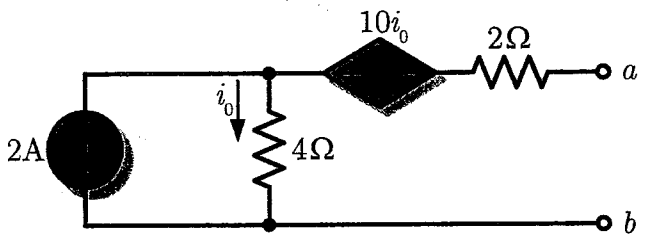



**Figure Q3(b)**

**[Total 20 Marks]**

## QUESTION 4

**a)** For the circuit depicted in Figure Q4(a) the switch is closed at $t = 0$ and $v_C(0) = 0$.

**i)** Obtain the capacitor voltage $v_C(t)$, for $t > 0$. **[6 Marks]**

**ii)** Hence find $i(t)$, for $t > 0$. **[2 Marks]**

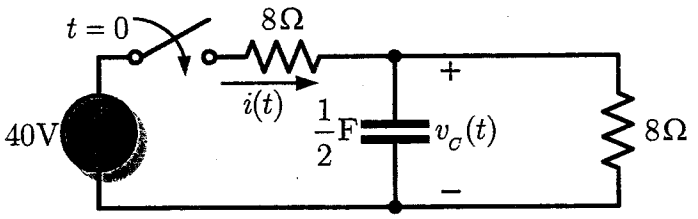



**Figure Q4(a)**

**b)** Find the Thevenin equivalent at terminals $a$-$b$ in the circuit depicted in Figure Q4(b). **[12 Marks]**

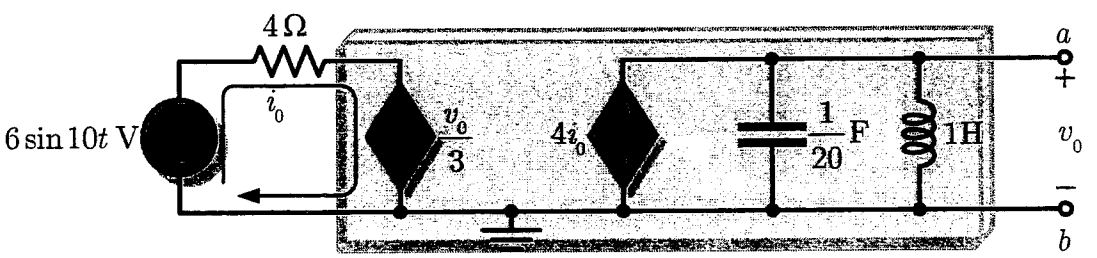



**Figure Q4(b)**

**[Total 20 Marks]**

## QUESTION 5

**a)** Find $i(t)$ and $v(t)$ for $t > 0$ in the circuit of Figure Q5(a). **[10 Marks]**

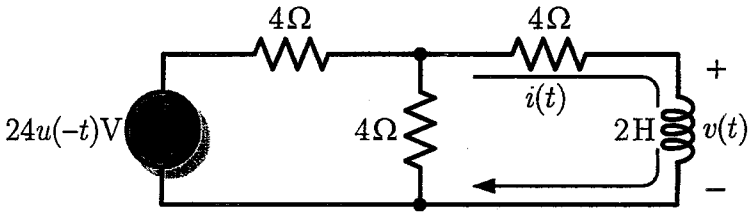



**Figure Q5(a)**

**b)** A power transmission system is modeled as shown in Figure Q5(b). Given the generator voltage $\mathbf{V}_{gen} = 220\angle 0^\circ\,\mathrm{V}$, generator impedance $\mathbf{Z}_{gen} = (1 + j0.5)\,\Omega$, line impedance $\mathbf{Z}_{\ell} = (0.4 + j0.3)\,\Omega$ and load impedance $\mathbf{Z}_L = (38.2 + j38.9)\,\Omega$,

**i)** Find the load current $\mathbf{I}_L$. **[8 Marks]**

**ii)** Hence, determine the overall system power factor and state whether it is leading or lagging. **[2 Marks]**

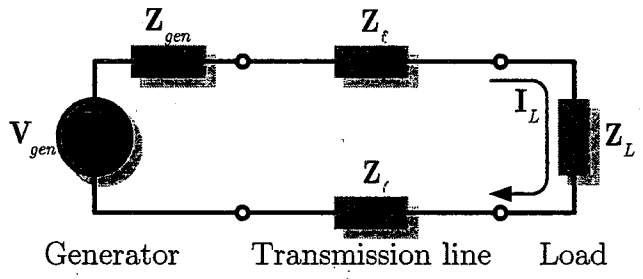



**Figure Q5(b)**

**[Total 20 Marks]**

## QUESTION 6

**a)** Find the mesh currents $i_1$, $i_2$ and $i_3$ in the circuit of Figure Q6(a). **[8 Marks]**

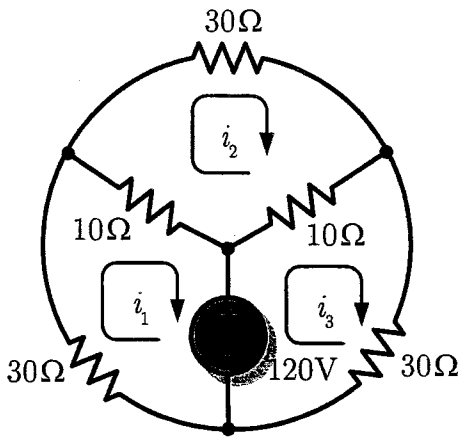



**Figure Q6(a)**

**b)** A 240 V rms, 50 Hz source supplies two loads in parallel, as shown in Figure Q6(b).

**i)** Find the power factor of the parallel combination. **[7 Marks]**

ii) Calculate the value of the capacitance connected in parallel that will raise the power factor to unity. [5 Marks]

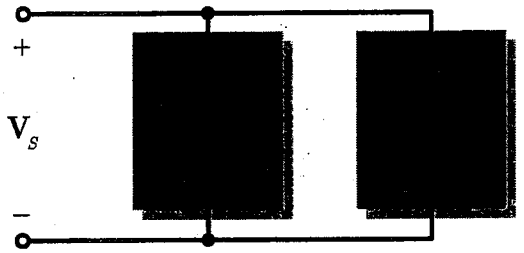



**Figure Q6(b)**

**[Total 20 Marks]**

## QUESTION 7

a) Calculate the rms value, $I_{rms}$ of the periodic ac current waveform of Figure Q7(a). [8 Marks]

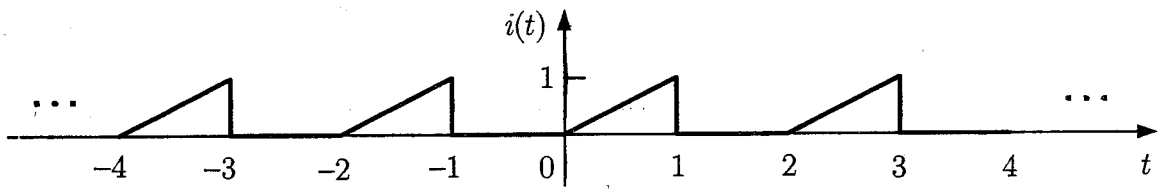



**Figure Q7(a)**

b) For the ac circuit shown in Figure Q7(b), determine the current $\mathbf{I}_0$. [12 Marks]

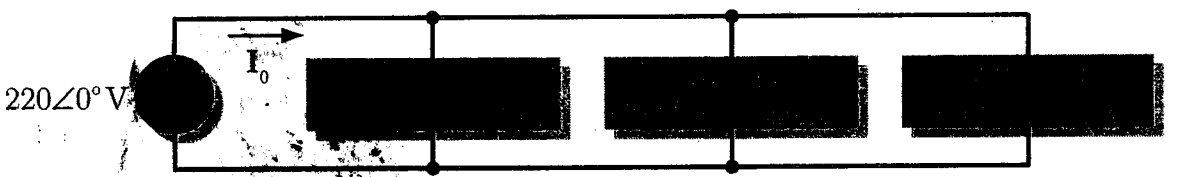



**Figure Q7(b)**

**[Total 20 Marks]**

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**END OF EEE 2019 EXAM**

# THE UNIVERSITY OF ZAMBIA

## SCHOOL OF ENGINEERING

## DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATIONS

SUPPLEMENTARY EXAM – 2021/2022 ACADEMIC YEAR
13 FEBRUARY, 2023

# EEE 2019

# PRINCIPLES OF ELECTRICAL AND ELECTRONIC ENGINEERING

TIME: THREE HOURS

INSTRUCTIONS: ANSWER FIVE Questions, AT LEAST TWO Questions from EACH SECTION.

Each Question carries [20 Marks], thus FIVE Questions yield [Total 100 Marks]

ADDITIONAL INSTRUCTIONS: Where not stated, resistances are in ohms.

## SECTION A

### QUESTION 1

a) For the circuit shown in Figure Q1(a), use the principle of superposition to find the current $i_0$. [8 Marks]

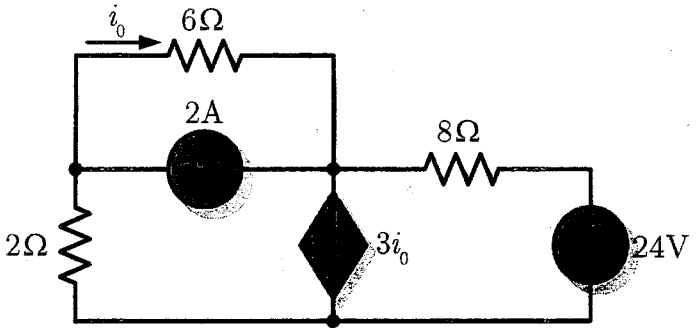


**Figure Q1(a)**

b) Consider the circuit depicted in Figure Q1(b),

i) Find the equivalent resistance $R_{AB}$. [8 Marks]

ii) Find the power delivered by the source of a value 12V connected between the terminals $A$ and $B$. [4 Marks]

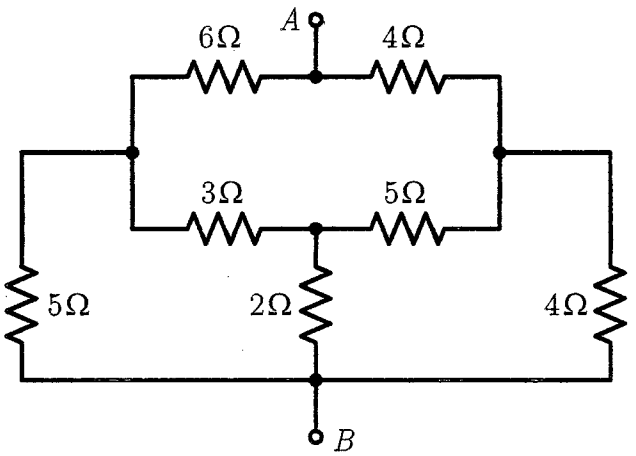


**Figure Q1(b)**

[Total 20 Marks]

### QUESTION 2

a) A circuit, ***ABCD*** is arranged as follows: Resistances between terminals *A-B*, *B-C*, *C-D*, *D-A*, and *B-D* are 10Ω, 20Ω, 15Ω, 5Ω and 40Ω respectively. A 20V source of negligible internal resistance is connected between terminals $A$ and $C$. Determine the current in each resistor. [10 Marks]

b) Use a Δ-to-Y transformation to find voltages, $v_1$ and $v_2$ in the circuit shown in Figure Q2(b). [10 Marks]

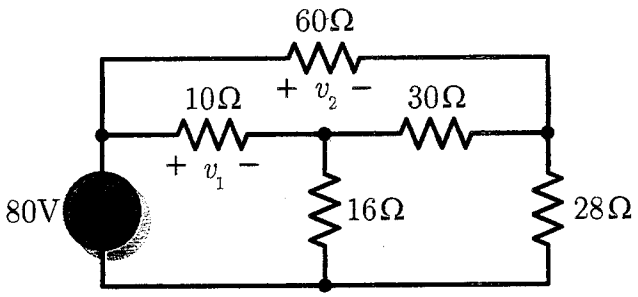


**Figure Q2(b)**

**[Total 20 Marks]**

## QUESTION 3

**a)** In the circuit of Figure Q3(a), using the knowledge you have acquired in EEE 2019,

**i)** Find the current $i_0$ using nodal analysis. **[6 Marks]**

**ii)** Find the current $i_0$ using mesh analysis. **[6 Marks]**

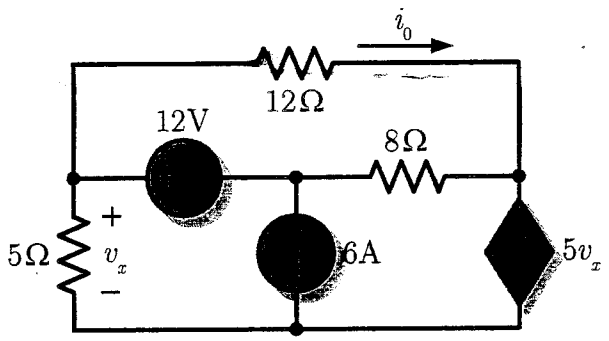


**Figure Q3(a)**

**b)** For the circuit shown in Figure Q3(b),

**i)** Use a series of source transformations to find the current $i_0$ through the 80kΩ resistor. **[6 Marks]**

**ii)** Using the result obtained in part (i), work back through the circuit to find the power developed by the 10V source. **[2 Marks]**

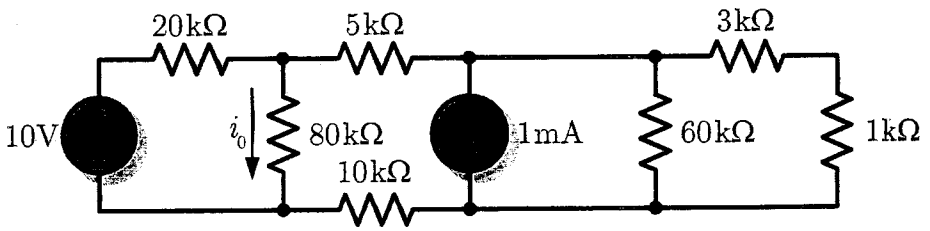


**Figure Q3(b)**

**[Total 20 Marks]**

## QUESTION 4

**a)** For the circuit of Figure Q4(a), find the total current $i_T$, the branch current $i_{bc}$ and the open circuit voltage $v_{ac}$. **[10 Marks]**

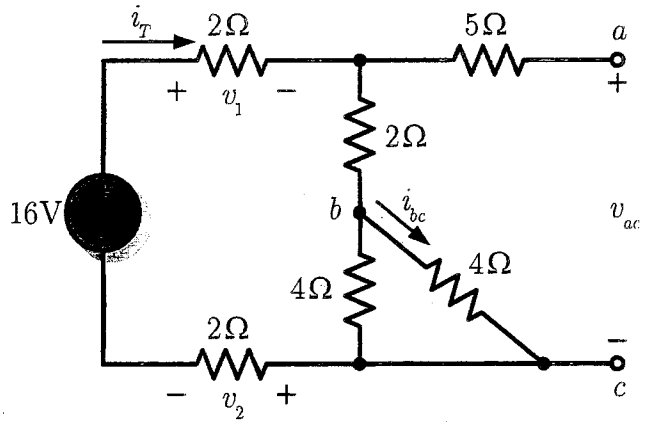


**Figure Q4(a)**

**b)** For the circuit shown in Figure Q4(b),

**i)** Use a series of source transformations to find the current $i_0$ through the 80kΩ resistor. **[7 Marks]**

**ii)** Using the result obtained in part (i), work back through the circuit to find the power developed by the 10V source. **[3 Marks]**

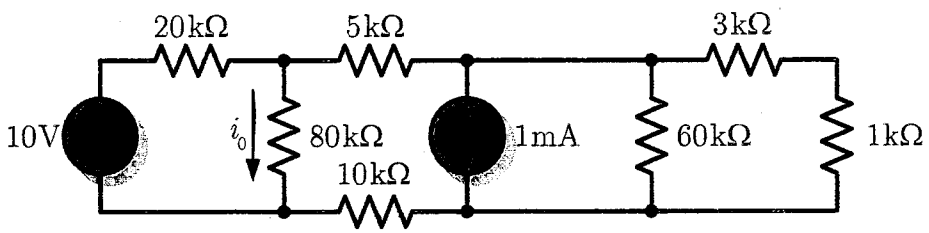


**Figure Q4(b)**

**[Total 20 Marks]**

## SECTION B

### QUESTION 5

**a)** For the circuit depicted in Figure Q5(a) the switch is closed at $t = 0$ and $v_C(0) = 0$.

**i)** Obtain the capacitor voltage $v_C(t)$, for $t > 0$. **[6 Marks]**

**ii)** Hence find $i(t)$, for $t > 0$. **[2 Marks]**

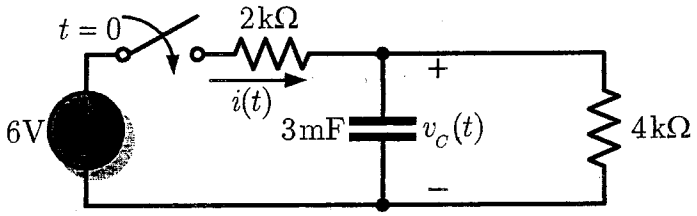


**Figure Q5(a)**

**b)** Find the Thevenin equivalent at terminals $a$-$b$ in the circuit depicted in Figure Q5(b). **[12 Marks]**

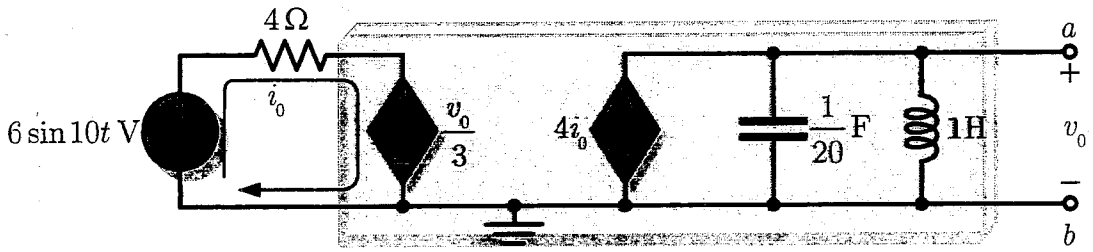


**Figure Q5(b)**

**Total 20 Marks]**

### QUESTION 6

**a)** Find $i(t)$ and $v(t)$ for $t > 0$ in the circuit of Figure Q6(a). **[10 Marks]**

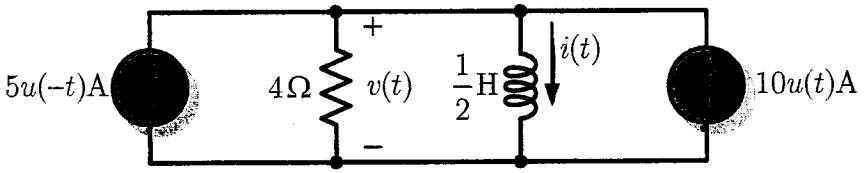


**Figure Q6(a)**

**b)** Two elements are connected in series as shown in Figure Q6(b). If $i(t) = 6\cos(314t - 30°)\,\text{A}$,

**i)** Find the element values. **[8 Marks]**

**ii)** Calculate the overall system power factor and state whether it is leading or lagging. **[2 Marks]**

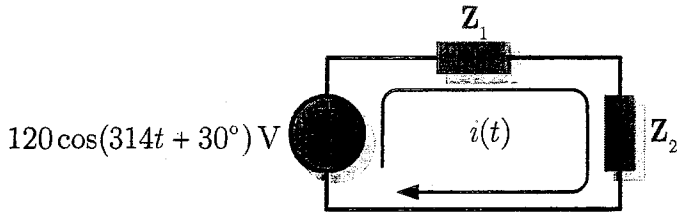


**Figure Q6(b)**

**[Total 20 Marks]**

## QUESTION 7

A power transmission system is modeled as shown in Figure Q7. Given the generator voltage $\mathbf{V}_{gen} = 220\angle 0^\circ\,\text{V}$, generator impedance $\mathbf{Z}_{gen} = (1 + j0.5)\,\Omega$, line impedance $\mathbf{Z}_{line} = (0.4 + j0.3)\,\Omega$ and load impedance $\mathbf{Z}_L = (38.2 + j38.9)\,\Omega$,

i) Find the load current $\mathbf{I}_L$. **[12 Marks]**

ii) Hence, determine the overall system power factor and state whether it is leading or lagging. **[8 Marks]**

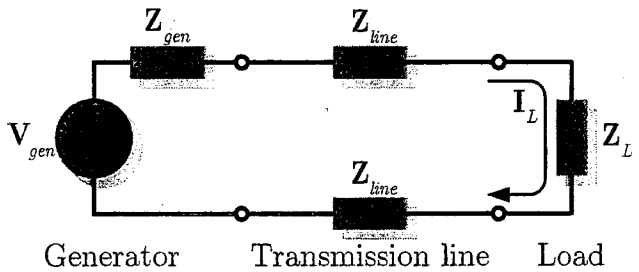


**Figure Q7**

**[Total 20 Marks]**

**END OF EEE 2019 SUPPLEMENTARY EXAM**

# THE UNIVERSITY OF ZAMBIA

## SCHOOL OF ENGINEERING

## DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATIONS

FINAL EXAM – November 2022

# EEE 3112

## ELECTRICAL ENGINEERING PRACTICE

| | | |
|---|---|---|
| **TIME** | : | Three (3) hours |
| **INSTRUCTIONS** | : | Answer two (2) questions (compulsory) in section B and any three Questions in section B. |
| **ADDITIONAL INFORMATION** | : | 1. Submit SECTION A and SECTION B in Separate Answer Booklets. |

## SECTION A: ANSWER ANY THREE (3) QUESTIONS FROM THIS SECTION

**Question One**

a) A 1 mA moving coil meter with internal resistance of 200 ohms is to be converted into a three range ammeter, namely 20 mA, 10 mA and 1 mA.
Design the Ammeter for the given ranges.

**[5 Marks]**

b) Convert a basic D'Arsonval meter with an internal resistance of 50 ohms and a full scale deflection current of 1 mA into a two range
voltmeter of 0 – 10V and 0 – 50 V.

**[5 marks]**

c) Design an Aryton shunt to provide an ammeter with a current range of 0-1 mA, 5 mA, 10 mA. A D' Arsonval movement with an internal
resistance of 100kΩ and full scale current of 50 μA is used.

**[10 Marks]**

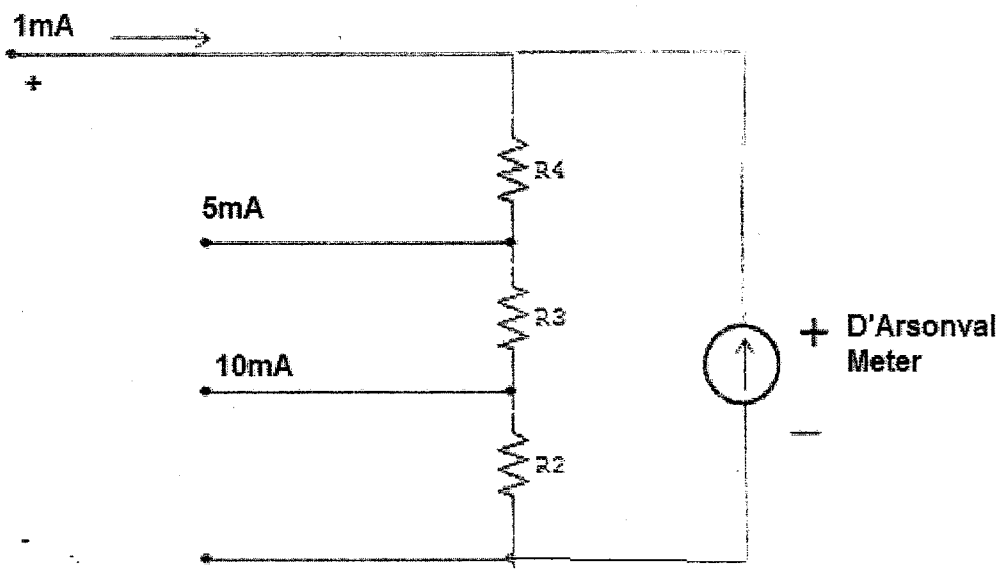


**Figure Q1 Aryton Shunt**

**Question Two**

**a)** Name any four classes of measuring instruments, giving one example for each.

**[4 Marks]**

b) Outline and explain briefly four methods of fault finding.

**[6 marks]**

c) How would you use an ohm-meter to tell whether: i) a diode is working, ii) an NPN transistor is working. **[2 Marks]**

d) The following amplifier circuits in figure Q2 a, b, c, and d, have voltages measured on the terminals of a transistor for each circuit and are shown on the circuits. Use the results to identify the faults in each circuit. **[5 Marks]**

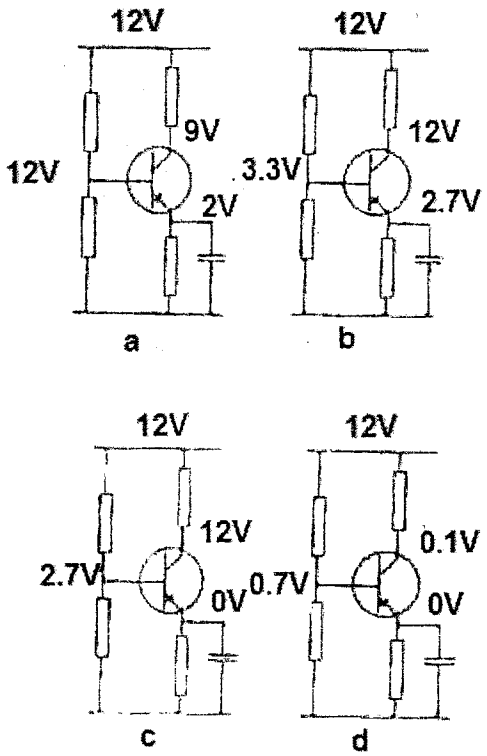


**Figure Q2 a, b, c, and d Amplifier circuits.**

e) Given a power supply circuit in figure Q2 e, what will be your three immediate check points for you to determine the fault if the power supply does not give you the output voltage? **[4 Marks]**

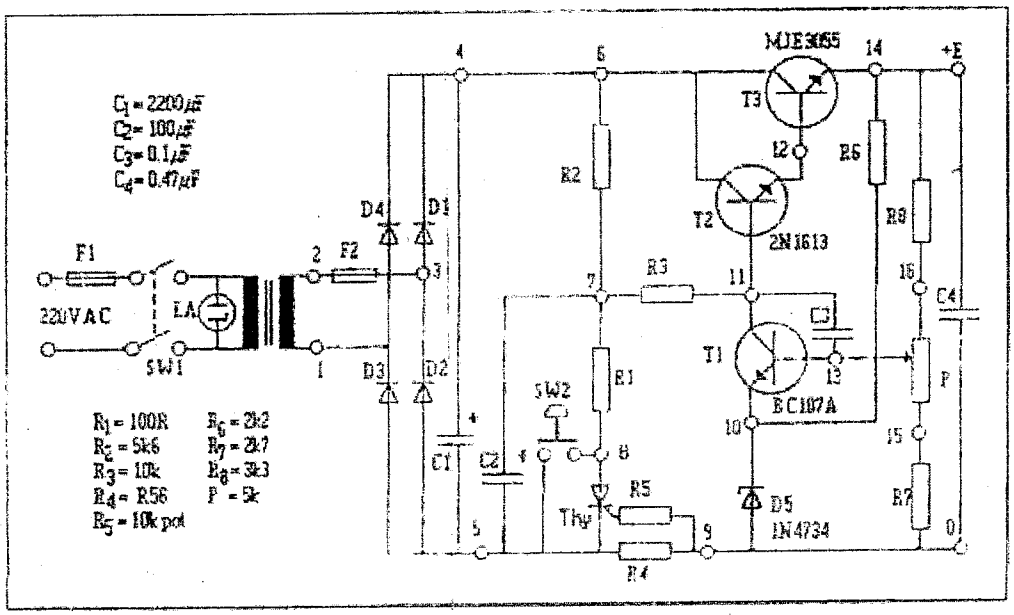


**Figure Q2, e Power supply.**

**[3 Marks]**

**Question Three**

(a) Name and briefly explain three classes of instruments. **[9 Marks]**

(b) Describe the constructional details and damping of a moving coil meter. **[11 Marks]**

**Question Four**

a) An engineer has two small resistors and two capacitors that they would like to use in the circuit diagram. The following are the colour codes of these components:

- Resistor 1: Red, Violet, Gold and Silver
- Resistor 2: Blue, Grey, Silver and Silver
- Capacitor 1: Black, Brown, and Orange
- Capacitor 2: Blue, Orange, Green and White Spot

i. State the values of each resistors and capacitors. **[2Marks]**

ii. State any four applications of capacitor. **[2Marks]**

b) Design and draw the circuit diagram of LED based reading lamp that can be supplied from both main 240VAC, 50Hz supply system and solar panel 12V, 15W. The circuit should consist of the following components.

- Transformer, 240V/12V
- Converter (AC/DC)

- Smoothing Capacitor,
- Regulator IC 5V, 3A
- Zener Diode, 5V, 1.5A
- 5 White LEDs, each rated 2.7V, 30mA
- Battery, 5V, 4.5Ah
- USB Port, 5V, 1A
- Solar PV 12V, 15W

**NOTE**: Neglect the power losses and voltage drops in the transformer and the converter.

A. Design, draw and briefly explain the function of each major component of the LED reading lamp; Transformer, Converter, Capacitor, Zener Diode, Battery, USB port and LEDs. **[8Marks]**

**B. Calculate**

i. The limiting resistors for the LEDs and Zener Diode. **[2Mark]**

ii. The smoothing capacitor C1 for 10% ripple **[1Mark]**

iii. The power rating of the LED Based Reading Lamp. **[3Marks]**

iv. The amount of energy the LED based reading lamp consume in a month if it operates for 10hours per day. **[2Marks]**

**Total [20Marks]**

**Question Five**

a) Figure Q1 shows a circuit diagram of a solar lamp used to charge the battery during the day and light the LEDs at night. The solar panel is rated 12V, 10W, each super white LED light 1 & 2 in the circuit is rated 2.5V, 1W and the Red LED is rated 2V, 20mA. The relay is rated 6V D.C. 100Ω. Diodes 1 to 3 are made of silicon (0.7V) and Battery is rated 6V, 4.5Ah.

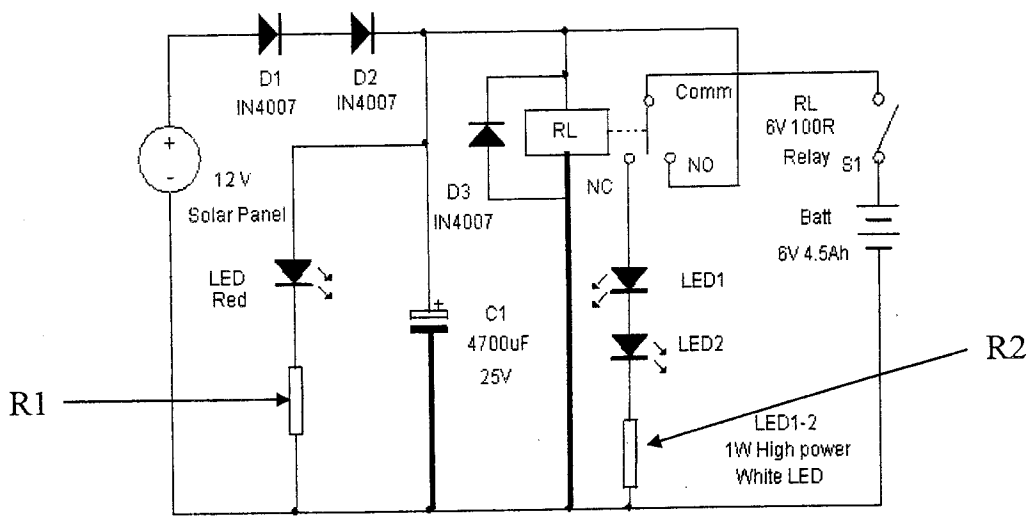


Figure Q1: Solar Lamp Circuit Diagram

**Calculate**

i. The number of hours that the battery can supply the two super white LEDs before it completely discharges. **[3Marks]**

ii. The value of limiting resistances R2 and R1. **[2Marks]**

iii. The number of hours required to charge the battery fully, if the battery was initially completely discharged. Assuming the panel is supplying constant power for 6 hours of sunshine. **[7Marks]**

iv. State one advantage and one disadvantages of connecting LED lights in series in line with the battery life and brightness of LED. **[2Marks]**

b) In the context of electrical and electronics diagram:

i. State any three uses of the circuit diagram. **[3Marks]**

ii. State the three main types of diagrams used in electrical and electronics to represent electrical systems or equipments. **[3 Marks]**

**Total [20 Marks]**

## SECTION B: YOU MUST ANSWER TWO (2) QUESTION FROM THIS SECTION

**Question Six**

A beam, which is supported through pin joints at its ends, is acted upon by a couple M in a plane containing the axis of the beam, applied at a point two thirds of the span from one end. Find expressions for the:

(a) slope of the beam at both ends **[10 Marks]**

**(b)** maximum deflection. **[10 Marks]**

**Question Seven**

A High performance car propeller shaft has external and internal $\phi_s$ of 10 cm and 9.8cm.

**(a)** What power can be transmitted at 7500 rpm with a maximum shearing stress of 83.5MN/ $m^2$ **[10 marks]**

**(b)** What will then be the twist in degrees of a 2.8m length of the shaft? Take G = 80GN/$m^2$.

**[10 marks]**

**Question Eight**

A 1m shaft carries 4 unbalanced masses spaced as follows:

Masses A, B, C, and D are 15, 12, 18, and 10kg respectively, rotating at radii 10, 15, 16, 12cm respectively, and spaced from one end of the shaft at 20, 40, 60, and 80 cm respectively. the angular spacing from A to B, C, and D are 60, 170, and 270° respectively.

(a) Balance the shaft using two 11 kg masses at either end **[20 marks]**

**END OF EEE3112 – EXAM**

THE UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATIONS

FINAL EXAMINATION-2021/2022

EEE 3132-COMPUTER ENGINEERING

**TIME: 3Hrs**

**INSTRUCTIONS**

**Answer all the Questions in Section A and *Two Questions only from Section B. Question Three is Compulsory.***

**Section A: Answer all the Questions**
**Question One.**

a) Explain what is meant by the following terms:

*i)* Class
*ii)* Object instance
*iii)* *Variables*
*iv)* Method overloading
*v)* Exception Handling

**[5 Marks]**

b) When would private and protected class members be used in an Object oriented program? Clearly distinguish between them with the help of a Sample program.

**[5 Marks]**

c) Differentiate between ordinary function and member functions in C++, Explain with a sample example

**[5 Marks]**

d) Explain how object oriented languages implement abstract data types.

**[5 Marks]**

**Question Two.**

a) Draw the block diagram of a computer's CPU at the level of registers, buses, and functional units. Your diagram must include a Program Counter, PC.

b) **[6 Marks]**

b) What is the purpose of a Program Counter (PC) in a computer?

**[2 Marks]**

c) Starting with the Program Counter (PC), explain how an instruction is fetched and executed.

**[2 Marks]**

d) Explain the five components of a data communication network.

1. Data
2. Sender
3. Receiver
4. Transmission Medium
5. Protocol **[10 Marks]**

**Section Two**
***Answer Two Questions only from this Section. Question Three is Compulsory***

**Question One**

1. The Fibonacci numbers are a sequence of integers starting 1, 1, generated such that every subsequent number is the sum of the previous two. For example, the third number in the Fibonacci sequence is 2 (because 1+1=2), and the fourth number is 3 (because 2+1=3).

Fibonacci numbers are used in several algorithms in Computer Science, including the Fibonacci Search and in the generation of fractals.

- In an object oriented programming language of your choice, create a class called **fibonacciClass** capable of holding Fibonacci numbers in an array called **F**.
- Include a data member called **currentNumbersHeld** that will record how many of the numbers are currently being held. Include a constant called **maxNumbers**, set to **100**, that stipulates the maximum number of Fibonacci numbers that can be held. At this stage, do not add any methods.

**[3 Marks]**

- Add a getter method that returns **currentNumbersHeld**.

**[2 Marks]**

- Add a method called **generateSequence** that will populate the array with the Fibonacci numbers accepting one integer argument, **N**, that specifies how many numbers to generate. Check that **N** is $\leq$ **maxNumbers**. If **N** exceeds **maxNumbers**, generate the maximum number of Fibonacci numbers.

**[3 Marks]**

d) Implement a method called **displaySequence** that will display the Fibonacci sequence currently stored in the array in the format

**F[1] = 1**
**F[2] = 1**
**F[3] = 2** and

so on.

**[2 Marks]**

**Question Two**

The fidelity of an audio clip is defined by a number of parameters, including the number of channels (1 or 2), the resolution (8, 16 or 24 bits per sample), and the sampling rate (22050, 44100, or 88200 samples per second).

a) In an object oriented programming language of your choice, write a definition for an audioClip class that contains:

(i) fields for storing the channels, resolution and sampleRate with appropriate visibility;

**[2 Marks]**

(ii) setter and getter methods for manipulating these fields, such that the setters methods ensure that channels can only have values 1 or 2, resolution can only have values 8, 16 or 32, and sampleRate can only have values 22050, 44100 or 88200;

**[2 Marks]**

(iii)a constructor that initialises new objects to have the lowest quality, where channels is set to 1, resolution is set to 8, and sampleRate is set to 22050.

**[2 Marks]**

b) Write a new method called isStudioQuality that will return true or false, depending upon whether the audio clip stored has the maximum possible quality (i.e., two channels, 24-bit resolution, and a sample rate of 88200 samples per second).

**[2 Marks]**

c) Write a new method called dataSize that accepts the duration that an audio clip lasts in seconds (as an integer), and returns the number of bytes that this audio clip would occupy on disk or in memory.

**[2 Marks]**

**Question Three**

1. Consider the following declaration and answer the questions given below:

```
class PPP
{
   int H:
 protected :
   int S;
 public :
   void input (int);
   void out();
};

class QQQ : private PPP
{
   int T;
 protected :
   int U;
 public :
   void indata(int, int);
   void outdata();
};

class RRR : public QQQ
{
   int M;
 public :
   void disp();
};
```

i. Name the base class and derived class of the class **QQQ**.

**[1 Marks]**

ii. Name the data member(s) that can be accessed from function **disp()**.

**[1 Marks]**

iii. Name the member function(s), which can be accessed from the objects of class **RRR**.

**[1 Marks]**

iv. Is the member function **out()** accessible by the object of the class **QQQ?**

**[2 Marks]**

2. In the University, a large amount of data is processed and the results are used in running the organization. The University management system maintains the list of colleges and their different streams along with the examination and result department. There are menus and sub menus in the output of the project which has given this project an organized look.

   To maintain the record of colleges, students, examination and result, the university management department prepares the record for each department, showing the total number of colleges and students. It also keeps track of any modification necessary related to students and colleges, and produces regular reports for the organization giving the total information required.

The university data file of this university management system project contains the following:

1. **Details of College information**: In this section, the project keeps the record of college id, college name, college location, college running the stream and the degree the college is running, and maintains the information in college.dat file.
2. **Details of Student information**: In this section, the university management system keeps the record of student id, student name, student address, father's name, contact number, degree stream, std code, and others relevant data.

The project is developed using the class and inheritance concepts of C++ programming language, data handling, and a number of user defined header files are used as well. Many data functions can be found in the project through which any one can know about any student or college by providing the respective student or college number.

**[10 Marks]**

3. Identify each method the Library class needs, giving the method name, return type, parameter types and any exceptions that should be thrown. For each method that throws exceptions write a pseudocode implementation of the method body showing why the exceptions are thrown.

**[5 Marks]**

**Screenshots:**

Listed below are the some sample output screens for the project outlook.

**UNIVERSITY MANAGEMENT SYSTEM**

1. ENTRY
2. DISPLAY
3. EQURY
4. MODIFICATION
5. PERFORMANCE
6. EXIT

**DISPLAY MENU**

1. COLLEGE
2. STUDENTS
3. EXAM FORM
4. EXAM SCHEDULE
5. RESULT
6. BACK TO PREVIOUS MENU

**COLLEGE-ENTRY**

1. DATE
2. COLLAGE ID
3. NAME
4. LOCATION
5. STREAM
6. DEGREE

DO U WANT TO SAVE THE RECORED?

ETC....

# THE UNIVERSITY OF ZAMBIA

## SCHOOL OF ENGINEERING

## DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATIONS

NOVEMBER 2022

# EEE 3352

## ELECTROMACHANICS AND ELECTRICAL MACHINES

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| | | |
|---|---|---|
| **TIME** | : | Three (3) hours |
| **INSTRUCTIONS** | : | Answer any five (5) questions |
| **ADDITIONAL INFORMATION** | : | *permeability of free space* $\mu_0 = 4\pi \times 10^{-7}$ H/m |
| | | *permittivity of free space* $\varepsilon_0 = 8.85\times 10^{-12}$ F/m |

---

**Question 1. [20 marks]**

(a) Derive from basic principles the expression for force per unit area due to an electric field.

**[8 marks]**

(b) Two identical copper plates measuring 20 cm and 10 cm acting as electrodes tightly enclose a slab of mica of thickness 2 mm and relative permittivity of 4. Find the

(i) capacitance of the arrangement from the point of view of the electrodes;

**[4 marks]**

(ii) force on the plates, if 1 kV dc is applied between the electrodes;

**[4 marks]**

(iii) stead-state rms value of the current through the mica, if 1 kV ac at 50 Hz is applied between the electrodes.

**[4 marks]**

**Question 2. [20 marks]**

(a) Derive the expression of the reluctance $S$ of a uniform magnetic circuit of constant cross-sectional area $A$, relative permeability $\mu_r$, length $l$. Hence derive the expression for inductance $L$, if the coil round the magnetic circuit has $N$ turns.

**[8 marks]**

(b) A magnetic core, in the form of a closed circular iron ring, has a mean length of 30 cm and a cross-sectional area of 4 $cm^2$. The relative permeability of iron is 2500.

(i) What dc current is needed in the coil of 500 turns wound around the ring to create a flux of 0.20 mWb in iron?

**[6 marks]**

(ii) If two gaps of 0.8 mm and 0.5 mm, respectively, are cut through the core perpendicular to the direction of the flux and positioned at diametric ends, what current is needed to have the same flux in the air gap as in the iron found in (i)?

**[6 marks]**

**Question 3. [20 marks]**

(a) Explain the causes of voltage variations at the output of a power transformer on load.

**[8 marks]**

(b) The results in Table Q3 were obtained for a 50 kVA, 50-Hz, 1900/240-V transformer.

Table Q3

| | Measurement side | Voltage (V) | Current (A) | Power (W) |
|---|---|---|---|---|
| Short circuit test | High voltage | 100 | 26 | 800 |

What is the regulation of the transformer, when delivering full load at 0.8 power factor lagging and rated primary voltage?

**[12 marks]**

[redacted]ages of having a three-phase system compared to a single-phase system in a power network.

**[6 marks]**

(b) A star-connected balanced load is supplied from a three-phase supply with a line voltage of 400 V at a frequency of 50 Hz. Each phase of the load consists of a resistance and a capacitor connected in series and the two wattmeters connected to measure load power supplied read 900 W and 2300 W, both positive. For this circuit, what is the

(i) power factor;

**[5 marks]**

(ii) line current;

**[5 marks]**

(iii) capacitance of each capacitor?

**[4 marks]**

**Question 5. [20 marks]**

(a) From "$v = Blu$", where $l$ is the length of a conductor, cutting a magnetic field of density $B$ at constant speed $u$, and experiences an induced voltage $v$, derive the expression for the brush terminal voltage for a commutator machine.

**[8 marks]**

(b) A separately-excited generator has the magnetisation characteristic which gives a no-load voltage of 200 V when driven at 3000 rpm at rated field excitation. The total armature circuit resistance is 0.10 Ω. If the generator supplies a load current of 100 A, determine the

(i) terminal voltage;

**[3 marks]**

(ii) power output;

**[3 marks]**

(iii) the electromagnetic power;

**[3 marks]**

(iv) electromagnetic torque input.

**[3 marks]**

**Question 6. [20 marks]**

(a) Three phase ac machines operate on the principle of a "rotating" magnetic flux. Describe the principal features which establish the ac machine as either an induction machine or a synchronous machine.

**[4 marks]**

(b) A 3-phase, 6-pole induction motor operates on a 50-Hz supply. The frequency of the rotor-induced current is 2 Hz. What is the

(i) slip;

**[2 marks]**

(ii) speed of the rotor;

**[2 marks]**

(iii) speed of the rotating mmf with respect to the rotor and with respect to the stator?

**[2 marks]**

(c) With the help of mmf, voltage and current phasor diagrams explain the operation of an ideal synchronous machine in generating mode.

**[10 marks]**

**Question 7. [20 marks]**

(a) With the help of equivalent circuits, predict the torque-speed characteristic of the DC Shunt motor.

**[6 marks]**

(b) Describe the problem of starting d.c. machines and explain, with a suitable sketch, how it is overcome in practice.

**[4 marks]**

(c) The no-load armature current of a 220-V d.c. shunt motor is 1.8 A at a speed of 1200 r/min. If the full-load armature current is 40 A, find the full-load speed and the torque developed. Assume that the armature resistance is 0.10 Ω and the field flux remains unchanged.

**[10 marks]**

**Question 8. [20 marks]**

(a) Deduce the expression for the relation between the illumination $E$ and any point on a plane surface due to a light source of luminous intensity $I$, suspended at height $h$ from the surface.

**[6 marks]**

(b) Two lamps with a rating of 100 W each, with a lamp efficacy of 80 lm/W, are mounted on two lamp posts 10 m apart. The posts have heights of 4 m and 5 m, respectively. Calculate the illuminance at a point mid-way between the lamp posts.

**[8 marks]**

(c) It is required to provide an illuminance of 100 lx in a factory hall of area 24 m x 12 m. Assume that the maintenance factor is 0.8 and the utilisation factor is 0.6 and the efficacy of the proposed 50-W lamps is 80 lm/W. What is the number of lamps needed?

**[6 marks]**

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**END OF EEE 3352 EXAMINATION**

# THE UNIVERSITY OF ZAMBIA

## SCHOOL OF ENGINEERING

## DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATIONS

**2022 ACADEMIC YEAR EXAMINATION**

# EEE 4242

## ELECTRICAL INSTRUMENTATION

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| | | |
|---|---|---|
| **TIME** | : | THREE (3) hours |
| **INSTRUCTIONS** | : | Answer Five questions only |
| **ADDITIONAL INFORMATION** | : | |

---

**Question one**

a) What is a dimension of a physical quantity? Derive the dimension of Force and Power **[1, 2, 2 Marks]**

b) A capacitor has a nominal value of 220pF ±5pF. If it was measured as 216pF ±1%, postulate a value for the capacitor, together with its possible tolerance. **[5 Marks]**

c) What is the difference between static and dynamic characteristics? Why do dynamic characteristics of an instrument or sensor have to be considered? Explain briefly the following terms related to static characteristics of an instrument: repeatability/reproducibility, zero drift and sensitivity. **[6 Marks]**

d) Mathematically express the general model for a measurement system and show how a first order instrument may be derived from the same model. **[2,2Marks]**

**Question two**

a) A thermometer, idealized as a first order system with a time constant of 2.2s is suddenly given an input of 160°C from 0°C.
   i) What will be the reading of a thermometer after 1.2s? **[2 Marks]**
   ii) Determine its reading if it is initially held at 20°C. **[2 Marks]**

b) A resistance temperature detector has a steady state gain of 2.96Ω/°C and a time constant of 4.8 seconds. It is subjected to step change of 80°C in temperature. If its stable resistance before the step change is 90Ω, write down the time-domain equation for the resistance and find its value after 12s of application of step input. **[4 Marks]**

c) A temperature sensitive transducer used to measure the temperature of a furnace has been modeled as a first-order instrument and subjected to a ramp input. If the time constant for the maximum permissible dynamic error is 19.5s, calculate the dynamic error. **[4 Marks]**

d) Find the two parameters of interest when determining frequency response of a first-order instrument with a time constant of 0.2s. Taking the input signals as $x(t) = 0.2\sin t$ and $x(t) = \sin 3t + 0.5\sin 10t$. **[4 Marks]**

e) From the mathematical model of a measurement system in Q1.d, formulate a Second-order instrument. State parameters of interest and how they can be determined. **[4 Marks]**

**Question three**

a) Define signal conditioning? **[1 Mark]**

b) Design an amplifier to condition a signal from LM35 temperature sensor which has an output of 10mV/°C. The output of the amplifier should be 1v/°C. Assume an input resistance of 2.2 KΩ **[4 Marks]**

c) A two-position mode controller is used to control the water level in a tank by opening or closing a valve which in the open position allows water at the rate of 0.4 $m^3/s$ to enter the tank. The tank has a cross sectional area of 12 $m^2$ and water leaves it at the constant rate of 0.2 $m^3/s$, the valves opens when the water level reaches 4.0 m and closes at 4.4 m. Calculate:-

i) the dead band(level) **[1 Mark]**
ii) What will be the time taken for the valve opening to closing **[2 Marks]**
iii) What will be the time taken the valve closing to opening **[2 Marks}**

d) Derive the transfer function of a PID controller (Clearly showing the constants of proportionality) given in Fig Q3. **[10 Marks]**

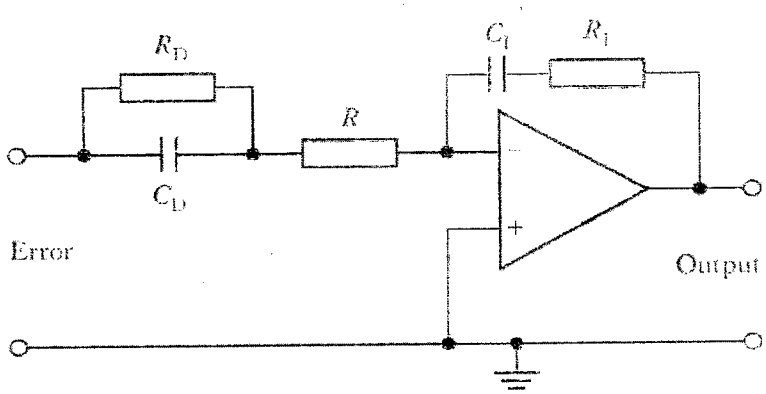


**Figure Q3. PID Controller**

**Question four**

a) Define Nyquist criterion or Shannon's sampling theorem. **[1 Mark]**

b) Design an anti-aliasing filter to be used as a signal conditioning circuit for a data acquisition system. The system should be able to load five input signals given as follows:

F1 = 1 kHz, f2 = 2 kHz, f3 = 5 kHz, f4 = 9 kHz, f5 = 11 KHz. Choose the resistor value for the filter as 2 KΩ. **[5 Marks]**

c) Describe with the help of diagram why sample and hold circuit (ZOH) is important in sampled data systems. **[2 Marks]**

d) Design a four bit (4 bits) weighted digital to analogue converter (DAC) that has 0.1 V resolution. Make the feedback resistor Rf = 10 KΩ. **[12 Marks]**

**Question five**

a) Describe briefly a 4 ½ digital display for digital volt meters. **[3 Marks]**

b) How would you represent 15.95 on a 20V range and 0.7562V on a 1V and 10V ranges respectively. **[3 Marks]**

c) Determine as a percent of error in a reading of 16.5 V given by the digital voltmeter that has a full scale reading of 99.9 V and accuracy specification of ±( 0.1% of reading ). **[2 Marks]**

d) Describe briefly with the help of a block diagram the working principle of the following:

i) A combined d.c and a.c digital volt meter **[6 Marks]**

ii) Frequency Meter **[6 Marks]**

**Question six**

a) Define repeatability of an instrument. **[2 Marks]**

b) If the standard deviation for 10 readings obtained from measurement of the output of a power supply is 0.8, determine the % repeatability of the measuring instrument having a full scale range output of 10 V. **[ 6 Marks]**

c) Comment on the result obtained in Q6.b regarding the repeatability of the instrument. **[2 Marks]**

d) A resistance box has the following components and tolerances:

10 resistors each of 100KΩ ±0.05%,

10 resistors each of 10KΩ ±0.05%,

10 resistors each of 1KΩ ±0.05%,

10 resistors each of 100Ω ±0.05%,

10 resistors each of 10Ω ±0.05%.

Determine both in ohms and as a percentage, the limit of uncertainty in a setting of 453.72 KΩ **[10 Marks]**

**Question seven**

The differential equation of a process plant, initial conditions, and computer voltage are given below:

$$5\frac{d^2x}{dt^2}+10\frac{dx}{dt}+20x=ft$$

The initial contions are: x(0) = 5cm and $\frac{dx}{dt}(0)=0$. Computer voltage is assumed to be 10 volts.

Develop an analog computer to simulate the process plant by:

a) Modify the above differential equation letting ft = 0. **[2 Marks]**

b) Prepare the scaling table for the variables assuming estimated maximum values to be x = 5cm, $\frac{dx}{dt}$ = 10cm/s, and $\frac{d^2x}{dt^2}$ = 20cm/s$^2$. **[3 Marks]**

c) Draw the computer circuit. **[10 Marks]**

d) If the time scale factor is β = 10, develop a time scaled computer. **[5 Marks]**

**End of Exam**

# THE UNIVERSITY OF ZAMBIA

## SCHOOL OF ENGINEERING

## DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATIONS

2021/22 ACADEMIC YEAR – November 2022

# EEE 4352

## ELECTRICAL MACHINES I

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**TIME** : Three (3) hours

**INSTRUCTIONS** : Answer any **five (5)** questions

: All questions carry equal marks **[20 marks]**

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## QUESTION 1

**1.1** What do you understand by parallel operation of transformers? What is its necessity? **[4 marks]**

**1.2** What are the conditions necessary for parallel operation of two three-phase transformers? **[4 marks]**

**1.3** Why is a tertiary winding also called auxiliary winding and stabilising winding? **[2 marks]**

**1.4** A 3300/400/110-V star-star-delta transformer take a magnetizing current of 6A and a balanced three-phase load of 750 kVA at pf 0.8 lagging and 200 kVA at 0.6 pf leading on the tertiary. Determine the primary current and its angle. **[10 marks]**

**[TOTAL: 20 MARKS]**

## QUESTION 2

**2.1** What is commutation in d.c. machines? **[2 marks]**

**2.2** What is critical speed in a d.c. shunt generator? **[2 marks]**

**2.3** A 150-kW, 250-V, 6-pole lap wound generator has 600 conductors on its armature. Due to armature reaction if the MNA are shifted by 18° electrical, determine:

i. Demagnetising ampere-turns

ii. Cross-magnetising ampere-turns **[4 + 4 marks]**

**2.4** The shaft torque required to drive a d.c. generator is 32 N.m when it is running at 1550 rev/min. If its efficiency is 91% under these conditions and the armature current is 21.5 A, determine the voltage at the terminals of the generator. **[8 marks]**

**[TOTAL: 20 MARKS]**

## QUESTION 3

**3.1** What do you mean by "energy loss" in a machine? **[2 marks]**

**3.2** What is back emf? Give its significance. **[2 marks]**

**3.3** What are the possible causes of sparking at brushes? **[3 marks]**

**3.4** A 6-pole, 250-V series motor is wave-connected. There are 240 slots and each slot has four conductors. The flux per pole is 17.5 mWb when the motor is taking 80 A. The field resistance is 0.05 Ω, the armature resistance is 0.1 Ω and the iron and frictional loss is 0.1 kW. Calculate:

i. Speed

ii. Base horse power of the motor

iii. Shaft torque **[6 + 3 + 4 marks]**

**[TOTAL: 20 MARKS]**

## Question 4

**4.1** Define the term over-excitation and under-excitation with reference to synchronous machines. **[2 marks]**

**4.2** Give any three (3) advantages of having a rotating field system over stationary field system in synchronous machines. **[3 marks]**

**4.3** A three-phase, star-connected 1200-kVA, 3300-V, 50-Hz, alternator has armature resistance of 0·25 ohm per phase. A field current of 40 A produces a short circuit current of 200 A and an open circuit emf of 1100 V between lines. Calculate the synchronous reactance $X_s$ of the machine. **[5 marks]**

**4.4** A 3-phase, star-connected synchronous generator is rated at 1200 kVA, 11 kV. On short-circuit a field current of 55 A gives full-load current. The OC voltage with the same excitation is 1580 V/phase. Calculate the voltage regulation at

i. 0.8 lagging and

ii. 0.8 leading power factor. Neglect armature resistance. **[5 + 5 marks]**

**[TOTAL: 20 MARKS]**

## Question 5

**5.1** Explain two important functions served by damper winding in a synchronous motor. **[2 marks]**

**5.2** Why is a synchronous motor designated as power factor improving device? **[2 marks]**

**5.3** Mention three (3) characteristic features of synchronous motor. **[2 marks]**

**5.4** How can a synchronous motor be used as a synchronous condenser? **[2 marks]**

**5.5** A 6-pole, 3-phase, 50-Hz synchronous motor is supplied from 6.6 kV busbars. Its open-circuit voltage is 3.3 kV/phase. The per phase resistance and synchronous reactance are 0.6 W and 4.8 W respectively. Calculate the current, power factor and torque developed, when the excitation emf lags the busbar voltage by 25° (elect). **[12 marks]**

**[TOTAL: 20 MARKS]**

## Question 6

**6.1** What is the major difference between a synchronous motor and an induction motor? **[2 marks]**

**6.2** Give three (3) reasons why the rotor of an induction motor is skewed? **[3 marks]**

**6.3** Draw the equivalent circuit of an induction motor. **[2 marks]**

**6.4** A 3-phase induction motor has a 6-pole, delta-connected stator winding. The motor runs at a line voltage of 415 V, 50-Hz supply. The motor resistance and stand-still reactance per phase are 0.25 ohm and 2 ohms respectively. The ratio of stator to rotor turns is 4. Calculate:

i. Starting torque;

ii. Full load torque, when the slip is 5%;

iii. Slip at which maximum torque occurs and rotor speed;

iv. Maximum torque; **[7 + 2 + 2 + 2 marks]**

**[TOTAL: 20 MARKS]**

## Question 7

**7.1** Which of the following is not a transformer specification? **[2 marks]**

a. Overload capacity

b. Rated power

c. Noise level

d. None of the above

**7.2** Which of the following makes testing of an electrical equipment/system vital? **[2 marks]**

a. Not all faults will be easily visible

b. Because it is easier to do

c. The test equipment is cheap

d. All of the above

**7.3** When is testing most suitably done? **[2 marks]**

a. At the beginning of the work

b. At the completion as well as during the installation process

c. At completion of work

d. none of the above

**7.4** Which of the following define an Electrical test? **[2 marks]**

a. Parametric

b. Functional

c. Timing performance

d. All of the above

7.5 During transformer testing, various instruments are used, which of the following is used to measure HV – Earth insulation resistance? **[2 marks]**

a. Multimeter

b. Megger

c. Clamp leaker

d. Ohm meter

7.6 Given that a transformer has winding taps made of correct turns and proper tap connections, what allowable value of the name plate data should the ratio test display? **[2 marks]**

a. ±2.5% of the value indicated on name plate

b. ±0.55% of the value indicated on name plate

c. ±0.5% of the value indicated on name plate

d. ±1.5% of the value indicated on name plate

7.7 What does the Magnetic balance test indicate? **[2 marks]**

a. The amount of moisture in transformer insulation

b. Machine standard

c. Noise level

d. Flux distribution in the core

7.8 Given the magnetic balance test results shown in table 7.8, would you say that the transformer has a magnetic balance? **[2 marks]**

Table 7.8

| **Tap No.** | **Voltage applied across** | **Voltage measured (V)** | | |
|---|---|---|---|---|
| | | **R-Y** | **Y-B** | **R-B** |
| **1** | **R-Y** | 400 | 284.4 | 115.0 |
| | **Y-B** | 190.3 | 402 | 210.6 |
| | **R-B** | 124.8 | 275.7 | 401 |

a. Yes

b. No

7.9 From the magnetizing current test, what value of the no load current is acceptable? **[2 marks]**

a. ≤4.5% of the rated current

b. 5.0% of the rated current

c. ≤4.0% of the rated current

d. None of the above

**7.10** Given a 0.5-kV Induction motor, what value of d.c. acceptance and d.c. maintenance test voltage is required during over – potential testing respectively? **[2 marks]**

e. 1920 V, 2560 V

f. 1920 V, 2880 V

g. 2560 V, 1920 V

h. 2560 V, 2240 V

**[TOTAL: 20 MARKS]**

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**END OF EEE 4352 EXAMINATION**

# THE UNIVERSITY OF ZAMBIA

## SCHOOL OF ENGINEERING

## DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATIONS

November 2022

# EEE 4362

## ELECTRICAL POWER SYSTEMS I

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Solutions

## QUESTION 1: SOLUTIONS

a) **[1Marks]**

- The use of bundled conductors for transmission or distribution lines leads to reduction in the overall inductance of the line due

b) to increase in the cross section area of the conductor.

**[2Marks]**

Transmission Line Voltage Levels in Zambia

- 330kV
- 220kV
- 132kV
- 88kV
- 66kV

c) **True (T) or False (F)** **[5Marks]**

1. TRUE
2. TRUE
3. FALSE
4. TRUE
5. FALSE

d) Discuss with reasons: **[12Marks]**

i.

- The AC current is not uniformly distributed due to skin effect causing the cross section area of conductor to reduce thus increasing the overall AC resistance of a conductor

ii.

- In bundled conductor overall cross section area increases due to increases in geometrical mean radius as compared to single conductor lines thus lowering the overall conductor inductance of the conductor.

iii.

- The 3 phase distribution line require 4 wire circuit which is essential for single phase loads connections while for 3 phase 3 wire circuit transmission line is economical and there is no connection of single phase loads at transmission lines thus, the neutral line is not essential for transmission line.

iv.

- The availability of reactive power flow in the line increase the voltage drops in the line, thus to maintain a good voltage profile on the line, the control of reactive power flow is necessary.

v.

- A long line draws substantial amount of charging current. Thus, if such a line is open circuit or very lightly loaded at the receiving end, the voltage at the receiving end may become higher than the sending end voltage due to Ferranti Effect. Both C and L are necessary to produce this phenomenon.

vi.

- Long lines leads to increase in reactive power due to presence of inductive and capacitive reactance in the line which leads to high voltage drops and power loss. Hence, to compensate for the losses and reduces voltage drop due to reactive power there is always a need for reactive power compensation.

**Total [20Marks]**

## QUESTION 2: SOLUTIONS

**a) SOLUTION** **[5MARKS]**

### ➢ Disadvantages of HVAC

- Requires more copper
- Construction of power lines is more complicated
- A.C lines have capacitances thus there is a continues loss of power due to charging current even when the line is open
- High voltage drop V=I Z for the same load and sending voltage
- Requires large land for right of way

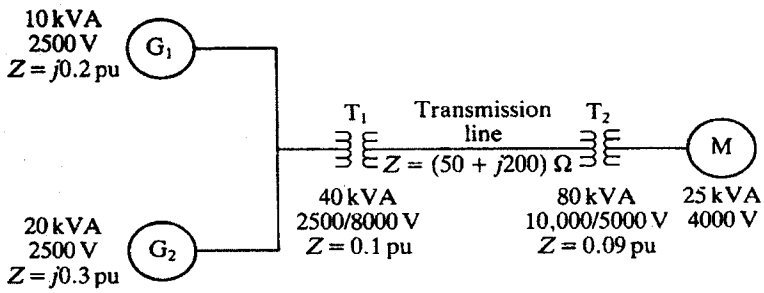
### ➢ Advantages of HVAC

- Able to transmit power at high voltage
- A.C s/s are cheap and easy to maintain
- Power transmitted can be stepped up or down by a transformer

**b) SOLUTION** **[8MARKS]**

### Per Unit Representation

**References: $S_{ref}$= 50kVA (3-Phase) $U_{3ref}$= 2.5kV (Line-to-line)**




**Generator 1:** **Generator 2:** **Transformer 1:**

**Transformer 2:**

S=10kVA S=20kVA S=40kVA

S=80kVA

U=2.5kV U=2.5kV U=2.5/8kV

U=10/5kV Z= j0.2pu Z= j0.3pu Z=0.1pu

Z=0.09pu

**Transmission Line:** ( 50+j200)Ω

$$Z_{punew} = \left(Z_{puold}\right) * \left(basekV_{old}/basekV_{new}\right)^2 * \left(basekVA_{new}/basekVA_{old}\right)$$

**Generator 1:**

$Z_{punew}$= 0.2(50/10)= j1.0 pu

**Generator 2:**

$Z_{punew}$=0.3(50/20)=j0.75pu

**Transformer 1:**

$Z_{punew}$=0.1(50/40)=j0.125pu

**Transformer 2:**

$Z_{punew}$=0.09(10/8)$^2$(50/80)=j0.0879pu

**Transmission Line**

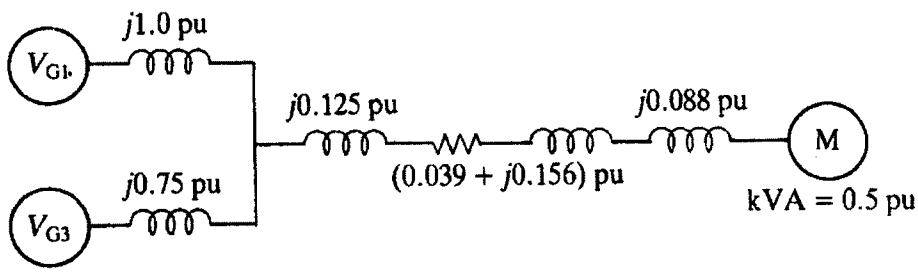
$Z_{ref}=U_{ref}^2/S_{ref}$ =8000$^2$/50000=1280Ω

$Z_{pu}=Z_{actual}/Z_{ref}$ =(50+j200)/1280=0.0391+j0.156 pu

**Motor:**

$kVA_{pu}=kVA_{actual}/kVA_{ref}$= 25/20 =0.5pu

1) **Impedance diagram of the power system**




c) **SOLUTION** **[7MARKS]**

**Four ways of Classifying Transmission Lines & Types of Conductors**

- **Transmission lines can be classified according to:**
  - **I. Circuit scheme**
    1. Single circuit- contains single three phase circuit
    2. Double Circuit-contains two three phase circuits
    3. Multi circuit-contains more than two three phase circuits

II. **Nature of current**

1. HVDC-underground cable or overhead.
2. HVAC-underground cable or overhead.

III. **Voltage levels**

1. In typical Zambian scenario, transmission voltages are: -330kV, 220kV, 132kV, 88kV, 66kV

IV. **Distance**

Transmission lines can be categorized into

1) Short transmission lines L< 80km
2) Medium transmission lines 80< L<240km
3) Long transmission lines L>240km

➢ **Types of Conductors used for transmission line**

1) **Copper:**
2) **ACSR:**-Aluminum Conductor Steel Reinforced Strands:
3) **AAAC:** -All Aluminum Alloy Reinforced strands:
4) **ACAR**: Aluminum Conductor Al Alloy Reinforced
5) **Expanded ACSR**: Same as ACSR but btn steel core and aluminum some filler materials usually paper or fiber are are added to increase conductor diameter

## QUESTION 3: SOLUTIONS

a) **SOLUTIONS** **[2.5MARKS]**

- Magnitude and phase of voltage
- Magnitude of real and reactive power flowing in each line
- Magnitude of real and reactive power line losses
- Initial conditions of the system when transient behaviour of the system to be studied

b) **SOLUTIONS** **[2.5MARKS]**

a. Transposition of a transmission line refers to placing each phase conductor in each position along the transmission line as shown below

**b.** To prevent unbalanced current and voltages due to line geometric asymmetry, three phase lines are transposed in positions as shown in diagram in above

- To make the magnitude of the shunt current and voltages drops along the lines for each phase equal.
- To make sure voltage and current at receiving end to be in balance, .i.e giving balanced sending end voltages and currents for three phases

c) **SOLUTION** **[3MARKS]**

❑ **Skin effect:** tendency of AC to concentrate near the surface of a conductor.

❑ **Factors Contributing to skin effect**

➢ Nature of material
➢ Diameter of wire: increases with diameter of wire

- Frequency: increases with increase in freq.
- Shape of wire: less for stranded conductor than for a solid conductor

**d) SOLUTIONS:** **[7MARKS]**

(i) Solution

p=1.73 x $10^{-6}$ohm-cm=1.73 x $10^{-8}$ohm-m
l=1km=1000m
Copper Area=1.5cm$^2$=1.5x$10^{-4}$ m$^2$
R=pl/a=(1.73 x $10^{-8}$ohm-m x 1000m)/1.5x$10^{-4}$ m$^2$=0.1153ohm/km
r=0.5x39.8x$10^{-3m}$=1.99x$10^{-2}$m
L=0.4605log(8/(0.7788x1.99x$10^{-2}$))=1.25mH/km
C=0.02412/(log(8/1.99x10-$^{2}$))=0.00926uF/km

(ii) Solution

Inductive Reactance $X_L$=2πfLl=2π x 50 x 240 x 1.25x$10^{-3}$=94.25Ω
Capacitive Reactance $X_C$=1/2πfCl=1/(2πx50x0.00926x$10^{-6}$x240)=1,432Ω

**e) SOLUTION** **[6MARKS]**

2 Conductor

$$D_s = \sqrt[4]{(r' \times d)^2} = \sqrt[2]{r' \times d}$$

r'=0.7788x3.53=2.75cm
$D_S$=(2.75 x 45)$^{1/2}$=11.12cm
$D_{eq}$=($D_{AC}D_{AB}D_{CB}$)$^{1/3}$=(11.3x11.3x22.6)$^{1/3}$= 28.86m
L=0.4605log ($D_{eq}/D_s$)
=0.46605log (28.86x100/11.12)
=10.12mH/km
C=0.02412/(log($D_{eq}$ /$D_s$)
=0.02412/(log(28.86x100/11.12))
=0.02412/0.2171
=0.1111μF/km
$I_C$=jω$CV_{LN}$=2πf$CV_{LN}$
=2πx50x0.1111x$10^{-6}$x(400x$10^3$/(3)$^{1/2}$)
=8.06A/km

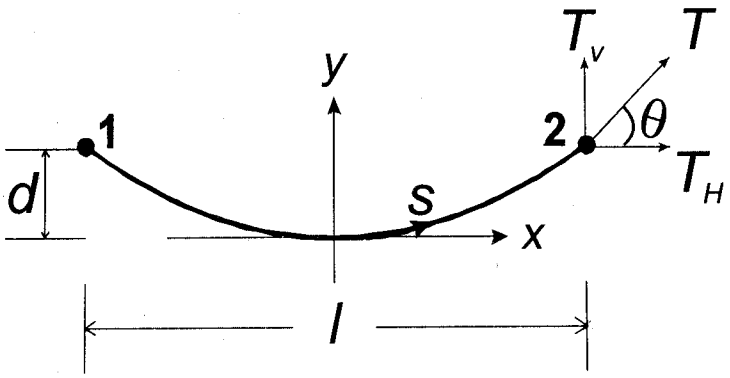
## QUESTION 4: SOLUTIONS [20 marks]

(a) Derive, with a definition of terms, the general expressions for the:
(i) length of conductor;
(ii) maximum sag of the conductor, and
(iii) maximum tension in a conductor,
in a span of overhead line supported at equal heights.

**[10 marks]**

---------- Answer ----------

Present definition of x, y, l, s, ω, TH, TV, T, d and show sketch as follows:




In this situation s ≠ x:

$$\frac{dy}{dx} = \frac{T_V(x)}{T_H(x)} = \frac{\omega s}{T_H};$$

$$ds^2 = dy^2 + dx^2$$

$$\left[\frac{ds}{dx}\right]^2 = \left[\frac{dy}{dx}\right]^2 + 1$$

$$dx = \frac{ds}{\sqrt{1+\left(\frac{\omega s}{T_H}\right)^2}};$$

$$x = \frac{T_H}{\omega}\sinh^{-1}\left(\frac{\omega s}{T_H}\right) + c_1$$

at x = 0, s = 0 and c1 = 0

Length of conductors, for 1/2S, x =l/2

$$s = \frac{T_H}{\omega}\sinh\frac{\omega x}{T_H}$$

(i) length

$$S = 2\frac{T_H}{\omega}\sinh\frac{\omega l}{2T_H}$$

$$\frac{dy}{dx} = \frac{\omega s}{T_H} = \sinh\frac{\omega x}{T_H}$$

$$y = \frac{T_H}{\omega}\cosh\frac{\omega x}{T_H} + c_2$$

at y = 0, x = 0 and c2 = -TH/ω

$$y = \frac{T_H}{\omega}\left(\cosh\frac{\omega x}{T_H} - 1\right)$$

Maximun sag d occurs at x = l/2

(ii) maximum sag

$$s = \frac{T_H}{\omega}\left(\cosh\frac{\omega l}{2T_H} - 1\right)$$

$$T^2 = T_H^2 + T_V^2$$

$$= T_H^2 + (\omega s)^2$$

$$= T_H^2\left(1 + \sinh^2\frac{\omega x}{T_H}\right)$$

$$= T_H^2 \cosh^2\frac{\omega x}{T_H}$$

$$T = T_H \cosh\frac{\omega x}{T_H}$$

Maximum tension Tmax occurs at x = l/2

(iii) maximum tension

$$T_{max} = T_H \cosh\frac{\omega l}{2T_H}$$

[4+3+3 marks]

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(b) A transmission line has a span of 200 m and phase conductors with a breaking capacity of 150 kN. Determine the maximum vertical sag of the conductor for a safety factor of 2.5, given that the weight of the conductor is 15 N/m and that there is a wind with a pressure of 300 N/m$^2$ acting over the projected areas of the conductors. The overall diameter of the conductor is 2.5 cm.

**[10 marks]**

---------- Answer ----------

$l$ = 200 m, $D$ = 2.5 cm; $\omega_c$ = 15 N/m; $T_{max}$ = 150 x $10^3$N, S.F. =2.5, Press$_w$ = 300 N/m2

$\omega w$ = 300 x 2.5 x $10^{-2}$ = 7.5 N/m

$$\omega = \sqrt{\omega_c^2 + \omega_w^2} = \sqrt{15^2 + 7.5^2} = 16.8 \text{ N/m}$$

$$\theta = \tan^{-1}\frac{7.5}{15} = 26.6^o$$

$$\cosh\frac{\omega l}{2T_H} \approx 1+\frac{\omega^2 l^2}{8T_H}$$

$$T_{\max} = T_H \cosh\frac{\omega l}{2T_H} \approx T_H + \frac{\omega^2 l^2}{8}$$

$$T_H^2 - T_{\max}T_H + \frac{\omega^2 l^2}{8} = 0$$

$$T_H = \frac{T_{\max}}{2} \pm \sqrt{\left(\frac{T_{\max}}{2}\right)^2 - \frac{\omega^2 l^2}{8}}$$

$$T_H = \frac{150\times10^3}{2} \pm \sqrt{\left(\frac{150\times10^3}{2}\right)^2 - \frac{16.8^2\times200^2}{8}} = \underline{\underline{149{,}990 \text{ N}}} \text{ or } 9.4 \text{ N}$$

$$d = \frac{T_H}{\omega}\left(\cosh\frac{\omega l}{2T_H} - 1\right) = \frac{149990}{16.8}\times\left(\cosh\frac{16.8\times200}{2\times149990} - 1\right) = \underline{\underline{0.56 \text{ m}}}$$

$$d_{vertical} = 0.56\cos 26.6^\circ = \underline{\underline{0.53 \text{ m}}}$$

---

## QUESTION 5: SOLUTIONS [20 marks]

(a) Show and justify how the four-step systematic method for fault calculation can be a reduced a two-step method.

**[6 marks]**

---------- Answer ----------

Systematic method for large network:

Step 1: Obtain steady-state solution of loaded system;

Step 2: Obtain a Thevenin network at point of fault by-
(a) replacing reactances of synchronous machines by their subtransient reactances
(b) short-circuiting all EMF sources;

Step 3: Excite the Thevenin network of step 2 by a negative of prefault voltage;

Step 4: Obtain fault current by adding results of step 1 step 2.

Assumptions:

1. Steady-state currents of loaded system can be neglected as fault current is much greater than load current of step 1.
2. Prefault voltages may be taken to be 1 pu, as steady-state voltage of step 1 does not vary much from rated value of 1 pu.
3.

These assumptions eliminate step 1 and 4

---

(b) A three-phase short-circuit occurs at the motor bus (bus 2) in the network shown in Figure Q5. The generator is operating at its rated voltage and prefault current may be

neglected. Using the superposition/Thevenin method as applied to large networks, calculate the

(i) subtransient fault current;

**[10 marks]**

(ii) fault current contributed by the motor.

**[4 marks]**

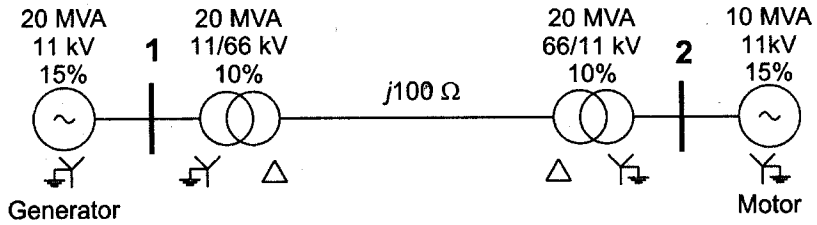
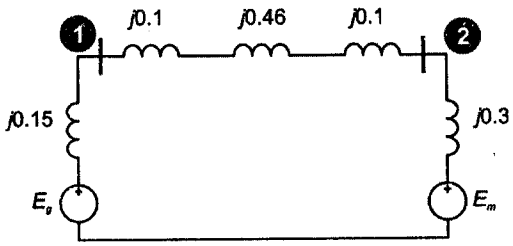
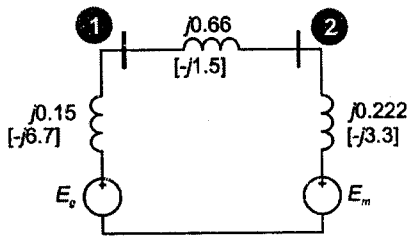



**Figure Q5. Two-bus power network**

---------- Answer ----------




$$I_{base} = \frac{20\times10^6}{\sqrt{3}\times11\times10^3} = 1050 \text{ A}$$

$$\mathbf{Y}_{\text{bus}} = j\begin{bmatrix} -8.2 & 1.5 \\ 1.5 & -4.8 \end{bmatrix} \text{ p.u.} \qquad \mathbf{Z}_{\text{bus}} = j\begin{bmatrix} 0.13 & 0.04 \\ 0.04 & 0.22 \end{bmatrix} \text{ p.u.}$$

$$I_F'' = \frac{V_F}{Z_{11}} = \frac{1\angle0^\circ}{j0.13} = \underline{\underline{-j7.7 \text{ pu} = 8083 \text{ A}}}$$

---

(iii)fault current through the transmission line.

**[4 marks]**

----------ANSWER----------

$$V_1 = \left(1-\frac{Z_{11}}{Z_{11}}\right)V_F = 0; \quad V_2 = \left(1-\frac{Z_{21}}{Z_{11}}\right)V_F = \left(1-\frac{0.04}{0.13}\right)\times1\angle0^\circ = 0.7\angle0^\circ$$

$$I_{12} = \frac{V_1 - V_2}{Z_{1-2}} = \frac{0-0.7\angle0^\circ}{j0.66} = \underline{\underline{j1.0 \text{ pu} = 1050 \text{ A}}}$$

---

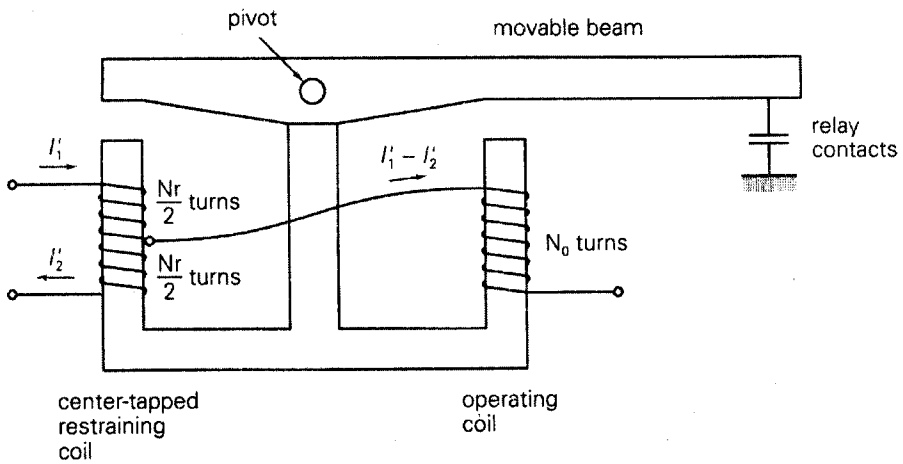
## QUESTION 6: SOLUTIONS [20 marks]

(a) Using suitable derivations and illustrations, show how a balance beam differential relay may be used to vary the sensitivity of the current picked from two points that define a protected zone.

**[5 marks]**

----------ANSWER----------

Realisation of balanced-beam differential relay:




Force $\propto$ mmf$^2$

$$\left[N_0(I_1' - I_2')\right]^2 > \left[N_r(I_1' + I_2')/2\right]^2$$

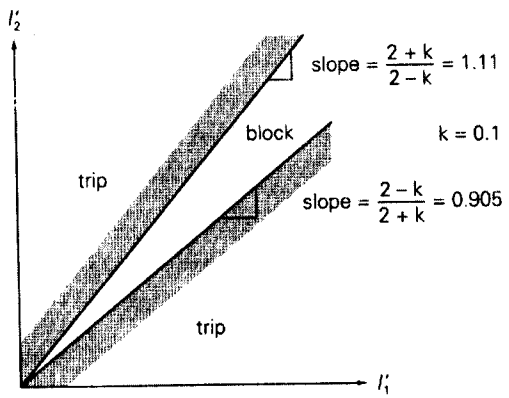
$$\left|I_1' - I_2'\right| > k\left|(I_1' + I_2')/2\right|$$

$$k = N_r / N_0$$

Assumming $I_1$'and $I_2$' are in phase

$$I_2' > \frac{2+k}{2-k} I_1' \text{ for } I_2' > I_1'$$

$$I_2' < \frac{2-k}{2+k} I_1' \text{ for } I_2' < I_1'$$



As $k$ changes, so does the block region (in proportion) and the sensitivity of the relay accordingly changes.

---

(b) Describe the use of the plug setting multiplier and time multiplier setting in an IDMT over-current relay.

**[5 marks]**

----------ANSWER----------

General characteristic is given for operating time $t$ when current is $I$ as

$t = \dfrac{k\theta}{I^2 - I_0^2}$ where $\theta$ is the angle of separation of the contacts and $I_0$ is the pick-up current.

Plug Setting: controls $I_o$, varies between 50%-200% in steps of 25%, and is associated with current grading

Time Multiplier Setting: controls $\theta$, varies between 0.1 – 1.0 continuously, and is associated with time grading

Adjacent protective schemes are time-graded to give back-up facility to subsequent relays downstream of feeder.

Discrimination time is chosen to let relay operate in shorter time for fault on own bus and longer time for faults in sections covered by relays downstream

---

(c) Consider a 220-kV transmission system shown in Figure Q6. The per phase impedances of the lines L12 and L23 are 2 + j20 and 2.5 + j25 Ω, respectively. The outputs of the CT and VT are standardised at 5 A and 110 V, respectively. If the maximum load supplied by the line L12 is 100 MVA with a lagging power factor of 0.95, design a three-zone distance-relaying system for the R12 distance relay by determining the following:

**[10 marks]**

(i) maximum load current;

---------- ANSWER ----------

$$I_{\max} = \frac{S_{\max}}{\sqrt{3} \times V_L} = \frac{100 \times 10^6}{\sqrt{3} \times 220 \times 10^3} = \underline{\underline{263 \text{ A}}}$$

---

(ii) CT and VT ratios;

---------- ANSWER ----------

Based on $I_{\max} = 263$ A, choose CT ratio $\underline{250/5}$, giving ~ 5 A output on max load.

$$V_p = \frac{V_L}{\sqrt{3}} = \frac{220}{\sqrt{3}} = 127 \text{ kV}$$

VT ratio: $\frac{127\times10^3}{110}\Rightarrow$

---

(iii) impedance measured by relay and load impedance referred to the output side of the sensors;

---------- ANSWER ----------

$$Z_s=\frac{V_s}{I_s}=\frac{V_p/VT_{\text{ratio}}}{I_p/CT_{\text{ratio}}}=\frac{V_p/(127\times10^3/110)}{I_p/(250/5)}=0.0433\times\frac{V_p}{I_p}=0.0433Z_{Line}$$

$$Z'_{Line12}=0.0433\times(2+j20)=\underline{\underline{0.087+j0.866\ \Omega}}$$

$$Z'_{Line23}=0.0433\times(2.5+j25)=\underline{\underline{0.108+j1.083\ \Omega}}$$

Power factor 0.95 lag: $0.9+j0.4356$

$$Z_L=\frac{V'_p}{I'_p}=\frac{110}{263\times(5/250)}\times(0.95+j0.31)=\underline{\underline{19.87+j6.48\ \Omega}}$$

---

(iv) Zone 1 and Zone 2 settings of relay R12.

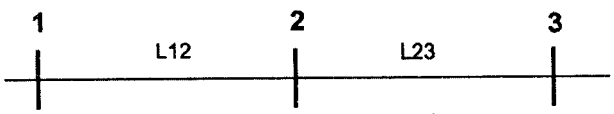



**Figure Q6. 220-kV transmission system**

---------- ANSWER ----------

$$Z_{relay1}=80\%\times Z'_{L12}=0.8\times(0.087+j0.866)=\underline{\underline{0.0696+j0.6928\ \Omega}}$$

$$Z_{relay2}=150\%\times Z'_{L12}=1.5\times(0.087+j0.866)=\underline{\underline{0.1305+j1.299\ \Omega}}$$

---

**COURSE OUTLINE:**

*A.C. Transmission & Distribution:*

Justification and disadvantages. General description of system connections, radial and ring systems. Interconnectors. Brief review of main items of equipment. Per unit representation.

*Transmission Lines:*

Overhead line and cable parameters. Equivalent circuits for short line, medium line with T or TT representation, long line with distributed constants. A,B,C,D constants. Voltage regulation. Power charts.

*Load Flow Calculation:*

Methods applicable to small networks, hand calculations. System economics, tariff structure.

*Symmetrical Fault Studies:*

Synchronous machine reactances. Calculations of faults on small networks using network reduction and similar techniques.

*Mechanical Construction of Overhead Lines:*

Poles, towers, insulators, sag and tension. Effect of wind, dust and pollution. Power System

*Protection and Instrumentation:*

General theory. Overcurrent relays, distance protection, differential protection, electromagnet and transistorised relays, carrier accelerated protection. Current and voltage transformers, capacitor voltage transformers.

# THE UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATIONS

SECOND- TERM EXAMINATION FOR 2022 ACADEMIC YEAR

16TH NOVEMBER 2022

TIME: 14:00 - 17:00 HRS

VENUE: S3/S4

# EEE 4670 - ELECTRONIC ENGINEERING III

| | | |
|---|---|---|
| DURATION | : | **THREE (3) HOURS** |
| INSTRUCTIONS | : | **ANSWER ONLY FOUR (4) QUESTIONS** |
| ADDITIONAL INFORMATION | : | **Useful constants and variables are listed at the end of this examination paper** |

**Q 1. (Compulsory Question to be answered by ALL CANDIDATES)**

A. A p-n junction forms the basis for the operation of a light emitting diode, photodiode and laser.

(i) Define a light emitting diode and using suitable diagram(s), detail or explain its construction (structure) and operation mode. ***(7 marks)***

(ii) Define a photodiode and using suitable diagram(s), detail or explain its construction (structure) and operation mode. ***(7 marks)***

(iii) Define a laser and using suitable diagram(s), detail or explain its construction (structure) and operation mode. ***(8 marks)***

B. When forming a p-n junction, both acceptor and donor impurities are added in the same semiconductor material until a desired doping concentration level in the n-type side and p-type side are achieved. Since both types of charge carriers are present in the same semiconductor material, calculate the charge concentrations per cubic metre in a silicon semiconductor doped with the following impurities stating the type of semiconductor obtained: (Assume room temperature and that all impurity atoms are ionised. Note that $N_d$ and $N_a$ denote donor and acceptor impurity atoms concentrations respectively).

(i) $N_d = 10^{20}\,cm^{-3}$ and $N_a = 10\,cm^{-3}$. ***(2 marks)***

(ii) $N_d = 10\,cm^{-3}$ and $N_a = 10^{10}\,cm^{-3}$. ***(2 marks)***

(iii) $N_d = 10^{20}\,cm^{-3}$ and $N_a = 10^{20}\,cm^{-3}$. ***(2marks)***

(iv) $N_d = 0$ and $N_a = 0$. ***(2 marks)***

**Q 2. (Compulsory Question to be answered by ALL CANDIDATES)**

A. Silicon is an important semiconductor material that is commonly used for fabricating solid state-based electrical engineering devices.

(i) Define quantum numbers that completely describe the electronic structure of a silicon atom. ***(6 marks)***

(ii) Using appropriate diagram(s), describe the formation of energy bands in a silicon crystal composed of X number of atoms. ***(13 marks)***

(iii) Using your energy bands formation concept developed in (ii) above, characterise energy bands for copper, gallium arsenide and silicon dioxide at room temperature. ***(3 marks)***

B. For a power engineering device made out of silicon, determine the wavelength and frequency of a photon which is able to just excite an electron from the valence band into the conduction band at:

(i) Room temperature. ***(4 marks)***

(ii) Absolute temperature. ***(4 marks)***

**(ANSWER ONLY TWO QUESTIONS OUT OF FIVE, FROM THE FIVE OPTIONS)**

**Q 3. (Optional Question)**

A. The process of adding of impurity atoms into the lattice of a pure semiconductor is called doping.

**(i)** Describe any two methods for doping a semiconductor, clearly illustrating the concentration of impurity atoms as a function of depth into the semiconductor material. ***(6 marks)***

**(ii)** Using suitable diagrams explain any two mechanisms through which dopant atoms occupy sites in the lattice of host semiconductor being. ***(4 marks)***

B. Boron decomposed from the gas diborane $(B_2H_3)$ is a common dopant for doping silicon. To enable the boron atoms to diffuse into the silicon semiconductor lattice the temperature in a doping chamber is maintained at 1000 °C, the concentration of $B_2H_3$ gas on the silicon wafer surface is $10^{20}\,cm^{-3}$ and the time for completing the doping process is 60 minutes. Given that a mathematical expression for the total number of dopant atoms per unit area Q(t) in the doped silicon semiconductor wafer is $Q(t) = 1.13C_S\sqrt{Dt}$, where $C_S$ is the concentration of dopant atoms at the surface of the silicon wafer, D is the impurity diffusion coefficient and t the exposure time of silicon semiconductor in the doping chamber in seconds:

i. Deduce the type of doping attained and type of majority charge carriers in the final doped silicon semiconductor. ***(2 marks)***

ii. Calculate the diffusion length of boron atoms in the silicon semiconductor. ***(4 marks)***

iii. Find the total number of boron atoms per unit area in the doped silicon semiconductor. ***(4 marks)***

**Q 4. (Optional Question)**

A. Semiconductor materials are either elemental or compound.

(i) Describe any three commonly used semiconductor materials in respect of their production method(s) and use suitability. ***(6 marks)***

(ii) Using specific dopant atoms, explain how pure germanium is doped n-type and p-type. ***(2 marks)***

(iii) Using specific dopant atoms, explain how pure gallium arsenide is doped n-type and p-type. ***(4 marks)***

B. For a pure silicon semiconductor crystal, compute its:

(i) Conductivity and resistivity at room temperature. ***(4 marks)***

**(ii)** Conductivity and resistivity at absolute temperature. ***(4 marks)***

**Q 5. (Optional Question)**

A. Electronic noise is undesirable when operating most semiconductor-based power engineering devices.

(i) Identify two main sources of noise in electronic devices and discuss their origins. ***(4 marks)***

(ii) Write brief notes on recombination, partition, flicker and intermodulation noise in power engineering devices. ***(4 marks)***

(iii) Define noise figure? Sketch a general graph showing variation of the noise figure with frequency in an electronic amplifier (clearly explain how noise the factor varies with amplifier operating frequency). In which region must an electronic amplifier be operated and why? ***(6 marks)***

B. A optoelectronic amplifying device of effective resistance 20 kΩ is operated on an average current of 10 mA over a bandwidth of 10 MHz. If the operating temperature of the device is 3 °C above room temperature, determine its:

**(i)** Shot noise current. ***(3 marks)***

(ii) Thermal noise current. ***(3 marks)***

**Q 6. (Optional Question)**

A. In a semiconductor material, electrons may exist either as Fermi-Dirac electrons or Maxwell Boltzmann electrons and thus being in a state either to take part or not to take part in electrical/electronic conduction processes:

(i) State two conditions upon which to distinguish Fermi-Dirac electrons from Maxwell Boltzmann electrons. ***(2 marks)***

(ii) Using appropriate condition(s), diagram(s) and equation(s), describe properties for electrons which obey Fermi-Dirac statistics. ***(6 marks)***

(iii) Using appropriate condition(s), diagram(s) and equation(s), describe properties for electrons which obey Maxwell-Boltzmann statistics. ***(6 marks)***

B. For a pure germanium semiconductor crystal at room temperature:

(i) Determine the chance of an electron being in the conduction band. ***(3 marks)***

(ii) Calculate the chance of a hole appearing in the valence band. ***(3 marks)***

**Q 7. (Optional Question)**

The fabricating of modern bipolar junction transistors (BJTs) employs the planar epitaxial process in which a BJT device is formed through growth of single-crystal films on the surface of a silicon wafer resulting in a structure shown figure 1. Contacts for connecting the BJT to the external circuit are then fused onto the active region through metallisation.

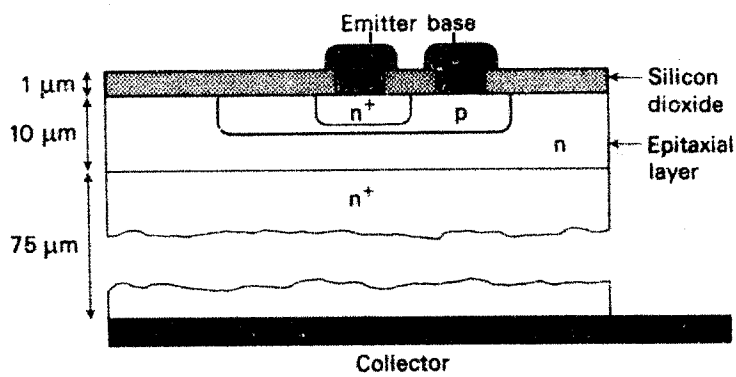



*Figure 1. A sectional view of an n-p-n BJT*

(i) For a BJT structure shown in figure 1, describe roles of the $n^+$ region on the emitter side, the $n^+$ region on the collector side, and the silicon dioxide layer? ***(3 marks)***

(ii) Using suitable diagrams describe three types of metallisation contacts formed between aluminium and doped silicon. ***(5 marks)***

(iii) Name the three device-thickness-dependent categories that are used to classify BJTs? ***( 3 marks)***

B. An n-type silicon semiconductor electronic device operating at room temperature has majority charge carrier drift velocity of $4x10^4$ cm/s when an external electric field of 1000 V/m is applied. For this device:

(i) Find the mobility of majority charge carriers. ***(3 marks)***

(ii) Compute the diffusivity of the majority charge carriers. ***(3 marks)***

(iii) Name any three factors that affect mobility of charge carriers and which to take into consideration, during the doping process and operation of the resulting electronic device. ***(3 marks)***

## *LIST OF USEFUL CONSTANTS AND VARIABLES*

| | | |
|---|---|---|
| 1. | 1 electron volt | $= 1.602 \times 10^{-19}$ J |
| 2. | Absolute temperature | $= -273^\circ$C |
| 3. | Assume room temperature if not specified. | |
| 4. | Boltzmann constant | $= 1.38 \times 10^{-23}$ JK$^{-1}$ |
| 5. | Boron diffusion coefficient at 1000 °C | $= 2 \times 10^{-14}$ cm$^2$ / s |
| 6. | Electronic charge | $= 1.602 \times 10^{-19}$ C |
| 7. | Germanium atom atomic number | $= 32$ |
| 8. | Germanium energy band gap | = 0.67 eV at room temperature & 0.75 eV at 0K |
| 9. | Mobility for electrons in silicon | $= 1300$cm$^2$ / V.s |
| 10. | Mobility for holes in silicon | $= 500$cm$^2$ / V.s |
| 11. | Planck's constant | $= 6.63x10^{-34}$ J.s |
| 12. | Room temperature | $= 27^\circ$C |
| 13. | Silicon atom atomic number | $= 14$ |
| 14. | Silicon energy band gap | = 1.12 eV at room temperature & 1.17eV at 0K |
| 15 | Silicon intrinsic carrier concentration | $= 1.5 \times 10^{16}$ m$^{-3}$ at room temperature |
| 16. | Speed of light | $= 3.0 \times 10^8$ m / s |

# THE UNIVERSITY OF ZAMBIA

## SCHOOL OF ENGINEERING

## Department of Electrical and Electronic Engineering

# EEE 5240: Dynamic Systems and Control Engineering

FINAL EXAM – NOVEMBER 2022

| | | |
|---|---|---|
| **TIME** | : | Three (3) hours |
| **INSTRUCTIONS** | : | Answer **at least two (2)** from **Section A** and **at least two (2)** from **Section B** plus **one (1)** from either section. Use **SEPARATE ANSWER BOOKLETS** for each section. |
| **ADDITIONAL INFORMATION** | : | *All Questions Carry Equal Marks (i.e. 20 marks)* |

## Section A (Classical control; Answer at least two (2) questions)

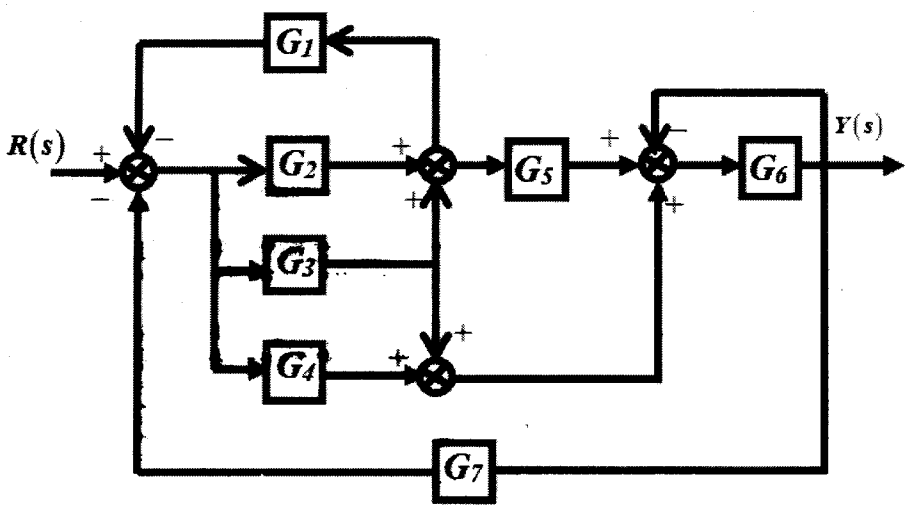
**QUESTION 1**

a) i) What are the main components of a feedback control system? **[1 Mark]**

ii) Compare the advantages and disadvantages of an open control system verses a closed-loop control system. **[2 Marks]**

iii) What are the motivations (give at least six) for feedback control? **[3 Marks]**

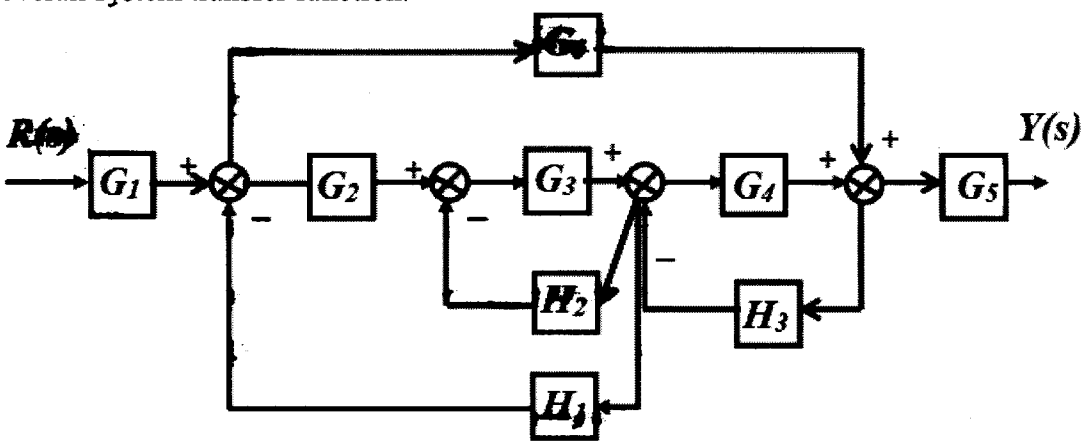
b) Use block diagram reduction techniques to determine an expression for the transfer function of the system shown in Figure Q1(b) below:




**[7 Marks]**

**Figure Q1(b)**

c) Draw the signal flow graph (SFG) corresponding to the block diagram shown in Figure Q1(c) below and use Mason's gain formula to determine an expression for the overall system transfer function.




**[7 Marks]**

**Figure Q1(c)**

**[Total 20 Marks]**

**QUESTION 2**

a) For the following closed-loop system shown in Figure Q2(a), find K1 and K2 such that the percentage overshoot for a unit step input is 16 % and the settling time is 0.2 seconds.

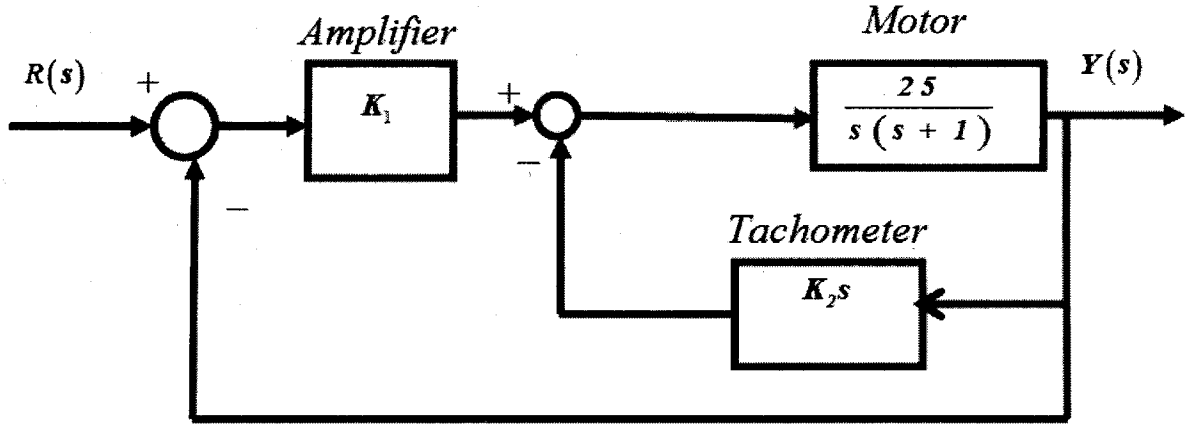



**Figure Q2(a)**

**[10 Marks]**

b) A control system is shown in Figure Q2(b). It is desired that the system be stable and the steady-state error for a unit step input to be less than or equal to 5%.

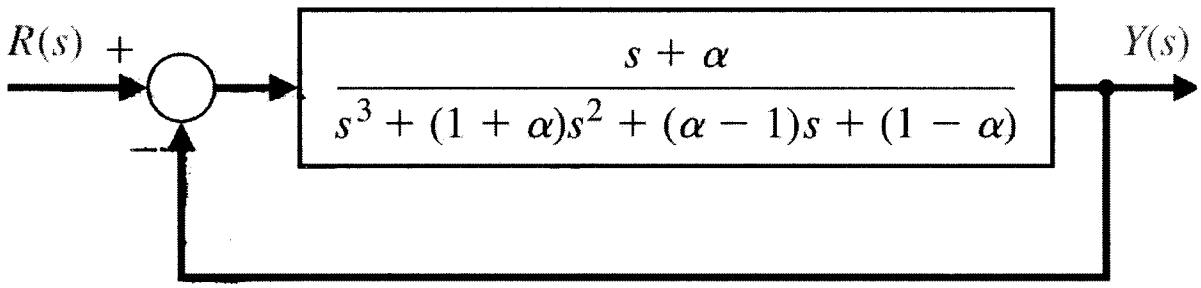



**Figure Q2(b)**

i) Determine the range of $\alpha$ that satisfies the error requirement. **[4 Marks]**

ii) Using Routh-Hurwitz stability criterion to determine the range of $\alpha$ that satisfies the stability requirement. **[4 Marks]**

iii) Select an $\alpha$ that meets both requirements. **[2 Marks]**

**[Total 20 Marks]**

## QUESTION 3

(i) ***Time domain Analysis: Transient Response Specifications of a Second Order System***

With the help of a graph, name at least four specific transient-response characteristics of a control system to a unit-step input, and define them in your own words. . **[ 6 *marks*]**

(ii) ***Frequency Domain Analysis: Performance Specification in Frequency Domain and its Relations to Time domain-Second Order System***

The magnitude response of a typical second order system characterized by

$$T(s) = \frac{Y(s)}{U(s)} = \frac{K\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

is given in Fig. Q.3-a-b &c

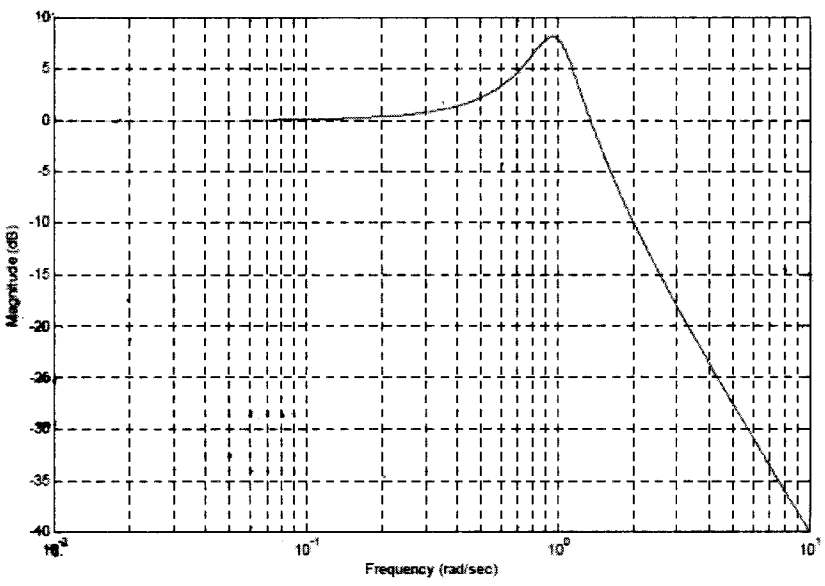



Fig.Q.3-a

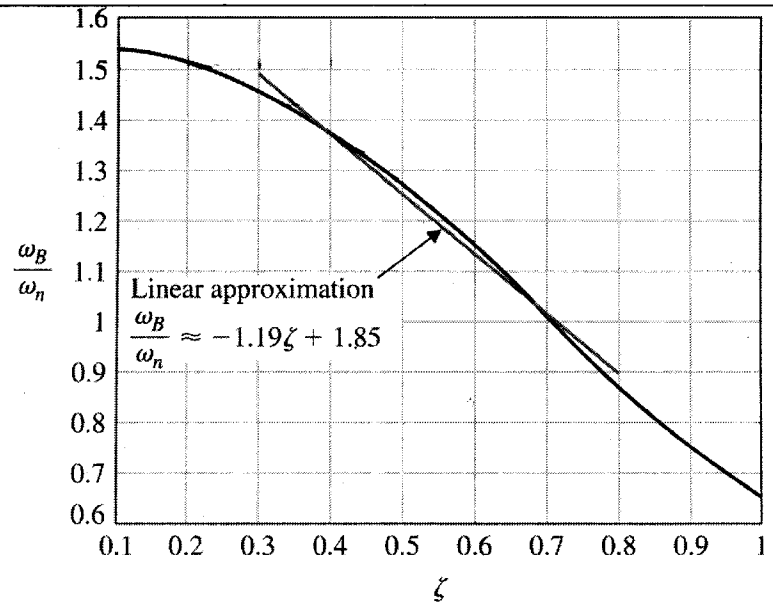



Fig.Q.3-b

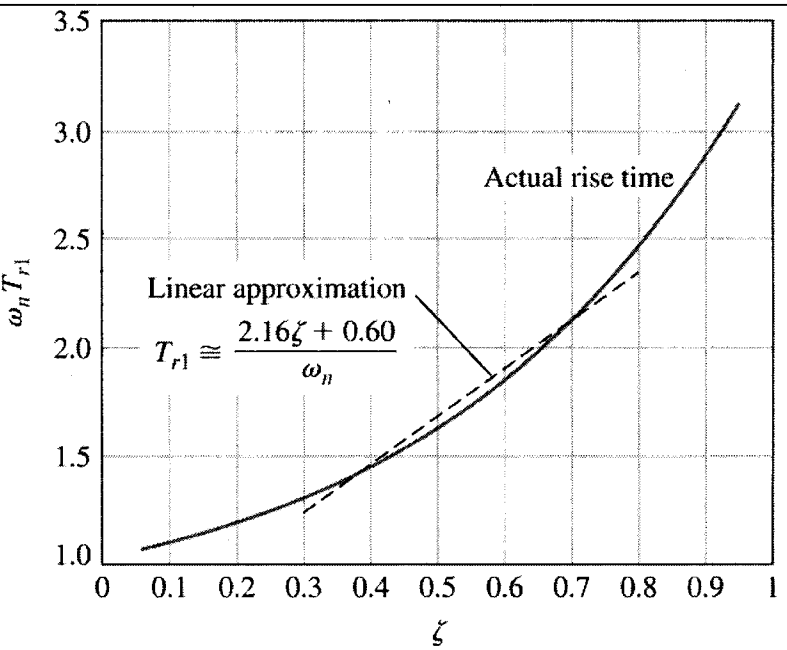



Fig.Q.3-c

(a). Find the DC gain, K, approximate bandwith and the corner frequency/resonance frequency, which is also the natural frequency, damping ratio using Fig.Q.3-b&c; and then . **[ 1x4 *marks*]**

(b) Find Tr, Tp, Ts and P.O.for a unit step input. . **[ 1x4 *marks*]**

(c) Given an input signal, u(t) = cos t, find its corresponding steady-state output, y(t).

**[ 2x2 *marks*]**

(d) Find the steady state error due to a unit step input. . **[ 1x2 *marks*]**

**QUESTION 4**

a) A unity feedback system has the loop transfer function

$$KG(s) = \frac{K(s+2)}{s(s+1)}$$

i) Find the breakaway and entry points on the real axis. **[5 Marks]**

ii) Find the gain and the roots when the real part of the complex roots is located at -2. **[5 Marks]**

b) An antenna pointing system is given in Figure Q4(b) below:

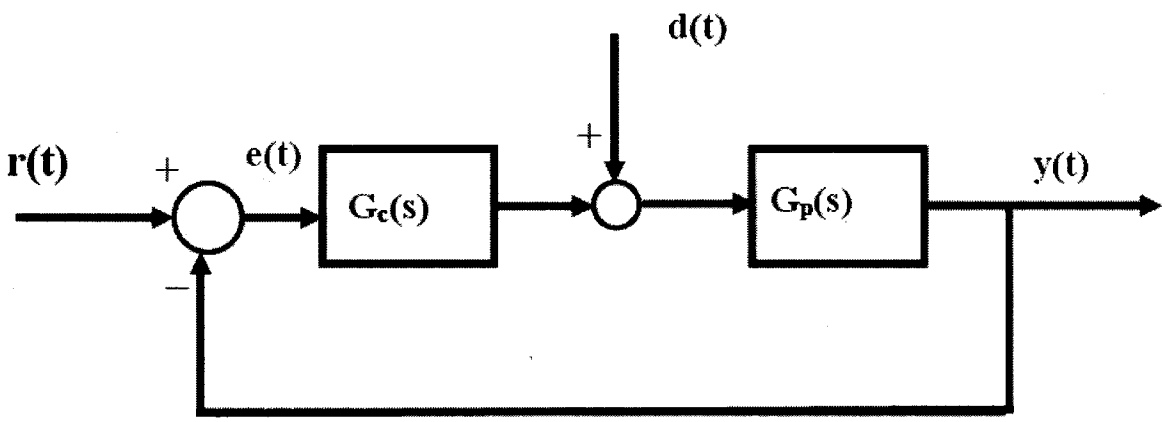



**Figure Q4(b)**

With $r(t)$ being the angle command and $d(t)$ the wind disturbance.

The antenna has the transfer function $G_p(s) = \frac{5}{s^2}$ in series with a PD controller with transfer function $G_s(s) = K_P + K_D s$.

i) Find the transfer function from $r(t)$ to $y(t)$. **[5 Marks]**

ii) Find PD gains $K_P$ and $K_D$ so that the system has a natural frequency of 5 rad/sec and the magnitude of the imaginary parts of the complex roots of its characteristic equation is 4 rad/sec. **[5 Marks]**

**[Total 20 Marks]**

## Section B (Answer at least two (2) questions)

**QUESTION 1**

**(i)** Consider the system defined by,

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\\ \dot{x}_3\end{bmatrix} = \begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ 0 & -24 & -10\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix} + \begin{bmatrix}1\\ -8\\ 106\end{bmatrix}u$$

$$y = \begin{bmatrix}1 & 0 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}$$

It is desired to design a regulator for this system. Using the pole-placement-with observer approach, design an observer controller.

Choose the desired closed-loop poles for the pole-placement part to be

$$s_{1,2} = -1 \pm j2, \qquad s_3 = -5$$

and choose the desired observer poles at

$$s = -10, \qquad s = -10$$

Obtain the transfer function of the observer-based controller.

[12]

**(ii)** Find the solution of

$$y(k+2) - 3y(k+1) + 2y(k) = r(k)$$

Where $r(k) = 3^k, y(0) = 0, y(1) = 1$

[3]

**(iii)** Consider the system below represented by a differential equation with input $k$ and output $z$;

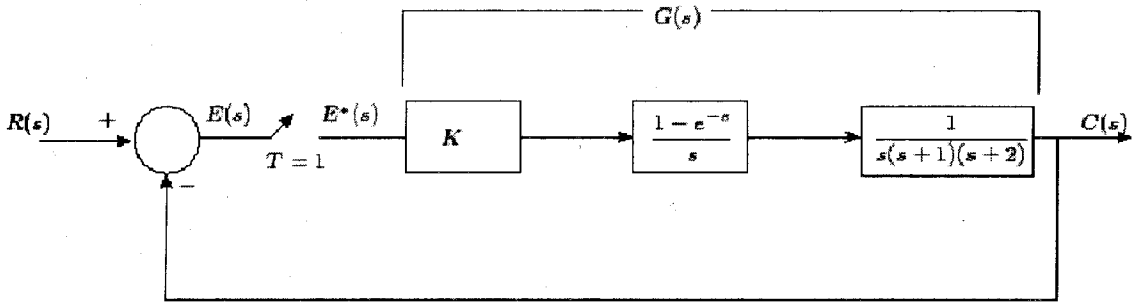
$$\frac{d^3z}{dt^3} + 7\frac{d^2z}{dt^2} + 19\frac{dz}{dt} + 13z = 13\frac{dk}{dt} + 26k$$

Obtain the state space representation of the system.

[5]

## QUESTION 2

**(i)** Consider the system shown below. Find out the range of $K$ for which the system is stable. (Using the bi-linear transformation)




[10]

**(ii)** Find $x_1(t)$ and $x_2(t)$ of the system described by

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}0 & 1\\ -3 & -2\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

Where the initial conditions are

$$\begin{bmatrix}x_1(0)\\ x_2(0)\end{bmatrix} = \begin{bmatrix}1\\ -1\end{bmatrix}$$

[8]

**(iii)** Consider the system described by

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}0 & 1\\ -2 & -3\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}u_1\\ u_2\end{bmatrix}$$

$$\begin{bmatrix}y_1\\ y_2\end{bmatrix} = \begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}u_1\\ u_2\end{bmatrix}$$

Is this system completely observable?

[2]

**QUESTION 3**

**(i)** Consider the plant transfer function;

$$G_p(z) = \frac{0.0004(z+0.2)(z+2.8)}{(z-1)^2(z-0.28)}$$

Design a dead-beat controller for a unit step input. After how many sampling instances does the output follow the input?

[10]

**(ii)** Consider the system defined by

$$\dot{\mathbf{x}} = \mathbf{A}\mathbf{x}$$

where,

$$\mathbf{A} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & -1 \\ -1 & -2 & -a \end{bmatrix}$$

$$a = adjustable\ parameter > 0$$

Determine the value of the parameter a so as to minimize the following performance index:

$$J = \int_0^\infty (\mathbf{x}^T\mathbf{x})dt$$

Assume that the initial state $\mathbf{x}(0)$ is given by

$$\mathbf{x}(0) = \begin{bmatrix} c_1 \\ 0 \\ 0 \end{bmatrix}$$

[6]

**(iii)** Consider the system matrix of a continuous time system, described in the state variable form is;

$$\mathbf{A} = \begin{bmatrix} x & 0 & 0 \\ 0 & y & -1 \\ 0 & 1 & -2 \end{bmatrix}$$

Determine the range of x & y so that the system is stable.

[4]

**QUESTION 4**

**(i)** Using Consider the system defined by

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\\ \dot{x}_3\end{bmatrix}=\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ 1.244 & 0.3956 & -3.145\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}+\begin{bmatrix}0\\ 0\\ 1.244\end{bmatrix}u$$

$$y=\begin{bmatrix}1 & 0 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}$$

Given the set of desired poles for the observer to be

$$s=-5+j5\sqrt{3}, s=-5-j5\sqrt{3}, s=-10$$

Design a full state observer.

[10]

**(ii)** Given the characteristic equation

$$P(z)=z^4-1.2z^3+0.07z^2+0.3z-0.08=0$$

Determine the stability of the system using the ***Jury*** test.

[8]

**(iii)** Give two (2) properties of the state transition matrix.

[2]

# THE END

# Appendix

FORMULA/INFO SHEET: Given a function F(s), the Cauchy Principle of the Argument states that Z=N+P, where Z and P are the number of zeros and poles, respectively, of F(s) enclosed by an arbitrary clockwise s-plane contour. This contour must not pass through any of the poles or zeros or F(s). N = the number of clockwise encirclements of the origin of the F(s) plane made as s takes values along the CW s-plane contour.

Initial Value Theorem: $f(0) = \lim_{s\to\infty} sF(s)$ Final Value Theorem: $f(\infty) = \lim_{s\to 0} sF(s)$

$$Laplace\left\{\frac{df}{dt}\right\} = sF(s) - f(0) \qquad Laplace\left\{\frac{d^2 f}{dt^2}\right\} = s^2F(s) - sf(0) - f'(0)$$

Time Delay Theorem: If $F(s)$ is Laplace trans of $f(t)u(t)$, then Laplace trans of $f(t-t_o)u(t-t_o)$ is $e^{-st_o}F(s)$

| f(t) | F(s) | f(t) | F(s) |
|---|---|---|---|
| $u(t)$ *or* $1(t)$ | $\frac{1}{s}$ | $te^{-at}u(t)$ | $\frac{1}{(s+a)^2}$ |
| $tu(t)$ *or* $t1(t)$ | $\frac{1}{s^2}$ | $2\lvert M\rvert e^{-\sigma t}\cos(\omega t+\varphi)u(t)$ | $\frac{\lvert M\rvert e^{j\varphi}}{s+\sigma-j\omega}+\frac{\lvert M\rvert e^{-j\varphi}}{s+\sigma+j\omega}$ |
| $e^{-at}u(t)$ | $\frac{1}{s+a}$ | $(\cos\omega t)u(t)$ | $\frac{s}{s^2+\omega^2}$ |
| $(\sin\omega t)u(t)$ | $\frac{\omega}{s^2+\omega^2}$ | Note: $u(t)\equiv 1(t)$, the unit step function | |

$R(s)$ $G(s)$ $C(s)$ $H(s)$ $\qquad T_c(s) = \frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)H(s)}$

Root locus angle condition: The phase of GH equals 180r, r is a positive or negative odd integer.
Root locus construction rules:

Root locus construction rules:

1. The root locus is symmetrical about the real axis of the s-plane.

2. The root locus on the real axis is found to the left of an odd number of real poles and zeros of GH.

3. The branches of the root locus begin at the poles of GH, and they terminate at the zeros of GH.

4. The points at which the root locus breaks away from and enters to the real axis can be determined by finding the maximum and minimum points of the gain K as a function of s with s restricted to real values.

5. Angle of asymptote: $\theta_l = \frac{(1+2l)(180^o)}{p_{ex}}, l = 0,1,...,p_{ex}-1$ Origin of asymptote: $\sigma_i = \frac{\sum_1^n \mathrm{Re}(p_i) - \sum_1^m \mathrm{Re}(z_i)}{p_{ex}}$

where $p_{ex}$ is the pole-zero excess (# poles - # zeros) of GH.

Steady state errors: $e_{ss_{step}} = \frac{1}{1+K_p} = 1 - T_c(0),\ K_p = \lim_{s\to 0} G(s)H(s)$ ;

$e_{ss_{ramp}} = \frac{1}{K_v},\ K_v = \lim_{s\to 0} sG(s)H(s)$

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For a second order system, $\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$. $t_p = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$, $PO = 100e^{-\zeta\pi/\sqrt{1-\zeta^2}}$

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The Nyquist Stability Criterion (based upon Cauchy's Principle of the Argument): Given that F(s)=1+G(s)H(s), Z=N+P, where the clockwise s-plane contour encloses the complete right half plane (RHP). Thus, Z = the number of RHP zeros of 1+G(s)H(s), P = the number of RHP poles of 1+G(s)H(s) (this is the same as the number of RHP poles of G(s)H(s)), and N = the number of clockwise encirclements of –1 made by the Nyquist diagram (in the complex G(s)H(s) plane). Note that Z is equivalently the number of RHP poles of the closed loop transfer function, and Z must equal zero for closed loop system stability.

Bode lag compensator design equations: $\omega_0 = 0.1\omega_d$, where $\omega_d$ is the desired zero dB gain crossover frequency (based upon the phase margin specification), and $\omega_p = \frac{\omega_0}{K|G(j\omega_d)|}$, where gain K is selected to satisfies a steady state accuracy specification.

***Linear algebra***

Determinant of a **2x2** matrix

$$|\mathbf{A}| = \begin{vmatrix} a & b \\ c & d \end{vmatrix} = ad - bc$$

Determinant of a **3x3** matrix

$$|\mathbf{A}| = \begin{vmatrix} a & b & c \\ d & e & f \\ g & h & i \end{vmatrix} = a\begin{vmatrix} e & f \\ h & i \end{vmatrix} - b\begin{vmatrix} d & f \\ g & i \end{vmatrix} + c\begin{vmatrix} d & e \\ g & h \end{vmatrix}$$

Inverse of a **2x2** matrix

$$\mathbf{A}^{-1} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}^{-1} = \frac{1}{\det \mathbf{A}} \begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

***Controllability matrix***

$$\begin{bmatrix} \mathbf{B} & \mathbf{AB} & \cdots & \mathbf{A}^{n-1}\mathbf{B} \end{bmatrix}$$

Output controllability

$$\begin{bmatrix} \mathbf{CB} & \mathbf{CAB} & \mathbf{CA}^2\mathbf{B} & \cdots & \mathbf{CA}^n \end{bmatrix}$$

***Observability matrix***

$$\begin{bmatrix} \mathbf{C}^* & \mathbf{A}^*\mathbf{C}^* & \cdots & (\mathbf{A}^*)^{n-1}\mathbf{C}^* \end{bmatrix}$$

***State feedback gain matrix***

Using the desired eigenvalues (desired closed-loop poles), write the desired characteristic polynomial:

$$(s-\mu_1)(s-\mu_1)\ldots(s-\mu_n) = s^n + \alpha_1 s^{n-1} + \cdots \alpha_{n-1} s + \alpha_n$$

and determine the values of $\alpha_1, \alpha_2, \ldots, \alpha_n$.

The required state feedback gain matrix **K** can be determined from Equation

$$\mathbf{K} = [\alpha_n - a_n \vdots \alpha_{n-1} - a_{n-1} \vdots \cdots \vdots \alpha_2 - a_2 \vdots \alpha_1 - a_1]\mathbf{T}^{-1}$$

$$\mathbf{T} = \mathbf{MW}$$

$$\mathbf{W} = \begin{bmatrix} a_{n-1} & a_{n-2} & \cdots & a_1 & 1 \\ a_{n-2} & a_{n-3} & \cdots & 1 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ a_1 & 1 & \cdots & 0 & 0 \\ 1 & 0 & \cdots & 0 & 0 \end{bmatrix}$$

***Ackerman's formula***

$$\phi(\tilde{\mathbf{A}}) = \tilde{\mathbf{A}}^n + \alpha_1\tilde{\mathbf{A}}^{n-1} + \cdots + \alpha_{n-1}\tilde{\mathbf{A}} + \alpha_n\mathbf{I} = \mathbf{0}$$

$$\mathbf{K} = [0 \quad 0 \quad \ldots \quad 0 \quad 1][\mathbf{B} \vdots \mathbf{AB} \vdots \cdots \vdots \mathbf{A}^{n-1}\mathbf{B}]^{-1}\phi(\tilde{\mathbf{A}})$$

$$\mathbf{K}_e = \phi(\mathbf{A})\begin{bmatrix} \mathbf{C} \\ \mathbf{CA} \\ \vdots \\ \mathbf{CA}^{n-2} \\ \mathbf{CA}^{n-1} \end{bmatrix}^{-1}\begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \\ 1 \end{bmatrix}$$

***Full state observer***

$$\dot{\tilde{x}} = (\mathbf{A} - \mathbf{K}_e\mathbf{C})\tilde{x} + \mathbf{B}u + \mathbf{K}_e y$$

***The transfer function of the observer controller;***

$$\frac{U(s)}{Y(s)} = -\mathbf{K}(s\mathbf{I} - \mathbf{A} + \mathbf{K}_e\mathbf{C} + \mathbf{BK})^{-1}\mathbf{K}_e$$

***Minimum order observer***

$$\begin{bmatrix} \dot{x}_a \\ \dot{\mathbf{x}}_b \end{bmatrix} = \begin{bmatrix} A_{aa} & \mathbf{A}_{ab} \\ \mathbf{A}_{ba} & \mathbf{A}_{bb} \end{bmatrix}\begin{bmatrix} x_a \\ \mathbf{x}_b \end{bmatrix} + \begin{bmatrix} B_a \\ \mathbf{B}_b \end{bmatrix}u$$

$$y = \begin{bmatrix} 1 & \vdots & \mathbf{0} \end{bmatrix}\begin{bmatrix} x_a \\ \mathbf{x}_b \end{bmatrix}$$

where $A_{aa}$ = scalar
$\mathbf{A}_{ab}$ = $1 \times (n-1)$ matrix
$\mathbf{A}_{ba}$ = $(n-1) \times 1$ matrix
$\mathbf{A}_{bb}$ = $(n-1) \times (n-1)$ matrix
$B_a$ = scalar
$\mathbf{B}_b$ = $(n-1) \times 1$ matrix

$$\dot{\tilde{\eta}} = (A_{bb} - K_eA_{ab})\tilde{\eta} + [(A_{bb} - K_eA_{ab})K_e + A_{ba} - K_eA_{aa}]y + (B_b - K_eB_a)u$$

$$\frac{U(s)}{-Y(s)} = \frac{num}{den} = -\left[\mathbf{C}(s\mathbf{I} - \mathbf{A})\mathbf{B} + D\right]$$

$$\mathbf{A} = \mathbf{A} - \mathbf{F}K_b$$

$$\mathbf{B} = \mathbf{B} - \mathbf{F}(K_a + \mathbf{K}_b\mathbf{K}_e)$$

$$\mathbf{C} = -\mathbf{K}_b$$

$$D = -(K_a + \mathbf{K}_b\mathbf{K}_e)$$

$$\mathbf{A} = \mathbf{A}_{bb} - \mathbf{K}_e\mathbf{A}_{ab}$$

$$\mathbf{B} = \mathbf{AK}_e + \mathbf{A}_{ba} - \mathbf{K}_e\mathbf{A}_{aa}$$

$$\mathbf{F} = \mathbf{B}_b - \mathbf{K}_eB_a$$

***Canonical forms***

Consider the system defined by;

$$\overset{(n)}{y} + a_1\overset{(n-1)}{y} + \cdots + a_{n-1}\dot{y} + a_n y = b_0\overset{(n)}{u} + b_1\overset{(n-1)}{u} + \cdots + b_{n-1}\dot{u} + b_n$$

With transfer function;

$$\frac{Y(s)}{U(s)} = \frac{b_0s^n + b_1s^{n-1} + \cdots + b_{n-1}s + b_n}{s^n + a_1s^{n-1} + \cdots + a_{n-1}s + a_n}$$

***Controllable canonical form***

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \vdots \\ \dot{x}_{n-1} \\ \dot{x}_n \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & \cdots & 0 \\ 0 & 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & 1 \\ -a_n & -a_{n-1} & -a_{n-2} & \cdots & -a_1 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_{n-1} \\ x_n \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \\ 1 \end{bmatrix}u$$

$$y = \begin{bmatrix} b_n - a_nb_0 & b_{n-1} - a_{n-1}b_0 & \cdots & b_1 - a_1b_0 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_{n-1} \\ x_n \end{bmatrix} + b_0u$$

***Observable canonical form***

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \vdots \\ \dot{x}_{n-1} \\ \dot{x}_n \end{bmatrix} = \begin{bmatrix} 0 & 0 & \ldots & 0 & -a_n \\ 1 & 0 & \ldots & 0 & -a_{n-1} \\ 0 & 1 & \ldots & 0 & -a_{n-2} \\ \vdots & \vdots & & \vdots & \vdots \\ 0 & 0 & \ldots & 1 & -a_1 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_{n-1} \\ x_n \end{bmatrix} + \begin{bmatrix} b_n - a_nb_0 \\ b_{n-1} - a_{n-1}b_0 \\ \vdots \\ b_2 - a_2b_0 \\ b_1 - a_1b_0 \end{bmatrix}u$$

$$y = \begin{bmatrix} 0 & 0 & \cdots & 1 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_{n-1} \\ x_n \end{bmatrix} + b_0u$$

***Quadratic optimal regulator***

$$J = \int_0^\infty \left(\mathbf{x}^*\mathbf{Q}\mathbf{x} + \mathbf{u}^*\mathbf{R}\mathbf{u}\right)dt$$

$$(\mathbf{A} - \mathbf{BK})^*\mathbf{P} + \mathbf{P}(\mathbf{A} - \mathbf{BK}) = -(\mathbf{Q} + \mathbf{K}^*\mathbf{RK})$$

$$\mathbf{K} = \mathbf{R}^{-1}\mathbf{B}^*\mathbf{P}$$

***The reduced matrix Ricatti equation***

$$\mathbf{A}^T\mathbf{P} + \mathbf{PA} - \mathbf{PBR}^{-1}\mathbf{B}^T\mathbf{P} + \mathbf{Q} = \mathbf{0}$$

$$\mathbf{P} = \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{12} & p_{22} & p_{23} \\ p_{13} & p_{23} & p_{33} \end{bmatrix}$$

***State transition matrix***

$$\boldsymbol{\phi}(t) = \mathrm{e}^{\mathbf{A}t} = \mathcal{L}^{-1}[(s\mathbf{I} - \mathbf{A})^{-1}]$$

$$\mathbf{G}^k = \mathrm{Z}^{-1}[(z\mathbf{I} - \mathbf{G})^{-1}z]$$

*Solution of homogenous state equation*

$$\mathbf{x}(t) = \boldsymbol{\phi}(t)\mathbf{x}(0)$$

*Solution of nonhomogeneous state equation*

$$\mathbf{x}(t) = e^{\mathbf{A}t}\mathbf{x}(0) + \int_0^t e^{\mathbf{A}(t-\tau)}\mathbf{B}u(\tau)d\tau$$

$$\mathbf{x}(k) = \mathbf{G}^k\mathbf{x}(0) + \sum_{j=1}^{k-1} \mathbf{G}^{k-j-1}\mathbf{H}u(j)$$

*Response to a unit step input of k;*

$$\mathbf{x}(t) = e^{\mathbf{A}t}\mathbf{x}(0) + \mathbf{A}^{-1}(e^{\mathbf{A}t} - \mathbf{I})\mathbf{B}k$$

*Properties of the state transition matrix;*

1. $\Phi(0) = e^{\mathbf{A}0} = \mathbf{I}$
2. $\Phi(t) = e^{\mathbf{A}t} = \left(e^{-\mathbf{A}t}\right)^{-1} = \left[\Phi(-t)\right]^{-1}$ or $\Phi^{-1}(t) = \Phi(-t)$
3. $\Phi(t_1 + t_2) = e^{\mathbf{A}(t_1+t_2)} = e^{\mathbf{A}t_1}e^{\mathbf{A}t_2} = \Phi(t_1)\Phi(t_2) = \Phi(t_2)\Phi(t_1)$
4. $\left[\Phi(t)\right]^n = \Phi(nt)$
5. $\Phi(t_2 - t_1)\Phi(t_1 - t_0) = \Phi(t_2 - t_0) = \Phi(t_1 - t_0)\Phi(t_2 - t_1)$

***The Jury Stability Test:***

$$P(z) = a_0 z^n + a_1 z^{n-1} + \cdots + a_{n-1} z + a_n$$

| Row | $z^0$ | $z^1$ | $z^2$ | $z^3$ | $\cdots$ | $z^{n-2}$ | $z^{n-1}$ | $z^n$ |
|---|---|---|---|---|---|---|---|---|
| 1 | $a_n$ | $a_{n-1}$ | $a_{n-2}$ | $a_{n-3}$ | $\cdots$ | $a_2$ | $a_1$ | $a_0$ |
| 2 | $a_0$ | $a_1$ | $a_2$ | $a_3$ | $\cdots$ | $a_{n-2}$ | $a_{n-1}$ | $a_n$ |
| 3 | $b_{n-1}$ | $b_{n-2}$ | $b_{n-3}$ | $b_{n-4}$ | $\cdots$ | $b_1$ | $b_0$ | |
| 4 | $b_0$ | $b_1$ | $b_2$ | $b_3$ | $\cdots$ | $b_{n-2}$ | $b_{n-1}$ | |
| 5 | $c_{n-2}$ | $c_{n-3}$ | $c_{n-4}$ | $c_{n-5}$ | $\cdots$ | $c_0$ | | |
| 6 | $c_0$ | $c_1$ | $c_2$ | $c_3$ | $\cdots$ | $c_{n-2}$ | | |
| . . . | . . . | | | | | | | |
| $2n-5$ | $p_3$ | $p_2$ | $p_1$ | $p_0$ | | | | |
| $2n-4$ | $p_0$ | $p_1$ | $p_2$ | $p_3$ | | | | |
| $2n-3$ | $q_2$ | $q_1$ | $q_0$ | | | | | |

$$b_k = \begin{vmatrix} a_n & a_{n-1-k} \\ a_0 & a_{k+1} \end{vmatrix}, k = 0,1,2,\ldots,n-1$$

$$c_k = \begin{vmatrix} b_{n-1} & b_{n-2-k} \\ b_0 & b_{k+1} \end{vmatrix}, k = 0,1,2,\ldots,n-2$$

$$\vdots$$

$$q_k = \begin{vmatrix} p_3 & p_{2-k} \\ p_0 & p_{k+1} \end{vmatrix}, k = 0,1,2$$

Stability criterion by the Jury Test: A system with the characteristic equation $P(z) = 0$ rewritten as $P(z) = a_0 z^n + a_1 z^{n-1} + \cdots + a_{n-1} z + a_n$ where $a_0 > 0$, is stable if the following conditions are all satisfied:

1. $|a_n| < a_0$
2. $P(z)|_{z=1} > 0$
3. $P(z)|_{z=-1} \begin{cases} > 0 \; for \; n \; even \\ < 0 \; for \; n \; odd \end{cases}$
4. $|b_{n-1}| > |b_0|$

   $|c_{n-2}| > |c_0|$

   $\vdots$

   $|q_2| > |q_0|$

***Deadbeat response design when the system poles and zeros are inside the unit circle***

Design criteria:

1. The system must have a zero steady state error at sampling instants.

2. The time to reach final output must be finite and minimum.

3. The controller should be physically realizable, i.e., it should be causal.

$$D_c(z) = \frac{1}{G_p(z)} = \frac{M(z)}{1 - M(z)}$$

Thus, if $G_p(z)$ does not have poles or zeros outside the unit circle, then $M(z)$ should have the following forms;

1. Step input:

$$R(z) = \frac{z}{z-1}$$

$$M(z) = \frac{1}{z^n}$$

2. Ramp input:

$$M(z) = \frac{(n+1)z - n}{z^{n+1}}$$

***Deadbeat response design when some of the poles and zeros are on or outside the unit circle***

Let the plant transfer function be;

$$G_p(z) = \frac{\prod_{i=1}^{K}(1 - z_i z^{-1})}{\prod_{j=1}^{L}(1 - p_j z^{-1})} B(z)$$

where, *K* and *L* are the number of zeros and poles on or outside the unit circle and $B(z)$ is a rational transfer function in $z^{-1}$ with poles and zeros inside the unit circle. This implies;

$$D_c(z) = \frac{\prod_{j=1}^{L}(1 - p_j z^{-1})}{\prod_{i=1}^{K}(1 - z_i z^{-1})} \frac{M(z)}{B(z)(1 - M(z))}$$

Since we should not cancel poles or zeros which are on or outside unit circle by the controller $D_c(z)$, we have to choose $M(z)$ such that these get canceled out.

$$M(z) = \prod_{i=1}^{K}(1 - z_i z^{-1})\left(m_k z^{-k} + m_{k+1} z^{-k-1} + \cdots\right)$$

$$1 - M(z) = \prod_{j=1}^{L}(1 - p_j z^{-1})(1 - z^{-1})^P (1 + a_1 z^{-1} + a_2 z^{-2} + \cdots)$$

$P$ equals either the order of the poles of $R(z)$ or the order of poles of $G_p(z)$ at $z = 1$ which ever is greater. Truncation depends on the following.

1. The order of poles of $M(z)$ and $(1 - M(z))$ must be equal.
2. Total number of unknowns must be equal to the order of $M(z)$ so that they can be solved independently.

## Table of Laplace and Z-transforms

| | $X(s)$ | $x(t)$ | $x(kT)$ or $x(k)$ | $X(z)$ |
|---|---|---|---|---|
| 1. | – | – | Kronecker delta $\delta_0(k)$<br>1 $k = 0$<br>0 $k \neq 0$ | $1$ |
| 2. | – | – | $\delta_0(n-k)$<br>1 $n = k$<br>0 $n \neq k$ | $z^{-k}$ |
| 3. | $\frac{1}{s}$ | $1(t)$ | $1(k)$ | $\frac{1}{1-z^{-1}}$ |
| 4. | $\frac{1}{s+a}$ | $e^{-at}$ | $e^{-akT}$ | $\frac{1}{1-e^{-aT}z^{-1}}$ |
| 5. | $\frac{1}{s^2}$ | $t$ | $kT$ | $\frac{Tz^{-1}}{\left(1-z^{-1}\right)^2}$ |
| 6. | $\frac{2}{s^3}$ | $t^2$ | $(kT)^2$ | $\frac{T^2z^{-1}\left(1+z^{-1}\right)}{\left(1-z^{-1}\right)^3}$ |
| 7. | $\frac{6}{s^4}$ | $t^3$ | $(kT)^3$ | $\frac{T^3z^{-1}\left(1+4z^{-1}+z^{-2}\right)}{\left(1-z^{-1}\right)^4}$ |
| 8. | $\frac{a}{s(s+a)}$ | $1-e^{-at}$ | $1-e^{-akT}$ | $\frac{\left(1-e^{-aT}\right)z^{-1}}{\left(1-z^{-1}\right)\left(1-e^{-aT}z^{-1}\right)}$ |
| 9. | $\frac{b-a}{(s+a)(s+b)}$ | $e^{-at}-e^{-bt}$ | $e^{-akT}-e^{-bkT}$ | $\frac{\left(e^{-aT}-e^{-bT}\right)z^{-1}}{\left(1-e^{-aT}z^{-1}\right)\left(1-e^{-bT}z^{-1}\right)}$ |
| 10. | $\frac{1}{(s+a)^2}$ | $te^{-at}$ | $kTe^{-akT}$ | $\frac{Te^{-aT}z^{-1}}{\left(1-e^{-aT}z^{-1}\right)^2}$ |
| 11. | $\frac{s}{(s+a)^2}$ | $(1-at)e^{-at}$ | $(1-akT)e^{-akT}$ | $\frac{1-\left(1+aT\right)e^{-aT}z^{-1}}{\left(1-e^{-aT}z^{-1}\right)^2}$ |
| 12. | $\frac{2}{(s+a)^3}$ | $t^2e^{-at}$ | $(kT)^2e^{-akT}$ | $\frac{T^2e^{-aT}\left(1+e^{-aT}z^{-1}\right)z^{-1}}{\left(1-e^{-aT}z^{-1}\right)^3}$ |
| 13. | $\frac{a^2}{s^2(s+a)}$ | $at-1+e^{-at}$ | $akT-1+e^{-akT}$ | $\frac{\left[\left(aT-1+e^{-aT}\right)+\left(1-e^{-aT}-aTe^{-aT}\right)z^{-1}\right]z^{-1}}{\left(1-z^{-1}\right)^2\left(1-e^{-aT}z^{-1}\right)}$ |
| 14. | $\frac{\omega}{s^2+\omega^2}$ | $\sin \omega t$ | $\sin \omega kT$ | $\frac{z^{-1}\sin\omega T}{1-2z^{-1}\cos\omega T+z^{-2}}$ |
| 15. | $\frac{s}{s^2+\omega^2}$ | $\cos \omega t$ | $\cos \omega kT$ | $\frac{1-z^{-1}\cos\omega T}{1-2z^{-1}\cos\omega T+z^{-2}}$ |
| 16. | $\frac{\omega}{(s+a)^2+\omega^2}$ | $e^{-at}\sin \omega t$ | $e^{-akT}\sin \omega kT$ | $\frac{e^{-aT}z^{-1}\sin\omega T}{1-2e^{-aT}z^{-1}\cos\omega T+e^{-2aT}z^{-2}}$ |
| 17. | $\frac{s+a}{(s+a)^2+\omega^2}$ | $e^{-at}\cos \omega t$ | $e^{-akT}\cos \omega kT$ | $\frac{1-e^{-aT}z^{-1}\cos\omega T}{1-2e^{-aT}z^{-1}\cos\omega T+e^{-2aT}z^{-2}}$ |
| 18. | – | – | $a^k$ | $\frac{1}{1-az^{-1}}$ |
| 19. | – | – | $a^{k-1}$<br>$k = 1, 2, 3, \ldots$ | $\frac{z^{-1}}{1-az^{-1}}$ |
| 20. | – | – | $ka^{k-1}$ | $\frac{z^{-1}}{\left(1-az^{-1}\right)^2}$ |
| 21. | – | – | $k^2a^{k-1}$ | $\frac{z^{-1}\left(1+az^{-1}\right)}{\left(1-az^{-1}\right)^3}$ |
| 22. | – | – | $k^3a^{k-1}$ | $\frac{z^{-1}\left(1+4az^{-1}+a^2z^{-2}\right)}{\left(1-az^{-1}\right)^4}$ |
| 23. | – | – | $k^4a^{k-1}$ | $\frac{z^{-1}\left(1+11az^{-1}+11a^2z^{-2}+a^3z^{-3}\right)}{\left(1-az^{-1}\right)^5}$ |
| 24. | – | – | $a^k\cos k\pi$ | $\frac{1}{1+az^{-1}}$ |

$x(t) = 0$ for $t < 0$
$x(kT) = x(k) = 0$ for $k < 0$

## Definition of the Z-transform

$$\mathcal{Z}\{x(k)\} = X(z) = \sum_{k=0}^{\infty} x(k) z^{-k}$$

## Important properties and theorems of the Z-transform

| | $x(t)$ or $x(k)$ | $Z\{x(t)\}$ or $Z\{x(k)\}$ |
|---|---|---|
| 1. | $ax(t)$ | $aX(z)$ |
| 2. | $ax_1(t)+bx_2(t)$ | $aX_1(z)+bX_2(z)$ |
| 3. | $x(t+T)$ or $x(k+1)$ | $zX(z)-zx(0)$ |
| 4. | $x(t+2T)$ | $z^2X(z)-z^2x(0)-zx(T)$ |
| 5. | $x(k+2)$ | $z^2X(z)-z^2x(0)-zx(1)$ |
| 6. | $x(t+kT)$ | $z^kX(z)-z^kx(0)-z^{k-1}x(T)-\ldots-zx(kT-T)$ |
| 7. | $x(t-kT)$ | $z^{-k}X(z)$ |
| 8. | $x(n+k)$ | $z^kX(z)-z^kx(0)-z^{k-1}x(1)-\ldots-zx(k1-1)$ |
| 9. | $x(n-k)$ | $z^{-k}X(z)$ |
| 10. | $tx(t)$ | $-Tz\dfrac{d}{dz}X(z)$ |
| 11. | $kx(k)$ | $-z\dfrac{d}{dz}X(z)$ |
| 12. | $e^{-at}x(t)$ | $X(ze^{aT})$ |
| 13. | $e^{-ak}x(k)$ | $X(ze^{a})$ |
| 14. | $a^kx(k)$ | $X\left(\dfrac{z}{a}\right)$ |
| 15. | $ka^kx(k)$ | $-z\dfrac{d}{dz}X\left(\dfrac{z}{a}\right)$ |
| 16. | $x(0)$ | $\lim\limits_{z\to\infty} X(z)$ if the limit exists |
| 17. | $x(\infty)$ | $\lim\limits_{z\to 1}\left[\left(1-z^{-1}\right)X(z)\right]$ if $\left(1-z^{-1}\right)X(z)$ is analytic on and outside the unit circle |
| 18. | $\nabla x(k)=x(k)-x(k-1)$ | $\left(1-z^{-1}\right)X(z)$ |
| 19. | $\Delta x(k)=x(k+1)-x(k)$ | $(z-1)X(z)-zx(0)$ |
| 20. | $\sum\limits_{k=0}^{n} x(k)$ | $\dfrac{1}{1-z^{-1}}X(z)$ |
| 21. | $\dfrac{\partial}{\partial a}x(t,a)$ | $\dfrac{\partial}{\partial a}X(z,a)$ |
| 22. | $k^mx(k)$ | $\left(-z\dfrac{d}{dz}\right)^m X(z)$ |
| 23. | $\sum\limits_{k=0}^{n} x(kT)y(nT-kT)$ | $X(z)Y(z)$ |
| 24. | $\sum\limits_{k=0}^{\infty} x(k)$ | $X(1)$ |

# THE UNIVERSITYOF ZAMBIA

## SCHOOL OF ENGINEERING

## DEPARTMENT OF MECHANICAL ENGINEERING

## END OF YEAR EXAMINATIONS FOR 2021 ACADEMIC YEAR

## ENG 2159 – MECHANICAL & ELECTRICAL WORKSHOP TECHNOLOGY

Time allowed: 3 HOURS plus 5 minutes reading time

Instructions to Candidates:

1. Check that you have the correct examination paper in front of you. This is a **Closed Book** examination.
2. The paper has Section A with TWO (2) Questions, Section B with Two (2) Questions, Section C with TWO (2) Questions and Section D with ONE (1) Question.
3. Attempt FIVE (5) Questions with at least ONE (1) question from each section. **The fifth question can be chosen from any section.**
4. Questions from each Section must be answered in SEPARATE examination answer booklets provided.
5. Write down the question number of each question that you have answered in the provided boxes on the cover of the examination answer booklet.
6. Begin each new solution to a question on a new page.
7. Non-programmable calculators and drawing instruments are allowed.
8. There shall be no form of communication between students during the examination. Any students caught doing this will be disqualified.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO

## SECCTION A

**QUESTION 1. (Compulsory)**

Builders Village Limited intends to engage you as a consultant to design an electrical wiring system for Kazungula Town Council CDF 1x3 with dimensions (12mx 45m) block of classrooms under lot 1.

(a) Draw the classroom and indicate the socket reticulation points.

**[5 Marks]**

(b) Draw and show in details the lighting system in the corridor there are two intermediate switches and fitted with photocell

**[6 Marks]**

(c) Professionally draw the DB supply circuit indicating all the protection and their ratings and connection provide for 3 spares

**[5 Marks ]**

(d) Indicate in the table the material schedule of your designed network are quantities **[4 Marks]**

**QUESTION 2.**

(a) State and define the principles of operation for 3 electrical protective devices found in the network

**[6 Marks]**

(b) State the procedure of resuscitating someone under electrical shock

**[4 Marks]**

(c) Write the switching program to isolate Annex building School of Engineering Transformer to under 52 weekly maintenance

**[10 Marks]**

## SECTION B

**QUESTION 3**

A 5.0V stabilised power supply is required to be produced from a 12V DC power supply input source. The maximum power rating $P_Z$ of the Zener diode is 2W. Using the Zener regulator circuit in Fig 1.1 calculate:

1.1 The maximum current flowing through the Zener diode.

**[3 Marks]**

1.2 The minimum value of the series resistor, $R_S$. **[3 Marks]**

1.3 The load current $I_L$ if a load of 1KΩ is connected across the Zener diode.

**[2 Marks]**

1.4 The Zener current $I_Z$ at full load. **[2 Marks]**

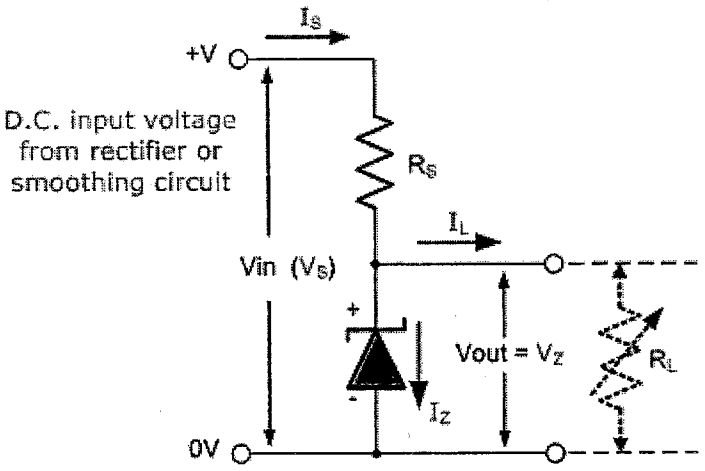


**Fig 1.1**

**1.5** Draw the circuit of a full wave rectifier showing clearly all the four (4) diodes. **[5 Marks]**

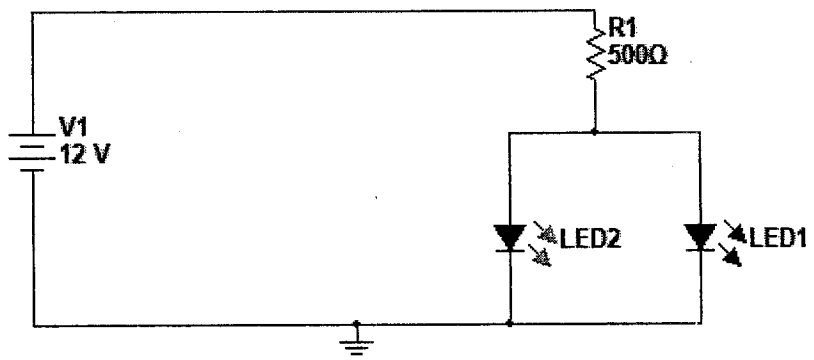


**Fig 1.2**

**1.6** From **Fig 1.3**, suppose LED1 requires 1.8V to light up and LED2 requires 2.1V to light up, state which LED will light up and explain why only one will light up and not the other. **[5 Marks]**

## QUESTION 4

2.1 What resistor attribute is used to determine its power rating? **[2 marks]**

2.2 Name any two types of resistors (based on physical or make). **[2 marks]**

2.3 What is the range of resistance for a 390Ω resistor with tolerance of ±10%?

**[2 marks]**

2.4 List any three uses of a capacitor and briefly explain each use.

**[6 marks]**

2.5 What is the function of resistors in electric circuits? **[2 marks]**

2.6 List all the resistor standard values of the **E6 Series.** **[6 marks]**

## SECTION C

***QUESTION 5* (Compulsory)**

(i) Outline the difference between the feed f and the feed rate ($f_r$) in lathe turning operations. What influence does the feed have on the turning process, **[8 Marks]**

(ii) A two-flute twist drill is used to drill a hole in a particleboard that is 19 mm thick. The drill diameter is 5 mm, the drill point angle is 90°, the spindle speed is 500 rpm and the feed rate is 0.5 mm/s. The specific cutting energy for particle board is 65 N/mm$^2$. Determine:

(a) The cutting speed **[3 Marks]**

(b) Material removal rate **[3 Marks]**

(c) The time required for drilling one hole **[4 Marks]**

(d) The power required for drilling **[2 Marks]**

**QUESTION 6**

(i) What are the ***Four (4)*** reasons of applying coating on electrodes? **[6 Marks]**

(ii) Write the ***Three (3)*** special features of Friction welding **[6 Marks]**

(iii) Distortion (warping) is a serious problem in fusion welding, particularly arc welding. What are some of the techniques ***(5 of them)*** that can be taken to reduce the incidence and extent of distortion? **[5 Marks]**

(iv) What is meant by the term faying surface in welding operations? **[3 Marks]**

## SECTION D

**QUESTION 7**

1.1 A downsprue of 180 mm length has a diameter of 20 mm at its top end. The liquid metal in pouring cup is maintained upto 60 mm height. What should be the diameter of the downsprue at its lower end to avoid aspiration?.

1.2 A mould of dimension 60 cm × 30 cm × 14 cm is to be filled by liquid metal using top pouring method (top gating). The liquid metal height above the top surface of the mould is 14 cm and the area of the gate is 6 cm$^2$. Find the time taken to fill the mould.

1.3 The line graph that represents change of phase of matter from liquid to solid is?

a) Cooling curve

b) Melting curve

c) Solid curve

d) Fusion line

1.4 In Casting, gating ratio is defined as the ratio of?

a) Sprue are: total runner area: total gate area

b) total gate area: sprue area: total runner area

c) total runner area: sprue area: total gate area

d) total runner area: total gate area: sprue area

1.5 Riser is designed so as to?

a) Freeze after the casting freezes

b) Freeze before the casting freezes

c) Maximise the time of pouring

d) Minimize the time of pouring

1.6 Which of the following is an example of permanent mould casting process?

a) Investment casting process

b) Die casting process

c) Full mould process

d) Vacuum casting process

1.7 Pickling treatment means cleaning the casting with?

a) Dilute acid

b) Soda ash

c) Iron shots

d) Compressed air and sand particles

1.8 Briefly explain the steps of investment casting process with neat sketch.

**[Q1 Total: 5+5+1+1+1+1+1+5 =20 Marks]**

**END OF ENG 2159 EXAMINATION**

THE UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

UNIVERSITY EXAMINATIONS

END OF YEAR EXAMINATIONS, 2021/2022

# ENG 3165 – FLUID MECHANICS AND THERMODYNAMICS

# QUESTION PAPER

**Read the following instructions carefully before you start writing:**

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1. ***This Examination is Closed Book.***
2. ***Time Allowed: Three (3) Hours.***
3. ***Answer: Five (5) questions, with at least two from Section A and two from Section B.***
4. ***All questions carry 20 marks each.***

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**[DO NOT TURN THE PAGE OVER UNTIL YOU ARE TOLD TO DO SO]**

## SECTION A – FLIUD MECHANICS:

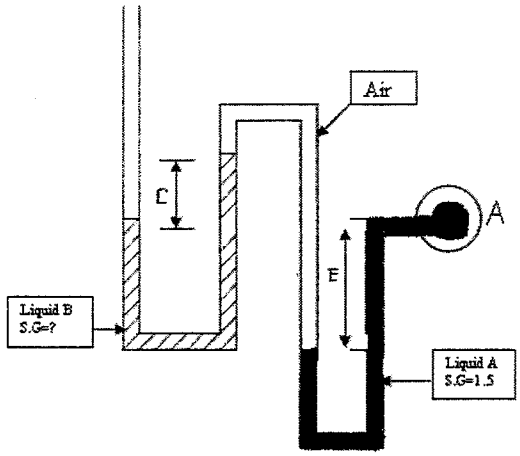
## ANSWER A MINIMUM OF TWO QUESTIONS IN THIS SECTION

### Question One

(a) State and explain Newton's law of viscosity.

(b) At an absolute pressure of 101.3kPa and temperature of 20°C, the absolute viscosity of a certain diatomic gas is 2 X $10^{-5}$ Pas and its kinematic viscosity is 15mm$^2$/s. Taking the universal gas constant as 8310 J/kg K and assuming the gas to be 'perfect', calculate its approximate relative molecular mass.

(c) For the Figure shown below, determine the specific gravity of gauge liquid B if the gauge pressure at A is -18 kN/m$^2$ The measurements in the diagram are C = 0.8m and E = 0.6m. The specific gravity for liquid A S.G = 1.5




**[4+6+10 marks]**

### Question Two

**a)** State Pascal's Law

**b)** Using diagrams where appropriate, differentiate between the following:
- i) Absolute Pressure and gauge pressure
- ii) Piezometer and differential manometer

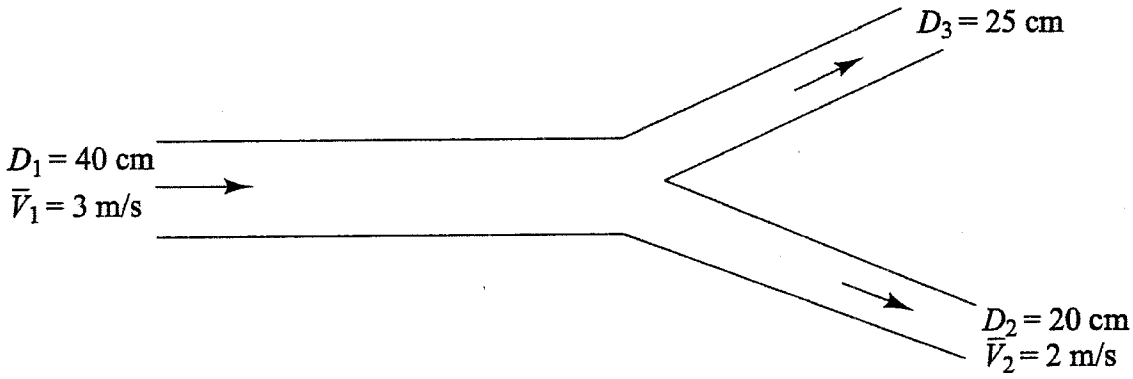
**c)** A differential manometer connected at the two points A and B in a pipe containing an oil (Liquid A and B) of specific gravity of 0.9 shows a difference in mercury levels as 175 mm.
- i) Illustrate this scenario using well defined labeled diagram
- ii) Find the difference in pressures (in heads of water) at the two points taking the specific gravity of the manometric fluid as 13.6.
- iii) Find the difference in pressures found in (b) in kN/m$^2$
- iv) Find the difference in pressures found in (b) in heads of mercury

**[2+8+10 marks]**

**Question Three**

a) Define fluid kinematics
b) Distinguish between;
   i) Steady flow and unsteady flow
   ii) Uniform flow and flow and non-uniform flow
   iii) Incompressible and compressible flow

c) A pipe 40cm long in diameter branches into two pipes of diameters 25cm and 20cm respectively as shown in the figure below. The average velocity in the 40cm pipe is 4m/s. Find,
   i) The discharge through the 40cm diameter pipe, and
   ii) The average velocity the 25cm diameter pipe if the average velocity in the 20cm pipe is 2m/s.



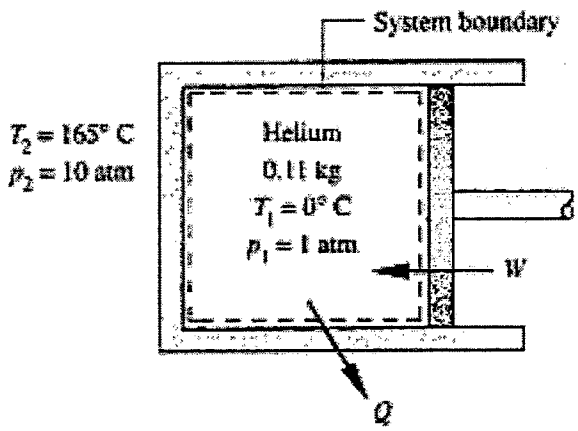

**[3+7+10 marks]**

## SECTION B – THERMODYNAMICS:

**ANSWER A MINIMUM OF TWO QUESTIONS IN THIS SECTION**

### Question Four

a) Differentiate between intensive and extensive properties.
b) Briefly explain why the Carnot cycle cannot be used for a real engine.
c) An inventor claims to have developed a heat engine that receives 700 kJ of heat from a source at 500 K and produces 300 kJ of network while rejecting the waste heat to a sink at 290 K. Is this a reasonable claim? Why?
d) A piston-cylinder compresses 0.11 kg of helium polytropically from 1 atm and 0°C to 10 atm and 165°C. Determine the work and heat for the process. For the gas, $C_v = 3.1189$ kJ/kgK and R=2.077 kJ/kgK




***Given one standard atmosphere = 1.01325 bar = 101,325 N/m²***

**[4+3+5+8 marks]**

### Question Five

a) What are the air-standard assumptions?
b) How does a diesel engine differ from a gasoline engine?
c) An air-standard Diesel cycle has a compression ratio of 16 and a cut-off ratio of 2. At the beginning of the compression process, air is at 95 kPa and 27°C. Accounting for the variation of specific heats with temperature, determine:

i) The temperature after the heat-addition process.
ii) The thermal efficiency.
iii) The mean effective pressure.

***[8+2+10 marks]***

## Question Six

**a)** Define the term refrigeration and explain how a refrigerator differs from a heat pump.

**b)** When selecting a refrigerant for a certain application, what three qualities would you look for in the refrigerant?

**c)** A refrigerator is to remove heat from the cooled space at a rate of 300 kJ/min to maintain its temperature at -8°C. If the air surrounding the refrigerator is at 25°C, determine the minimum power input required for this refrigerator.

**[6+8+6 marks]**

## Question Seven

(a) Define conduction, convection and radiation in relation to heat transfer

(b) Define a black body in relation to emissivity.

(c) A brick wall 300 mm thick is faced with concrete 75 mm thick. The brick has a coefficient of thermal conductivity of 0.69 W/m K while that of the concrete is 0.93 W/mK. If the temperature of the exposed brick face is 45°C and that of the concrete is 12°C.

(i) Determine the heat lost per hour through a wall 15 m long and 6 m high.

(ii) Determine, also, the interface temperature.

**[6+4 +10 marks]**

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# END OF ENG 3165 EXAMINATION – NOVEMBER 2022

**F. K. CHITALU**

**UNIVERSITY OF ZAMBIA**

**SCHOOL OF ENGINEERING**

**2022 ACADEMIC YEAR**

# ENG 4129 – ENGINEERING MANAGEMENT AND SOCIETY I

**FINAL EXAMINATION**

**DATE: NOVEMBER 18, 2022**

**TIME: 14:00 – 17:00HRS**

**VENUE: SPORTS HALL**

INSTRUCTIONS:

1. This examination paper contains two sections and nine questions. You are expected to answer seven questions.
2. Questions in **Section A** are COMPULSORY. Choose any four (4) questions from **Section B**.
3. Each question in **Section A** contains 20 marks, and in **Section B**, each question contains 10 marks.
4. Make sure the student number is clearly indicated on all booklets together with the questions attempted.
5. The answer for each question should begin on a new sheet
6. Where specific information is not given, make and state your assumptions
7. Marks will be lost for illegible, untidy and unorganised presentation
8. The examination is strictly closed book
9. Total marks for this examination is 100 but contributes 70% towards the final assessment for this course.

## SECTION A – ALL QUESTIONS MUST BE ANSWERED (COMPULSORY)

1. Your good friend Mulenga Muzamai, a sole trader, extracted the following Trial Balance (TB) from his books at the close of business on December 31, 2021.

| | Dr (ZMW) | Cr (ZMW) |
|---|---|---|
| Purchases and sales | 22,860 | 41,970 |
| Stock 1 January 2021 | 5,160 | |
| Capital 1 January 2021 | | 7,200 |
| Bank overdraft | | 4,350 |
| Cash | 90 | |
| Discounts | 1,440 | 930 |
| Returns inwards | 810 | |
| Returns outwards | | 570 |
| Carriage outwards | 2,160 | |
| Rent and Insurance | 1,740 | |
| Fixtures and Fittings | 1,200 | |
| Drawings | 2,880 | |
| Wages and salaries | 8,940 | |
| General office expenses | 450 | |
| Debtors and creditors | 11,910 | 6,060 |
| Provision for bad and doubtful debts | | 660 |
| Delivery van | 2,100 | |
| | **61,740** | **61,740** |

Notes

a) Stock at December 31, 2021 K4,290
b) Wages and salaries accrued at December 31, 2021 K210
c) Office expenses owing K20
d) Rent prepaid at December 31, 2021 K180
e) Increase the provision for bad and doubtful debts by K150 to K810
f) Provide for depreciation as follows: Fixtures and fittings K120; Delivery van K300

**Required**

a) Draw up the Statement of Profit or Loss and Other Comprehensive Income for the year ended December 31, 2021 together with the Statement of Financial Position as at December 31, 2021
(10 + 6) *16 marks*
b) Give four (4) reasons why accounting is important for the success of your friend's business. *4 marks*

***(Total: 20 marks)***

2. The market for pizza has the following demand and supply schedules:

| Price (ZMW) | Quantity demanded | Quantity supplied |
|---|---|---|
| 4 | 135 | 26 |
| 5 | 104 | 53 |
| 6 | 81 | 81 |
| 7 | 68 | 98 |
| 8 | 53 | 110 |
| 9 | 39 | 121 |

**Required:**

i) Define a market and give two reasons why markets are important for the Zambian economic transformation. *3 marks*

ii) Graph the demand and supply curves. What is the equilibrium price and quantity in the market? *6 marks*

iii) If the actual price in this market were above the Equilibrium price, what would drive the market towards the equilibrium? *2 marks*

iv) If the actual price in this market were below the equilibrium price, what would drive the market towards the equilibrium? *2 marks*

v) State two differences between microeconomics and macroeconomics. *2 marks*

vi) What is the role of Bank of Zambia (BoZ) in the transformation of the Zambian economy? *5 marks*

***(Total: 20 marks)***

3. (a) The Zambian economy needs a vibrant private sector to accelerate its economic recovery.
In relation to the above statement, you are required to:

*i)* State the factors of production. *4 marks*

*ii)* Why is a vibrant private sector important to Zambia's economic recovery? *6 marks*

b) The initial investment for Project Lusaka is K150, 000. It is expected to provide incomes of K13, 600, K86, 000, K92, 000 and K30, 000 for the first, second, third and fourth years, respectively.

**Required:**

(i) What is the net present value (NPV) for the project if the company's cost of capital is 15%? Is it a worthwhile investment? *5 marks*

(ii) Calculate the payback period for the project. State two advantages and disadvantages of the payback method for investment appraisal. *5 marks*

Discount tables are provided.

***(Total: 20 marks)***

## SECTION B - ANSWER ANY FOUR QUESTIONS

4. Suppose that a country can produce two goods: food and clothing. To produce one unit of food it requires one worker. To produce one unit of clothing it requires two workers. The total amount of workers available in the economy is fixed and is equal to 100. Denote by L the total amount of workers available, F the units of food produced, and C the units of clothing produced. Denote by $a_F$ the amount of workers needed to produce one unit of food and $a_C$ the amount of workers needed to produce one unit of clothing. The resource constraint for the economy can be written as: $L = a_F F + a_C C$.

**Required:**

a) Define the production possibility frontier. *1 mark*

b) Show how to construct the production possibility frontier (PPF) curve from that resource constraint. *3 marks*

c) On a graph with C on the vertical axis and F on the horizontal axis, plot the PPF of this economy. *5 marks*

d) What is the slope of the PPF? *1 mark*

***(Total:10 marks)***

5. Write up the assets, and liability and capital accounts to record the following transactions in the records of Goodfellow Lyondo.

| **2022** | |
|---|---|
| July 1 | Started business with K2,500 in the bank |
| July 2 | Bought office furniture by cheque |
| July 3 | Bought machinery for K750 on credit from Planers Limited |
| July 5 | Bought a motor vehicle paying by cheque K600 |
| July 8 | Sold some of the office furniture – not suitable for the firm for K60 on credit to John Walker Muzamai. |
| July 15 | Paid the amount owing to Planers Limited K750 by cheque. |
| July 23 | Received the amount due from John Walker Muzamai K60 in cash |
| July 31 | Bought more machinery by cheque K280 |

***(Total: 10 marks)***

6. The Government of the Republic of Zambia (GRZ) is encouraging every citizen, more especially the youth to engage into entrepreneurship.

**Required:**

In relation to the above statement answer the following questions:

a) What has motivated GRZ to encourage the youths to go into business? *4 marks*

b) What excites you about being an entrepreneur? *2 marks*

c) What do you understand by the terms; spending multiplier and crowding-out effect in economics? *4 marks*

***(Total: 10 marks)***

7. You are to enter up the necessary accounts for the month of October from the following details, and then balance off the accounts and extract a trial balance as at October 30, 2022:

| 2022 | |
|---|---|
| Oct, 1 | Started business with K600 in the bank and K50 cash in hand |
| Oct 2 | Bought K500 goods on credit from Chinjanja Jones |
| Oct, 3 | Credit sales: Hamusankwa Henry K66, Naluca Neita K25, Pilato Potter K43 |
| Oct 4 | Goods bought for cash K23 |
| Oct, 5 | Bought motor van paying by cheque K256 |
| Oct, 7 | Paid motor expenses by cheque K12 |
| Oct, 9 | Credit sales: Banda Barnes K24; Kulima Lyn K26; Monde Moore K65 |
| Oct, 11 | Goods bought on credit: Chanda Jones K240; Nonde Moss K62, Obvius Hughes K46 |
| Oct, 13 | Goods returned by us to Chanda Jones K25 |
| Oct, 15 | Paid motor expenses by cash K5 |
| Oct, 19 | Goods returned to us by Naluca Neita K11 |
| Oct, 31 | Cash taken for own use (drawings) K10 |

***10 marks***

8. The new dawn administration is working hard to revitalise the Zambian economy. One of the things its working on is to reduce unemployment.

**Required:**
Related to the above statement please answer the following questions:

a) What is unemployment? *1 mark*
b) Define two types of unemployment. *2 marks*
c) What are the causes of unemployment? *3 marks*
d) What is the relationship between inflation and unemployment? *4 marks*

***(Total: 10 marks)***

9. The table below shows consumer spending by households and income from 1999 to 2009, both in ZMW billion.
   a. Plot a scatter diagram with consumption on the vertical axis and income on the horizontal axis. Fit a line through these points. *6 marks*
   b. Are consumption and income related; explain? *4 marks*

| Zambia | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Income | 1067 | 1109 | 1136 | 1160 | 1192 | 1227 | 1254 | 1290 | 1323 | 1330 | 1265 |
| Consumption | 644 | 673 | 695 | 720 | 743 | 767 | 784 | 796 | 815 | 822 | 796 |

(Total: ***10 marks)***

**The End**

# PRESENT VALUE TABLE

| *r* = interest rate; *n* = number of periods until payment or receiptpt. | Interest rates (*r*) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1% | 2% | 3% | 4% | 5% | 6% | 7% | 8% | 9% | 10% |
| 1 | 0.990 | 0.980 | 0.971 | 0.962 | 0.952 | 0.943 | 0.935 | 0.926 | 0.917 | 0.909 |
| 2 | 0.980 | 0.961 | 0.943 | 0.925 | 0.907 | 0.890 | 0.873 | 0.857 | 0.842 | 0.826 |
| 3 | 0.971 | 0.942 | 0.915 | 0.889 | 0.864 | 0.840 | 0.816 | 0.794 | 0.772 | 0.751 |
| 4 | 0.961 | 0.924 | 0.888 | 0.855 | 0.823 | 0.792 | 0.763 | 0.735 | 0.708 | 0.683 |
| 5 | 0.951 | 0.906 | 0.863 | 0.822 | 0.784 | 0.747 | 0.713 | 0.681 | 0.650 | 0.621 |
| 6 | 0.942 | 0.888 | 0.837 | 0.790 | 0.746 | 0705 | 0.666 | 0.630 | 0.596 | 0.564 |
| 7 | 0.933 | 0.871 | 0.813 | 0.760 | 0.711 | 0.665 | 0.623 | 0.583 | 0.547 | 0.513 |
| 8 | 0.923 | 0.853 | 0.789 | 0.731 | 0.677 | 0.627 | 0.582 | 0.540 | 0.502 | 0.467 |
| 9 | 0.914 | 0.837 | 0.766 | 0.703 | 0.645 | 0.592 | 0.544 | 0.500 | 0.460 | 0.424 |
| 10 | 0.905 | 0.820 | 0.744 | 0.676 | 0.614 | 0.558 | 0.508 | 0.463 | 0.422 | 0.386 |
| 11 | 0.896 | 0.804 | 0.722 | 0.650 | 0.585 | 0.527 | 0.475 | 0.429 | 0.388 | 0.350 |
| 12 | 0.887 | 0.788 | 0.701 | 0.625 | 0.557 | 0.497 | 0.444 | 0.397 | 0.356 | 0.319 |
| 13 | 0.879 | 0.773 | 0.681 | 0.601 | 0.530 | 0.469 | 0.415 | 0.368 | 0.326 | 0.290 |
| 14 | 0.870 | 0.758 | 0.661 | 0.577 | 0.505 | 0.442 | 0.388 | 0.340 | 0.299 | 0.263 |
| 15 | 0.861 | 0.743 | 0.642 | 0.555 | 0.481 | 0.417 | 0.362 | 0.315 | 0.275 | 0.239 |
| 16 | 0.853 | 0.728 | 0.623 | 0.534 | 0.458 | 0.394 | 0.339 | 0.292 | 0.252 | 0.218 |
| 17 | 0.844 | 0.714 | 0.605 | 0.513 | 0.436 | 0.371 | 0.317 | 0.270 | 0.231 | 0.198 |
| 18 | 0.836 | 0.700 | 0.587 | 0.494 | 0.416 | 0.350 | 0.296 | 0.250 | 0.212 | 0.180 |
| 19 | 0.828 | 0.686 | 0.570 | 0.475 | 0.396 | 0.331 | 0.277 | 0.232 | 0.194 | 0.164 |
| 20 | 0.820 | 0.673 | 0.554 | 0.456 | 0.377 | 0.312 | 0.258 | 0.215 | 0.178 | 0.149 |

| *r* = interest rate; *n* = number of periods until payment or receipt. | Interest rates (*r*) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 11% | 12% | 13% | 14% | 15% | 16% | 17% | 18% | 19% | 20% |
| 1 | 0.901 | 0.893 | 0.885 | 0.877 | 0.870 | 0.862 | 0.855 | 0.847 | 0.840 | 0.833 |
| 2 | 0.812 | 0.797 | 0.783 | 0.769 | 0.756 | 0.743 | 0.731 | 0.718 | 0.706 | 0.694 |
| 3 | 0.731 | 0.712 | 0.693 | 0.675 | 0.658 | 0.641 | 0.624 | 0.609 | 0.593 | 0.579 |
| 4 | 0.659 | 0.636 | 0.613 | 0.592 | 0.572 | 0.552 | 0.534 | 0.516 | 0.499 | 0.482 |
| 5 | 0.593 | 0.567 | 0.543 | 0.519 | 0.497 | 0.476 | 0.456 | 0.437 | 0.419 | 0.402 |
| 6 | 0.535 | 0.507 | 0.480 | 0.456 | 0.432 | 0.410 | 0.390 | 0.370 | 0.352 | 0.335 |
| 7 | 0.482 | 0.452 | 0.425 | 0.400 | 0.376 | 0.354 | 0.333 | 0.314 | 0.296 | 0.279 |
| 8 | 0.434 | 0.404 | 0.376 | 0.351 | 0.327 | 0.305 | 0.285 | 0.266 | 0.249 | 0.233 |
| 9 | 0.391 | 0.361 | 0.333 | 0.308 | 0.284 | 0.263 | 0.243 | 0.225 | 0.209 | 0.194 |
| 10 | 0.352 | 0.322 | 0.295 | 0.270 | 0.247 | 0.227 | 0.208 | 0.191 | 0.176 | 0.162 |
| 11 | 0.317 | 0.287 | 0.261 | 0.237 | 0.215 | 0.195 | 0.178 | 0.162 | 0.148 | 0.135 |
| 12 | 0.286 | 0.257 | 0.231 | 0.208 | 0.187 | 0.168 | 0.152 | 0.137 | 0.124 | 0.112 |
| 13 | 0.258 | 0.229 | 0.204 | 0.182 | 0.163 | 0.145 | 0.130 | 0.116 | 0.104 | 0.093 |
| 14 | 0.232 | 0.205 | 0.181 | 0.160 | 0.141 | 0.125 | 0.111 | 0.099 | 0.088 | 0.078 |
| 15 | 0.209 | 0.183 | 0.160 | 0.140 | 0.123 | 0.108 | 0.095 | 0.084 | 0.079 | 0.065 |
| 16 | 0.188 | 0.163 | 0.141 | 0.123 | 0.107 | 0.093 | 0.081 | 0.071 | 0.062 | 0.054 |
| 17 | 0.170 | 0.146 | 0.125 | 0.108 | 0.093 | 0.080 | 0.069 | 0.060 | 0.052 | 0.045 |
| 18 | 0.153 | 0.130 | 0.111 | 0.095 | 0.081 | 0.069 | 0.059 | 0.051 | 0.044 | 0.038 |
| 19 | 0.138 | 0.116 | 0.098 | 0.083 | 0.070 | 0.060 | 0.051 | 0.043 | 0.037 | 0.031 |
| 20 | 0.124 | 0.104 | 0.087 | 0.073 | 0.061 | 0.051 | 0.043 | 0.037 | 0.031 | 0.026 |

# THE UNIVERSITY OF ZAMBIA
# SCHOOL OF ENGINEERING

## FINAL EXAMINATIONS

**(November to December 2022)**

**COURSE TITLE: ENGINEERING MANAGEMENT II**

**ENG 5129**

## INSTRUCTIONS

1. **EXAM DURATION IS 3 HOURS**

2. **Answer a TOTAL of FIVE Questions i.e. Any TWO from Section A plus any THREE from Section B**

## SECTION A (Answer ANY TWO Questions from this Section)

## QUESTION ONE

**(a)** Figure 1 below illustrates Three types of planning (**A**, **B**, and **C**) done in an organization by different three level of management. Name and briefly describe the characteristics of each type of planning illustrated in the figure. **(6 marks)**

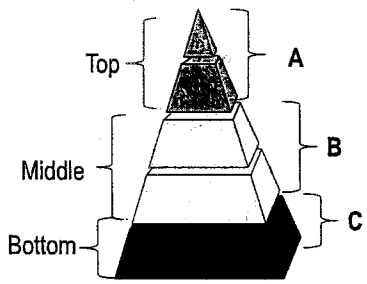


**Figure 1:** Illustrating the Three Types of Planning in an Organization

**(b)** Name and briefly explain the marketing mix. **(4 marks)**

**(c)** Name and briefly describe the Four basic functions of management (in the order of their importance) that constitute the management process. **(4 marks)**

**(d)** Figure 2 below illustrates the SWOT Framework. Name the labels A, B, C, D, X, and Y, to complete the SWOT Framework illustrated in Figure 2. **(6 marks)**

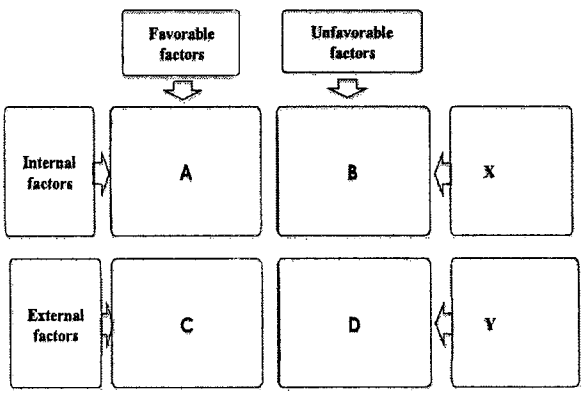


**Figure 2:** The SWOT Framework

**(Total 20 Marks)**

## QUESTION TWO

(a) Briefly explain why personnel specifications should be prepared when planning recruitment, indicating the 4 components that are critical in the preparations. **(4 marks)**

(b) What is a job description? Describe the role of a job description for **(i)** employer, **(ii)** employee. **(6 marks)**

(c) Planning is a process comprising of six steps. Describe each of these steps. **(6 marks)**

(d) Briefly describe the 4 main organization structures. **(4 marks)**

SLPDCD

**(Total 20 Marks)**

## QUESTION THREE

(a)Name and briefly describe the three managerial skills that are important for successful management performance (in the order of one`s work experience upon joining a company from the university) **(6 marks)**

(b) Discuss the three components involved in the environmental levels analysis in strategic planning. **(6 marks)**

(c) Briefly describe two main areas when managing human resource. **(2 marks)**

(d) Briefly explain what managerial effectiveness and efficiency is. **(2 marks)**

(e) The Chief Executive Officer (CEO) is said to be the chief planner. Describe the roles of the CEO regarding his/her roles as company planner. **(4 marks)**

**(Total 20 Marks)**

## SECTION B (Answer ANY THREE Questions from this Section)

## QUESTION FOUR

(a) Fully Differentiate between the terms Management Contract and Service Contract **(10 Marks)**

(b) The National Electricity Utility Intends to improve revenue collection from 65% to 90% and have therefore decided to enter into a partnership with the private sector who have the availability institute measures to improve revenue collection. As an expert advisor which PPP option would you recommend giving reasons for your preference **(10 Marks)**

**(Total 20 Marks)**

## QUESTION FIVE

(a) Explain fully **FOUR** key **FUNDAMENTAL** features required for the formation of an Engineering Contract **(8 Marks)**

(b) What is a voidable contract? Hint: Use an example to support your answer **(6 Marks)**

(c) In the Alternative Dispute Resolution Process for resolving contractual disputes outline a scenario **where the outcome is decided by introducing a third party who assists the two parties in dispute by communicating their position on the issues and exploring possible solutions.** **(6 Marks)**

**(Total 20 Marks)**

## QUESTION SIX

The Director of Marketing wants to compare the benefits of the PMO information system with developing a new line of business by creating an online project management training curriculum. For the PMO information system the initial investment is $750,000 and $45,000 per year to maintain. The benefits would not be available until the second year. The enhanced infrastructure is expected to generate revenue, as shown in the table, for Years 2 through 5 before needing to be replaced. The online project management training investment is $325,000 in Year 1 and $35,000 in Years 2 through 5 to maintain. You expect to have $1,500,000 in sales the first year and $3,500,000 in Years 2 through 5. The table below shows the information presented above

The table below shows the information presented above.

| | **PMO Upgrade** | | | **Virtual Training** | | |
|---|---|---|---|---|---|---|
| Year | Benefits | Costs | NPV | Benefits | Costs | NPV |
| 1 | — | 750,000 | | 1,500,000 | 325,000 | |
| 2 | 2,500,000 | 45,000 | | 3,500,000 | 35,000 | |
| 3 | 5,250,000 | 45,000 | | 3,500,000 | 35,000 | |
| 4 | 6,000,000 | 45,000 | | 3,500,000 | 35,000 | |
| 5 | 6,000,000 | 45,000 | | 3,500,000 | .35,000 | |

The discount rate is 8 percent

Which is the better option?

**(Total 20 Marks)**

## QUESTION SEVEN

**(a)** List any FIVE reasons why a project may fail and suggest ways to rectify these failures **(5 Marks)**

**(b)** With the aid of an illustration give a detailed outline of what is contained in a project charter. **(15 Marks)**

**(Total 20 Marks)**

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**END OF EXAMINATION**

*Dr Simon Tembo 2022*
*Dr Ian N. Banda 2022*
*Dr Joseph M. Chileshe 2022*

# The University of Zambia

## Department of Mathematics & Statistics

## 2021/2022 Academic Year Final Examinations

## MAT2110 - Engineering Mathematics I

Time allowed : Three (3) hours | Full marks : 100

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**Instructions:**
- There are **six (6)** questions in this paper. Attempt **any five (5)** questions. All questions carry **equal** marks.
- **Full credit** will only be given when **necessary work** is shown.
- Indicate your **computer number** on all answer booklets.

*This paper consists of two pages of questions.*

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1. a) Given that $9x^2 - 4y^2 - 36x - 24y = 36$ is an equation of a conic section.
   i) Express it in standard form and identify it. [6 marks]
   ii) Sketch the graph of the given conic section. [4 marks]

   b) Change the polar equations to Cartesian equations and identify or describe it.
   i) $r^2 = r\sin\theta$. [3 marks]
   ii) $r = 4\csc\theta$. [3 marks]

   c) If the $xy$-axes are rotated through $30^o$, find the $XY$-coordinates of the point $(x, y) = (2, 6)$. [4 marks]

2. a) Use Linearization to approximate $\sqrt{50}$. [4 marks]

   b) i) Given that $2x + y - \sqrt{2}\sin(xy) = \frac{\pi}{2}$. Find $\frac{dy}{dx}$ implicitly. [4 marks]
   ii) Find the length of the portion of the curve given by

$$x = \frac{2}{3}e^{\frac{3}{2}t},\ y = e^t,\ \ln 3 \leq t \leq \ln 8. \quad [5\ marks]$$

   c) A water tank is in the shape of an inverted right cone with top radius $10m$ and depth $8m$. Water is flowing in at a rate of $\frac{1}{10}m^3/min$. How fast is the depth of the water in the tank increasing when the water is $4m$ deep? [7 marks]

3. **Evaluate**

i) $\int \frac{\sin^3(\ln x)\cos^3\ln(x)}{x}dx$. [5 marks]

ii) $\int x^3e^{2x}dx$. [5 marks]

**b) Find the arc length** of the cardioid $r = 2 + 2\cos\theta,\ 0 \le \theta \le 2\pi$. [5 marks]

**c) Determine** the volume of the solid obtained by rotating the region bounded by $y = x^2 - 2x$ and $y = x$ about the line $y = 4$ [5 marks]

4. **a)** A thin plate in the $xy$-plane is covering the finite region bounded by the curve $y = (x-1)^3$, the line $x = 2$ and the $x$-axis. Assuming unit density of the plane, find

i) the moment about the $y$-axis. [4 marks]

ii) the moment of inertia about the $x$-axis. [3 marks]

b) i) Using the definition (first principles) find $\frac{\partial f}{\partial x}$ for $f(x,y) = \frac{\sqrt{y}}{x^2}$. [4 marks]

ii) Find the Taylor series of $f(x) = \ln x$ about $x = 1$ [3 marks]

c) Test the convergence of the following series

i) $\sum_{n=2}^{\infty} \frac{2}{n-1}$. [3 marks]

ii) $\sum_{n=0}^{\infty} \frac{(\ln 2)^n}{n!}$ [3 marks]

5. a) Locate and classify the critical points of $f(x,y) = x^2 - 3xy + y^3$. [8 marks]

b) Use Lagrange multiplier method to find the shortest distance from the origin to the curve $x^2y = 16$. [8 marks]

c) Let $z = \sqrt{x^2+y^2}$, $x = u^2$ and $y = uv$. Show that $\frac{\partial z}{\partial u} = \frac{2u^2+v^2}{\sqrt{u^2+v^2}}$. [4 marks]

6. a) Find the general solution of $\frac{dy}{dx} = x - 1 + xy - y$. [4 marks]

b) Given the Bernoulli equation $\frac{dy}{dx} = \frac{y}{x} + \frac{3x^3\cos x^2}{y}$.

i) By an appropriate change of variable, transform it in a linear equation. [3 marks]

ii) Hence or otherwise, find the general solution. [5 marks]

c) Find the particular solution of the differential equation $y'' - \frac{3}{2}y' - y = 0$ under the initial conditions $y(0) = 0$ and $y'(0) = 2$. [8 marks]

END OF EXAMINATION!

# The University of Zambia
# School of Natural Sciences
# Department of Mathematics and Statistics

**2021/22 Academic Year Examinations**

## MAT 3110 Engineering Mathematics II

**November 21, 2022.**

*Duration: THREE Hours*

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**Instructions:**

- This paper consists of seven questions, each carry 20 marks. Attempt any FIVE questions. Total marks is 100.
- Show all the essential working to earn full marks.
- Non programmable calculators are allowed.
- This paper consists of four (4) printed pages.

---

1. (a) For each of the following power series, find the second derivative, $y''$, and then shift the index of the second derivative so that the power under the summation sign is $x^m$.

i. (3 mark

$$y = \sum_{m=1}^{\infty} \frac{m(m+1)}{m^2+1} x^{m-1}$$

ii. (3 mark

$$y = \sum_{m=0}^{\infty} \frac{m^2}{m+1} x^{m+4}$$

(b) Find a series solution for the following differential equations.

i. $y'' - xy = 0$ (5 mark

ii. $(x^2+1)\,y'' - 4xy' + 6y = 0$ (6 mark

(c) Show that (3 mark

$$y = \sum_{m=0}^{\infty} \frac{2^m x^m}{m!} = 1 + 2x + 2x^2 + \frac{4x^3}{3} + \cdots$$

is a solution to the differential equation

$$y' - 2y = 0.$$

2. (a) Find the solution to the following differential equations.

i. $x^2y'' - 7xy' + 16y = 0$ (3 mark

ii. $x^2y'' + 3xy' + 4y = 0$ (3 mark

(b) Find the eigenvalues and eigenvectors of the following matrices.

i. $A = \begin{pmatrix} 1 & -1 \\ \frac{4}{9} & -\frac{1}{3} \end{pmatrix}$ (4 mark

ii. $B = \begin{pmatrix} 2 & 7 \\ -1 & -6 \end{pmatrix}$ (4 mark

(c) Find the solution to the following system of first order ordinary differential equation. (6 mark

$$x'_1 = x_1 + 2x_2 \qquad x_1(0) = 0$$
$$x'_2 = 3x_1 + 2x_2 \qquad x_2(0) = -4$$

3. (a) Find the Laplace transforms of the given functions.

i. $f(t) = 6e^{-5t} + e^{3t} + 5t^3 - 9$ (2 mar

ii. $g(t) = e^{3t} + \cos(6t) - e^{3t}\cos(6t)$ (3 mar

(b) Find the inverse transform of each of the following.

i. $F(s) = \dfrac{19}{s+2} - \dfrac{1}{3s-5} + \dfrac{7}{s^5}$ (3 mar

ii. $G(s) = \dfrac{6s}{s^2+25} + \dfrac{3}{s^2+25}$ (2 mar

(c) Solve the following initial value problem. (10 mar

$$y'' + 2y' - 3y = u(t-2)\,e^{4-2t}, \qquad y(0) = 0 \quad y'(0) = 0$$

4. (a) Evaluate the following double integrals.

i. (3 mar

$$\int_0^1 \int_0^2 4 - y^2 \, dy \, dx$$

ii. (3 mar

$$\int_0^{\pi} \int_x^{\pi} \frac{\sin y}{y} \, dx dy$$

(b) Evaluate the following double integrals.

i. (4 mar

$$\int_0^{\ln 2} \int_0^{\sqrt{(\ln 2)^2 - y^2}} e^{\sqrt{x^2+y^2}} \, dx \, dy$$

ii. (4 mar

$$\int_{-1}^{1}\int_{-\sqrt{1-x^2}}^{\sqrt{1-x^2}} \frac{2}{(1+x^2+y^2)^2}\, dy\,dx$$

(c) i. Sketch the region in the $xy$-plane bounded by $x = y - y^2$ and $y = -x$. (2 mar

ii. Use a double integral to find the area of the region in i. (4 mar

5. (a) Evaluate the following triple integrals

i. (3 mar

$$\int_1^e \int_1^e \int_1^e \frac{1}{xyz}\, dy\, dz\, dx$$

ii. (3 mar

$$\int_{-1}^{1}\int_{-1}^{1}\int_{-1}^{1} x + y + z\; dz\, dy\, dx$$

(b) i. Evaluate the following triple integrals by first converting the integral into cylindrical coordinates. (4 mar

$$\int_0^3 \int_{-\sqrt{9-x^2}}^{\sqrt{9-x^2}} \int_{-\sqrt{2x^2+2y^2}}^{6+x^2+y^2} 15z\; dz\, dy\, dx$$

ii. Evaluate the following triple integrals by first converting the integral into spherical coordinates. (5 mar

$$\int_{-\sqrt{5}}^{\sqrt{5}} \int_0^{\sqrt{5-y^2}} \int_{-\sqrt{10-x^2-y^2}}^{-\sqrt{x^2+y^2}} 3xz\;\; dz\, dx\, dy$$

(c) Use a triple integral to determine the volume of the region behind $x = z + 3$, in front of $x = -z - 6$ and inside the cylinder $y^2 + z^2 = 4$. (5 ma

6. (a) Show that the following vector fields are conservative

i. $\vec{\mathbf{F}}(x,y,z) = \left(12x - 5z^2\right)\vec{i} + \ln\left(1+z^2\right)\vec{j} - \left(10xz - \dfrac{2yz}{1+z^2}\right)\vec{k}$ (4 ma

ii. $\vec{\mathbf{F}}(x,y) = 2x\cos y\;\vec{\mathbf{i}} - x^2\sin y\;\vec{\mathbf{j}}$ (2 ma

(b) Find a potential function $f$ for each of the following vector fields.

i. $\vec{\mathbf{F}}(x,y,z) = \left(12x - 5z^2\right)\vec{i} + \ln\left(1+z^2\right)\vec{j} - \left(10xz - \dfrac{2yz}{1+z^2}\right)\vec{k}$ (6 ma

ii. $\vec{\mathbf{F}}(x,y) = 2x\cos y\;\vec{\mathbf{i}} - x^2\sin y\;\vec{\mathbf{j}}$ (4 ma

(c) Evaluate the line integral

$$\int_C \left(2x\cos y\;\vec{\mathbf{i}} - x^2\sin y\;\vec{\mathbf{j}}\right)\cdot \mathrm{d}r$$

along the following paths $C$ in the $xy$-plane.

i. The parabola $y = (x-1)^2$ from $(1,0)$ to $(0,1)$. (2 marks

ii. The line segment from $(-1,\pi)$ to $(1,0)$. (2 marks

✓ 7. (a) Evaluate the following line integrals

i. (3 marks

$$\int_C x + y \, ds$$

where $C$ is the straight line segment from $(0,1,0)$ to $(1,0,0)$.

ii. (3 marks

$$\int_C xy + y + z \, ds$$

where $C$ is given by the vector equation $\vec{\mathbf{r}}(t) = 2t\ \vec{\mathbf{i}} + t\ \vec{\mathbf{j}} + (2-2t)\ \vec{\mathbf{k}}$, $0 \leq t \leq 1$.

(b) Evaluate the following line integrals

i. (4 mark

$$\int_C \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}}$$

where $\vec{\mathbf{F}}(x,y) = y\ \vec{\mathbf{i}} - x\ \vec{\mathbf{j}}$ and $C$ is along the unit circle from $(1,0)$ to $(0,1)$ in the counterclockwise direction.

ii. (4 mark

$$\int_C \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}}$$

where $\vec{\mathbf{F}}(x,y) = xy\ \vec{\mathbf{i}} + (y-x)\ \vec{\mathbf{j}}$ and $C$ the straight line from $(1,1)$ to $(2,3)$.

(c) Use Green's theorem to evaluate (6 mark

$$\int_C \vec{\mathbf{F}} \cdot dr,$$

where $\vec{\mathbf{F}}(x,y) = \tan^{-1}\left(\frac{y}{x}\right)\ \vec{\mathbf{i}} + \ln(x^2+y^2)\ \vec{\mathbf{j}}$ and $C$ is the boundary of the region defined by the polar coordinate inequalieties $1 \leq r \leq 2$ and $0 \leq \theta \leq \pi$.

*End of Examination*

# THE UNIVERSITY OF ZAMBIA
## SCHOOL OF ENGINEERING
## DEPARTMENT OF MECHANICAL ENGINEERING

### 2022 UNIVERSITY FINAL EXAMINATION

### MEC 2009 – ENGINEERING DRAWING I

**TIME ALLOWED:** FOUR (4) HOURS

**CLOSED BOOK EXAMINATION:** TEXT BOOKS AND MARKED TUTORIAL SHEETS ARE NOT ALLOWED

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**INSTRUCTIONS**

1. Answer questions as follows:

   a. SECTION **A**: This section is compulsory.
   b. SECTION **B**: Answer any **TWO (2)** question from this section.
   c. SECTION **C**: Answer any **ONE (1)** question from this section.

2. **ONLY** Section **A** should be done on the drawing paper face which will bear the **Title Block**.

3. Sections **B** should be answered on a **SEPARATE DRAWING ANSWER SHEET. Indicate ONLY your Computer Number on this drawing sheet.** Clearly label answered questions.

4. Section **C** should be answered on a **SEPARATE DRAWING ANSWER SHEET. Indicate ONLY your Computer Number on this drawing sheet.** Clearly label answered question.

5. Indicate only your computer number in the title block and on all other drawing sheets used. **DO NOT INDICATE YOUR NAME ON ANY ANSWER SHEET.**

6. Construction lines should not be erased and should be clearly visible.

7. Do not dimension your work unless otherwise stated.

8. Marks will be awarded for: correct Solution, Neatness, Layout and Good Line Work.

9. All dimensions in millimetres unless stated otherwise.

**SECTION A. The question in this section is compulsory .** **Total Marks: 40 Marks**

**Question 1**

Figure Q1 shows an isometric drawing of a **BRACKET BEARING ASSEMBLY**, deliberately partially sectioned for the purpose of exposing the configuration of the top bearing cap. Draw in 1st angle projection and scale 1-1 the following:

a) An assembled front elevation, with the top bearing cap shown in full. **[12 Marks]**
b) An assembled full sectional end elevation along cutting plane A-A. **[12 Marks]**
c) Insert **Six (6) important dimension.** **[6 Marks]**

**[Title Block + Neatness – 10 Marks]**

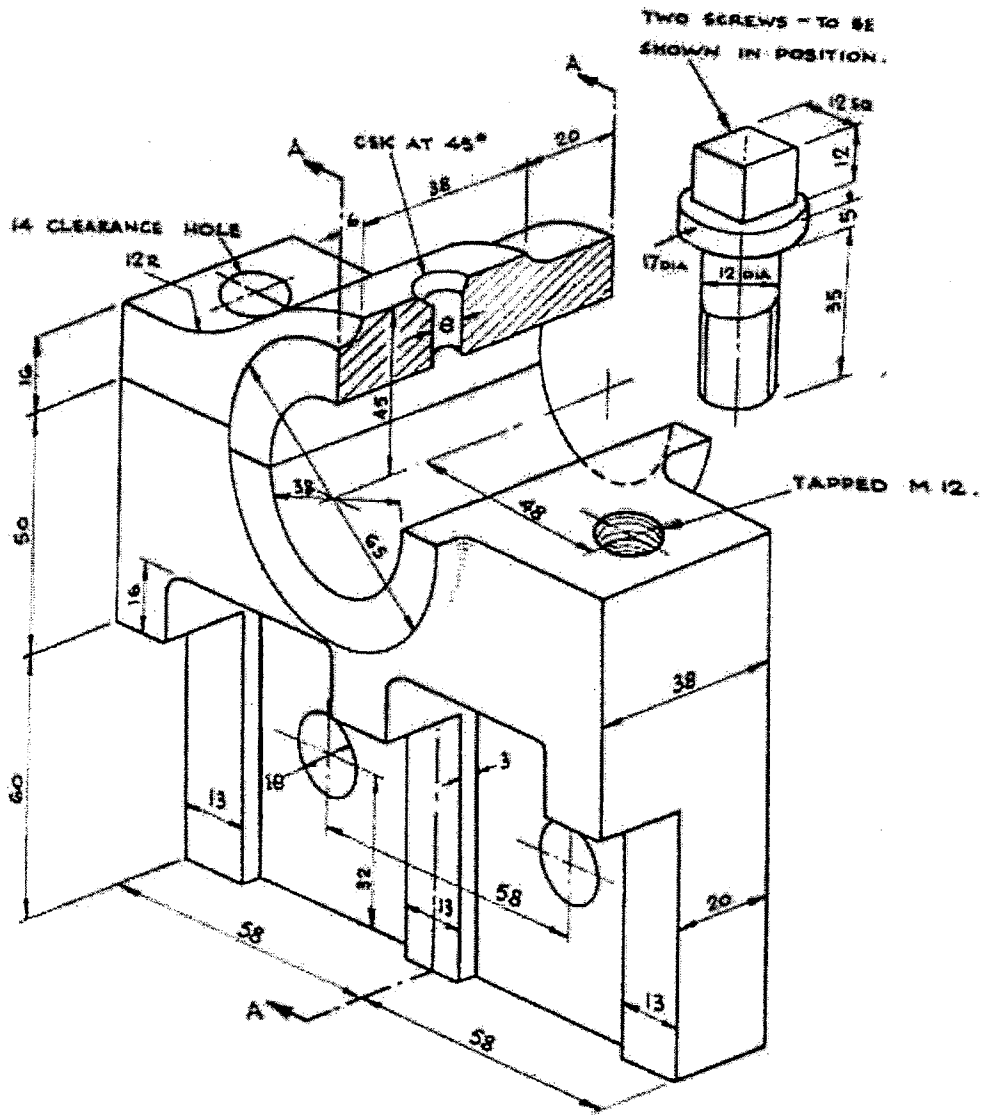



Figure Q1: Bracket Bearing Assembly

**SECTION B**
**Answer ANY TWO (2) Questions** **Total Marks: 30 Marks**

## Question 2

Copy and neatly fill into the Table Q2 with the appropriate relative polar coordinates (from A to O) needed to draw this profile shown in Figure Q2 using standard input format accepted in the AutoCAD Command prompt. DO NOT DRAW THE PROFILE.

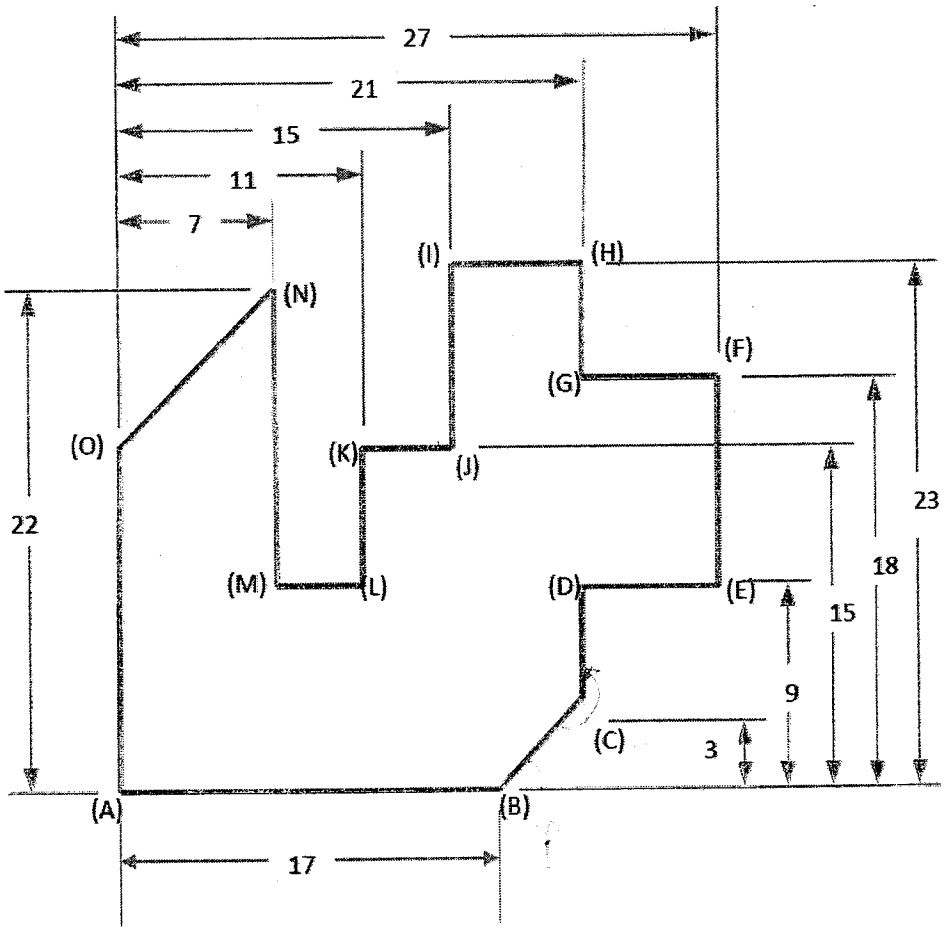



**Figure Q2**

**Table Q2**

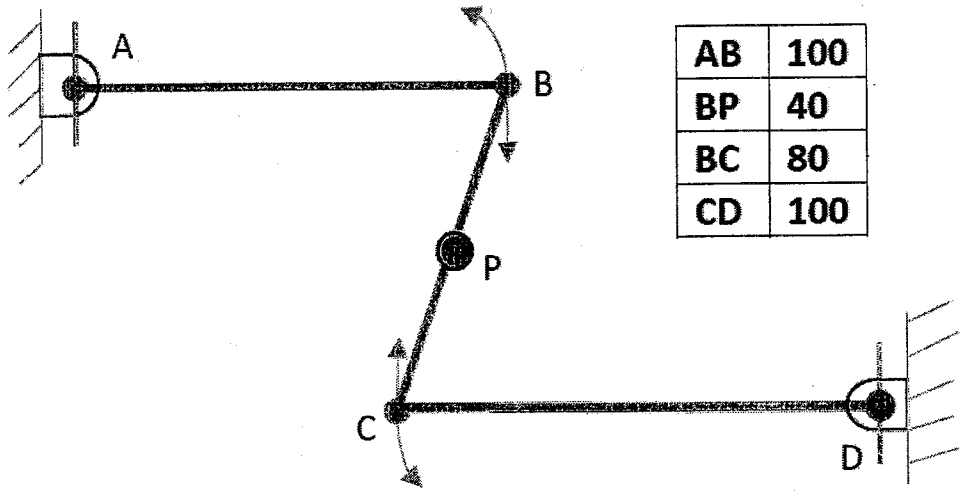
| Line Segment | Relative Polar Coordinates |
|---|---|
| A to B | |
| B to C | |
| C to D | |
| D to E | |
| E to F | |
| F to G | |
| G to H | |
| H to I | |
| I to J | |
| J to K | |
| K to L | |
| L to M | |
| M to N | |
| N to O | |
| O to A | |

## Question 3

A cylinder of base 120 mm and axis 160 mm long is resting on its base on the horizontal plane. It has a circular hole of 90 mm diameter, drilled centrally through such that the axis of the hole is perpendicular to the vertical plane and bisects the axis of the cylinder at right angles. Using projections develop the lateral surface of the cylinder.

## Question 4

The Watt's straight-line motion mechanism is shown in Figure Q4. Two levers AB and CD are connected by a link BC, in addition the two levers are hinged at points A and D. Trace the locus of a point P located at a distance in the current position as shown in the figure. Show also in one selected position, the linkage representing this mechanism using standard graphical components.




| | |
|---|---|
| AB | 100 |
| BP | 40 |
| BC | 80 |
| CD | 100 |

Figure Q4

---

## SECTION C - Electrical Engineering Component

### INSTRUCTIONS

1. **Answer** any **ONE (1) Question from this section on a SEPARATE DRAWING PAPER.**
2. Make sure you draw correct component symbols while following the **DIMENSIONS.**
3. Design and draw **CORRECT** and **WORKING** circuits.
4. **NO TITLE BLOCK REQUIRED** (Indicate only your **COMPUTER NUMBER** at the bottom right corner of the drawing paper).
5. **FOR ADDITIONAL INFORMATION:** Use Appendixes A and B.

---

## Question 5

a) Figure 5.1 shows a circuit that utilizes a Transistor (NPN) as a switch. It is required to use Figure 5.1 as a building block to design a two input **NAND** Logic Gate. Draw the required gate and construct the associated truth table.

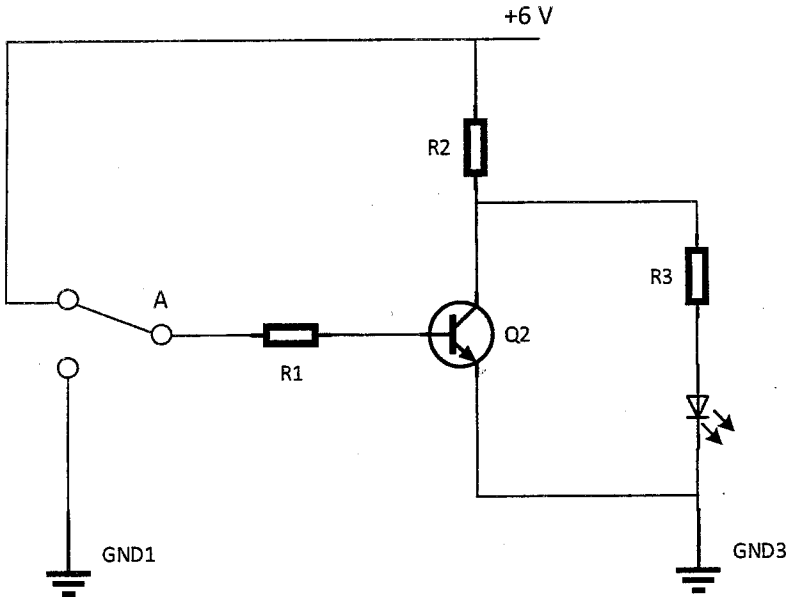



Fig. 5.1: RTL Inverter

**[10 Marks]**

a. Zebedee and Sons Company Ltd intend to install a hoist crane in their mechanical workshop. The crane will be driven by a three-phase induction motor for its operations. You are required to **Design** and **draw** the **POWER** and **CONTROL** circuits to fulfil the required operating conditions using only appropriate materials from the following list provided:

**Operating conditions**:

i. Pressing the start push button (S1) should cause the motor to running in the forward direction in order to lift the load.
ii. Tripping the overload relay (O/L) or pressing the stop push button (S) should bring the crane to a stop.
iii. Pressing the start push button (S2) should cause the motor to running in the reverse direction in order to lower the load.

**Materials**:

i. 1 x 220 V, 50 Hz relay
ii. 2 x Start push button
iii. 1 x Stop push button
iv. 1 x 400 V, 50 Hz, 3-phase squirrel cage Induction motor

v. 2 x on delay timer, with both NO (normally open) and NC (normally closed) contacts
vi. 2 x 400 V, 50 Hz contactor with 2 NO contacts each

**[10 + 10 marks]**

**[TOTAL: 30 MARKS]**

## Question 6

A three-phase synchronous motor is one of the different types of three-phase a.c motors which runs a constant speed called synchronous speed. One characteristic of this motor is that, it is inherently a none self-starting motor. In order to make it start, A small three-phase induction motor called the pony motor (auxiliary motor) is mounted on the same shaft or coupled to the synchronous motor as shown in Figure 6.1. The auxiliary motor should have the same number of poles as that of synchronous motor or preferably one pole pair less so that it can rotate the rotor of the synchronous motor to nearly synchronous speed. Once this speed is achieved, the pony motor is disconnected from main supply. You are now required to **Design** and **draw** the **POWER** and **CONTROL** circuits to fulfil the required operating conditions described below.

**Operating conditions**:

i. Pressing the start push button (STT) should cause the pony motor (M1) to start rotating first.
ii. 15 seconds later, the Synchronous motor (M2) should energize (connected to power supply).
iii. 5 seconds after M2 is energized, M1 should be disconnected the power supply.
iv. Tripping the overload relay ($O/L_1$) should only stop the pony motor.
v. Tripping the overload relay ($O/L_2$) should only stop the synchronous motor.
vi. Pressing the stop push button (STP) should stop the entire system.

**Materials**:

i. 2 x Overload relays
ii. 1 x Start push button
iii. 1 x Stop push button
iv. 1 x 230 V, 50 Hz, 3-phase squirrel cage Induction motor (M1)
v. 1 x 400 V, 50 Hz, 3-phase Synchronous motor (M2)
vi. 2 x On delay timers, with both NO (normally open) and NC (normally closed) contacts
vii. 1 x 400 V, 50 Hz contactor with 2 NO contacts each
viii. 1 x 230 V, 50 Hz contactor with 2 NO contacts each

**[10 + 20 marks]**

**[TOTAL: 30 MARKS]**

THE UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

UNIVERSITY EXAMINATIONS

END OF YEAR EXAMINATION, 2021/2022
NOVEMBER 2022

MEC 2309 - PROPERTIES OF ENGINEERING MATERIALS I

# QUESTION PAPER

**Read these instructions carefully.**

---

**This Examination is Closed Book**

**Time Allowed: Three (3) Hours**

**Answer any Five Questions**

**All questions carry equal marks**

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[DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO]

Q1.

(a) Two hypothetical metals *C* and *D* are dissolved in each other and the following information is available from the experiment:

- The melting temperatures of *C* and *D* are 700 °C and 900°C, respectively.
- The metals form a eutectic at a composition of 55% *D* at 400 °C.
- The maximum solubilities possible are found to be 20% of *D* in *C* and 25% of *C* in *D*.
- At room temperature, maximum solubility of *D* in *C* is 5% and *C* in *D* is 10%.

Using the graph paper provided, draw the phase diagram to scale and label the main features. All lines may be assumed to be straight. [10 marks]

(b) Describe the changes which would occur when a 60% *C* / 40% *D* alloy composition is allowed to cool slowly from the liquid state to room temperature. Mention the temperatures where the changes occur. [05 marks]

(c) For the 60% *C* / 40% *D* alloy, give the phases present, their relative proportions and their compositions at 500°C [05 marks]

Q2.

(b) Discuss in detail what semiconductors are and how they are made? [10 marks]

(c) Distinguish between *n*-type and *p*-type semiconductors. [10 marks]

Q3.

(a) (i) Sketch a unit cell of the face-centred cubic crystal system and show the following planes: (100), (110) and (111). [06 marks]

(ii) How many atoms are there in each of these planes ((100) and (110))? [04 marks]

(b) Show by calculation that the (111) planes in the face-centred cubic crystal system possess a greater density of atomic packing and a smaller inter-planner spacing than either the (100) or (110) planes. [10 marks]

Q4.

(a) Using the data in Table Q4 show that copper is denser than iron at room temperature. [15 marks]

(b) Show that all atoms in the bcc crystal structure are lattice points. [05 marks]

Table Q4: Useful data for copper, lead and molybdenum

| Element | Symbol | Structure | Atomic mass (kg) | Lattice constant (nm) |
|---|---|---|---|---|
| Copper | Cu | fcc | $1.05359 \times 10^{-25}$ | 0.36147 |
| Iron | Fe | bcc | $9.26028 \times 10^{-26}$ | 0.28664 |

Q5.

(a) Iron has bcc structure and its density is 7874 kg/m$^3$. Given that the mass of an iron atom is $9.26028 \times 10^{-26}$ kg. Find the unit cell dimensions (lattice parameter) and atomic diameter. [10 marks]

(b) In the cubic crystal system, planes are described using miller indices. Using clear diagrams, draw the following planes.

(i) (110)

(ii) (010) [10 marks]

Q6.

Consider the iron carbon diagram shown in Figure Q6.

(a) What compositions are at points 1, 2, 3, 4 and 5? [05 marks]

(b) What phases are represented by the numbers 6, 7, 8, 9 and 10? [05 marks]

(c) Give the name and values of temperatures 11 and 12? [04 marks]

(d) A 1 kg sample of hypereutectoid steel is heated to 722°C. Analysis of the sample reveals that it contains 760 g ferrite. Is this possible? If so, what is the overall composition of the sample? [06 marks]

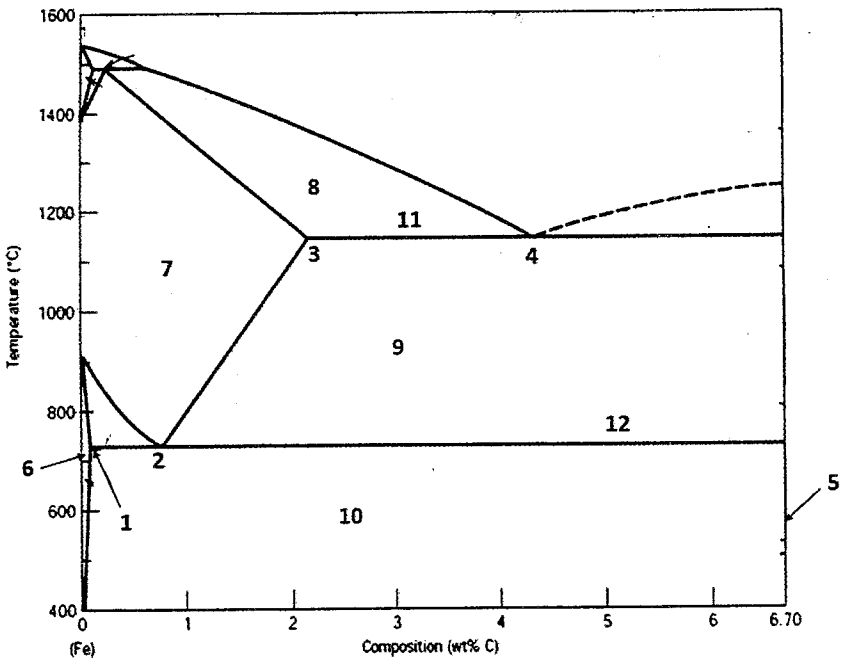


*Figure Q6a: Unlabelled Fe-C Diagram*

Q7.

(a) Define corrosion and state three of its major consequences. [04 marks]

(b) Describe in detail the following forms of corrosion.

(i) Uniform Attack

(ii) Intergranular Corrosion

(iii) Stress Corrosion

(iv) Corrosion Fatigue

(v) Fretting Corrosion [08 marks]

(c) Describe cathodic protection with suitable sketches and state at least three of its disadvantages. [08 marks]

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**END OF MEC 2309 FINAL EXAMINATION, NOVEMBER 2022**

**G M Munakaampe, F K Chitalu & E Chibwe**

# THE UNIVERSITY OF ZAMBIA

# SCHOOL OF ENGINEERING

## MEC3102 PRODUCTION ENGINEERING I, ELECTRICITY & ELECTRONICS II

## 2021/2022 ACADEMIC YEAR, TERM II

## NOVEMBER 2022

**TERM EXAM**

**TIME: THREE HOURS.** **CLOSED BOOK**

---

**INSTRUCTIONS**

1. Answer **FIVE** (5) Questions.
2. **Answer** not more than **Two (2) Questions from SECTION B** and answer any **Three (3) Questions** from **SECTION A**
3. **All** Questions carry **Equal Marks**, that is, **20 Marks** per Question.
4. This Exam has **Five (5) pages** including this cover.
5. No external Materials are allowed in the Exam.
6. The Answer scripts should be bound/stapled separately, i.e., **SECTION A** and **SECTION B** separately.

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## SECTION A

**Question 1**

(a) What is an orthogonal cutting operation? **[2 marks]**

(b) Why is the orthogonal cutting model useful in the analysis of metal machining? **[2 marks]**

(c) The following data was obtained from an orthogonal cutting test.

Rake angle = 20°, Depth of cut = 6 mm, Feed rate = 0.25 mm/rev, Cutting speed = 0.6 m/s

Chip length before cutting = 29.4 mm, Vertical cutting force = 1050 N, Horizontal cutting force = 630 N, Chip length after cutting = 12.9 mm

Using **Merchant's** analysis, calculate,

(i) Magnitude of resultant force, **[4 marks]**

(ii) Shear plane angle, **[4 marks]**

(iii) Friction force and friction angle, **[4 marks]**

(iv) Various energies consumed. **[4 marks]**

**Total Marks [20]**

**Question 2**

(a) What is the difference between peripheral milling and face milling? **[4 marks]**

(b) Name and briefly describe the four types of chips that occur in metal cutting; describe with aid of sketches. **[4 marks]**

(b) A face milling operation removes 6.0 mm from the top surface of a rectangular piece of aluminum that is 300 mm long by 90 mm wide by 75 mm thick. The cutter follows a path that is centred over the workpiece. It has four teeth and is 100 mm in diameter. Cutting speed = 2.0 m/s, and chip load = 0.27 mm/ tooth.

Determine:

(i) Machining time, **[6 marks]**

(ii) Maximum metal removal rate during cutting. **[6 marks]**

**Total Marks [20]**

**Question 3**

*(a) Name the three modes of tool failure in machining.* *[3 Marks]*

(b) What is meant by the parameter $C$ in the Taylor tool life equation? **[3 Marks]**

(c) What are the two principal locations on a cutting tool where tool wear occurs? **[2 Marks]**

(d) Tool life tests in turning yield the following data: (1) $v = 100$ m/min, $T = 10$ min; (2) $v = 75$ m/min, $T = 30$ min.

(i) Determine the $n$ and $C$ values in the Taylor tool life equation. **[4 Marks]**

m/min²

(ii) Based on your equation; compute the tool life for a speed of 90 m/min. **[4 Marks]**

(iii) The speed corresponding to a tool life of 20 min. **[4 Marks]** } 8 marks

Dual gauge 90 m/min.

**Total Marks [20]**

**Question 4**

(a) What is metrology? **[2 marks]**

(b) Explain what is meant by standards for measurement. **[2 marks]**

(c) What is the basic difference between direct-reading and indirect-reading linear measurements? **[2 marks]**

(d) What is meant by comparative length measurement? **[2 marks]**

(e) Explain how flatness is measured. What is an optical flat? **[2 marks]**

(f) What is the difference between bilateral and unilateral tolerance? **[2 marks]**

(g) Why have coordinate measuring machines become important instruments? **[4 marks]**

(h) What factors contribute to deviations in the dimensions of the same type of parts made by the same machine? **[4 marks]**

Accuracy, speed, minimization of human Error.

**Total Marks [20]**

20/18



These are what are used as the basis of measurements,

$$n = \frac{\log V_1 - \log V_2}{\log T_2 - \log T_1}$$

Direct reading involves getting the actual reading or measurement of something while indirect read involves measuring something in order to get measure of something else eg

- ~~This has to do~~ the methods used to the amplify, compare and measu dimensions of things.

) Flatness is measured by the mechanical means

## SECTION B

### Question 5

**5.1** Define the following:

i. Coercive force **[2 marks]**

ii. Lenz's Law **[2 marks]**

iii. Ampere's Law **[2 marks]**

**5.2** A shunt generator supplies a 50-kW load at 400 V through cables of resistance 0.2 Ω. If the field winding resistance is 50 Ω and the armature resistance is 0.05 Ω, determine

i. The terminal voltage,

ii. The e.m.f. generated in the armature. **[2 + 2 marks]**

**5.3** A ferromagnetic core with a relative permeability of 2000 is shown in Figure. The dimensions are as shown in the diagram, and the depth of the core is 7 cm. The air gaps on the left and right sides of the core are 0.050 and 0.070 cm, respectively. If there are 300 turns in the coil wrapped around the center leg of the core and if the current in the coil is 1.0 A, what is the flux in each of the left, center, and right legs of the core? What is the flux density in each air gap? **[10 marks]**

**Total Marks [20]**

### Question 6

**6.1** Define power system. **[2 marks]**

**6.2** Name any four (4) factors you need to consider before choosing the appropriate electric power generation method. **[4 marks]**

**6.3** Differentiate between Primary and Secondary power distribution. **[2 marks]**

**6.4** Each phase of star connected load consists of non-inductive resistance of 50Ω in parallel with a capacitance of 63.6μF. Calculate:

i. The line current,

ii. Total power absorbed, and

iii. Power factor. **[1 + 2 + 1 marks]**

**6.5** Two Wattmeters are used for measuring the power input and the power factor of an over-excited synchronous motor. If the readings on the meters are (7.0 kW) and (2.0 kW) respectively. Calculate the input power and power factor of the motor.

**[1 + 3 marks]**

**Total Marks [20]**

### Question 7

**7.1** Find the binary equivalent of the decimal number 15.625 **[2 marks]**

**7.2** Explain the principle behind the numbering of columns and rows in a Karnaugh map.

**[1 mark]**

**7.3** Convert the following expression into expanded form and use the Karnaugh map method to obtain the minimal sum-of-products expression: **[5 Marks]**

$$Y = A \cdot \overline{B} + B \cdot C + \overline{A} \cdot \overline{B}$$

**7.4** The sum-of-products Boolean expression in short form notation is given by

$$f(A,B,C) = \sum 3,5,6,7$$

i. Draw the Minterm Karnaugh map for the given expression. **[4 Marks]**

ii. Using the Karnaugh map in (i) find the minimized Boolean expression. **[2 Marks]**

**7.5** For the circuit shown in figure 7.5(i)

i. Determine the relationship between the output **Z** and the three inputs A, B and C. **[3 marks]**

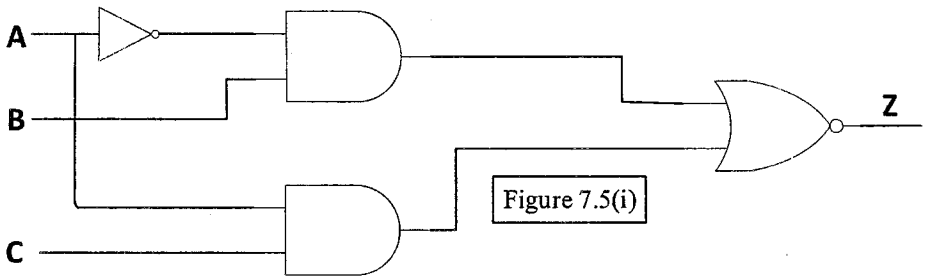


Figure 7.5(i)

ii. Construct a truth table for the function. **[3 marks]**

**Total Marks [20]**

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**END OF MEC 3102 NOVEMBER 2022 EXAMINATION**

**Dr. V MUSONDA & Mr. B. MUNKOMBWE**

THE UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

UNIVERSITY EXAMINATIONS

END OF YEAR EXAMINATIONS, 2020/2021

NOVEMBER 2022

MEC 3352 – STRENGTH OF MATERIALS II

# QUESTION PAPER

**Read the following instructions carefully before you start writing:**

1. *This Examination is Closed Book.*
2. *Time Allowed: Three (3) Hours.*
3. *Answer: Any five (5) questions.*
4. *All questions carry 20 marks each.*
5. *This paper has 4 printed pages including this cover page.*

**[DO NOT TURN THE PAGE OVER UNTIL YOU ARE TOLD TO DO SO]**

Q1.

A spherical vessel of internal diameter 500 mm is required to withstand an internal pressure of 1035 bars. If the circumferential tensile stress at the inner surface is to be limited to 230 MPa,

(a) Determine the required wall thickness. [10 marks]

(b) Find also the change in internal diameter when under full pressure. [10 marks]

$E = 207$ GPa, $\nu = 0.29$.

Q2.

(a) For a disc of uniform stress, show that the thickness $t$ at any radius $r$ is given by the expression:

$$t = t_0 e^{-\frac{\rho r^2 \omega^2}{2\sigma}}.$$

Where:

$t_0$ = thickness at the centre of the disc

$\rho$ = the density of the material

$\sigma$ = the stress on the material

$\omega$= the angular velocity of the disc. [10 marks]

(b) A turbine disc is 600 mm in diameter at the blade ring and is keyed to a 50 mm diameter shaft. If the minimum thickness is 10 mm, what should be the thickness at the shaft for uniform stress of 205 MPa at 10,000 rpm? Density of the material is 7750 kg/m$^3$. [10 marks]

Q3.

(a) State the five theories of failure and using the relevant equations for each one, briefly explain what they postulate. [10 marks]

(b) A shaft is loaded by a torque of 5 kNm. The material has a yield point of 350 MPa. Find the required diameter using the

(i) Maximum shear stress theory

(ii) Maximum distortion energy theory

Take a factor of safety of 2.5. [10 marks]

Q4.

(a) Find the diameter (to the nearest 10mm) of a solid steel shaft to transmit 20 kW at 200 rpm. The ultimate shear stress for the steel may be taken as 360 MPa and a factor of safety as 8. [08 marks]

(b) If a hollow shaft is to be used in place of the solid shaft, find the inside and outside diameter (to the nearest 5 mm and 10 mm, respectively) when the ratio of inside to outside diameters is 0.5. [08 marks]

(c) Which shaft would you choose for your operation? Give reasons. [04 marks]

Q5.

A curved bar of square cross section, 30 mm sides and mean radius of 45 mm is initially unstressed.

(a) If a bending moment of 300 Nm is applied to the bar tending to straighten it, find the stresses at the inner and outer faces. [12 marks]

(b) Sketch the stress distribution based on your results. [08 marks]

Q6.

(a) Lame's equations are given below for radial and hoop stresses at any radius $r$ for a thick cylinder of inner and outer radii $r_i$ and $r_o$ and under internal and external pressures $P_i$ and $P_o$, respectively.

$$\sigma_r = \frac{P_i r_i^2 - P_o r_o^2}{(r_o^2 - r_i^2)} - \frac{(P_i - P_o) r_i^2 r_o^2}{(r_o^2 - r_i^2) r^2}$$

and

$$\sigma_\theta = \frac{P_i r_1^2 - P_o r_o^2}{(r_o^2 - r_i^2)} + \frac{(P_i - P_o) r_i^2 r_o^2}{(r_o^2 - r_i^2) r^2}$$

From these equations or otherwise, find the expressions for $\sigma_r$ and $\sigma_\theta$ for a thick cylinder under internal pressure only. [10 marks]

(b) A thick cylinder of inner radius 10 cm and outer radius 15 cm is subjected to an internal pressure of 12 MPa. Determine the radial and hoop stresses in the cylinder at the inner and outer surfaces. [10 marks]

Q7.

(a) Consider a cube of an element, Figure Q7, being acted upon by three mutually perpendicular principal stresses $\sigma_1$, $\sigma_2$ and $\sigma_3$.Show that the volumetric strain is given by the expression

$$\varepsilon_V = \varepsilon_1 + \varepsilon_2 + \varepsilon_3.$$

where $\varepsilon_1$, $\varepsilon_1$ and $\varepsilon_1$ are the principal strain in the three principal directions. [10 marks]

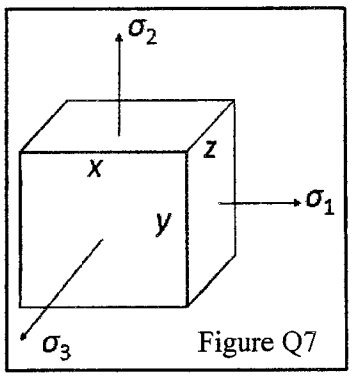

Figure Q7

(b) The principal stresses at a point in an elastic material are 60 MPa tensile, 20 MPa tensile and 50 MPA compressive. Calculate the volumetric strain and the resilience. $E$ = 100,000 MPa and $v$ = 0.35. [10 marks]

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**END OF MEC 3352 EXAMINATION**

**G M Munakaampe**

UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

# END OF YEAR EXAMINATIONS FOR THE 2022 ACADEMIC YEAR

## MEC3705 - DYNAMICS

**TIME ALLOWED: THREE (3) HOURS** **CLOSED BOOK**

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**INSTRUCTIONS**

1. Answer a **TOTAL OF FIVE (5)** questions.
2. All Questions carry **20 Marks.**
3. Draw neat sketches and graphs where necessary and clearly state any assumptions made.

---

## QUESTION 1

(a) Define the law of gravitation.

(b) The rectangular coordinates of a particle are given in millimeters as functions of time t in seconds by $x = 30\cos(2t\ rad), y = 40\sin(2t\ rad)\ and\ z = 20t + 3t^2$.

At time $t = 2s$, determine

(i) the angle $\theta_1$ between the position vector $\boldsymbol{r}$ and the velocity $\boldsymbol{v}$ and
(ii) the angle $\theta_2$ between the position vector $\boldsymbol{r}$ and the acceleration $\boldsymbol{a}$

***[4+8+8=20 Marks]***

## QUESTION 2

***Figure Q2*** shows a drag racer whose acceleration is modeled according to $a = a_o - kv^2$, where $a_o$ is the constant acceleration resulting from the engine thrust and $-kv^2$ is the acceleration due to aerodynamic drag.

If $a_o = 19.2m/s^2$, $k = 0.00003m^{-1}$, and $v$ is in meters per second, determine the speed of racing car at the finishing line if the drag term is (a) excluded and (b) included

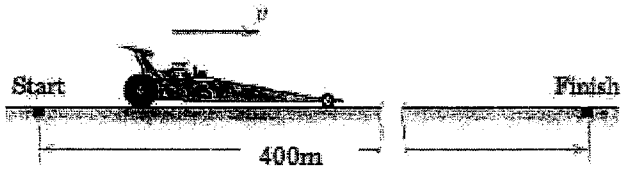



**Figure Q2**

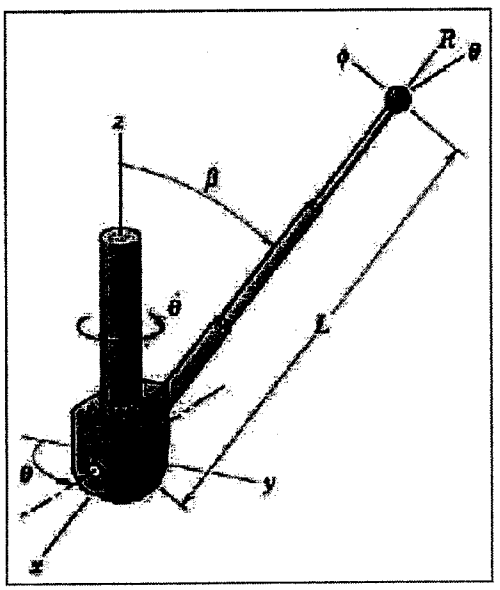
***[10+10=20 Marks]***

## QUESTION 3

In a design test of the actuating mechanism of ***Figure Q3***, for a telescoping antenna on a spacecraft, the supporting shaft rotates about the fixed z-axis with an angular rate $\dot{\theta}$.

Determine in the spherical $R, \theta, and\ \phi$ coordinates the velocity $\boldsymbol{v}$ and acceleration $\boldsymbol{a}$ of the end of the antenna at the instant when $L = 1.2m$ and $\beta = 45^o$ if the rates $\dot{\theta} = 2rad/s$, $\dot{\beta} = \frac{3}{2}rad/s$, and $\dot{L} = 0.9m/s$ are constant during the motion.

**Figure Q3**




*[20 Marks]*

## QUESTION 4

Under the action of force $P$ in ***Figure Q4*** the constant acceleration of block $B$ is $a_B = 3\,m/s^2$ to the right. At the instant when the velocity of $B$ is $v_B = 2\,m/s$ to the right, determine

(i) the velocity of B relative to A
(ii) the acceleration of B relative to A
(iii) the absolute velocity of point C of the cable
(iv) the number of degrees of freedom for this system, give reasons

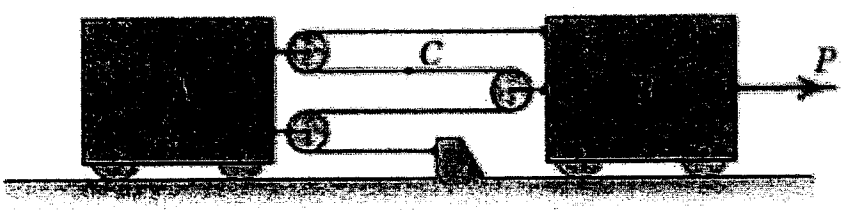



**Figure Q4**

*[6+6+6+2=20 Marks]*

## QUESTION 5

(a) In the study of dynamics, what is an inertial frame of reference?

(b) A rocket is fired vertically and then tracked by the radar station as shown in **Figure Q5b.** At the instant when $\theta = 60^o$, measurements give $\dot{\theta} = 0.03rad/s$ and $r = 7.5km$, and the vertical acceleration of the rocket is found to be $a = 19.2m/s^2$. For this instant determine the values of $\ddot{r}$ and $\ddot{\theta}$

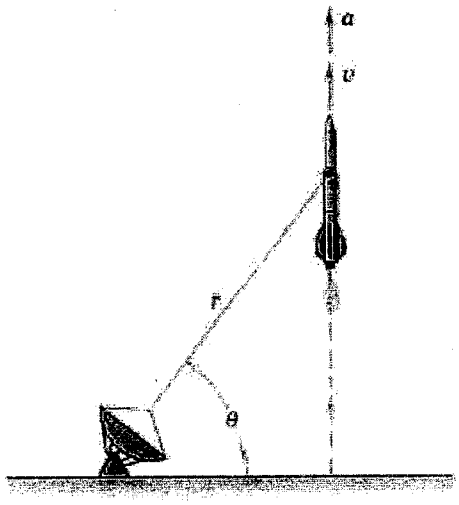



**Figure Q5b**

***[4+16=20 Marks]***

## QUESTION 6

(a) Give the linear impulse-momentum equation and explain in words the terms on the equation

(b) Give the angular impulse-momentum equation and explain in words the terms in the equation

(c) The 2.4 kg particle in (**Figure Q6 c**) moves in the horizontal x-y plane and has the velocity shown at time $t = 0$. If the force $F = 2 + \frac{3}{4}t^2$ newtons, where $t$ is time in seconds, is applied to the particle in the y-direction beginning at time $t = 0$, determine the velocity $v$ of the the particle 4 seconds after $F$ is applied and specify the corresponding angle $\theta$ measured counterclock-wise from the $x - axis$ to the direction of the velocity.

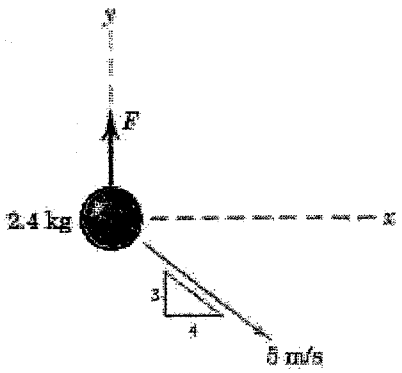



**Figure Q6c**

***[4+4+12=20 Marks]***

## QUESTION 7

(a) In 3D – dynamics of rigid bodies what is meant by body cone and space cone

(b) In **Figure Q7b**, the right-circular cone *A* rolls on the fixed circular cone *B* at a constant rate and makes one complete trip around B every 4 seconds.

(i) Determine the angular velocity Ω about the Z – axis in radians per second.

(ii) Determine the angular velocity $\omega_z$ of the body about the z-axis in radians per second.

(iii) Compute the magnitude of the angular acceleration $\boldsymbol{\alpha}$ of cone *A* during its motion.

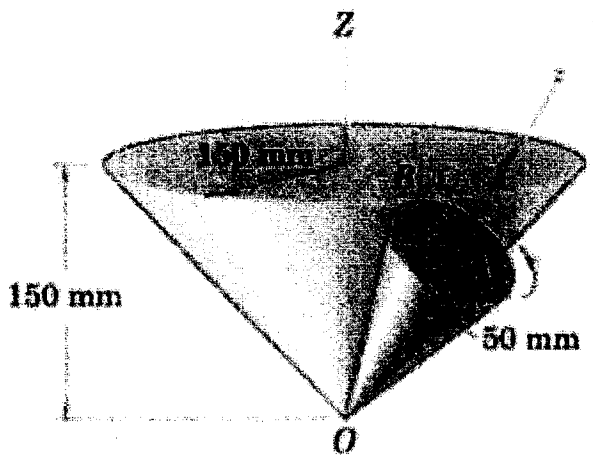



**Figure Q7b**

***[4+16=20 Marks]***

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**END OF MEC3705 DYNAMICS FINAL EXAMINATION, NOVEMBER - DECEMBER 2022**

**Prepared by:** Kando H. Moonga

THE UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

UNIVERSITY EXAMINATIONS FOR 2021-2022 ACADEMIC YEAR
NOVEMBER 2022

# MEC 4055 – MACHINE DESIGN I
## PAPER II

**INSTRUCTIONS TO CANDIDATES:**

1. Candidates are allowed to use books, and notes (**Open Book Examination**).
2. Time: **Three (3) hours**
3. **Answer** ALL questions. Please note questions are of different mark values as shown.
4. Calculators and drawing instruments are permitted.

**DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO**

An entrepreneur has been issued with a manufacturing licence by the Zambia Development Agency (ZDA). She intends to set up a plant to manufacture key rings. Her market survey reveals that some 500,000 key rings are required per month in Zambia and the neighbouring countries. In order for her to have some tax concessions, she needs to have the machines for making the key rings manufactured in Zambia. Your company has been approached to design a machine for making key rings as shown in Figure 1

She requires five (5) machines and the rings would be manufactured from 100m rolls of 2mm diameter steel wire. Each machine should be capable of producing 2 sizes of rings: 20 and 30mm outside diameters, and both overlap on three quarters of the circumference. There should not be more than two operators per machine. The machines should be powered by electricity. You are required to do the following:

Q1. Write a detailed product design specification (PDS) for the machine [20 marks]

Q2. Produce TWO (2) different functional designs for the above machine and explain how they will be operated. [60 marks]

Q3. Select the better of the two designs using four (5) relevant design factors. [20 marks]

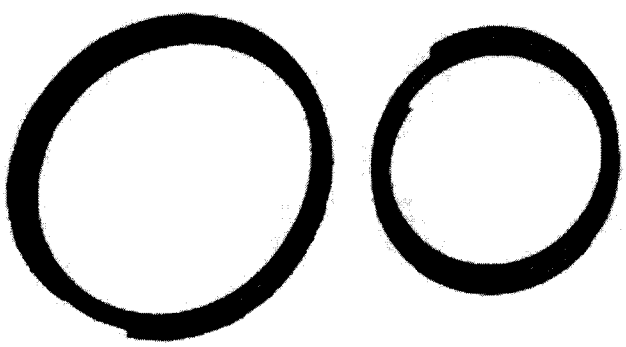

Figure 1: Key rings

**END OF MEC4055 EXAMINATION PAPER II**

**Prof. S. B. Kanyanga, Dr. C. G. Chizyuka, G. M. Munakaampe & E. Chibwe**

**THE UNIVERSITY OF ZAMBIA**

**SCHOOL OF ENGINEERING**

**DEPARMENT OF MECHANICAL ENGINEERING**

**END OF YEAR FINAL EXAMINATIONS FOR 2022 ACADEMIC YEAR**

**MEC 4402- THERMODYNAMICS II & HEAT ENGINES**

**TIME: THREE (3) Hours** **Closed Book**

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**INSTRUCTIONS**

1. Answer a total of **FIVE (5)** questions only.
2. Answer **Two (2)** Questions from Section A, and **Three (3)** from Section B.
3. Draw sketches and graphs where necessary and clearly state any assumptions made. All questions carry equal marks.

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**SECTION A:** Answer TWO QUESTIONS from this section

**Question 1.**

**(a)** State the various properties of a lubricating oil for an internal combustion engine, necessary for the lubricant to achieve its functions.

**(b)** Mention the various functions of the lubricating oil in an internal combustion engine.

**(c)** What are the important requirements of the high voltage ignition source for the spark ignition system of an internal combustion engine?

**[9+5+6 Marks]**

**Question 2.**

**(a)** Describe the two main characteristics of an efficient cooling system designed for an internal combustion engine?

**(b)** Explain briefly the various disadvantages of a gas turbine plant that have inhibited successful application of gas turbine for passenger cars application?

**[10+10 Marks]**

**Question 3.**

**(a)** Define carburetion.

**(b)** Describe the laboratory method for determining the Octane Number.

**(c)** Describe the laboratory method for determining the Cetane Number.

**[6+7+7 Marks]**

**SECTION B:** Answer THREE (3) QUESTIONS from this section

**Question 4.**

Steam with a velocity of 600 m/s enters an impulse turbine row of blades at an angle of 25° to the plane of the rotation of the blades. The mean blade speed is 255 m/s. The exit angle from the blades is 30°. There is a 10% loss in relative velocity due to friction in the blades.

Determine the following;

(i) The entry angle of the blades.
(ii) The work done.
(iii) The diagram efficiency.
(iv) The end thrust per kg steam per second.

**[20 Marks]**

**Question 5.**

An 8-cylinder, 4-stroke diesel engine has a brake power output of 368 kW at 800 revolutions per minute. The brake specific fuel consumption is 0.238 kg/kWh. The pressure in the cylinder at the beginning of injection is 35 bar and the maximum cylinder pressure is 60 bar. The injector is expected to open at 210 bar and the maximum pressure at the injector is set to be at about 600 bar. Calculate the orifice area required per injector if the injection takes place over 12° crank angles.

Assume the coefficient of discharge for the injector to be 0.6, specific gravity of fuel to be 0.85, and the atmospheric pressure 1.013 bar. Take the effective pressure difference to be the average pressure difference over the injection period.

**[20 Marks]**

**Question 6.**

Air enters the compressor of a gas turbine plant operating on Brayton cycle at 101.325 Pa, at 27°C. The pressure ratio in the cycle is 6. Calculate the maximum temperature in the cycle and the cycle efficiency.

Assume $W_T=2.5W_C$ where $W_T$ and $W_C$ are the turbine and compressor work respectively. Take $\gamma = 1.4$.

**[20 Marks]**

**Question 7.**

A-four-stroke spark ignition gasoline engine delivers a brake power of 36.8 kW with a mechanical efficiency 80%. The air-fuel ratio is 15:1 and the brake specific fuel consumption is 0.4068 kg/kWh. The heating value of the fuel is 42000 kJ/kg.

Calculate;

(i) The indicated power.
(ii) Frictional power.
(iii) Brake thermal efficiency.
(iv) Indicated thermal efficiency.
(v) The total fuel consumption in kg per second.
(vi) The air consumption in kg per second.

**[20 Marks]**

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**END OF EXAMINATION**

Prepared by Mr. C Siakachoma.

# THE UNIVERSITY OF ZAMBIA
## SCHOOL OF ENGINEERING
## DEPARTMENT OF MECHANICAL ENGINEERING

## MEC 5855 - AUTOMOBILE ENGINEERING

## TERM II FINAL EXAMINATIONS – NOVEMBER 2022

**TIME: THREE (3) Hours** **[Closed Book]**

## Instructions:

1. Answer **TWO (2)** questions from section A and **Three (3)** questions from section B.
2. All questions carry **equal marks**.
3. Show **ALL** your workings (draw sketches, graphs, etc.) and state any assumptions made.
4. Write your **computer number** on each and every sheet used.
5. All mobile phones **MUST** be switched off or put on flight mode.

## SECTION A

### Question 1

1.1 Discuss the various methods you can use to measure the degree of wear of motor vehicle components under operational, road laboratory and in-situ laboratory conditions. Begin by defining wear and summarising what type of wear are typical to motor vehicles, in particular the engine, gearbox and valve timing mechanism.

**[Q1 Total: = 20 Marks]**

### Question 2

2.1 What is the main function of a shock absorber in an automobile? Explain the construction and working of a Telescopic type of shock absorber.

2.2 Today's almost all automobiles are fitted with power assisted steering system to reduce the steering effort by the driver. Explain the operation of the power assisted steering system commonly used in automobiles.

2.3 Discuss in brief how you would determine the service life of a motor vehicle based on experience and observation.

**[Q2 Total: 10+5+5 = 20 Marks]**

### Question 3

3.1 Describe, with help of sketches, design features, and function of each element of the power transmission system of a motor vehicle.

3.2 Operating fuel economy of an automotive vehicle depends on a number of factors. Briefly explain the various factors that affect automotive fuel economy.

**[Q3 Total: 10+10 = 20 Marks]**

## SECTION B

### Question 4

A motor car weighing 13341.6 N and has an engine developing 40.5 bkW at 4000rpm. The transmission system has an efficiency of 90% in top gear and 85% in second gear. The top gear ratio is 1:1 and the second gear ratio 1.64: 1, when running on level with wide open throttle, the car reaches 112 km/h at 4000 rpm and at the same engine speed in second gear it will just climb a hill of 1 in 12. If the resistance to motion on level is given by the formula $R = A + BV^2$, where R is in N and V in km/h. Calculate;

(i) A and B.
(ii) The maximum speed with which the car can climb a grade of 1 in 20 in top gear.
(iii) What is corresponding engine speed? Assume that engine power is proportional to the speed in the above range.

**[Q4 Total: 20 Marks]**

### Question 5

A motor vehicle with wheel base of 2.54 m and weighing 12400 N has its CG 1.32 m behind the front axle, and 0.7875 m above ground level. The vehicle is fitted with brakes on all four wheels and the coefficient of adhesion between the tyres and road is 0.6. If the vehicle is going up on an incline of angle $\sin\theta = 0.1$, determine the load distribution at the front and rear wheels and also the distance at which it can be brought to rest from a speed of 40 km/h when

(i) Only rear wheels brakes are applied, and
(ii) The four wheel brakes are applied.

**[Q5 Total: 20 Marks]**

### Question 6

FISCAL International (Pvt) Limited is bargaining to purchase a car for their newly appointed CEO. Apparently, there are two identical Cadillac SRX crossovers from which to make a choice. One is a rear wheel drive (RWD) and the other is a front wheel drive (FWD). Each car weighs 21336.75 N and has a static weight distribution on the axles of 50:50. The wheel base is 3000 mm and the height of the centre of gravity above the ground is 550 mm. Most critical information on the User Profile is that a road leading to his residence has an ascent of 30% with a coefficient of friction (for grip) being 0.6. Being an Automotive Expert in a Consultancy Firm, make recommendations to this company as to which of the two cars should be purchased as far as gradability is concerned, if the engine power is not a limitation. Neglect the change in the reactions on the wheels. Support you answer with calculations and figures.

**[Q6 Total: 20 Marks]**

## Question 7

7.1 Consider a vehicle resting on a slope with an inclination angle θ to the horizontal in Figure Q 7.1.

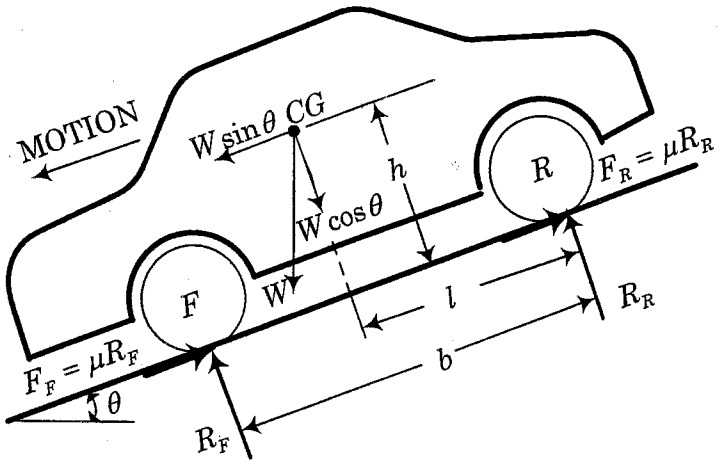


**Figure Q7.1**

(i) Derive the equations for normal reactions at the wheels in Figure Q7.1.

The vehicle in Figure Q7.1 has total mass of 5000 kg and is held at rest on a slope of 10°. It has a wheel base of 225 cm and its center of gravity is 100 cm in front of the rear axle and 150 cm above the ground level. Find:-

(ii) What are the normal reactions at the wheels?

(iii) Assuming that sliding does not occur first, what will be the angle of slope so that the vehicle will overturn?

(iv) Assuming all the wheels are to be braked, what will be the angle of the slope so that the vehicle will begin to slide if the co-efficient of adhesion between the tyre and the ground is 0.35?

7.2 For a motor vehicle, the rolling resistance is given by 13.6 + 0.6965 V and the air resistance by the expression 0.0827 $V^2$ the resistance being in N and V the speed in km/h. If the transmission efficiency is 88%, calculate the bkw required for a top speed of 128 km/h. Assuming that the engine torque at 48 km/h in top gear is 25% more than that at 128 km/h and the vehicle inertia corresponds to a weight of 17805 N, calculate the acceleration in $m/s^2$ at 48 km/h.

**[Q7 Total: 15+5 = 20 Marks]**

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**END OF MEC 5855 – AUTOMOBILE ENGINEERING EXAMINATION, NOVEMBER, 2022.**

Prepared by: Mr. J.K. Musa