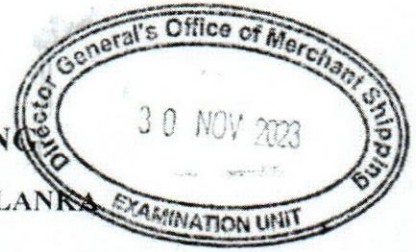




MINISTRY OF PORTS AND SHIPPING
MERCHANT SHIPPING SECRETARIAT - SRI LANKA



CERTIFICATE OF COMPETENCY
CHIEF ENGINEER & SECOND ENGINEER OFFICER ON SHIPS OF 3000KW
PROPULSION POWER OR MORE

FINAL EXAMINATION QUESTION PAPER

AUTOMATION & CONTROLS

- TIME ALLOWED - THREE HOURS
- Answer all SIX questions
- Marks for each part of the question are shown in the brackets
- Pass marks - 50%
- Date - 2023

Answers with clear sketches/diagrams, neat handwriting and clear expression will get full marks.

1. With regards to the process control concepts,
 - a. Describe the control block diagram of a PID controller with the aid of a sketch. (06 Marks)
 - b. Describe the structure of a Digital process controller. (04 Marks)
 - c. State the steps of manual tuning of an electronic PID controller. (06 Marks)
2. With regards to the programmable logic controllers (PLC),
 - a. Draw and describe the internal structure of a PLC. (06 Marks)
 - b. Briefly describe the types and applications of PLCs in ships. (05 Marks)
 - c. Describe the programming concerns of a PLC before it is applied for industrial process control. (05 Marks)
3. With regards to instrumentation, alarm and monitoring systems.
 - a. Describe the construction and operation of a capacitive level probe for liquid level detection. (06 Marks)
 - b. Describe the principle of crankcase oil mist detection element with a sketch. (05 Marks)
 - c. Describe the operation of optical smoke detector with the aid of a sketch. (05 Marks)

4. Electro pneumatic controllers are widely used in control systems in modern vessels, replacing conventional nozzle flapper controllers.
- a. Sketch and describe the operation of Electro Pneumatic Controller. (08 marks)
 - b. List the features and major parts in above controller. (04 Marks)
 - c. What are the advantages when comparing to nozzle flapper type controller? (04 Marks)
5. With regards to mechanical control systems,
- a. Briefly explain the function of a "Cascade" control system and "Split range" control System. (06 Marks)
 - b. Sketch and describe a cascade control system for Jacket Water Cooling automatic control system of a two-stroke diesel engine. (06 Marks)
 - c. Define Split range control system in combined with the above application. (04 Marks)
6. With regards to the protection systems used in ships,
- a. Describe the operation of flame and smoke detectors used in ship's fire detection system. (08Marks)
 - b. Describe Ship's fire detection system with the aid of sketches. (08 marks)



MINISTRY OF PORTS AND SHIPPING
MERCHANT SHIPPING SECRETARIAT - SRI LANKA



Examination for Preparatory Course Chief Engineer & Second Engineer Officer
On Ships Of 3000kW Propulsion Power or More
Electro Technology

- Time Allowed - Three Hours
- This Question Paper Consist 09 Questions.
- Answer Three Questions from Part 'A' Section.
- Answer 1 Question from Part 'B' Section.
- Answer Two Questions from Part 'C' Section

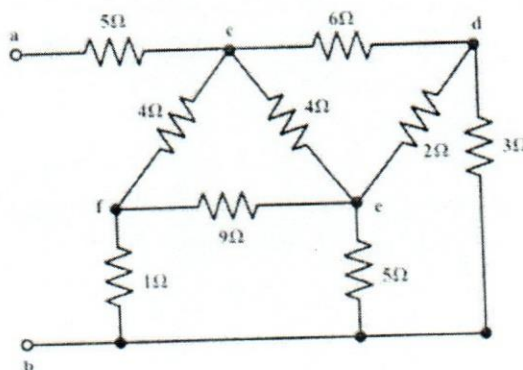


Date:

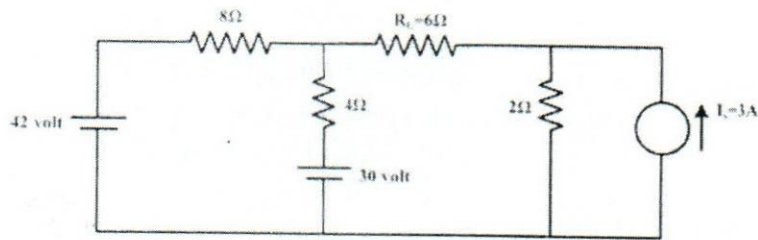
Answers with clear sketches/diagrams, neat handwriting and clear expression will get full marks

PART A Answer any Three Questions from PART A section.

- a) A copper wire of diameter 1 cm had a resistance of 0.15 ohm. It was drawn under pressure so that its diameter was reduced to 50%. What is the new resistance of the wire? (04 Marks)
 - b) Determine the equivalent resistance between the terminals A and B of resistors network (05 Marks)



- c) If internal resistance of current source is infinity and all voltage source are ideal, find the current I_x through 6 Ω resistor using Thevenin's theorem. (07 Marks)



2. a) Define magnetic flux density and magnetic flux intensity. (06 Marks)
- b) A magnetic circuit consists of an iron ring of mean length 2500 mm and an average cross-sectional area of 500 mm², together with an air gap of 4 mm. To allow for any fringing that might occur in the air gap, assume that the flux density within the metal ring must be 1.1 times greater than that required within the air gap. The magnetic circuit is manufactured from a material whose magnetizing curve may be constructed from the following table.

$H / (\text{A/m})$	500	600	800	1000
B / T	1.01	1.09	1.17	1.19

What magnetic field strength is required to produce a flux of 0.5 mWb within the air gap?

(10 Marks)

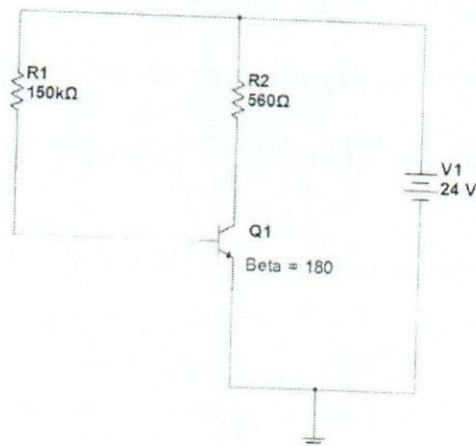
3. a) A coil of resistance 50 ohm and inductance 0.318H is connected in parallel with a circuit comprising a 75 ohm resistor in series with a 159uF capacitor. The circuit is connected to 240 V, 50Hz supply. Calculate
- supply current. (06 Marks)
 - phase angle between supply current and applied voltage. (06 Marks)
- b) Find resistance and reactance of equivalent series circuit which will take the same current at the same power factor as the parallel circuit. (04 Marks)
4. a) Define power factor in A.C. circuits. (04 Marks)
- b) A single phase a.c. generator supplies the following loads: (08 Marks)
- Lighting load of 20 kW at unity power factor.
 - Induction motor load of 100 kW at p.f. 0.707 lagging.
 - Synchronous motor load of 50 kW at p.f. 0.9 leading.
- Calculate the total kW and kVA delivered by the generator and the power factor at which it works.
- c) Discuss the various methods of power factor improvement. (04 Marks)

PART B Answer 1 Question from PART B section.

5. With regards to the Thyristors

- a. Describe the **operation of a SCR** with the aid of sketches. (04 Marks)
- b. Sketch the **circuit diagram of Single phase full wave-controlled rectifier** using thyristors and describe its operation. (06 Marks)
- c. Describe how the 3 phase AC power is controlled for,
i. Star connected loads (06 Marks)
ii. Delta connected loads, using thyristors
6. With regards to the Transistors,

- a. Expand following abbreviations for different kinds of transistors. (04 Marks)
i. BJT
ii. JFET
iii. MOSFET
iv. IGBT
- b. Briefly describe the operating modes of the transistor with indicating examples for each and every mode of operation. (04 Marks)
- c. In following BJT arrangement, find (Consider the V_{BE} of transistor as 0.75V)
i. The base current (03 Marks)
ii. The collector current (02 Marks)
iii. The voltage across collector and emitter terminals (03 Marks)



PART C Answer any two questions from PART C section

7. a) Sketch and label each basic component of a complete DOL Motor Starter used on-board ships (06 Marks)
- b) Re-draw control circuit with additional components to modify your control Circuit to suite an Oil Transfer pump with (06 Marks)
- i) One Emergency stop & remote Stop push buttons,
 - ii) One remote start button,
 - iii) One Run Indication Lamp indicates Pump on /off.
- d) Compare two advantages and two disadvantages of auto transformer and Star/Delta motor starter (04 Marks)
8. a) Sketch complete circuit of an alternator static excitation system and name all components. (05 Marks)
- b) Describe in brief the functions of each components of compound static excitation system. (03 Marks)
- c) Explain why Primary of compound transformer has less number of turns with thick winding and the other has many number of turns with thin winding. (02 Marks)
- d) What is the information shown by the pointer and direction of synchroscope. (03 Marks)
- e) Explain manual synchronizing procedure without synchroscope in case of emergency situation. (03 Marks)
9. a) What are the requirements of a marine AVR with regard to the allowable voltage dip, correction time and max off set? (04 Marks)
- i) What are the factors that would cause voltage dips on an AC circuit? (03 Marks)
 - ii) With a simple diagram explain a soft starting system used on an induction motor. (04 Marks)
- b) With the aid of a diagram explain the starting of a wound rotor induction motor. (04 Marks)



MINISTRY OF PORTS AND SHIPPING
MERCHANT SHIPPING SECRETARIAT - SRI LANKA

EXAMINATION FOR CERTIFICATE OF COMPETENCY
CHIEF ENGINEER & SECOND ENGINEER OFFICER ON SHIPS OF 3000KW
PROPULSION POWER OR MORE

Maritime Law

- TIME ALLOWED - THREE HOURS
- Answer any SIX (6) questions
- Marks for each part of the question are shown in the brackets
- Pass marks - 50%
- Date - 2023

Answers with clear sketches/diagrams, neat handwriting and clear expression will get full marks.

1. There are fourteen (14) chapters in SOLAS convention which was introduced by IMO with the objectives of preventing accidents & casualties may involve with merchant ship operation.
 - a. With regard to SOLAS, state the areas/items of the ship covered by the following chapters.

I. Chapter II-1.	(04 Marks)
II. Chapter II-2.	(03 Marks)
III. Chapter III.	(01 Marks)
IV. Chapter IV.	(01 Marks)
V. Chapter IX.	(01 Marks)
 - b. Name the Certificates required to be carried on board the merchant ships under above chapters. (06 Marks)

2. As per the IMO conventions ships operating in international trade require survey and certification to verify the compliance with applicable rules & regulations.
 - a. State 06 main statutory certificates that required carrying on board ship operating in international waters with the name of relevant convention or code. (06 Marks)
 - b. What is the difference between Statutory & other trading certificates? (03 Marks)
 - c. What are the areas covers under the Certificate of class of a ship? (05 Marks)
 - d. State the advantages of Harmonized System of Survey & certification for ships? (02 Marks)

3. With reference to ISM Code

- a. What are the objectives of SOLAS Chapter IX -ISM Code? (03 Marks)
- b. Define the terms "Non-Conformity" & "Major Non-Conformity". (04 Marks)
- c. During an internal ISM audit carried out on board following deficiencies were noted
 Arrival Departure Check lists was not completed as required by SMS.
 Bunkers check List incomplete & not signed by the C/E.
 Overhauling of 02 Main Engine units overdue.
 Hot works has been carried out on board without permits.
 Ballast water pump running with abnormal noise & no spares o/b for repairs.

Write suitable Non-conformity note(s) stating applicable ISM clause(s) with the Objective Evidence for each non-conformity note(s). (09 Marks)

4. Amendments to the STCW in 2010 mandates application and use of leadership, Managerial and team work skills.

- a. Differentiate the qualities of a Leader & a Manager. (06 Marks)
- b. State the key steps(hierarchy) follows in "Effective Managing". (06 Marks)
- c. State the new Rest Hour & Working Hours requirements as per STCW 2010. (01 Marks)
- d. Under What circumstances the rest hour requirements stated above may be overridden and state the follow up actions to be taken if rest hours requirements were breached. (03 Marks)

5. Marpol Annex VI came into force with the objectives of controlling emission of certain gases from the ship to the atmosphere.

- a. Name types of emissions comes under control of this annex. (02 Marks)
- b. State the information that should contain in an Engine Technical File? (03 Marks)
- c. What are the main areas to be considered when preparing the Shipboard Energy Efficiency Management Plan required by Marpol Annex VI? (03 Marks)
- d. State the details that you could find in EEDI technical file. (03 Marks)
- e. Suggest the steps that could be taken to improve the Energy Efficiency during a ship operation. (05 Marks)

- 6.
- a. State ships which are required to certify under International Load Line Convention? (01 Marks)
 - b. State the factors affecting the validity of International Load Line Certificate of a ship. (05 Marks)
 - c. State the deferent types of free boards assigned (Ship Types) to ships under this convention. (02 Marks)
 - d. State the factors effecting floodable length of a ship. (02 Marks)
 - e. State steps that the ship's staff could take in preparation for a load line survey on board ship. (06 Marks)
7. With reference to Polar Code
- a. State the sea areas identified as Polar area by the code. (01 Marks)
 - b. Name 06 major hazards identified for vessels operating in Polar areas. (06 Marks)
 - c. What are the documents to be carried on board vessels comes under Polar Code? (04 Marks)
 - d. What are the exemptions that could be granted for the existing vessels operating in Polar areas? (05 Marks)
8. Referring to Risk Management on board ships,
- a. Explain the Terms "Hazard" & "Risk" with related to Risk Assessment. (04 marks)
 - b. Assuming a situation that you as a newly joined 2nd engineer on board a ship, prepare a risk assessment for Bunkering Operation, identifying six (06) significant Hazards, Risk Involve & Control Measures that could take to mitigate the Measured Risk during your assessment. (12 marks)
9. With reference to MLC 2006 Convention,
- a) While working on board, what can cause fatigue for people? (04 marks)
 - b) How do you recognize Fatigue (Signs/Symptoms)? (04 marks)
 - c) What can be done to reduce Crew fatigue on board ship? (04 marks)
 - d) What rules and regulations are in place to prevent and deal with fatigue? (04 marks)



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MINISTRY OF PORTS AND SHIPPING
MERCHANT SHIPPING SECRETARIAT - SRI LANKA

EXAMINATION FOR CERTIFICATE OF COMPETENCY
CHIEF ENGINEER & SECOND ENGINEER OFFICER ON SHIPS OF 3000KW
PROPULSION POWER OR MORE

Naval Architecture and Ship Constructions

- TIME ALLOWED - THREE HOURS
- Answer ANY FOUR questions from part A and ANY TWO questions from part B
- Marks for each part of the question are shown in the brackets
- Pass marks - 50%
- Date - 2023

Answers with clear sketches/diagrams, neat handwriting and clear expression will get full marks.

Part A: (Answer any four Questions from PART A section)

Q1.

- a. Define Centre of gravity of an object (2 marks)
- b. A ship of 7500 tonne displacement has its Centre of gravity 6.5 meter above the keel. Structural alterations are made, when 300tonne are added 4.8m above the keel, 1000 tonne of oil fuel are then added 0.7m above the keel.
- i. Calculate the new position of the Centre of gravity. (8 marks)
- ii. Calculate the final Centre of gravity when 500 tonne of oil fuel are used (6 marks)

Q2.

- a. Explain the meaning of MCT1cm. (2 marks)
- b. A ship of 130m long floating at 4800tonne displacement with 3.20m LCG aft of mid-ship.
- Following operation took place while the vessel is in a port.
- 1560 tonne of cargo loaded @Lcg 6.0 m forward of mid ship.
- 1010 Cargo discharged @ 4.245m forward of mid-ship
- 20tonne of fuel consumed @36.00 m aft of mid-ship

15 tonne of fresh water consumed @ 34.6m aft of mid-ship

5 tonne of stores loaded @ 36m forward of mid-ship

Following hydrostatic particulars are given in the vessels stability booklet.

Mean draught- m	Displacement - tonne	MCT1cm-tonne meter	LCB from mid- ship	LCF from mid- ship
7.5	5320	47.05	0.60F	3.50A

Calculate the end draughts of the vessel.

(14 marks)

Q3.

Construct the curve of statical stability from the attached KN graph of the vessel, when the displacement of the vessel is 28000tonnes and the KG is 9.0meters.

(08marks)

From the curve find following

- (a) The range of stability (0.5marks)
- (b) The maximum GZ and the heel at which it occurs (0.5marks)
- (c) The initial metacentric height (GM) (0.5marks)
- (d) The angle of vanishing stability (0.5marks)
- (e) The moment of statical stability at 35° (1 mark)
- (f) Calculate the dynamical stability to 40° (05 marks)

Q4. A vessel of 9250 tonne displacement is fitted with a propeller of 6.0m diameter and pitch.

Ratio 0.85.

During a fuel consumption trial of 8 hrs duration, a steady shaft speed of 1.75 revs/second was maintained and 9.76 tonne of fuel was consumed.

The following results also recorded

Real slip ratio	0.33
Taylor wake fraction	0.31
Shaft power	5950kW

Transmission losses	3%
Quasi-propulsive coefficient	0.71
Propeller thrust	645kN

Calculate for above condition.

- (a) The speed of the ship (4 marks)
- (b) The apparent slip ratio (1 mark)
- (c) The propeller efficiency (3 marks)
- (d) The thrust deduction factor (3 marks)
- (e) The fuel coefficient (3 marks)
- (f) The specific fuel consumption (2 marks)

Q5.

Prove that statutory fresh water allowance of a ship could be calculated from $FWA = \Delta / 40 TPC$

When the density of fresh water is $1.0t/m^3$ and density of sea water is $1.025t/m^3$ (6 marks)

A wall sided ship of 10000 tonnes displacement in river berth floats at even keel and the draft noted is 40mm below the summer load water line.

The water plane area of the vessel at the summer draft is $1756m^2$

- a. Find the distance between the summer & freshwater load line marks. (5 marks)
- b. Calculate the mass of cargo that could be additionally loaded on board in order for vessel to floats at summer load waterline when entering to seawater. (5 marks)

Q6.

A rudder with $26m^2$ effective area & 4m in length is fitted to a single screw ship with a service speed of 16.0 Knots. The axis of rotation of the rudder is 0.4m from the forward end of the rudder. The Centre of effort of the rudder is found 30% of the rudder length from the leading edge at 35° deg rudder angle.

The force on the rudder normal to the plane of the rudder at rudder angle α is given by the expression $F_n = 577 AV^2 \sin\alpha(N)$

Where A = Rudder area in m^2 V = Speed of the water across the rudder in m/s

The maximum shear stress of the material used for rudder stock is $70 MN/m^2$

Calculate the following at the rudder angle of 35° deg.

- a. The minimum diameter of the rudder stock to operate the vessel in given service speed ahead. (8 marks)
- b. The maximum safe speed of the ship could maneuver in stern direction without exceeding the maximum stress of the rudder stock. (8 marks)

Part B: (Answer any two Questions from PART B section)

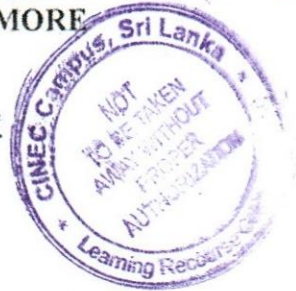
- Q7. a. Describe with the aid of sketches type of joints used in welding. (6 marks)
- b. Name five types of welding defects and briefly describe. (6 marks)
- c. Explain complete procedure for DP test method. (4 marks)
- Q8. a) Describe 6 types of dynamic forces acting on a ship. (4 marks)
- b) With respect to fore end of a ship explain what is panting and pounding. (4 marks)
- c) Draw fwd part of a ship up to fore peak bulk head naming all strength members (4 marks)
- d) What are the factors deciding the position of collision bulk head. (4 marks)
- Q9. a) With the aid of sketch explain the strengthening method of a transverse cargo hold of a Container ship. (6 marks)
- b) Explain the advantages of torsion box in a container ship. (5 marks)
- c) Sketch hatch cover sealing arrangement and describe how sealing is achieved. (5 marks)



MINISTRY OF PORTS AND SHIPPING
MERCHANT SHIPPING SECRETARIAT - SRI LANKA

EXAMINATION FOR CERTIFICATE OF COMPETENCY
CHIEF ENGINEER & SECOND ENGINEER OFFICER ON SHIPS OF 3000KW
PROPULSION POWER OR MORE

ELECTROTECHNOLOGY



- **TIME ALLOWED - THREE HOURS**
- **Attempt SIX questions only as follows:**
 - **THREE (3) questions from Part A**
 - **ONE (1) questions from Part B**
 - **TWO (2) questions from Part C**
- **Marks for each part questions are shown in brackets**
All questions carry equal marks

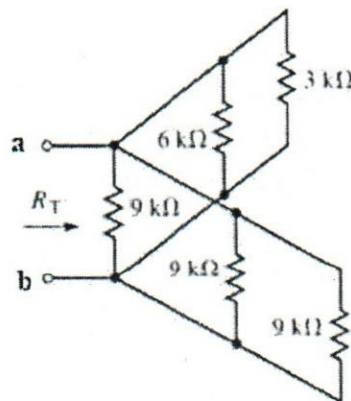
Date: 2023/08/08

Pass mark: 50%

Answers with clear sketches/diagrams, neat handwriting and clear expression will get full marks

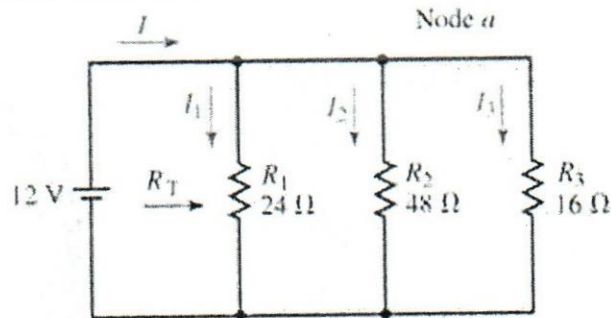
PART A: (Answer any Three Questions from PART A section)

1. a) i. Define the terms resistance and resistivity. (02 marks)
 ii. Determine the total resistance of the circuit below. (03 marks)

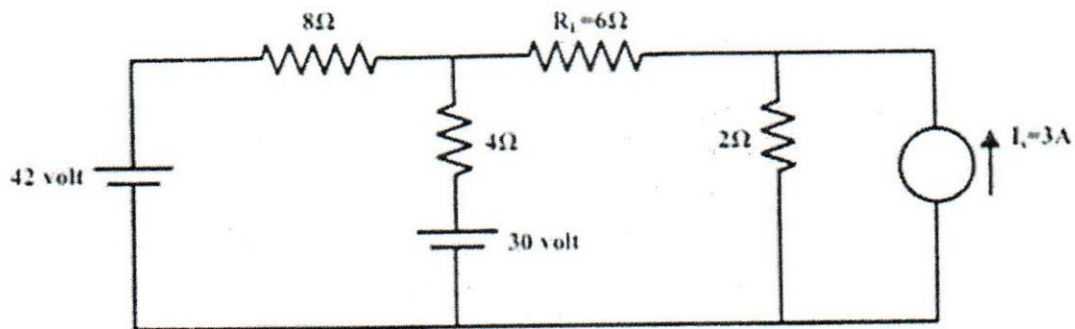


- iii. Determine the current I and power P delivered by a 9 V dc voltage source applied at terminals a-b, with 'a' being at higher potential than 'b'. (02 marks)

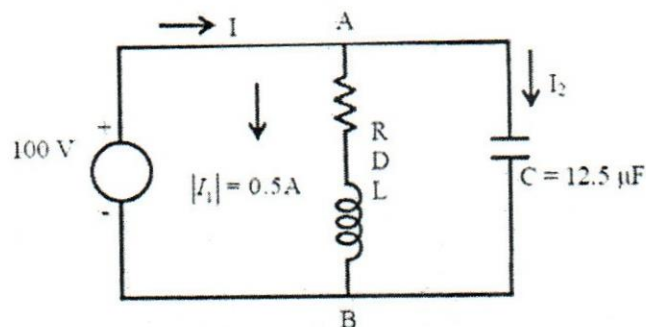
- b) i. Express Kirchhoff's laws (02 marks)
 ii. Using Kirchhoff's current law, Find the magnitude and direction of unknown currents I_1 , I_2 , I_3 and I shown in below. (02 marks)



- c) Find the current I_L through $6\ \Omega$ resistor using Thevenin's theorem or otherwise. (05 marks)

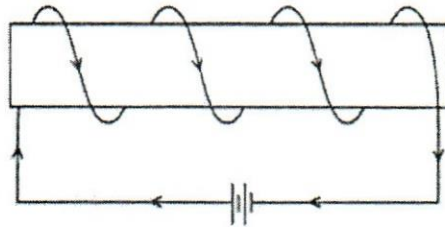


2. a) i. Define the terms capacitive reactance, inductive reactance, and impedance of electric circuit. (03 marks)
 ii. Explain the behaviour of current in RLC series circuit operating with unity power factor. (02 marks)
 b) An inductive load (R in series with L) is connected in parallel with a capacitance C of $12.5\ \mu F$. The input voltage to the circuit is $100\ V$ at $31.8\ Hz$. The phase angle between the two branch currents, ($I_1 = I_L$) and ($I_2 = I_C$) is 120° , and the current in the first branch is $I_1 = I_L = 0.5\ A$. Find the total current, and the values of R & L . (07 marks)

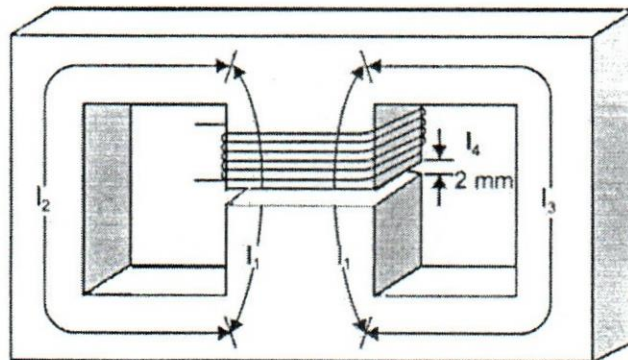


- c) Explain power factor and methods of its improvement. (04 marks)

3. a) Explain the changes in current, voltage, and power of star and delta connected power systems. (06 marks)
- b) The three line leads of a 400/230V, 3-phase, 4-wire supply are designated as R, Y and B respectively. The fourth wire or neutral wire is designated as N. The phase sequence is RYB. Compute the currents in the four wires when the following loads are connected to this supply;
 From R to N: 23kW, unity power factor
 From Y to N: 27.6kVA, 0.866 lag
 From B to N: 27.6kVA, 0.866 lead
 If the load from B to N is removed, what will be the value of currents in the four wire? (10 marks)
4. a) State Ampere's work rule. (04 marks)
- b) Draw the direction of the magnetic field inside the coil in the below. (04 marks)



- c) The magnetic core shown in following diagram has the following dimensions : (08 marks)
 $l_1 = 10 \text{ cm}$; $l_2 = l_3 = 18 \text{ cm}$;
 cross-sectional area of l_1 path = $6.25 \times 10^{-4} \text{ m}^2$;
 cross-sectional areas of l_2 and l_3 paths = $3 \times 10^{-4} \text{ m}^2$;
 length of air gap, $l_4 = 2 \text{ mm}$. ($\mu_0 = 4\pi \times 10^{-7} \text{ H.m}^{-1}$)



Determine the current that must be passed through the 600-turn coil to produce a total flux of $100 \mu\text{Wb}$ in the air gap. Assume that the metal has relative permeability of 800.

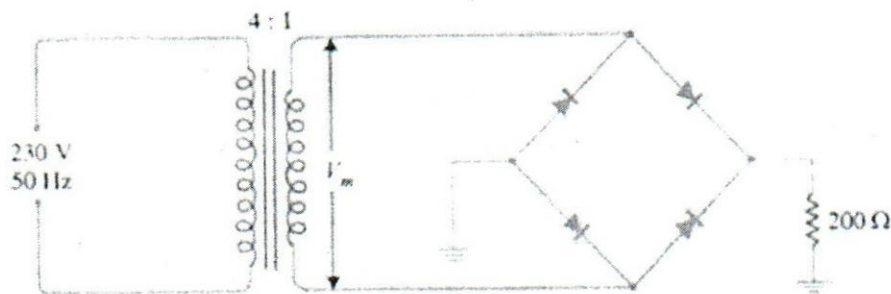
PART B: (Answer 1 Question from PART B section)

5. With regards to rectifiers and op-amps

a) In the bridge type circuit shown below diodes are assumed to be ideal.

Find:

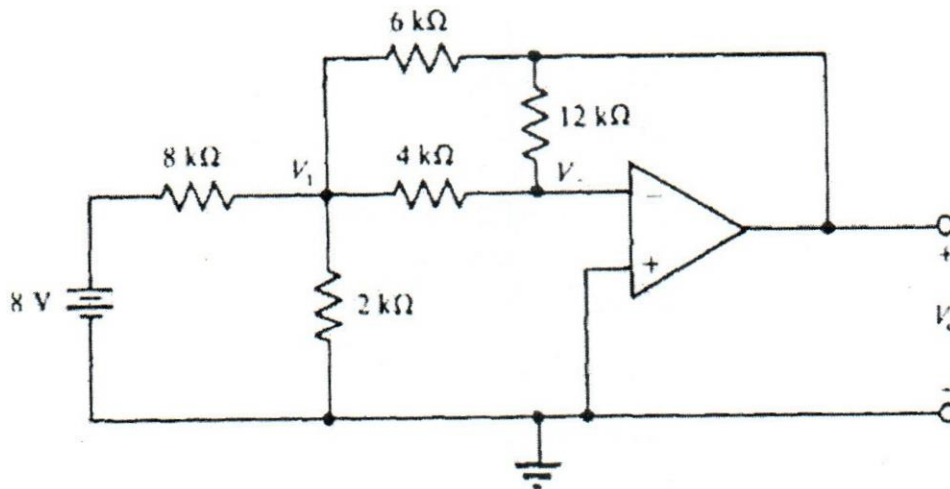
- The DC output voltage
- Peak inverse voltage
- Output frequency
- Current through the 200 ohms resistor



(06 marks)

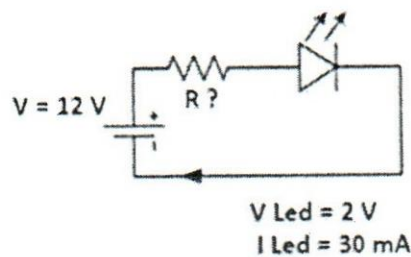
b) Draw the complete circuit diagram of the centre tapped full wave rectifier with input and output wave forms. (04 mark)

c) Determine V_0 in the following op-amp circuit. (06 marks)



6. With regards to semiconductor diodes

- What is the difference between intrinsic and extrinsic semiconductors and briefly describe the process of forming extrinsic semiconductors? (02 marks)
- Draw the circuit diagram of a forward biased and reverse biased diode by indicating the polarity of the voltage source. (02 marks)
- Describe the difference between Active and passive electronic components with examples. (02 marks)
- What are the conditions to be satisfied in order to emit light from a LED? (02 Marks)
- How to identify the polarity of a LED. (02 marks)



- What should be the value of ballast resistor? (03 marks)
- If the resistance is much lower than above value what can you observe? (03 marks)

Part C: (Answer 2 Questions from PART C section)

- What are the requirements of a marine AVR with regard to the allowable voltage dip, Correction time and max off set? (04 marks)
 - Sketch a block diagram and explain the function of an AVR. (05 marks)
 - Explain how reactive power shared between paralleled Gensets. (07 marks)
- Sketch a compound generator and name all components. (04 marks)
 - Describe in brief the function of above including components. (08 marks)
 - State the advantages and disadvantages of the compound generator. (04 marks)
- Draw the construction and explain the function of a three-phase squirrel cage induction motor. (08 marks)
 - State three types of motor starters suitable to start squirrel cage induction motors which has only three terminals. (03 marks)
 - Why fuses are used in addition to the over current relay protection in the motor starter. (5 marks)



DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

MINISTRY OF PORTS AND SHIPPING

DIRECTOR GENERAL'S OFFICE OF MERCHANT SHIPPING

Merchant Shipping Secretariat

Certificate of Competency Chief & Second Engineer Officers

THERMODYNAMICS



- TIME ALLOWED - THREE HOURS
- Answer ANY Six questions only
- Date:

Pass marks: 50%

Answers with clear sketches/diagrams, neat handwriting and clear expression will get full marks

For air $c_p = 1.005 \text{ kJ/kg K}$, $c_v = 0.717 \text{ kJ/kg K}$, $\gamma = 1.4$

Composition of air (mass proportions): 77 % of Nitrogen and 23 % of Oxygen

Specific heat capacity of water 4.2 kJ/kg K

1.

- a. State the steady flow energy equation in full, defining the symbols and unit used (5 marks)
- b. Air passes through a gas turbine at the rate of 10 kg/s . The gas enters the turbine with a velocity of 100 m/s and specific volume of $0.68 \text{ m}^3/\text{kg}$. The gas leaves the turbine with a specific volume of $1.85 \text{ m}^3/\text{kg}$. The exit area of the turbine is 0.045 m^2 . In its passage through the turbine system, the specific enthalpy of air is reduced by 300 kJ/kg and there is a heat transfer loss of 48 kJ/kg . Determine
 - i. The inlet area of the turbine in m^2 (5 marks)
 - ii. The exit velocity of the air m/s (5 marks)
 - iii. The power developed by the turbine system in kW (5 marks)

2. Initially steam at a pressure and temperature of 2 bar and 165°C is compressed isothermally to a state where the specific volume is 0.15 m^3 .

- a. Sketch the process on T - S and P - v diagrams (4 marks)
- b. Calculate the followings
 - i. The change of internal energy (4 marks)
 - ii. The change of entropy (4 marks)

- iii. The heat transfer during the process (4 marks)
- iv. The work done (4 marks)
3. LNG/Heavy fuel oil engine working on an ideal Dual cycle has the bore and stroke of the cylinder are **800 mm** and **3200 mm**, respectively. The clearance volume of **0.0375 m³**. The blower inlet At the beginning of isentropic compression the air in the cylinder has a pressure of **2.0 bar** and temperature of **40 °C**, the maximum pressure of the cycle is **140 bar** and temperature of the cycle is **1960°C**. Estimate
- a. The compression ratio (4 marks)
- b. The temperature and pressure at the end of compression (4 marks)
- c. The efficiency of the cycle (8 marks)
- d. The fraction of the stroke at which the combustion is theoretically complete (4 marks)
- 4.
- a. Describe the overall heat transfer coefficient (4 marks)
- b. Steam at **460 °C** and **40 bar** flows through a **10 m** length of steel pipe which has a bore of **50 mm** and a thick of **10 mm**. The steam temperature falls to **450 °C** at the exit of the pipe and steam flow rate is **10 kg/s**. The ambient temperature of the air is **30 °C**. Calculate the followings
- i. The rate of heat loss through the surface of the pipe (4 marks)
- ii. The interface temperature between steel and insulation (5 marks)
- iii. Thickness of the insulation (7 marks)
- Thermal conductivities of steel and insulation are **52** and **0.45 W/m K**.
- Hint: Rate of heat transfer through thick cylinder is given by

$$\frac{Q}{t} = 2\pi kl \frac{\theta_2 - \theta_1}{\ln \frac{r_2}{r_1}} \text{ where } r_1 \text{ and } r_2 \text{ are inner radius and outer radius of the cylinder}$$

5. In a regenerative steam power plant, steam enters the turbine at a pressure of **40 bar** and a temperature of **450 °C** and expands to **0.2 bar** under constant entropy. Certain mass of steam is bled from the turbine at a pressure of **10 bar** and supplied to a direct feed heater. The feed water leaves the feed heater at the saturation temperature of the bled steam and there is no undercooling in the condenser. Neglect the feed pump work.
- a. Draw the **T-S** diagram of the plant (4 marks)
- b. Estimate

- i. The condition of the bled steam (3 marks)
- ii. The fraction of the steam used for feed heating (5 marks)
- iii. Thermal efficiency of the plant (8 marks)

6.

- a. The critical pressure ratio of a convergent divergent nozzle is given by $\frac{P_c}{P} = \left(\frac{2}{\gamma + 1} \right)^{\gamma/(\gamma-1)}$

determine the critical pressure ratio

- i. For the steam entering as dry and saturated, $\gamma = 1.135$ (2 marks)
 - ii. For the steam entering as superheated, $\gamma = 1.3$ (2 marks)
- b. Superheated steam at **40 bar** and **450 °C** expand in a convergent-divergent nozzle to **10 bar**. Assume that the inlet velocity is negligible and the isentropic expansion is **0.87** (throat to exit) The mass flow rate is **10 kg/s**. Estimate
- i. The pressure at the throat (2 marks)
 - ii. The throat area (6 marks)
 - iii. The exit area and the exit velocity (8 marks)

7. A test of Marine slow speed, LNG/Heavy fuel oil with seven-cylinder resulted the following data at the full load or maximum continuous rating (MCR): The brake torque with all cylinders working **3865.02 kN m**.

Brake torque with No. 1 cylinder cut-off = **3312.88 kN m**

Brake torque with No. 2 cylinder cut-off = **3312.77 kN m**

Brake torque with No. 3 cylinder cut-off = **3312.82 kN m**

Brake torque with No. 4 cylinder cut-off = **3312.37 kN m**

Brake torque with No. 5 cylinder cut-off = **3312.17 kN m**

Brake torque with No. 6 cylinder cut-off = **3312.01 kN m**

Brake torque with No. 7 cylinder cut-off = **3312.57 kN m**

The engine has a bore of **800 mm** and stroke of **3200 mm** at a speed of **78 rev/min**, the specific gas and pilot oil fuel consumption (*break*) is **165g/kWh** and lower calorific value of Gas and pilot fuel is **42.7 MJ/kg**.

Estimate

- a. The brake power, indicated power and mechanical efficiency (12 marks)

- b. The indicated mean effective pressure and brake mean effective pressure (4 marks)
- c. Indicated thermal efficiency and brake thermal efficiency (4 marks)
8. A single stage, single-acting, reciprocating compressor has a bore and stroke of 50.8 mm and 49.2 mm . The refrigerant intake conditions are 0.8435 bar and $-30 \text{ }^\circ\text{C}$ and the delivery conditions are 8.8672 bar and $45 \text{ }^\circ\text{C}$. The compressor runs at standard speed of 1750 rpm and its clearance volume is 4.5% of the swept volume. Assuming refrigerant behave like a gas in the given conditions, estimate the followings.
- a. Polytropic index of the compression (4 marks)
- b. The volumetric efficiency (4 marks)
- c. The volume of gas delivered per minute (6 marks)
- d. The power of the compressor (6 marks)
9. *Refrigerant -134a* uses to operate a reefer container in the temperature range of $-30 \text{ }^\circ\text{C}$ and $35 \text{ }^\circ\text{C}$. The refrigerant leaves the compressor as a superheated vapour at 8.8672 bar and $45 \text{ }^\circ\text{C}$ and the compression is isentropic.
- a. Estimate
- i. The dryness fraction of the refrigerant at the evaporator exit (3 marks)
- ii. Compressor work done per kg of refrigerant (4 marks)
- iii. Coefficient of performance if the refrigerant leaves the condenser at $25 \text{ }^\circ\text{C}$ (5 marks)
- b. Draw the *TS* and *PH* diagrams (4 marks)
- c. 10 kg of water at $30 \text{ }^\circ\text{C}$ turns into ice at $-30 \text{ }^\circ\text{C}$ within 20 minutes inside the refer container. Estimate the refrigeration load and refrigerant flow rate through the evaporator. (4 marks)
- Hint : Specific heat of ice – 2.04 kJ/kg K , Latent heat of fusion of ice – 335 kJ/kg

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APPLIED MECHANICS

- TIME ALLOWED - THREE HOURS
- Answer ANY Six questions only
- Date:

Pass marks: 50%

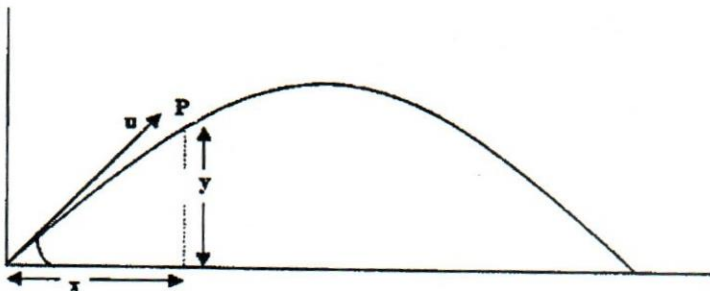
Answers with clear sketches/diagrams, neat handwriting and clear expression will get full marks

1

- 1.1. Write down three assumptions you made while considering Bernoulli's equation in hydro dynamics. (4 Marks)
- 1.2 Write down Bernoulli's equation considering two points (point 1 and 2) of a pipe flowing a liquid, having elevations to the datum line Z_1 and Z_2 . Identify all variables with relevant units. (6 Marks)
- 1.3 In a smooth pipe of uniform diameter 100 cm, it is recorded that at elevation 'A' having pressure of 55 kPa and height of 15 m. The section B having elevation of 20 m its pressure recorded as 30 kPa. The flow rate through a pipe is 1000 l s^{-1} . Determine the direction of flow between section A and B. What is the total head loss? (10 Marks)

2.

- 2.1 A particle projected upwards at an angle of α with the horizontal with an initial velocity ' u ' ms^{-1} from point A is shown below.



Show that y is given by,

$$y = x \tan \alpha - \frac{gx^2}{2u^2 \cos^2 \alpha}$$

(4 marks)

2.2 Hence or otherwise find the firing angle of bullet to hit on a target, where the bullet is fired with an initial velocity of 250 ms^{-1} at a target located at a horizontal distance of 4km and vertical distance of 700m above the gun.

(8 marks)

2.3 find an expression for the maximum height.

(8 marks)

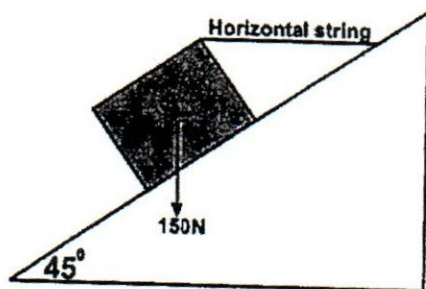
3.

3.1 Briefly describe static friction and dynamic friction. Show the shape of its variation against the applied force in a graph.

(2 marks)

3.2 A rectangular prism weighing 150N is lying on an inclined plane whose inclination with the horizontal is shown in the figure below. The block is tied up by a horizontal string which has a tension of 50N. Find;

- The frictional force on the block (6 marks)
- The normal force of the inclined plane (6 marks)
- The frictional coefficient between the surface of contacts (6 marks)



4.

4.1 Describe the relationship between the work done, energy and power (5 marks)

4.2 An army truck of mass 5 tons has tractive resistance of 150 N/tonne. Find the power required to propel the truck at a uniform speed of 36 km/h;

- Up an incline of 1 in 100 (5 marks)
- On a level track (5 marks)
- Down an incline of 1 in 100 (5 marks)

5

5.1 A tank having square base of side length 30cm contains 3m pure water and 2.5m another liquid with Relative Density 1.2. Assuming liquids are not mixed with each other calculate the force acting on one side of the wall of the tank. (10 marks)

5.2 Show that Moment of Inertia of a triangular section about an axis passing through the Center of Gravity and parallel to the base is given by,

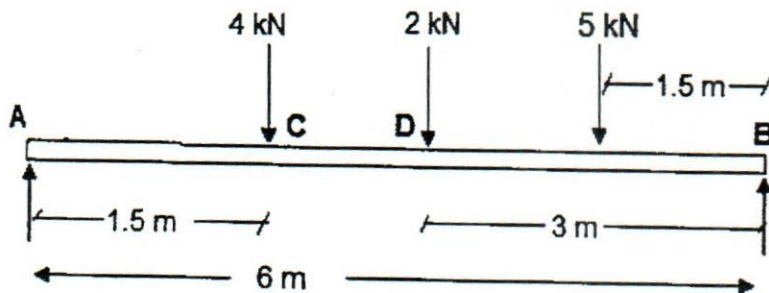
$$\frac{\text{base} \times \text{height}^3}{36}$$

(4 Marks)

If a triangle of height d and base b is vertical and submerged in liquid with its base at the liquid surface, derive an expression for the depth to its Center of Pressure. (6 Marks)

6.

6.1 A simply supported beam of AB, 6m long is load as shown in the following figure. Construct the S.F. and B.M. diagrams for the beam and find the position and value of maximum bending moment. (20 marks)



7.

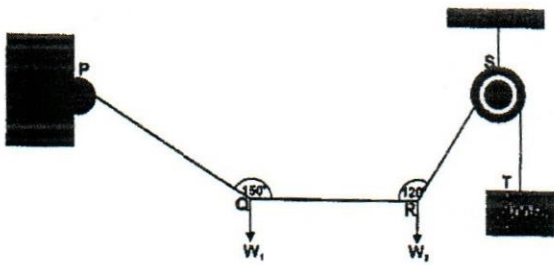
7.1 State Lami's theorem using suitable figure and notations. (4 Marks)

7.2 A light string PQRS whose extremity P is fixed, has weights W_1 and W_2 attached to it at Q and R. It passes round a small smooth peg at S carrying a weight of 400N at the free end T as shown in the figure. If in the equilibrium position, QR is horizontal and PQ and RS make 150° and 120° with QR respectively, find;

- Tensions in the portions PQ, QR, RS of the string
- Magnitudes of W_1 and W_2

(8 Marks)

(8 Marks)



8.

8.1 Briefly discuss the concept of "conservation of energy"

(4 Marks)

8.2 A Bullet of mass 30g is fired in to a body of mass 10kg which is suspended by a string 0.8m long. Due to this impact, the body swings through an angle 30° . Find the velocity of the bullet. (8 Marks)

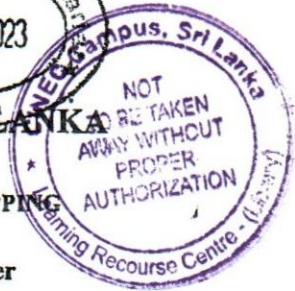
8.3 If the body of mass increased by another 10kg, what will be the angle of swing after the impact for a bullet travelling at the same speed as in mentioned in 8.2. (8 Marks)

9.

9.1 A multi-plate clutch consists of five contact surfaces in driving shaft and four contact surfaces in driven shaft, providing total of eight contact surfaces. The outside and inside diameters of the contact surfaces are 550 mm and 350 mm respectively. The maximum intensity of pressure at any point in the contact surface is not to exceed 0.45 N/mm^2 . The coefficient of friction between contact surfaces are 0.45. Determine the amount of power transmission when clutch runs at 2500 rpm. (20 marks)

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Mathematics

- TIME ALLOWED - THREE HOURS
- Answer ANY FOUR questions from part A and ANY TWO questions from part B
- Date: Pass marks: 50%

Answers with clear sketches/diagrams, neat handwriting and clear expression will get full marks

1. a) Simplify $\frac{1}{1+x^{b-a}+x^{c-a}} + \frac{1}{1+x^{a-b}+x^{c-b}} + \frac{1}{1+x^{a-c}+x^{b-c}}$ (5 marks)
- b) If $x = \log_a bc$, $y = \log_b ac$ and $z = \log_c ab$, prove that $xyz = x + y + z + 2$ (7 marks)
- c) The equation has $x^{\left[(\log_5 x)^2 - \frac{9}{2}(\log_5 x) + 5\right]} = 5\sqrt{5}$ exactly three real roots. (8 marks)
- i. Substituting $\log_5 x = q$, express above equation in term of q
- ii. Hence, Determine the value of x .
2. a) If the matrix $\begin{pmatrix} 2k & 3 \\ -4 & 3 \end{pmatrix}$ has no inverse find the value of k . (7 marks)
- b) If $A = \begin{pmatrix} 1 & 2 & 2 \\ 2 & 1 & 2 \\ 2 & 2 & 1 \end{pmatrix}$ show that $A^2 - 4A - 5I = 0$ where $I, 0$ are unit and null matrix of order 3 respectively. (8 marks)
- Use this result to find A^{-1} .
- c) Solve, with the help of matrices, the simultaneous equations (5 marks)
- $$\begin{aligned} x - y + z &= 2 \\ x + 6y + 3z &= 22 \\ x + 4y + z &= 11 \end{aligned}$$

3. If Taylor's series of function $f(x)$ around 'a' is given by

$$f(x) = \frac{f(a)}{0!}(x-a)^0 + \frac{f'(a)}{1!}(x-a)^1 + \frac{f''(a)}{2!}(x-a)^2 + \frac{f'''(a)}{3!}(x-a)^3 \dots$$

Where $f'(a)$, $f''(a)$ and $f'''(a)$ are derivatives of $f(x)$ when $x = a$.

a) Find the Taylor's series of $f(x) = e^{x^2}$ around $x = 0$. (12 marks)

b) Hence, Integrate $\int_0^1 e^{x^2} dx$ (8 marks)

4. a) Evaluate

i. $\lim_{x \rightarrow 0} \frac{x \tan x}{1 - \cos x}$ ii. $\lim_{x \rightarrow 0} \frac{1 - \cos(\sin x)}{\sin x}$ (6 marks)

b) If $y = \frac{x}{\sqrt{1+x^2}}$, prove that $(1+x^2) \frac{d^2y}{dx^2} + 3x \frac{dy}{dx} = 0$. (7 marks)

c) A cylindrical tin, with lid, is made from a thin sheet of metal of area S . The radius, height and volume of the tin are r , h and V respectively. (7 marks)

i. Find S in terms of V and r .

ii. Given that r can vary and that there is no wastage of metal, show that, for a given V , S is a minimum when $h=2r$

5. a) i. Resolve into partial fractions (6 marks)

$$\frac{1}{(x-3)(x^2-1)}$$

ii. Hence, Evaluate the following integral. (6 marks)

$$\int \frac{1}{(x-3)(x^2-1)} dx$$

b) Figure shows the variation of height of a lamina along the x - axis from 0 to 10m



x (m)	0	1	2	3	4	5	6	7	8	9	10
y (m)	0	3.75	4.95	5	5	5	5	4.75	3.5	2.4	0

Determine the area of the lamina in the figure by using the coordinates given in the table. (Hint: Simpson's 1/3 rule). (8 marks)

6. a) Prove that following identities (8 marks)

i. $(\operatorname{cosec} x - \sin x)(\sec x - \cos x)(\tan x + \cot x) = 1$

ii. $\frac{\sin x}{1 + \cos x} + \frac{1 + \cos x}{\sin x} = 2 \operatorname{cosec} x$

- b) Solve the trigonometric equation $\tan^{-1}\left(\frac{x-1}{x-2}\right) + \tan^{-1}\left(\frac{x+1}{x+2}\right) = \frac{\pi}{4}$ (6 marks)

- c) Show that $\cos^{-1}(-\theta) = \pi - \cos^{-1} \theta$ for $-1 \leq \theta \leq 1$. (6 marks)

7. a) Using $\cos^2 x + \sin^2 x = 1$, express $\cos^4 x + \sin^4 x$ in form of $f(x) = A + B \cos 4x$ (10 marks)

- b) Hence, Sketch the graph of $f(x) = 4(\cos^4 x + \sin^4 x)$ in the domain of $-2\pi \leq x \leq 2\pi$. (10 marks)

8. a) If $z = e^{xy}$, find one of third order partial derivative $\frac{\partial^3 z}{\partial x^2 \partial y}$. (6 marks)

- b) If $z = e^{ax+by} \cdot f(ax-by)$ prove that $b \frac{\partial z}{\partial x} + a \frac{\partial z}{\partial y} = 2abz$. (8 marks)

- c) The power P required to propel a ship of length l moving with a velocity V is given by $P = kV^3 l^2$. Find the percentage increase in power if increase in velocity is 3% and increase in length is 4%. (6 marks)

Hint: total derivative of $z = f(x, y)$ is $dz = \frac{\partial z}{\partial x} dx + \frac{\partial z}{\partial y} dy$

9. a) Find the modulus and principal argument of the complex number (6 marks)

$$\frac{1+2i}{1-(1-i)^2}$$

- b) Find cubic root of $1+i$ (7 marks)

- c) If $a^2 + b^2 + c^2 = 1$ and $b+ic = (1+a)z$, prove that $\frac{a+ib}{1+c} = \frac{1+iz}{1-iz}$ (7 marks)