GENERAL ENGINEERING SCIENCE II

Attempt ALL questions

Marks for each question are shown in brackets.

Section A

1. A quantity of Air has a volume of 1.3 m^3 at 4.5 bar and an initial temperature of 25°C. The Air is heated in its vessel until the pressure reaches 1.75 MN/m^2, the volume is unchanged.

   Determine EACH of the following:

   (a) the mass of Air; (4)

   (b) the final temperature of the Air. (4)

   Note: the characteristic gas constant for air has a value of 290J/kgK.

2. During a heat treatment process a steel component with a mass of 8 kg is cooled from a temperature of 400°C by being completely immersed in a tank containing 12 kg of oil which was originally at a temperature of 20°C.

   Assuming there are no heat losses from the tank calculate the final equilibrium temperature of the oil and the steel component. The effect of the tank can be ignored.

   Note: specific heat capacity of steel = 0.48 kJ/kgK
   specific heat capacity of oil = 1.8 kJ/kgK (8)

3. The following parameters may be determined during the analysis of a diesel engine.

   Define EACH of the following terms and state a formula for calculating the values of each:

   (a) indicated power, indicating reason for variations between 2 & 4 stroke cycles; (2)

   (b) shaft power; (3)

   (c) Engine mechanical efficiency indicating reasons for losses; (3)

   (d) Power loss to exhaust. (2)

4. (a) Describe how changes of state occur without change in temperature. (4)

(b) A metal component with a mass of 1.15 kg at 600°C is quenched by immersion in 5 kg of water at 20°C. The combined final temperature of the water and metal is 36°C.

Determine the Specific Heat Capacity of the metal. (4)

Note: the Specific Heat Capacity of water is 4.18 kJ/kgK.

5. Butane (C_4H_{10}) is completely burned in 30% excess air by mass.

Determine EACH of the following:

(a) the mass of carbon dioxide in the exhaust gases per kg of fuel; (4)

(b) the mass of nitrogen in the exhaust gases per kg of fuel. (4)

Note: Assume air to be 23% Oxygen and 77% Nitrogen

6. (a) State TWO thermodynamic and two general properties required of a good refrigerant. (4)

(b) For the FOUR key points in a simple refrigeration circuit state the physical condition of the refrigerant including relative temperature and pressure (4)

Section B

7. (a) Briefly describe the principal molecular characteristic of materials that differentiates those that conduct electricity well from those that do not. (2)

(b) State examples of an electric current being used for EACH of the following:

(i) its magnetic effect; (2)

(ii) its chemical effect; (2)

(iii) its heating effect. (2)

8. (a) State the THREE main effects of an electric current. (3)

(b) State TWO practical examples of EACH effect in Q8(a). (2)

(c) List THREE means by which electricity may be produced. (3)

9. (a) Explain how does the resistance of metals change as there temperature decreases; (2)

(b) Give an example of where the changing property described in Q9a is used; (2)

(c) Determine the total resistance across a,b in the circuit shown in FIG Q9: (4)

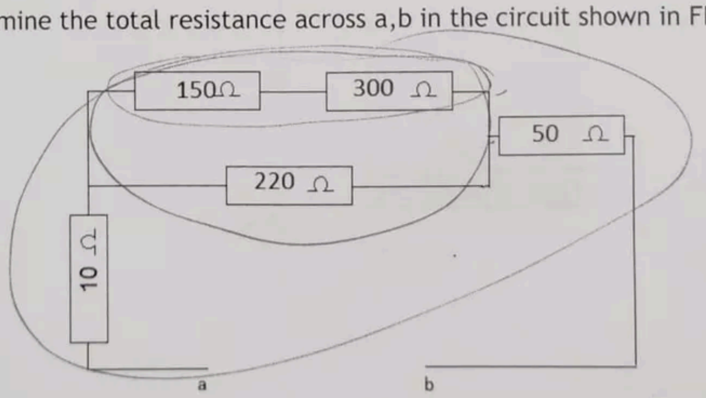

FIG Q9

10. (a) In a moving coil instrument explain the purpose of a shunt resistor. (2)

(b) Describe with the aid of a diagram, the operation of a moving coil instrument. (6)

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11. A ship has a displacement volume of 7500 m^3 in sea water.

Calculate the mass, m, which when loaded on the centre line at a Kg of 4.8 m will cause a change of +0.25 m in the position of the ship's centre of gravity.

Note: KG = 3.5 m and density of sea water = 1025 kg/m³ (8)

12. A tank has a round inspection hatch 700 mm diameter situated as shown in FIG Q12. The tank is filled to a height of 4.5 m with seawater.

Determine EACH of the following:

(a) The pressure at the centre of the hatch. (2)

(b) The thrust on the hatch. (4)

(c) Was the pressure calculated in 12a(i) an absolute pressure or a gauge pressure. (2)

(d) Describe the difference between absolute and gauge pressure (2)

Note: the density of seawater is 1025 kg/m³

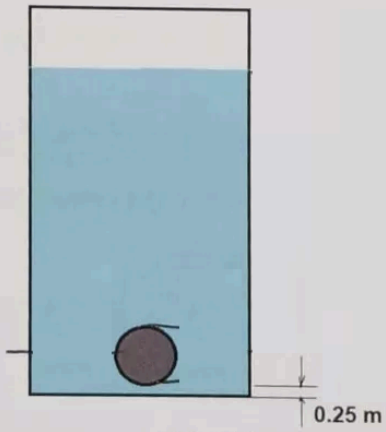


FIG Q12

A quantity of Air has a volume of 1.3 m³ at 4.5 bar and an initial temperature of 25°C. The Air is heated in its vessel until the pressure reaches 1.75 MN/m², the volume is unchanged.

Determine EACH of the following:

(a) the mass of Air; (4)

(b) the final temperature of the Air. (4)

Note: *the characteristic gas constant for air has a value of 290J/kgK.*

$Pv = mRt$

$P_1 = 450{,}000\ (Pa)$ $\quad P_2 = 1{,}750{,}000\ (Pa)$

$V_1 = 1.3\ m^3$ $\quad V_2 = 1.3$

$T_1 = 25°C = 298\ K$ $\quad T_2 = x$

a) $450{,}000 \times 1.3 = x(290)298$

$585000 = 86420x$

$\frac{585000}{86420} = x$

$\boxed{6.769266\ kg}$

b) $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

$\frac{450{,}000}{298} = \frac{1{,}750{,}000}{x}$

$1510.067 = \frac{1{,}750{,}000}{x}$

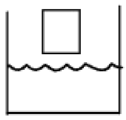
$x = \frac{1750{,}000}{1510.067}$

$\boxed{x = 1158.89\ K}$

During a heat treatment process a steel component with a mass of 8 kg is cooled from a temperature of 400°C by being completely immersed in a tank containing 12 kg of oil which was originally at a temperature of 20°C.

Assuming there are no heat losses from the tank calculate the final equilibrium temperature of the oil and the steel component. The effect of the tank can be ignored.

Note: specific heat capacity of steel = 0.48 kJ/kgK
specific heat capacity of oil = 1.8 kJ/kgK (8)



Heat loss = Heat gain

$Q_{steel} = Q_{oil}$

Name	initial	final	Δt	$Q = mc\Delta t$
Steel	m = 8 kg C = 480 J/kgK t = 400 °C	t = x	(400 − x)	$Q_{steel} = 8 \times 480 (400 - x)$
Oil	m = 12 kg C = 1800 J/kgK t = 20 °C	t = x	(x − 20)	$Q_{oil} = 12 \times 1800 (x - 20)$

$$Q_{steel} = Q_{oil}$$

$$8 \times 480 (400 - x) = 12 \times 1800 (x - 20)$$

$$3840 (400 - x) = 21600 (x - 20)$$

$$1536000 - 3840x = 21600x - 432000$$

$$1536000 + 432000 = 21600x + 3840x$$

$$1968000 = 25440x$$

$$77.358 = x$$

$$\boxed{77.358\ °C}$$ Final temp

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(b) shaft power; (3)

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(d) Power loss to exhaust. (2)

(a) Describe how changes of state occur without change in temperature. (4)

(b) A metal component with a mass of 1.15 kg at 600°C is quenched by immersion in 5 kg of water at 20°C. The combined final temperature of the water and metal is 36°C.

Determine the Specific Heat Capacity of the metal. (4)

Note: *the Specific Heat Capacity of water is 4.18 kJ/kgK.*

b) $Q = mc\Delta t$

Heat loss = Heat gained

$Q_{metal} = Q_{water}$

$$m c \Delta t = m c \Delta t$$

$$1.15(x)(600-36) = 5(4180)(36-20)$$

$$1.15 \times 564 = 5 \times 4180 \times 16$$

$$648.6x = 334400$$

$$x = \frac{334400}{648.6}$$

$$x = 515.572 \text{ J/kgK}$$

Butane (C_4H_{10}) is completely burned in 30% excess air by mass.

Determine EACH of the following:

(a) the mass of carbon dioxide in the exhaust gases per kg of fuel; (4)

(b) the mass of nitrogen in the exhaust gases per kg of fuel. (4)

Note: Assume air to be 23% Oxygen and 77% Nitrogen

H = 1 C = 12 O = 16 Air 23% oxy

Carbon

$4 \times 12 = 48$

$\frac{48}{58} \times 1\,kg = 0.827586\,kg$

Hydrogen

$10 \times 1 = 10$

$\frac{10}{58} \times 1\,kg = 0.1724138\,kg$

total

$48 + 10 = 58$

Burn Carbon

$C + O_2 = CO_2$

mols = $\frac{mass}{RAM}$

$\frac{0.827586}{12} = \frac{x}{32}$

2.206896 kg of oxy Req to burn Carbon

Burn Hydrogen

$H_2 + O = H_2O$

mols = $\frac{mass}{RAM}$

$\frac{0.1724138}{2} = \frac{x}{16}$

1.37931 kg of oxy Req to burn Hydrogen

a) Mass of CO_2 = Mass of Carbon + Mass of oxy

0.827586 + 2.206896

3.034482 kg

b) Stoich oxygen = 2.206896 kg + 1.37931 kg

3.586206 kg

Stoich Air @ 23% oxy

$x \times 0.23 = 3.586206\text{ kg}$

$x = \frac{3.586206\text{ kg}}{0.23}$

$x =$ **15.5922 kg**

Include excess @ 30%

15.5922 kg × 1.3 = 20.26986 kg

Nitrogen @ 77%

20.26986 kg × 0.77 = **15.60779 kg**

6. (a) State TWO thermodynamic and two general properties required of a good refrigerant. (4)

(b) For the FOUR key points in a simple refrigeration circuit state the physical condition of the refrigerant including relative temperature and pressure (4)

7. (a) Briefly describe the principal molecular characteristic of materials that differentiates those that conduct electricity well from those that do not. (2)

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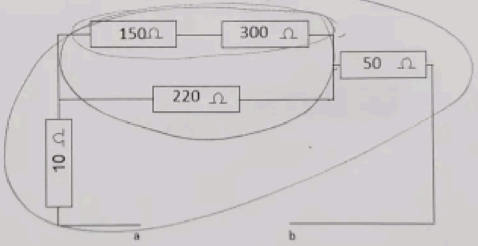
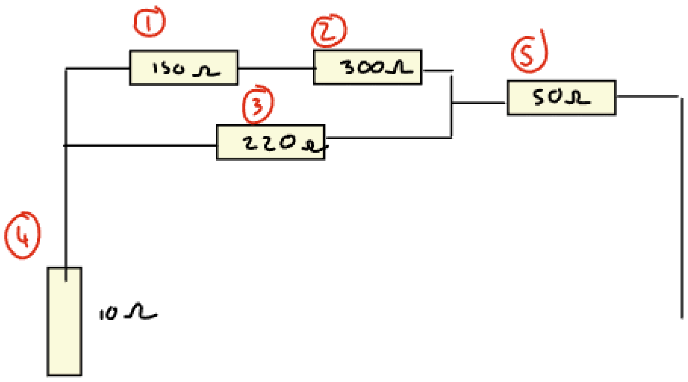


FIG Q9



Series

$R_T = R_1 + R_2$

$R_T = 150 + 300 = 450\ \Omega$

Parallel

$\frac{1}{R_T} = \frac{1}{450} + \frac{1}{R_3}$

$\frac{1}{R_T} = \frac{1}{450} + \frac{1}{220}$

$R_T = 147.76\ \Omega$

Series

$R_T = 10 + 147.76\ \Omega + 50$

207.76 Ω

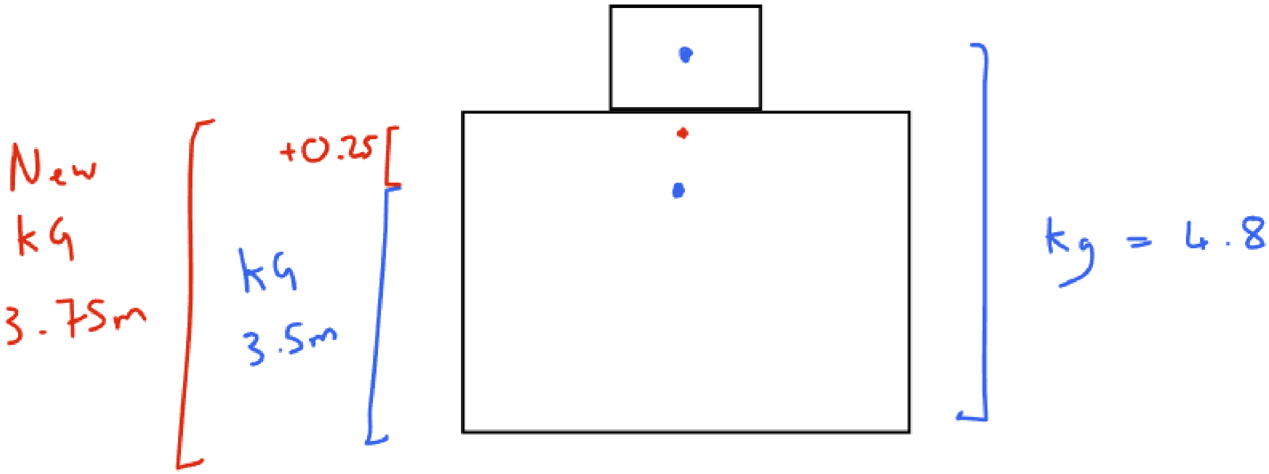
10. (a) In a moving coil instrument explain the purpose of a shunt resistor. (2)

(b) Describe with the aid of a diagram, the operation of a moving coil instrument. (6)

4. A ship has a displacement volume of 7500 m^3 in sea water.

Calculate the mass, m, which when loaded on the centre line at a Kg of 4.8 m will cause a change of +0.25 m in the position of the ship's centre of gravity.

Note: KG = 3.5 m and density of sea water = 1025 kg/m^3 (8)



Mass of ship

$$m = d \times v$$

$$1.025 \times 7500 = 7687.5 \text{ t}$$

taking moments about K

Name	Mass (t)	F	Distance (m)	Moment (tm)	Dir A/C
Ship	7687.5		3.5	26906.25	C
load	x		4.8	$4.8x$	C
Ship+load	$7687.5 + x$		3.75	$3.75(7687+x)$	A

sum of clockwise moments = sum of anticlockwise moments

$$26906.25 + 4.8x = 3.75(7687+x)$$

$$26906.25 + 4.8x = 28826.25 + 3.75x$$

$$1.05x = 1920$$

$$x = \boxed{1828.57\ t}$$

A tank has a round inspection hatch 700 mm diameter situated as shown in FIG Q12. The tank is filled to a height of 4.5 m with seawater.

Determine EACH of the following:

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Note: *the density of seawater is 1025 kg/m³*

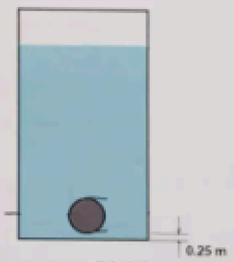
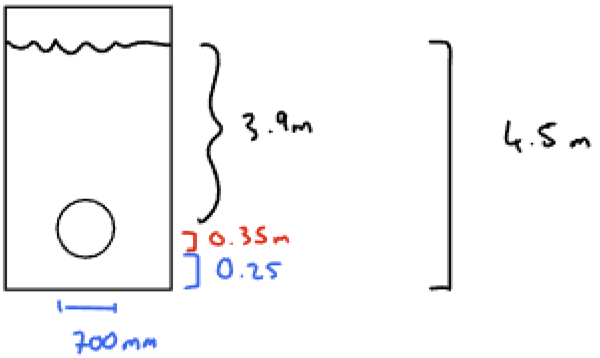


FIG Q12



a) $P = \rho g h$

$P = 1025 \times 9.81 \times 3.9$

$\boxed{39215.475\ (Pa)}$

b) $F = \rho g A h$

$A = \left(\frac{700}{2000}\right)^2 \pi = 0.3848451\ m^2$

$F = 1025 \times 9.81 \times 3.9 \times 0.3848451$

$\boxed{15091.8834\ N}$

c) gauge