SECTION A PHYSICAL SCIENCE

Answer ONE question from this section.

1. (a) (i) State **four** safety measures observed when handling radioactive materials.

[handwritten: - meaning of protective clothes.
- wearing of protective gloves.
→ Minimise the time spent near radioactive materials.
→ The materials should be placed in lead boxes.]

(ii) Write the nuclear equation for carbon-14 that undergoes a beta decay.

(7 marks)

(b) State **three** forms of heat transfer.

(3 marks)

[handwritten: - Radiation. - Convection - Conduction.]

(c) (i) Define ideal gas.

(ii) A sample of a gas occupies a volume of 0.250 L at a temperature of 27°C and pressure of 0.850 Pa. The gas is then compressed to a volume of 0.193 L at a temperature of 0°C. Determine the new gas pressure.

[handwritten working:
$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$
$T_1 = 27° + 273\,k$
$T_2 = 0 + 273\,k$
$V_2 = 0.193\,L$
$P_2 ?$
$P_1 = 0.850\,Pa$
$V_1 = 0.250\,L$
$$\frac{0.850 \times 0.250}{300} = \frac{P_2 \times 0.193}{273}$$
$3 \cdot (P_2 \times 0.193) =$]

(5 marks)

(d) A light ray passes from water to glass making an angle of 30° with the normal at the interface. The refractive indices of water and glass are $\frac{4}{3}$ and $\frac{3}{2}$ respectively. Determine the:

(i) angle of refraction;
(ii) critical angle.

(5 marks)

2. (a) (i) State **three** properties of electromagnetic waves.

(ii) A radio station transmits at a frequency of 100.5 MHz. Determine the wavelength for its signal.

(6 marks)

(b) (i) Define acid-base indicator.

(ii) Explain the steps taken to determine pH value of a solution.

(5 marks)

(c) (i) Differentiate between 'covalent' and 'dative' chemical bonds.

(ii) Name **one** example of each of the bonds in (c)(i).

(4 marks)

(d) A simple pendulum comprises of a bob and a string of length 1.2 m.

(i) Determine the periodic time;

(ii) Describe the energy changes as the bob swings.

(5 marks)

(handwritten: $Stress = strain =$)

SECTION B: MECHANICAL SCIENCE

Answer ONE question from this section.

3. (a) State **three** properties of pressure applied to a fluid. (3 marks)

   (b) (i) Draw a labelled construction diagram of orifice plate used as a flow meter in pipelines.

   (ii) Explain the operation of the flow meter in (b)(i).

   (7 marks)

   (c) A motor rated at 2.4 kW develops a constant force of 950 N to move a load for 4 seconds.
   Determine the:

   (handwritten: $P = 2.4 \times 10^3 W$, $F = 950 N$, $T = 4 sec$)

   (i) Work done;
   (ii) Distance moved by load.

   (4 marks)

   (d) A structural metal bar is 2 m long and has a cross-sectional area of 5.76 cm². The bar can withstand a maximum tensile force of 3000 N which causes its length to change by 0.32 mm. Determine the:

   (i) stress; *(handwritten: $= \frac{original\ length}{change\ in\ length}$)*
   (ii) strain;
   (iii) Young's modulus of elasticity. *(handwritten: $= \frac{stress}{strain}$)*

   (6 marks)

4. (a) (i) State **three** types of mechanical couplings;

   (ii) Explain the purpose of engine speed governors. (5 marks)

   (b) (i) State the principle of conservation of momentum.

   (ii) An object of mass 100 g and moving at 6 m/s collides with a stationary object of mass 50 g. After the impact, the two objects couple together. Determine their velocity. (4 marks)

   (c) State the following laws of forces:

   (i) parallelogram law;

   (ii) triangle law.

   (4 marks)

(d) Figure 1, shows a system of coplanar forces. Determine the magnitude of the resultant force and its direction. (7 marks)
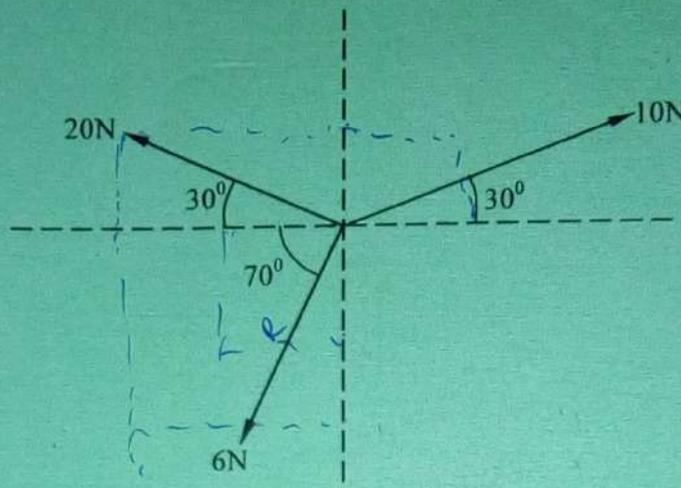

Fig. 1

SECTION C: ELECTRICAL ENGINEERING PRINCIPLES

Answer THREE question from this section.

5. (a) State **two** merits and **one** demerit of a battery with cells in parallel. (3 marks)

(b) A 12 V battery consists of six identical cells in series. The battery delivers 3.5 A at 10.95 V. Determine the internal resistance of each cell.
$V = E - Ir$ (4 marks)

(c) (i) Two 220 µF capacitors connected in series are required to store 2.5 J of energy. Determine the charging voltage. $C = \frac{Q}{V}$ $Q = IV$ $V = IR$ $E = P \times t$ $P = I$ $2.5 \times V$

(ii) State **three** factors that affect the capacitance of a capacitor. (7 marks)

(d) (i) Describe the construction of an electrolytic capacitor.

(ii) State **two** applications of the capacitor in (d)(i) (6 marks)

6. (a) Outline **three** differences between moving-coil and moving-iron instruments. (6 marks)

(b) With the aid of a labelled diagram, explain the operation of a thermocouple instrument. (5 marks)

(c) Figure 2 shows a d.c circuit.
Determine the:

(i) Current through 16 Ω resistor.

(ii) Value of resistor, Rx.

(9 marks)

Handwritten (left margin):

$I = \frac{V}{R}$

$I - I_a = \frac{V}{R}$

$10.82 - I_a = \frac{185}{16}$

$10.82 - I_a = 11.5625$

$I_a = 10.82 - 11.5625$

$I_a = -0.7625 A$

Current in 16 Ω

$10.82 - -0.7625$

$= 11.5625 A$

Fig. 2

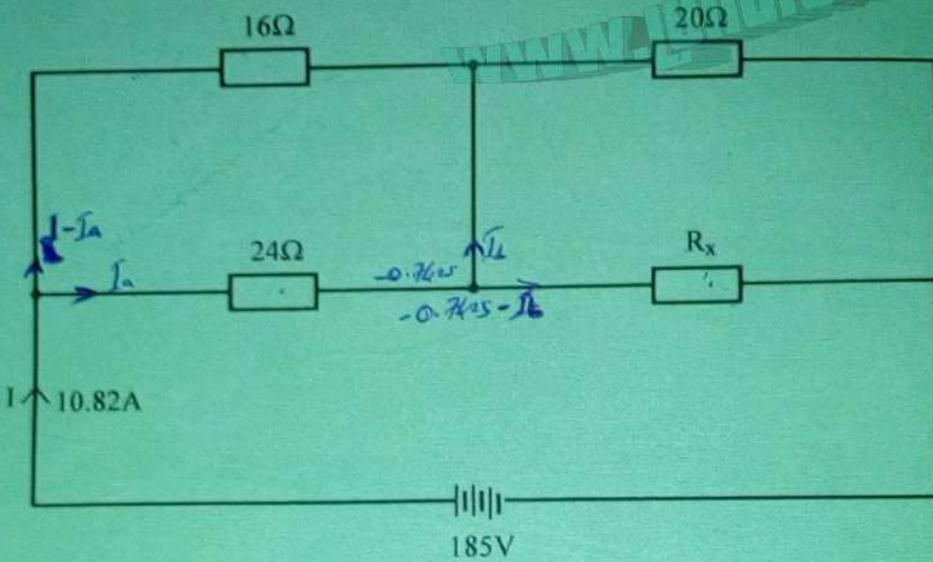Handwritten labels on figure: 16Ω, 20Ω, 24Ω, Rx, 1-Iₐ, Iₐ, Iₗ, -0.7625, -0.7625-Iₗ, I ↑ 10.82A, 185V

Handwritten (right side):

(ii) $R_x = \frac{V}{I_a}$

$V = 185 V$

$I_a =$

$\frac{20 \times R_x}{2 + R_x} = \frac{784}{40}$

$\frac{20 R_x}{2 + R_x} = \frac{784}{40}$

$800 R_x = 784 (2 + R_x)$

$800 R_x = 768 + 3.2 R_x$

$416 R_x = 718$

7. (a) Table 1 shows engineering quantities and their corresponding SI units. Complete the table.

Table 1

Engineering quantity	SI Units
Amount of light	Candela, Cd
Electromotive force	Volts, V
Power	Kilowatt hour, kWh

(3 marks)

(b)   Figure 3 shows graph of voltage against current for two resistors, P and Q. State with
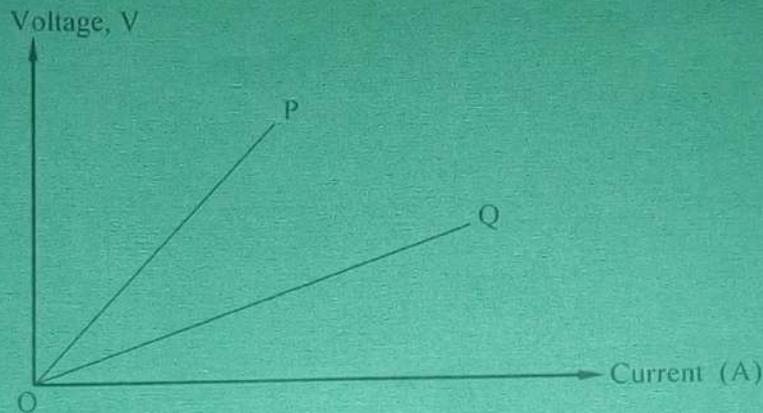   reason the resistor with higher resistance: (2 marks)

Voltage, V

Fig. 3

(c)   (i)   Explain each of the following transformer losses:

              (I)   Copper losses;
              (II)   Hysteresis losses;
              (III)   Eddy current losses.

       (ii)   State **one** way of minimizing each of the losses in (c)(i).
                                                                              (9 marks)

(d)   A 300 kVA transformer has full-load copper losses of 1.7 kW and iron losses of 0.9 kW.
       Determine the transformer full-load efficiency at a power factor of 0.82 lagging.
                                                                              (6 marks)

       $p.f = cos\theta$

       $cos 0.82$
       $= 0.99089$ $\eta =$

8. (a)   With the aid of a hysteresis loops, explain the difference between 'hard' and 'soft'
           magnetic materials.   (6 marks)

    (b)   An alternating voltage, V, has a frequency of 50 Hz and a peak value of 110 V.
           The voltage is -55V at time, t = 0.

           (i)   Determine in terms of π the:

                  (I)   angular velocity;
                  (II)   phase angle.

           (ii)   Write the sinusoidal equation of the voltage in (b)(i).
                                                                              (7 marks)

(c) A magnetic ring has a cross-sectional area of 16 cm^2 and a radial air gap of 2 mm. The mean length of the ring is 34 cm and its relative permeability is 422. Determine the magnetomotive force required to produce a magnetic flux of 1.4 mWb.

c.A = 16cm

distal.

(7 marks)

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