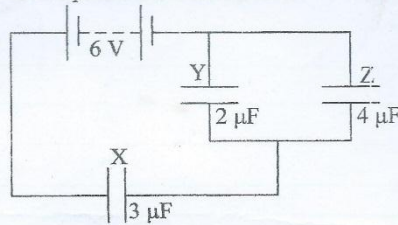


Section I
(One hour)

(Answer ALL questions in this Section)

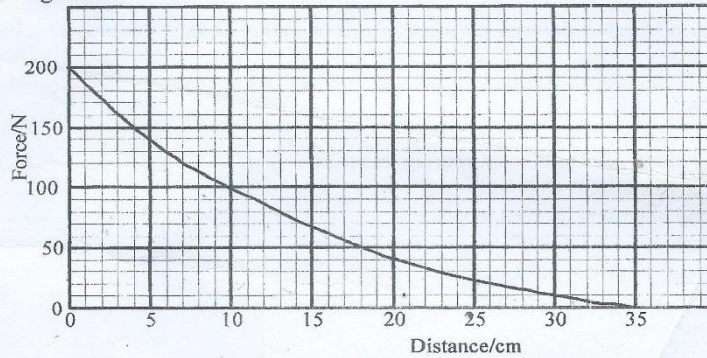
1. The diagram below shows a capacitor network circuit.



- What is the potential difference across the capacitor X?
- Determine the charge on the plates of the capacitor Y.
- Calculate the energy associated with the charge stored in the capacitor Z.

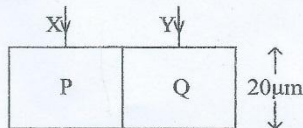
(7 marks)

2. A stone of mass 80 g is fired horizontally by a catapult. The graph below shows the variation of the force on the stone with distance through which the stone is accelerated from rest as it is being fired.



- From the graph, estimate the work done on the stone by the catapult. Explain your working. (4 marks)
- Determine the value of the speed with which the stone leaves the catapult. State the assumption you have made in your working. (4 marks)

3. Two light beams, X and Y, of wavelength $0.45\mu\text{m}$ travelling in air are incident on a composite crystal as shown below.



The speed of light in P is $\frac{3}{1.4} \times 10^8 \text{ms}^{-1}$ and the speed of light in Q is $\frac{3}{1.45} \times 10^8 \text{ms}^{-1}$. If the beams are in phase as they enter the composite crystal, calculate the phase difference between them as they leave the crystal. (5 marks)

4. In a nuclear reaction, a mass defect of 8.8×10^{-30} kg occurs in the decay of ${}^{226}_{88}\text{Ra}$. It is found that radium nucleus decays with the emission of an alpha particle of energy 4.6 MeV and a gamma ray photon.
- Write down the nuclear equation representing the decay.
 - Calculate the energy released during the reaction.
 - Calculate the frequency of the gamma ray photon emitted.
- (6 marks)

5. An alternating voltage of 20 V r.m.s. and frequency 10 kHz is applied to a resistor of resistance 15Ω in series with a capacitor of capacitance $4.0\mu\text{F}$
- Calculate the r.m.s. potential difference across
 - the resistor
 - the capacitor
 - Explain why the sum of these potential differences is not 20 V.
- (8 marks)

$v = f\lambda$
 $f = \frac{v}{\lambda}$

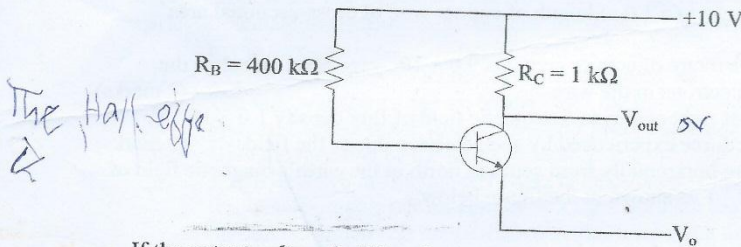
6. a) Define the following terms
- Stiffness
 - Strength
- b) The force of attraction F , between two particles in a given solid varies with their separation according to the equation

$$F = \frac{7.8 \times 10^{-28}}{d^2} - \frac{3.0 \times 10^{-96}}{d^{10}}$$

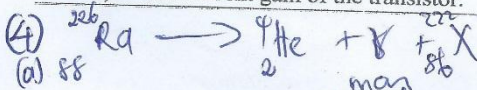
Calculate a value for the equilibrium separation of the molecules, explaining your method.

(5 marks)

7. The diagram below shows a transistor in the common emitter mode.



- If the output voltage is 5 V, calculate
- the potential difference across the load and hence the collector current.
 - the base current if $V_{BE} = 0.6$ V
 - the current gain of the transistor.
- (6 marks)



mass defect = $\frac{\text{number of nucleons} - \text{mass of nucleus}}{\text{nucleons}}$

Bonding Energy = $4.6 \times 4 = 18.6 \text{ MeV}$

total Bonding Energy = $932 \times 8.8 \times 10^{-30} \text{ kg} = ?$

total Bonding Energy = $? + 18.6 \text{ MeV}$

energy release = $932 \times$

[Handwritten scribbles]

Section II

(One and a half hours)

(Answer ALL questions in this Section)

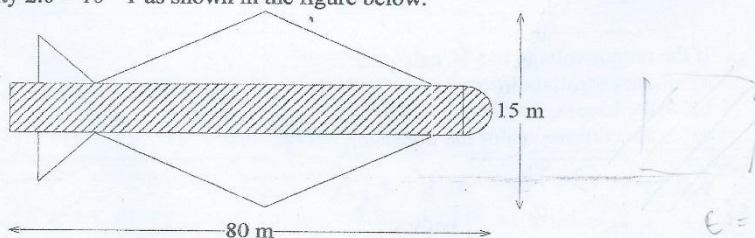
Answer **EITHER** question 8 a, b, c, and d **OR** questions 8 e, f, g and h.

Either

8. a) State Newton's laws of motion. (3 marks)
 ii) Explain a practical situation each in everyday life where the first and second laws apply. (2 marks)
 b) Describe an experiment you would carry out in the laboratory to show how the acceleration of a body varies with the force applied on it. (7 marks)
 c) A sphere of mass $m = 2.0$ kg moving with velocity of 5.0 m/s makes a head-on, elastic collision with a stationary sphere of mass $M = 5.0$ kg. Calculate the velocities of m and M after the collision. (4 marks)
 d) Differentiate between a conservative and a non-conservative force, giving one example of each. (4 marks)

Or

8. e) State Kirchhoff's laws. (2 marks)
 ii) State and explain how each of the laws is essentially a statement of either the conservation of energy or the conservation of electric charge. (4 marks)
 f) Describe an experiment you would carry out in the laboratory to investigate the electrical characteristic of a copper wire. In your experiment, give a sketch of the expected characteristic giving the technical name of such a characteristic. (7 marks)
 g) A current of 1.0 A flows in a 1.0 m length of copper wire of cross-sectional area 1.0mm^2 .
 i) Given that each cubic metre of copper contains 9.0×10^{28} electrons, calculate the average drift of the electrons in the wire. (2 marks)
 ii) If the wire is placed at right angles to a magnetic field of flux density 1.0×10^{-2} T, calculate the average force experienced by each electron due to the field. (2 marks)
 h) An aeroplane is flying horizontally from south to north in the earth's magnetic field of flux density 2.0×10^{-5} T as shown in the figure below.



If the direction of the earth's magnetic field is pointing 5° below the horizontal, determine the magnitude of the induced e.m.f. across the wings of the plane given that the plane is moving with constant velocity of 250 m s^{-1} . (3 marks)

Answer **EITHER** question 9 a, b and c **OR** questions 9 d, e, f, g and h.

Either

9. a) Compare thermionic emission with photoelectric emission. (2 marks)
 b) The four lowest energy levels in a mercury atom are -10.4 eV, -5.5 eV, -3.7 eV and -1.6 eV.
 i) Explain why the values of the energies are negative.
 ii) What is the ionization energy of mercury?

- iii) Calculate the wavelength of the radiation emitted when an electron goes from the -1.6 eV energy level to -5.5 eV energy level. (4 marks)
- b) Gamma rays of one wavelength are passed through lead. The intensity of the radiation before entering the lead is I_0 and the intensity of the radiation as it emerges from the lead is I . It is found that the intensity of the radiation varies with thickness of lead according to the equation

$$I = I_0 e^{-\alpha x}$$

where α is the linear absorption coefficient of lead.

- i) Given that 4 cm of lead reduces the intensity of the radiation by 90%, calculate the value of α and state its unit. (4 marks)
- ii) Sketch a graph of $\ln I$ versus x and explain how the value of α can be obtained from the graph. (2 marks)
- c) A laser is used to produce Young's fringes with slits separated by 0.50 mm. The screen is 1.0 m from the slits. Ten fringes occupy a distance of 12.5 mm on the screen.
- i) Given that a thin sheet of clean glass of refractive index 1.5 and thickness t is placed along the path of one of the slits and this causes the central bright fringe to shift through a distance of 12.5 mm, determine the thickness of the glass sheet. (4 marks)
- ii) Explain how the fringe spacing would change if
- the slit separation were increased.
 - the slit-screen distance were increased. (4 marks)

Or

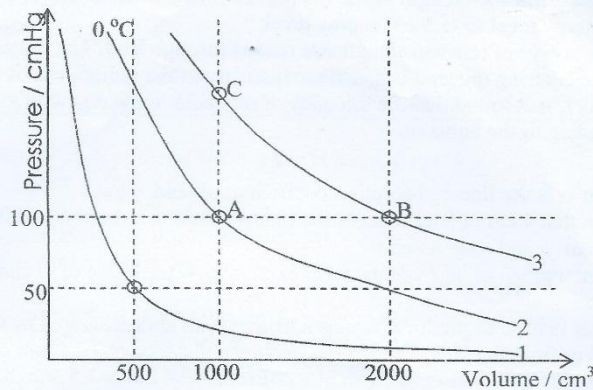
- 9 d) Compare thermal and electrical conduction. (2 marks)
- e) A metal cylinder of mass 0.5 kg is heated electrically by a 12 W heater in a room at 15°C. The cylinder's temperature rises uniformly to 25°C in 5 min and later become constant at 45°C.
- i) What is the rate of loss of heat from the cylinder at 45°C? Explain your answer.
- ii) Calculate the specific heat capacity of the cylinder, taking into account the loss of heat to the surrounding. (6 marks)
- f) Explain how the p-n junction operates as a rectifier. (3 marks)
- g) The following terms are associated with the transmission of signals in a communication system: *Carrier wave*, *lower side band*, and *bandwidth*.
- i) Give the meaning of the terms in italic. (3 marks)
- ii) A carrier wave of frequency 1 MHz is modulated with an audio signal containing frequencies ranging from zero to 50 kHz. Calculate the range of frequencies in the modulated signal and hence, calculate the bandwidth of the signal. (3 marks)
- h) Outline three advantages of optical fibre communication systems over copper cable communication systems. (3 marks)

Answer **EITHER** question 10 a, b and c **OR** questions 10 d, e, f, g and h.

Either

10. a) According to the kinetic theory of gases, the pressure exerted by a perfect gas on the walls of its container is given by $P = \frac{1}{3} \rho c^2$ where P is the pressure of the ideal gas, ρ is the density of the gas and c is the velocity of a gas molecule. Derive the equation (6 marks)
- b) The velocities in m s^{-1} of five molecules of an ideal gas are 1.5×10^3 , 1.7×10^3 , 2.4×10^3 , 2.6×10^3 and 2.8×10^3 . Show that the root-mean square (r.m.s.) velocity of the molecules is different from the mean velocity of the molecules. (4 marks)
- c) The figure below shows three curves relating the pressure and volume of a fixed mass of a perfect gas at three different temperatures 1, 2 and 3. Curve 2 is for 0°C.

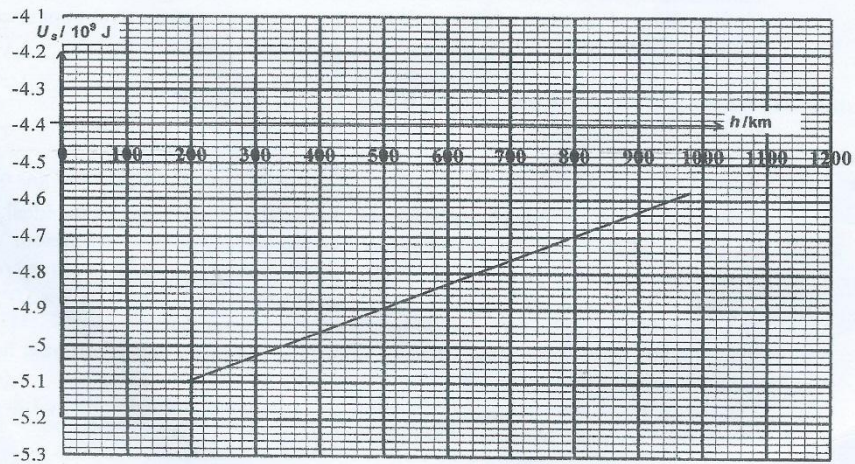
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- Name and state the law that any one of the three curves 1, 2 and 3 represents. (2 marks)
- What are the temperatures for curve 1 and 3? (3 marks)
- Deduce the pressure at the point C, explaining your method. (Do not attempt to read it from the graph). (3 marks)
- Calculate the external work done in joules in order to take the gas from the state represented by A to the state represented by B. (2 marks)

Or

- Define the terms *electric potential* and *electric field strength*. Sketch graphs to show how the electric potential V , and the electric field strength vary with distance r from the centre of a hollow metal sphere carrying charge Q to a point well outside the sphere. (4 marks)
- The gravitational potential at a point, distance r from the centre of a spherical planet of radius R_E ($R_E < r$) and mass M is given by the equation $U = -\frac{GM}{r}$.
 - Deduce an equation for the escape velocity, v_e , of a projectile of mass m from the surface of the planet. (3 marks)
 - Calculate the escape velocity of a projectile shot from the surface of the planet, given that the radius of the planet is $R_E = 6.4 \times 10^6$ m (2 marks)



- f) The diagram above represents the graph of the potential energy U_s as a function of height, h of the first artificial Earth satellite, Sputnik I, whose mass was 84 kg. At a certain point in its orbit, the total mechanical energy of the satellite is -2.41×10^9 J and its velocity was 7.8 km s^{-1} . Determine the potential energy of the satellite at this moment, and hence find from the graph, the altitude at that point in its orbit. (5 marks)
- g) Sputnik I described an orbit such that its minimum altitude was 260 km and its maximum altitude was 920 km. Using the graph, determine the kinetic energies of the satellite at these altitudes. Hence determine the velocities of the satellite at the minimum and maximum altitudes. (6 marks)
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