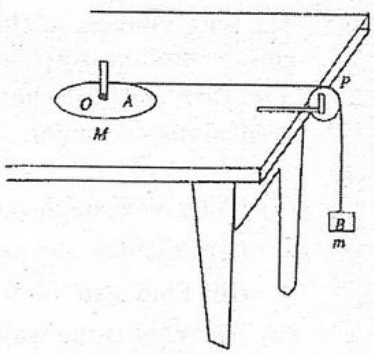
PAPER II PART A - STRUCTURED ESSAY

1. A uniform circular disc A of mass M and radius R is mounted horizontally on a smooth table so that it is free to rotate about a frictionless axle passing through its centre O. A light string which is tightly wrapped few times around the circumference of the disc passes over a **light** pulley P and carries a weight B of mass m at the free end as shown in the figure. The moment of inertia of the disc about axis of rotation, $I = \frac{1}{2} MR^2$. The system is held at rest with the string taut and released at time $t = 0$.



(a) What type of motions will A and B have ?

A .....

B .....

(b) (i) If the angular acceleration of the disc A is α and the acceleration of the weight B is a, write down the relation between a and α. *(one line)*

(ii) What is the relation between the torque (Γ) acting on the disc and α.

Γ = ...

(C) After a short time if the string breaks suddenly, what will happen to the motions of A and B.

A : .....

B : .....

(d) After the string has broken as mentioned in (c), a second disc of the same radius but of mass $M/2$ which is at rest is dropped symmetrically on the disc A. The two discs were found to stick together and rotate.

(i) What principle would you use to determine the new angular velocity of the discs ? *(one line)*

(ii) Under what condition is the above principle valid. *(one line)*

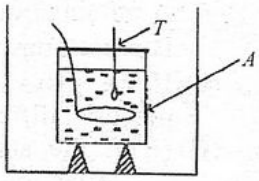
(iii)If the angular velocity of disc A prior to dropping the second disc is ω_0, find the new angular velocity of the discs in terms of ω_0. *(3 lines)*

(e) Instead of the string breaking as mentioned in (c), suppose the axle breaks and the disc becomes free to move.

(i) What type of motion will A have ?*(one line)*

(ii) Will the angular acceleration of A remain same as in (b) (i) ? Explain you answer. *(2 lines)*

2. Figure shows an experimental arrangement that can be used to determine the specific heat capacity of a liquid using the method of cooling.



(a) Identify the vessel A. *(one line)*

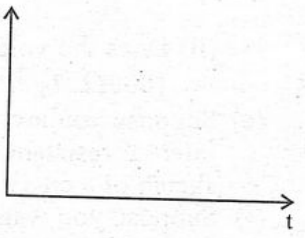
(b) What are the additional essential measuring instruments required for this experiment ? *(2 lines)*

(C) What are the physical factors of the vessel A, Which determine the rate of loss of heat to the surroundings? *(3 lines)*

(d) In this experiment separate cooling curves are obtained for water and the liquid.

(i) What amount of liquid have to be used with respect to that of water ? *(one line)*

(ii) Give the reason for your answer in d (i). *(2 lines)*



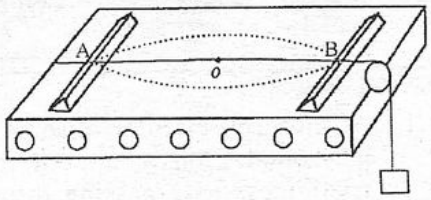
(e) Draw sketches of the two cooling curves you may obtain in this experiment assuming that the heat capacity of water is greater than that of the liquid used. Clearly label the curves.

(f) Two quantities have to be extracted from the curves in order to determine the specific heat capacity of the liquid. Show the necessary constructions on the diagram given in (e) in order to obtain these quantities.

(g) If the heat capacity of A with the stirrer is W, masses of water and the liquid are m_w and m_l and specific heat capacities of water and the liquid are s_w and s_l, respectively, write down an expression relating these quantities with the quantities mentioned in (f). *(3 lines)*

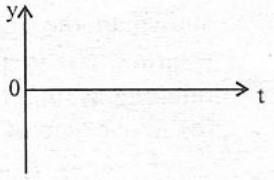
(h) Can you perform this experiment properly by filling the space between A and the outer vessel with water ? Explain your answer. *(2 lines)*

3. A sonometer wire is stretched between two points A and B, 1.0 m apart as shown in the diagram. This wire is made to vibrate transversely with a single loop, by plucking the middle of the wire at O.



The wire vibrates in simple harmonic motion in a vertical plane and the motion is given by

$a = -16\pi^2 \times 10^4 y$, where a (ms^{-2}) is the acceleration and y is the vertical displacement.



(a) (i) Draw a rough sketch to show the variation of y with time t.

(ii) Calculate the periodic time of the vibration of the wire. *(2 lines)*

(iii) Find also the frequency of the vibration. .....Hz

(b) (i) What is the wavelength of the wave produced. *(one line)*

(ii) Hence calculate the velocity of the transverse wave in the wire. *(one line)*

(C) (i) Write down an expression relating the transverse wave velocity (V), tension (T) and the mass per unit length (m) of the wire. *(one line)*

(ii) If $m = 1.0 \times 10^{-4}$ kg m^{-1}, what is the tension in the wire? *(2 lines)*

(d) (i) When students were asked to resonate to sonometer wire using a vibrating tuning fork they used the following methods.

(1) Holding the tuning fork just above the middle of the wire.

(2) Keeping the tuning fork on the middle of the wire.

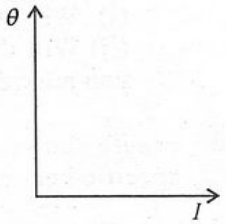
(3) Placing the tuning fork on the sonometer box.

Which one of the above method is correct. Explain your answer. *(2 lines)*

(ii) What should be the lowest frequency of the tuning fork which would resonate with the wire. *(one line)*

(e) If a paper rider is placed at the middle of the wire, at O, for what minimum displacement of the wire the rider will begin to fly off from the wire. (Hint: This will happen when the reaction on the paper rider by the wire becomes zero) *(3 lines)*

4. (a) A current I is passed through a moving coil galvanometer. Draw a rough sketch to show how the galvanometer deflection θ varies with the current I.



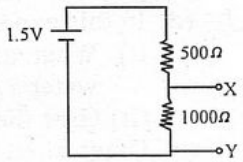
A moving coil galvanometer gives full scale deflection when a current of I mA is passed through it. Internal resistance of the galvanometer is 50Ω

(b) If the galvanometer is calibrated as a voltmeter what will be the maximum potential difference that can be measured with this meter ? *(one line)*

(C) (i) If the above mentioned galvanometer is to be converted to a voltmeter with a full scale deflection of 1 V, show by means of a diagram how you would achieve this. (Clearly label the components with standard symbols.)

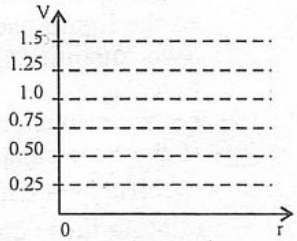
(ii) Calculate the value of the resistor needed. *(2 lines)*

(d) (i) If the voltmeter mentioned in (c) is connected across XY of the circuit shown what will be the reading on the meter. (Neglect the internal resistance of the cell) *(2 lines)*



(ii) Does the voltmeter read the actual value of the potential difference across 1000Ω ? *(2 lines)*

(e) Suppose you are provided with several other voltmeters having different internal resistances r to measure the voltage V across XY. Draw a rough sketch of a curve that you would expect if V is plotted against r.

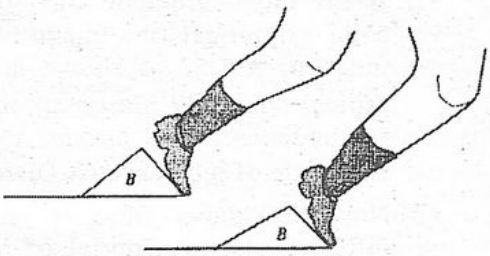


(f) Suppose you want to construct a voltmeter having a full scale deflection of 1 V and an internal resistance of $10{,}000\Omega$ What is the full scale deflection current of a moving coil galvanometer required for this purpose ? *(one line)*

(g) Give one reason as to why it is practically difficult to increase the internal resistance of the voltmeter mentioned in (f) to extremely large values of the order of $10M\Omega$. *(2 lines)*

PAPER II PART B - ESSAY

1. A 70kg sprinter running a race of 100m pushes on the starting blocks (B) for 0.2 s and leaves them with a speed of 5 ms^{-1}. He then accelerates for a further 5s so that his speed becomes 12 ms^{-1} and continues with that speed until the finish line.



   (i) Find the reaction force exerted by the starting blocks on the sprinter.

   (ii) Calculate the distance covered by the sprinter by the time he attains the maximum velocity of 12 ms^{-1}.

   (iii) What is the mechanical work done by the sprinter during the accelerating period of 5 s?

   (iv) Find the time taken by the sprinter to complete the race.

   (v) In this race another sprinter who took a better start by achieving an initial velocity of 5.4 ms^{-1} in the same period of 0.2 s as above, however, spent 5.4 s to reach his maximum speed of 12ms^{-1}. Calculate the time at which the former sprinter overtakes the latter.

   [Hint: overtaking takes place during the accelerating period of the former sprinter].

2. **Answer either part (a) or part (b) only.**

(a) An empty boat floats in water with 10% of its volume submerged, and when it is loaded with 1200kg, the volume submerged will increase to 70% of the total volume.

   (i) Calculate the mass of the empty boat.

   (ii) If a leak develops and water starts to enter the boat which is loaded with 1200 kg at a constant (average) rate of 100 kg per minute, for how long the boat can float before sinking?

   (iii) What is the minimum force required to lift the sunk boat (without the load) up to the surface of water. Average density of the material of the boat is 2500 kg m^{-3} and the density of water is 1000 kg m^{-3}.

   (iv) The mended boat with another load of 1200 kg on board, while sailing, suddenly enters a region where water is uniformly mixed with tiny air bubbles. If the average volume of an air bubble is 1 mm^3 and the air bubble concentration is 3.5 x 10^8 m^{-3}, find the effective density of water. Neglect the mass of air. Hence show that the boat will sink.

   (v) Use the effect described in (iv) to explain the danger in the following act.

   'There is a deep pool at the foot of a tall water fall. A person starts to swim closer to the foot of the fall'!

(b) Explain what is meant by the Doppler effect. How would you demostrate this effect using a ripple tank. Give an application of the Doppler effect.

   A boat is travelling at 18 km per hour towards a small cliff, sounding its horn at 335 Hz. The speed of sound in air is 340 ms^{-1}.

   (i) Find the frequency of the horn as heard by a boy on the cliff.

   (ii) An echo of the horn is produced by the cliff. Find the frequency of the echo as heard by a man in the boat.

   (iii) If the man hears the sound emitted by the horn and the echo together, find the number of beats per second heard by him.

   (iv) If the boat now turns back and moves away form the cliff with the same speed, what is the frequency of the echo as heard by the man?

3. State the necessary conditions that has to be satisfied in order for a ray of light to undergo total internal reflection.

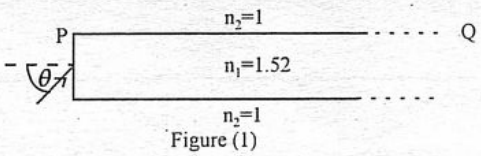


Figure (1)

(i) A ray monochromatic light travelling in air enters a long solid cylindrical fibre made of plastic material of refractive index $n_1 = 1.52$ as shown in the figure (1). Calculate the critical angle for plastic-air interface. Hence show that the ray undergoes total internal reflection at the surface PQ for any angle of incidence θ. Disregard $\theta = 0$ situation.

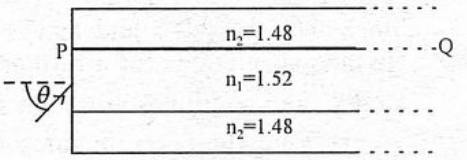


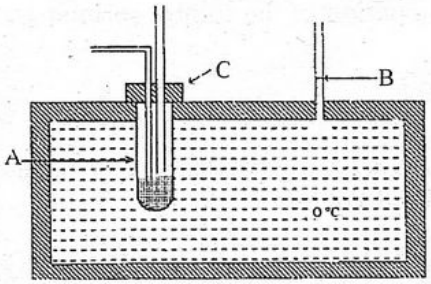
Figure (2)

(ii) Now the above fibre is completely surrounded with a different plastic material of refractive index $n_2 = 1.48$, as shown is figure (2). Determine the **maximum value** of angle θ for a ray which would undergo total internal reflection at the interface PQ.

(iii) Show that a ray incident with $\theta = 80^0$ will not emerge into the air.

4. **Answer either part (a) or part (b) only.**

(a)



A test tube *A* and a narrow tube *B* are fixed to a container filled with water at 0^0C. Container walls are made of a poor conducting material having a uniform thickness. *C* is the lid of the test tube made of the same material. 10^{-2} kg of ether at 0^0C is inserted to the test tube and made to evaporate **quickly** by blowing air through it.

(i) As ether evaporates what change can be observed on the outer of the test tube?

(ii) If the area of cross-section of the tube *B* is 10^{-5} m^2, calculate the change in height of the water level in *B* due to the evaporation of ether.

Density of water at 0^0C = 1000 kg m^{-3}

Density of ice at 0^0C = 920 kg m^{-3}

Specific latent heat of evaporation of ether at 0^0C = 3.84×10^5 J kg^{-1}

Specific latent heat of fusion of ice at 0^0C = 3.36×10^5 J kg^{-1}

(iii) Once the evaporation of ether is completed and the apparatus is left in a room of room temperature $30\ ^0$C, the height of the water level in *B* starts to change slowly at a rate of 1 mm per second. If the thickness of the walls of the container is 2×10^{-2} m and its effective total surface area is 0.4 m^2, calculate the thermal conductivity of the material of the wall. Assume that the temperature of water remains at $0\ ^0$C.

(b) Identify the symbols in the expression $PV = \frac{1}{3}\, n\, m\, \overline{c^2}$

Use the above expression and the ideal gas equation to show that the average kinetic energy of a molecule of an ideal gas at a temperature *T* can be written as $\frac{3}{2}\, kT$ where $k = \frac{R}{N_A}$, *R* is the universal gas constant and N_A is the Avogadro's Number.

(i) An automobile tyre is found to have a pressure of 250 kPa at $27\ ^0$C. What volume of compressed air at $27\ ^0$C and at a pressure of 500 kPa should be pumped into the tyre to increase the pressure to 300 kPa. Assume that the volume of the tyre remains constant at 0.05 m^3 and

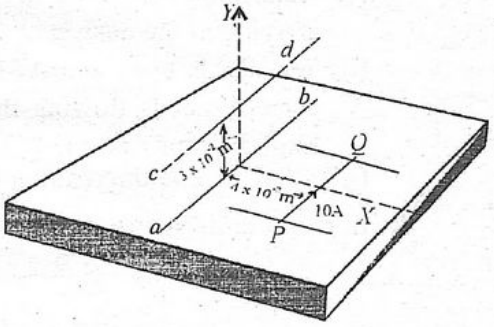
the final temperature of the air in the tyre is also 27 ^{0}C.

(ii) After the automobile has been driven at high speed the temperature of the air inside the tyre has increased to 57 ^{0}C. If the initial air pressure in the tyre was 300 kPa and the tyre expands so that its volume increased by 5%, find the new pressure of air in the tyre.

$R = 8.3\ J\ K^{-1}\ mol^{-1}$

(iii) Determine the root mean square speed of air molecules at 57 ^{0}C. $N_A = 6.02 \times 10^{23}\ mol^{-1}$
Average relative molecular mass of air = 27.
Do all the molecules of air in he tyre move with the speed calculated above? Explain your answer.

5. State Biot Savart law in the form of an expression and identify all the symbols used.
Write down an expression for the magnetic flux density B at a point, a distance r from a long straight wire carrying a current I.



ab is long straight wire placed on a table, and cd is a similar wire kept 3×10^{-2} m vertically above ab and run parallel to it, as shown in the figure. PQ is a small current carrying conductor placed on the table parallel to ab. The distance between ab and PQ is 4×10^{-2}m. PQ is free to move on two horizontal conducting rails. Length of PQ is 10^{-1} m and a current of 10 A flows through it in the **direction, P to Q.**

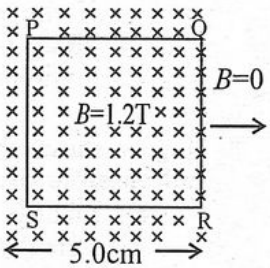
(i) If the write ab carries a current of 5 A in the direction a to b, find the magnitude and direction of the force acting on PQ due to this current $\left(\frac{\mu_0}{2\pi} = 2 \times 10^{-7}\ Tm\ A^{-1}\right)$

(ii) In addition to the current in ab, if cd also carries a current of 6.25 A in the direction d to c, find the magnitude of the force acting on PQ due to this current. Indicate the direction of the force on a diagram.

(iii) If the mass of the conductor PQ is 10^{-4} kg find the direction of motion, and the magnitude of the initial acceleration of PQ.

(iv) Find the magnitude and direction of the **minimum** current that should be setup in cd in order to lift PQ from rails.

6. A square coil $PQRS$ of side 5.0cm contains 200 turns and is positioned perpendicular to a uniform magnetic field of flux density B = 1.2 T as shown in the figure. It is then pulled at an uniform velocity to the right, to a region of zero magnetic field while keeping the plane of the coil perpendicular to the magnetic field. It takes 0.2 s for the whole coil to reach the field free region.



(i) Calculate the e.m.f. induced in the coil during the 0.2 s time period.

(ii) Name the side/sides of the coil in which the e.m.f is induced and indicate the direction of the induced current on a diagram.

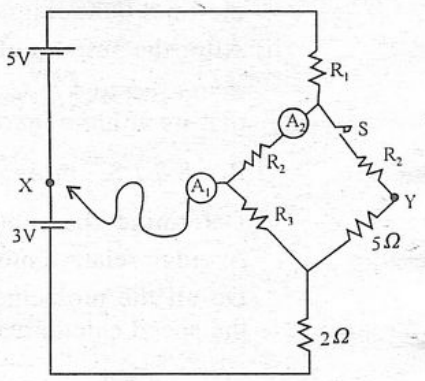
(iii) If the resistance of the coil is 100Ω calculate the energy dissipated in the coil during the 0.2 s time interval.

(iv) Hence, deduce the work needed to pull the coil out of the field. State the law in physics that you have used to arrive at the answer.

(v) If the magnetic field is reduced to zero uniformly during the same time interval of 0.2 s, instead of pulling the coil, will you observe the same induced e.m.f. as in (i). Give reasons for your answer.

7. **Answer either part (a) or part (b) only.**

(a) In the circuit shown, cells and both ammeters A_1 and A_2 have negligible internal resistance. S is a switch. Once the switch S is closed, the ammeter A_1 indicates a zero reading, when its free terminal is connected either to point X or Y. It is also found that when S is opened and A_1 is connected to X, the ammeter A_2 reads $\frac{5}{12}$ A.



(i) Determine the value of R_3. Clearly state your arguments in arriving at the answer. Also calculate the values of R_1 and R_2.

(ii) When S is open and A_1 is connected to X, will a part of the current that is flowing through R_2, pass through R_3 as well? Explain your answer.

(iii) What will be the reading of the ammeter A_1 in (ii).

(b) In the circuits shown D is a silicon junction diode.

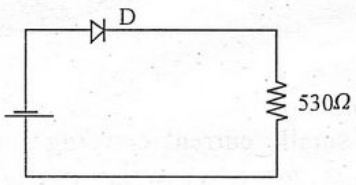


Figure (1)

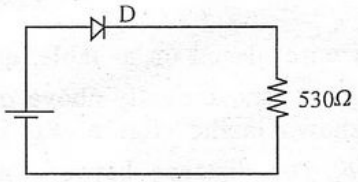
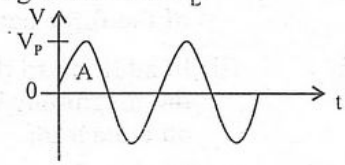


Figure (2)

(i) Identify the circuit in which the diode id forward biased. If a current of 10mA flows in that circuit by considering the potential drops across components, estimate the voltage of the cell.

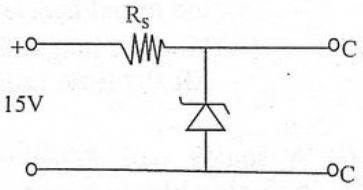
(ii) Suppose you are provided with four silicon rectifier diodes, a smoothing capacitor C and a load resistor R_L. Draw a circuit diagram of a bridge rectifier including the C and R_L.

(iii) The voltage V applied at the input of the rectifier is shown in the figure. Peak voltage, V_P = 12V. Indicate the path of the current in the circuit drawn in (ii) during the first half cycle A of the input using arrows.

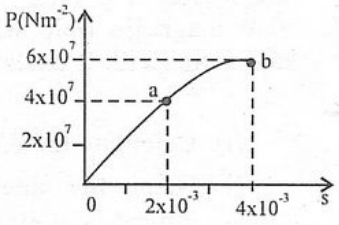


(iv) Draw the output voltage waveform of the rectifier circuit including C and R_L, and estimate the peak value of the output voltage.

(v) The circuit shown is provided to obtain a 10 V regulated dc voltage from an unregulated voltage of 15 V.
If the maximum current that can be sent through the zener diode is 200 mA, and the zener voltage is 10 V estimate a minimum value for R_S.



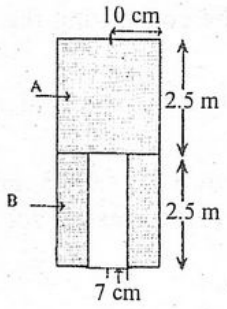
8. Figure shows the stress (P) - strain (S) curve obtained for a material for **all possible** stress values.



(i) Identify the points a and b on the curve.

(ii) Calculate the Young's modulus of the material. What is the energy stored per unit volume when the strain in the material is 2×10^{-3} ?

(iii)



A vertical cross- section of a cylindrical pillar consisting of a solid cylinder A and a hollow cylinder B each of height 2.5m and made of the above mentioned material is shown in the figure. Radius of A is 10cm and the external and internal radii of B are 10 cm and 7 cm respectively. (The diagram is not drawn to the scale).

(a) What is the compression of the pillar when a load of 1×10^5 N is supported by it?

(b) What is the maximum load that can be supported by the pillar **without breaking** it?