PAPER II PART A - STRUCTURED ESSAY

1. You are provided with suitable measuring insturments and a piece of light string to determine th the material of a metal ball, whose mass is of the order of 100 g. The metal ball has a hook f material permanently attached to it.

   (a) If you have access to a set of spring balances having mass ranges of 75 g, 150 g, 200 g which one would you select for the mass measurement ? Give the main reason for your sele

   (2 lines)

   (b) A student performing this experiment obtained following measurements correctly for the diar the ball.

   3.523 cm, 3.519 cm, 3.551 cm, 3.542 cm, 3.521 cm state the reason why the readings are diffe

   (one line)

   (c) Indicate the measuring instrument he may have used assuming that he has selected a instrument for this purpose. *(one line)*

   (d) Considering the fluctuation of the above readings, suggest another measuring instrum different accuracy that can also be used to obtain the diameter of the ball. Give reason for your

   Instrument : *(one line)*

   Reason : *(2 lines)*

   (e) If the mass of the ball with the hook is m and the diameter of the ball is D write down an exp for the density. Assume that the mass of the hook is $\frac{m}{50}$ *(2 lines)*

   (f) If a suitable measuring cylinder and water are provided, indicate major steps of an alternative which gives the volume of the ball. *(3 lines)*

   (g) If the scale of the measuring cylinder can be read with sufficient accuracy, write down two adv of the method mentioned in (f) over the method indicated in (b) *(2 lines)*

2. An experiment is designed to estimate the temperature of a bunsen flame. In this method a small st is to be heated to the temperature of the bunsen flame, and the temperature is to be determined method of mixtures. A known mass m of water in a plastic cup, a thermometer and a stirrer are The specific heat capacity of water (C_1) and the specific heat capacity of steel (C_2) are gi absorbed by the cup and the stirrer can be neglected.

   (a) (i) What are the three quantities that you will need to measure ? Indicate them in the order take these measurements ?

   X_1 =
   X_2 = *(one line each)*
   X_3 =

   (ii) State precautions that you should take in this experiment to ensure accuracy of the measure

   (1) *(one line)*

   (2) *(one line)*

   (b) (i) Write down an expression for the temperature (θ) of the bunsen flame in terms of the q mentioned above. *(2 lines)*

   (ii) Even though the heat loss to the surrounding by conduction, convection and radiation is n still there is one more process through which heat can be lost from the system due temperature of the ball being high. What is this process ? *(one line)*

   (iii) The heat loss due to the reason mentioned in (b) (ii) can be reduced by selecting a prop l. instead of water, what is the most important property that the liquid must process ? *(one lin*

   (c) Can you perform this experiment with a lead ball instead of steel ball ? Explain your answer .*(one*

   (d) Name an instrument which can be used to measure the temperature of the flame directly, instead of above method. *(one line)*

1. A block of mass 1.4 kg is hung by a light inextensible string. A bullet of mass 0.1 kg moving horiztally with a velocity of 60 m s^{-1} collides with the block and gets embedded to the block.
   (i) What is the kinetic energy of the bullet before the collision ?
   (ii) Calculate the percentage loss of the kinetic energy of the system due to the collision. Does the loss imply that the law of conservation of energy is violated here ? Explain your answer.
   (iii) Calculate the maximum height to which the block is raised after the collision.
   (iv) When the block swings back to its original position for the first time, a second identical bullet with same velocity hits the block and gets embedded. What is the final velocity of the block just at the collision ?
   (v) If the above string is replaced by a light elastic string repeat the calculation in (iii) above, for the collision of the first bullet. Extension of the string before the collision is 0.2 m, and the extension what is at the maximum height is 0.1 m.

2. **Answer either part (a) or part (b) only.**
   (a) Write down the Bernoulli equation for a fluid flow. clearly identifying the symbols used, What quantity does each term in this equation represent.
   State the conditions under which the Bernoulli equation is valid.
   During heavy wind, sometimes roofs of closed buildings are blown off. Use the Bernoulli equation to explain this phenomenon.
   (i) A narrow stream of gas blows out of a gas jet in the horizontal direction. In order to measure the speed of gas at the outlet of the jet, a student uses a U tube which is open at both ends and containing an oil. When the U tube is held vertically and close to the outlet so that only one of the ends is in the stream of gas, he notices a difference of 2.4 cm between the oil levels of the U tube. Find the speed of gas at the outlet of the jet.
   (ii) If the area of cross - section of the gas stream at the outlet is 10^{-4} m^2, find the rate of mass flow of the gas in the stream.
   (iii) Calculate the power of the gas jet,
   Density of gas = 1.2 kg m^{-3}
   Density of oil = 800 kg m^{-3}

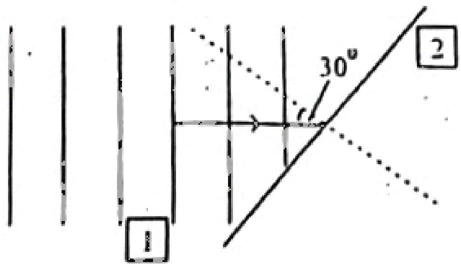
   (b) **Read the following passage carefully, and answer the questions given below.**
   Ripple tank is an apparatus used to demonstrate the wave propagation, and to study the wave properties such as interference and diffraction. In a riple tank, waves with a circular wave front can be produced by dipping a vibrating pointer in the water. However, by replacing the point vibrator with a thin vibrating plate, waves with a straight wave front can be generated. In this case the motion of the wave is such that the wave fronts remain parallel to the plate.

   The speed of waves on a water surface depends on the depth of water. To study the effect of depth on the speed, one can make part of the tank shallow by placing a thick glass plate at the bottom of the ripple tank, and it divides the tank into two regions. The two regions can be considered as two different media for wave propagation. If h is the depth of water, the speed of water waves is given by $v = \sqrt{gh}$, where g is the acceleration due to gravity. This relation applies only when the wavelength of the wave is greater than the depth of water, and the amplitude of the wave is small compared with the depth as in the case of the ripple tank. when the depth is very small, surface tension effects are significant.

   Water waves obey laws of refraction and reflection similar to light waves . These phenomena may also be studied using the ripple tank. Suppose straight wave fronts propagating in the deeper region (region - 1) meets the boundary between the two regions in such a way that the wave crests are parallel to the boundary. The wave will propagate into the shallow region (region -2) without any change in the direction but with a decrease in wavelength. However, if the straight wave fronts meet the boundary making an angle other than a right angle, the wave fronts will change the direction of propagation as they enter the shallow region. Using a stroboscope, adjusted to the relevant frequency, the wave patterns in both region can be made to appear stationary simultaneously. Hence it can be deduced that the frequency of waves is same in both regions.
   (i) Give two phenomena which can be explained only by considering the wave nature.
   (ii) State the conditions under which the relationshop $v = \sqrt{gh}$ is valid.

(iii) What is the purpose of placing a glass plate and produce two regions in the ripple tank to study refraction ?

(iv)(a) If the depths of the two regions of the ripple tank are 4 cm and 1 cm respectively, what is the ratio of the wavelengths, (λ_1 / λ_2) of a wave in the regions 1 and 2.



(b) The parallel lines drawn in the region 1 of the figure shown represent the straight wave fronts of a wave in that region. Copy the figure and draw the subsequent wave fronts in the region 2. Indicate λ_1 and λ_2 on the diagram. If the angle of incidence of the wave is 30°, find the angle of refraction.

(v) Explain why the frequency of the waves in both regions is same.

(vi) The difference in radii between the first and the sixth circular crests of periodic waves produced by a vibrating point source was measured to be 20 cm. What is the wavelength of waves ?

(vii) What is the fundamental difference between the water waves produced in a ripple take and sound waves ?

(viii) If you wish to study the total internal reflection of water waves, in which region of the ripple tank (1 or 2) would you place the source ? Explain your answer.

(ix) Give a suitable labelled diagram showing diffraction of water waves in a ripple tank.

3. Write down an expression which relates the velocity v of a transverse wave, setup on a stretched string with its tension T and mass per unit length m.
If the string is stretched between two horizontal supports, distance d apart, what is the frequency of the fundamental note of vibration. Draw the corresponding standing wave pattern in the string. A heavy rope of length L and mass per unit length m is suspended from a ceiling.

(i) What is the tension in the rope at a height x from its lower end ?

(ii) If a transverse wave is initiated at the lower end of the rope. what will be the velocity of the wave at the height x from that end.

(iii) If $L = 10$ m find velocities of the wave at the lower end and the upper end of the rope.

(iv) Assuming that the average velocity of the wave in the rope is the average of the two velocities calculated in (iii) , and if the wave travels with this average velocity ,find the time taken for the transverse wave to travel from the lower end to the upper end.

(v) If the lower end of the rope is also fixed draw the standing wave pattern corresponding to the fundamental note of vibration.

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

(a) A person inhales, 5×10^{-4} m^3 of dry air at atmospheric pressure at 27^0C in a single breath. This air gets warmed to the body core temperature of 37^0C in the lungs. If the person takes twelve such breaths per minute.

(i) Calculate the rate at which heat is transferred (in Watts) to the inhaled air from the body. (Density of dry air at 27 ^{0}C and atmospheric pressure = 1.2 kg m^{-3}, specific heat capacity of dry air at atmospheric pressure = 1.0×10^3 J kg^{-1} K^{-1})

(ii) Calculate the final volume occupied by air when it is in the lungs, for a single breath. Assume that the pressure of the inhaled air inside the lungs remains at atmospheric pressure.

(iii) When breathe out, calculate the rate of work done (in Watts) by the lungs to expel the air completely. (Atmospheric pressure = 1.0×10^5 Pa)

(iv) During each breath, 2.1 $\times10^{-5}$ kg of water in the body. which is in liquid form is added into the inhaled air in vapour form, and is then expelled with the exhaled air, calculate the rate of loss of heat (in Watts) from the body due to this process (Latent heat of vaporization of water at 37 ^{0}C is 2.5×10^6 J kg^{-1})

(v) A mini bus carries 40 passengers. If suddenly the windows and the door are closed, calculate the rate (per minute) at which the relative humidity of the bus begins to increase due to the water vapour present in the exhaled air. Assume that he temperature inside the bus remains constant

(b) The sun can be considered as a black body. Surface temperature of the sun is 6000 K, and its radius is 7.0×10^8 m.

(i) Calculate the total power radiated by the sun into space.

(The Stefan constant = 5.7×10^{-8} W m^{-2} K^{-4})

(ii) What are the three regions in the electromagnetic spectrum to which most of the electromagnetic radiation emitted from the sun falls in ?

(iii) At what wavelength does the sun radiate most strongly ? (Wien's constant = 2.9×10^{-3} m K)

(iv) Calculate the loss of mass of the sun during an year due to the emission of electromagnetic radiation (speed of light = 3.0×10^{8} m s^{-1})

(v) Use the value calculated in (i) above, to estimate the total energy incident on the earth surface per second per square meter of area at right angles to the sun's rays. Assume that the atmosphere absorbs 10% of the energy radiated by the sun. (The distance between the sun and the earth = 1.5×10^{11} m)

(vi) What is the rate of absorption of energy from the sun by a person lying flat on the beach on a clear day if the sun makes an angle of 30^0 with the vertical ? Assume that the area of the body exposed to the sun is 0.8 m^2 and that the surface absorptivity of the skin is 0.7.

5. Write down Newton's law of gravitation in the form of an expression, identifying the symbols used. Obtain an expression for the acceleration due to gravity (g) at the earth in terms of mass (M) and radius (R) of the earth.

A satellite of 1000 kg is placed in a circular orbit so that it goes round the earth 10 times a day. Radius of the earth is 6.4×10^6 m.

(i) Find the height of its orbit from the surface of the earth.

(ii) Calculate the total energy of the satellite in its orbit.

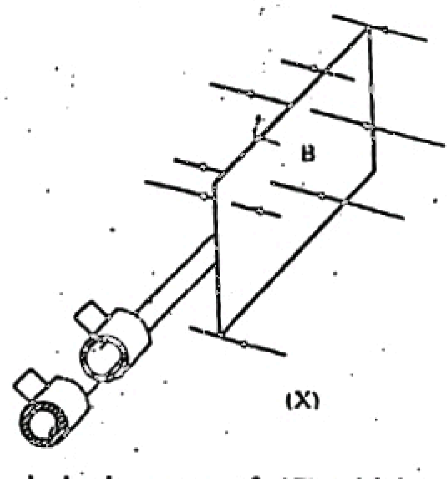
(iii) Find the minimum energy required to take the satellite from the surface of the earth to its orbit.

(iv) Explain why the values obtained for (iii) and (ii) are different.

(v) At what height above the earth surface, the satellite must orbit to be a geostationary satellite ?

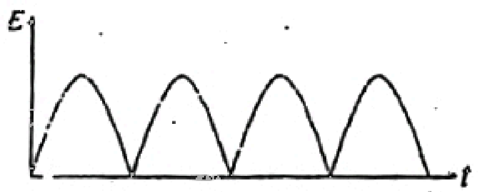
(vi) If a satellite in orbit losses energy due to friction what happens to the speed o the stellite and the radius of the orbit.

6. A coil wound round an armature in the form of a rectangular loop is shown in th figure (X) . The loop contains N turns of wire each having length a and width b. The armature rotates at a constant angular velocity ω in a uniform magnetic field of flux density B.



(X)

(i) Show that the maximum e.m.f. generated by the coil is $NabB\omega$.



(Y)

(ii) The above arrangement can be modified to use as a dc generator, and obtain an e.m.f. (E) which varies with time (t) as shown in the figure (Y).

Explain with a labelled diagram how you would modify the above arrangement shown in figure (X) to achieve this.

(iii) Now another identical loop is fixed to the same armature so that the plane of the loop is perpendicular to that of the former loop, and the armature is rotated with the above angular speed.

Copy the figure (Y) and draw in the same time scale, the variation of e.m.f. with time that you would expect from the second loop. Draw also on the same figure, the resultant e.m.f. when both outputs are connected in series. Clearly label all the curves.

State two advantages of having many such coils evenly-spaced and fixed to an armature, outputs of which are connected in series.

(iv) The dc generator mentioned in (ii) can be used as an electric motor by connecting an external voltage source across the output. Explain how a back e.m.f is generated in the loop under this situation.

A motor has an internal resistance of 10Ω. When it is driven by a voltage source of 200 V, a current of 6 A is found to be drawn from the supply at its operating speed. Find the back e.m.f. of the motor. Find also the current drawn by the motor at the moment it is turned on.

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

(a) (i) You are provided with a DC supply of voltage V and a variable resistor with a sliding contact. Using these apparatus, the voltage across a load is to be increased steadily from zero to the maximum value , V

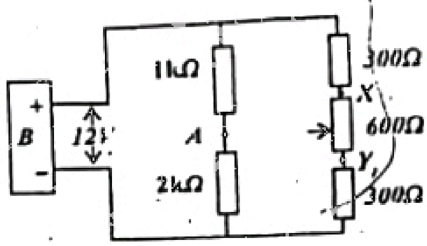
Draw a suitable circuit diagram to obtain such a voltage, clearly indicating the terminals to which the load is to be connected.

Sketch a graph of load current against the voltage applied when the load is

(a) a constant resistance (b) a tungsten filament lamp.

Explain why the two graphs are different.

(ii) In the circuit shown, B is a battery with negligible internal resistance. A variable resistor of 600 Ω with a sliding contact is connected across the points X and Y. An ideal voltmeter is connected between the terminals A and the sliding terminal of the variable resistor.

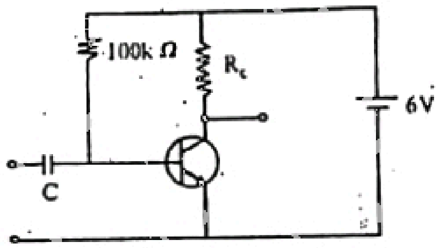


(a) Find the current through XY

(b) Find the readings of the voltmeter when the sliding terminal is at X, and Y respectively.

(c) If the above voltmeter is a 0 - 12 V moving coil type voltmeter, can it be used to measure both values calculated in (b) above ? Explain your answer.

(b) (i) The circuit shown below uses a silicon trasistor and a 6V battery. The collector potential is set at 3 V.



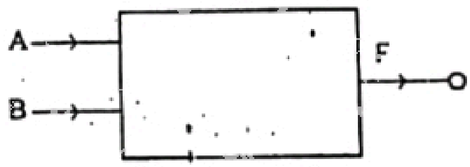
(a) Show that in this circuit the transistor is biased in the active mode.

(b) Find the base current in the circuit.

(c) If $\beta = 50$ find the value of R_c.

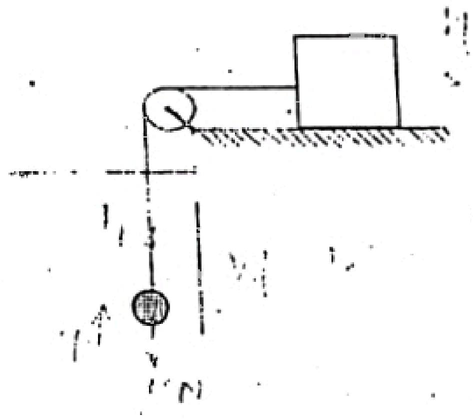
(d) What is the purpose of having a capacitor C at the input?

(ii) Block diagram of a circuit used to detect the binary numbers corresponding to the decimal numbers 2 or 3 in a string of binary numbers is shown below.



AB is the binary input, and the output F will produce a binary 1 whenever a proper detection is made. Design a circuit using logic gates for this purpose. state all the design steps clearly.

8. A sphere of radius 2×10^{-2} m attains the terminal velocity 3 ms^{-1} when it is allowed to fall from rest in a viscous liquid.



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

(ii) When the sphere is connected to a block of mass 0.1 kg by a string passing over a pulley as shown in the figure, and allowed to fall in the same liquid , it attains the terminal velocity of 1.5 $m\ s^{-1}$ The coefficient of kinetic friction between the block and the horizontal surface on which it is placed is 0.4 . The pulley is light and frictionless.

(a) What is the tension of the string when the sphere attains the terminal velocity ?

(b) Calculate the coefficient of viscosity of the liquid.

(c) Draw a rough sketch to show the variation of the velocity of the sphere with time on the same graph drawn in (i) above. Label the sketches properly.

(d) Calculate the new terminal velocity attained by the sphere if a layer of the same liquid of thicknes 1 mm is present between the block and the surface. Contact surface area of the block. $2.5 \times 10^{-4}\ m^2$