6244

Department of Examinations, Sri Lanka

අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2017 අගෝස්තු
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2017 ஓகஸ்ற்
General Certificate of Education (Adv. Level) Examination, August 2017

භෞතික විද්‍යාව II
பௌதிகவியல் II
Physics II

01 E II

පැය තුනයි
மூன்று மணித்தியாலம்
Three hours

Index No. : ....

Important :

- *This question paper consists of **13** pages.*
- *This question paper comprises of **two** parts, Part **A** and Part **B**. The time allotted for **both parts** is **three hours**.*
- *Use of calculators is **not** allowed.*

PART A — Structured Essay :
(pages 2 - 7)

*Answer **all** the questions on this paper itself. Write your answers in the space provided for each question. Note that the space provided is sufficient for your answers and that extensive answers are not expected.*

PART B — Essay :
(pages 8 - 13)

*This part contains **six** questions, of which, **four** are to be answered. Use the papers supplied for this purpose.*

- *At the end of the time allotted for this paper, tie the **two parts together** so that **Part A** is **on top** of **Part B** before handing them over to the Supervisor.*
- *You are permitted to remove **only Part B** of the question paper from the Examination Hall.*

For Examiners' Use Only

For the second paper		
Part	**Question Nos.**	**Marks Awarded**
A	1	
	2	
	3	
	4	
B	5	
	6	
	7	
	8	
	9 (A)	
	9 (B)	
	10 (A)	
	10 (B)	
Total		

Final Marks

In numbers	
In words	

Code Numbers

Marking Examiner 1	
Marking Examiner 2	
Marks checked by	
Supervised by	

[see page two

Do not write in this column

PART A – Structured Essay

*Answer **all four** questions on this **paper itself**.*

(Acceleration due to gravity, $g = 10\,\mathrm{N\,kg^{-1}}$)

1. You are asked to find the mass M of a piece of rock of irregular shape having a mass of the order of 60 g by performing the experiment which uses the principle of moments. You are provided with **only** the following items to carry out the experiment.

   - A weight of mass m (=50 g) 

   - A metre ruler
   - A knife-edge and a suitable wooden block
   - Pieces of thread

(*a*) As the first step of this experiment, you are asked to balance the metre ruler on the knife-edge. What is the purpose of this step?

....

(*b*) Draw a diagram of the arranged experimental setup, on the table shown below, for the balanced situation just before you take a reading. Mark the balanced lengths l_1 and l_2 correctly (Take the larger balanced length as l_1) measured from the balanced point, in the diagram. Label the items.

Table

(*c*) Write down an expression for l_2 in terms of m, M and l_1 when the system is balanced.

....

....

(*d*) You are supposed to draw a graph in this experiment. What position of the metre ruler would you place on the knife-edge every time when you take a different set of readings for l_1 and l_2?

....

(*e*) Suppose you have plotted a graph as shown in figure (1) to find the mass M.

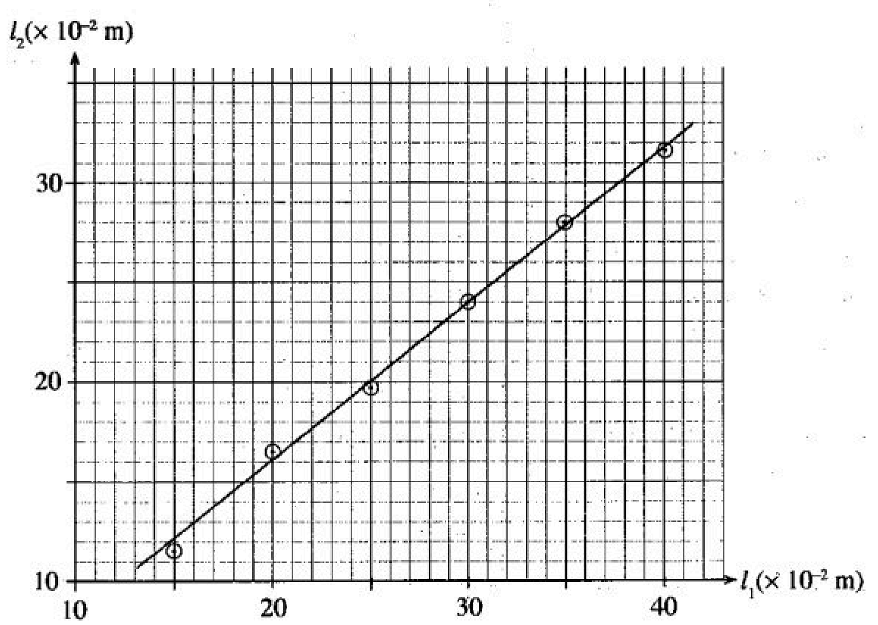


Figure (1)

[see page three

Do not write in this column

(i) In this experiment, you have been asked **not** to take readings for small values of l_1 and l_2. What is the reason for this?

....

....

(ii) By selecting the two **most suitable** points on the graph, calculate the gradient of the graph given in figure (1). The **two** points selected should be clearly marked on the graph using arrows.

....

....

....

(iii) Calculate the mass M of the piece of rock in kilograms.

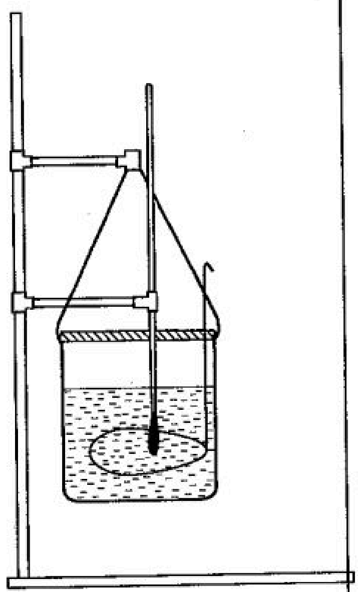
....

....

....

(*f*) You are also asked to find the mass m_0 of the metre ruler using only the other items provided above **except** the piece of rock. Draw a suitable diagram of an experimental setup that could be used for this situation in the space given below. The centre of gravity of the metre ruler should be clearly labelled as G.

2. The diagram shows an experimental setup that can be used to verify Newton's law of cooling, and to determine the specific heat capacity of a given liquid. It consists of a calorimeter with a lid and a stirrer made of copper, heated water, thermometer and a stand to hang the calorimeter setup. An experimental procedure similar to the method used in the standard experiment is performed by keeping the setup closer to an open window of the laboratory.
The advantage of doing this experiment near an open window where you get a slow uniform flow of wind is that you can verify the validity of the Newton's law of cooling for higher temperature differences.



(*a*) (i) What are the readings you would take in this experiment to verify the Newton's law of cooling?

(1) ....

....

(2) ....

....

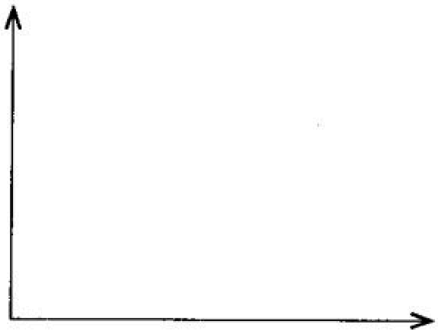
[see page four

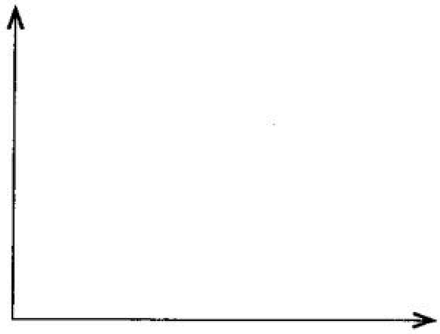
Do not write in this column

(ii) What is the experimental procedure to be performed which enables you to reliably assume that the reading of the thermometer is same as the temperature of the outer surface of the calorimeter?

....

(iii) Draw rough sketches of the two graphs that you would plot to verify the Newton's law of cooling. Label the axes properly with appropriate units.





(*b*) In order to determine the specific heat capacity of a given liquid, the same procedure used in (*a*) above is repeated for the liquid after obtaining relevant readings for water.

(i) What is the reason for using the same calorimeter used in part (*a*) to perform this experiment?

....

(ii) In addition to the using of same calorimeter, what is the reason for using the same volume of water and liquid in this experiment?

....

....

(iii) The mass and specific heat capacity of the calorimeter with the lid and the stirrer are m and s respectively. Mass and the specific heat capacity of the liquid are m_l and s_l respectively. The average **rate** of loss of heat and the average **rate** of drop of temperature of the calorimeter with the liquid for a given temperature range are H_m and θ_m respectively. In terms of these quantities, write down the relationship between H_m and θ_m.

....

....

....

(iv) Let $m = 0.15\,\text{kg}$, $s = 400\ \text{J kg}^{-1}\ \text{K}^{-1}$ and $m_l = 0.25$ kg. For a certain temperature difference, the average rate of heat loss of the calorimeter with **water** was found to be $90\ \text{J s}^{-1}$. The average rate of drop of temperature of the calorimeter with the **liquid** for the same temperature difference was found to be $0.125\,\text{K s}^{-1}$. Determine the specific heat capacity s_l of the liquid.

....

....

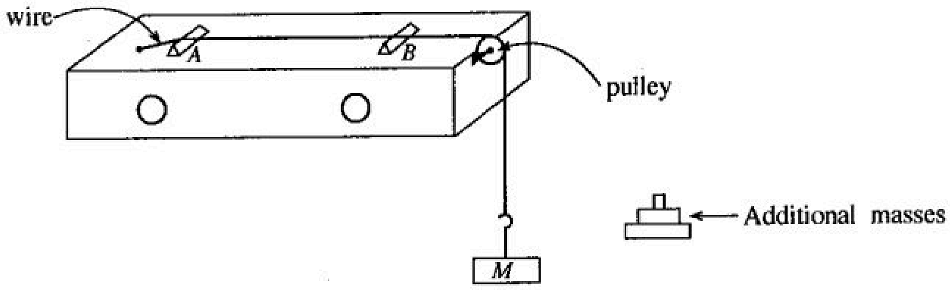
....

....

[see page five

Do not write in this column

3. You are asked to determine the mass per unit length of a given wire by taking only one measurement using a sonometer and a tuning fork. Figure shows a standard sonometer setup used in a school laboratory fixed with the **given wire**. The wire is stretched with a tension T between two bridges A and B. In this setup the bridge A is fixed and bridge B is allowed to move. The tension in the wire could be changed by varying the load mass M. A tuning fork with known frequency f is provided to you.



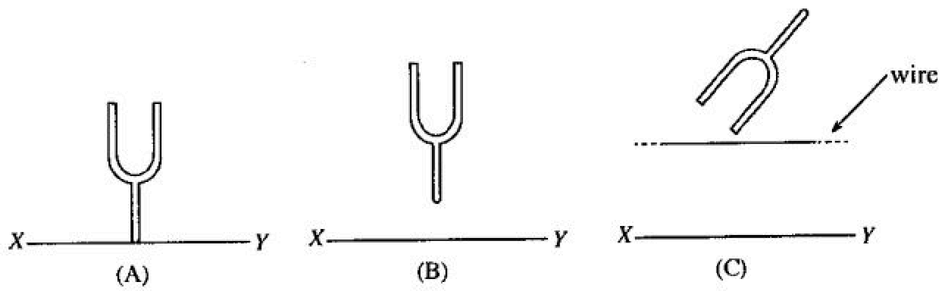
(*a*) What type of vibrations is produced in the surrounding air due to the vibration of a tuning fork in this experiment?

....

(*b*) If m is the mass per unit length of the stretched wire of tension T, write down an expression for the speed v of transverse waves on the wire in terms of T and m.

....

(*c*) In this experiment you are supposed to measure the resonant length (l) of the wire resonating with the tuning fork at the fundamental note. A student suggested that there can be three ways (A), (B) and (C) of keeping a vibrated tuning fork to obtain the resonance state, as shown in the figure.



XY represents a part of the surface of the sonometer box.

(A) Tuning fork held normal to XY and touching XY.

(B) Tuning fork held normal to XY and without touching XY.

(C) Tuning fork held above the stretched wire.

In order to obtain maximum amplitude for resonance, out of the above three ways, which way would you select to keep the vibrated tuning fork? [(A) or (B) or (C)]. Give the reason for you selection.

....

....

(*d*) Write down the other item that you normally use in this experiment to detect the **resonance state** experimentally.

....

(*e*) Write down the main experimental steps you follow to detect the **optimum** resonance state.

....

....

[see page six

Do not write in this column

(*f*) Obtain an expression for m in terms of f, l and T.

....

....

....

(*g*) If the resonant length that you have obtained in this experiment is small, how do you adjust the above sonometer setup in a suitable manner to obtain a reasonably large resonant length for the given tuning fork.

....

(*h*) When $M = 3.2$ kg and $f = 320$ Hz the resonant length was found to be 25.0 cm. Find the mass per unit length of the wire in kg m^{-1}.

....

....

....

4. An experiment can be designed to determine the internal resistance r_0 of a voltmeter V using the setup shown in the figure (1). E_0 is the e.m.f. of a cell with a certain internal resistance. R_0 is a fixed resistance and R is a resistance connected across X and Y. Assume that the ammeter A has negligible internal resistance.

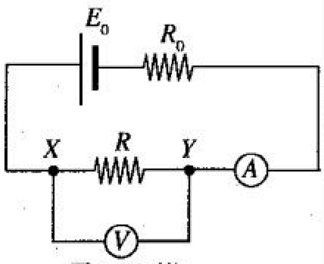


Figure (1)

(*a*) When the voltmeter is connected across XY as shown in the figure (1),

(i) draw below the relevant part of the circuit to show as to how the resistances R and r_0 appear across the points X and Y using circuit-symbols.

(ii) write down an expression for the equivalent resistance R_{XY} across X and Y in terms of r_0 and R.

....

....

(*b*) The voltmeter now appears to have been connected across R_{XY}. Under this situation, will the reading of the voltmeter be equal to the value indicated by an ideal voltmeter connected across R_{XY}? (Yes/No). Justify your answer.

....

....

....

(*c*) If V is the reading of the voltmeter and I is the current through the ammeter, write down an expression for I in terms of V, r_0 and R.

....

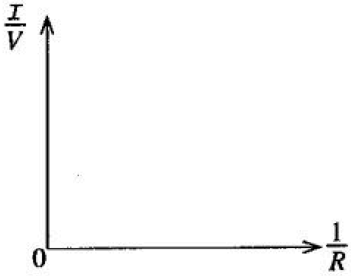
....

[see page seven

Do not write in this column

(*d*) Rearrange the expression given in (*c*) to plot a graph of $\frac{I}{V}$ on the *y*-axis and $\frac{1}{R}$ on the *x*-axis.

(*e*) Draw the shape of the graph expected in (*d*) above, on the set of axes given below.



(*f*) Write down an expression relating r_0, and the relevant information extracted from the graph.

(*g*) If you are asked to perform an experiment in the laboratory, and plot the graph mentioned in (*e*) above, name the item which you would use for *R*.

(*h*) Suppose the resistance R_0 is now removed from the circuit shown in figure (1). Assume that $r_0 = 1000\,\Omega$. Consider the magnitudes of the following **voltages**.

- The reading of the voltmeter (say V_1)
- The voltage generated across *XY* when the voltmeter is removed from the circuit (say V_2).
- If a digital multimeter having an internal resistance $10\,\mathrm{M}\Omega$, is now connected across *XY*, the reading of the multimeter (say V_3)

Write down E_0, V_1, V_2 and V_3 in the ascending order according to their magnitudes.

* *

[*see page eight*

අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2017 අගෝස්තු
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2017 ஓகஸ்ற்
General Certificate of Education (Adv. Level) Examination, August 2017

භෞතික විද්‍යාව II
பௌதிகவியல் II
Physics II

01 E II

PART B — Essay

*Answer **four** questions only.*

(Acceleration due to gravity $g = 10\,\text{N kg}^{-1}$)

5. The 'pile-driver' is a heavy weight which is used to drive poles called piles into the ground for use as foundations of buildings and other structures. As shown in the figure (1), the pile-driver is lifted up by a cable and then dropped so that it falls freely under gravity and strikes the top of the pole. This process is repeated until the pole is pushed to the desired depth into the ground.

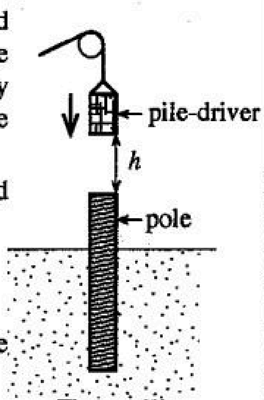


Figure (1)

(*a*) Consider a situation where a pile-driver of mass $M = 800\,\text{kg}$ is raised and then released from rest on to a vertical cylindrical pole of mass $m = 2400\,\text{kg}$ from a height $h = 5\,\text{m}$.

(i) State the energy conversion that takes place **during** the fall of pile-driver.

(ii) Calculate the speed of the pile-driver just before the collision.

(iii) Calculate the magnitude of the momentum of the pile-driver just before the collision.

(*b*) Assume that after collision between the pile-driver and the top of the pole, the pile-driver does not bounce back, instead it remains in contact with the pole and drives the pole into the ground vertically. Also assume just after the collision, only the momentum is conserved in the system. Calculate, the following.

(i) The speed of the pile-driver with pole just after the collision.

(ii) The kinetic energy of the pile-driver with pole just after the collision.

(iii) In each collision 40% of the energy calculated in (*b*)(ii) is used usefully to drive the pole into the ground. If in one particular collision it drives the pole 0.2 m into the ground, calculate the average resistive force acting on the pole.

(*c*) Consider a situation where a uniform cylindrical wooden pole of 10 m height and 0.3 m radius is pushed entirely into a sandy soil as shown in the figure (2). The maximum load F the pole can hold when keeping it as shown in figure (2) could be written as $F = A_s f_s + A_b f_b - W$,

where W is the weight of the pole, A_s is the area of the curved surface of the pole which is in contact with the soil, f_s is the average resistive force on the curved surface of the pole per unit area, A_b is the cross sectional area of the base of the pole and f_b is the average resistive force from the ground on the base of the pole per unit area.

If $f_s = 5 \times 10^4\,\text{N m}^{-2}$, $f_b = 2 \times 10^6\,\text{N m}^{-2}$ and the density of the wood is $8 \times 10^2\,\text{kg m}^{-3}$, calculate the value of F for the pole. Take the value of π as 3.

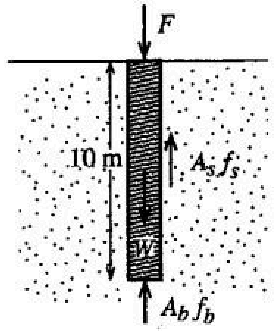


Figure (2)

(*d*) System of four poles, each similar to the pole used in (*c*) but having a radius equal to half of the radius of the pole used in (*c*), is pushed entirely into a sandy soil. This is shown in the figure (3) when seen from the above.

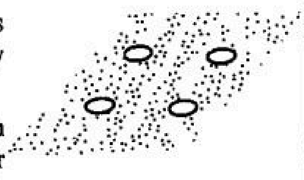


Figure (3)

(i) As given in (*c*) above, the F has three components as $A_s f_s$, $A_b f_b$ and W. When using the system of four poles for a construction, which component of the F, for the system of four poles, is contributing to increase its value in compared with the situation considered in (*c*) above.

(ii) Calculate the value of F for the system of four poles.

6. (*a*) (i) A thin convex lens of focal length f is used as a simple microscope. Draw a ray diagram for a situation when a distinct image is seen using the simple microscope by a person having the least distance of distinct vision D. Clearly mark the positions of the eye, f and D.

(ii) Derive an expression for the linear magnification of a simple microscope in terms of f and D.

(iii) A thin convex lens of focal length 10 cm is used by the person mentioned in (i) above as a simple microscope to read very small letters. To see the clear image of a letter, what would be the distance from the lens to the letter. Calculate the linear magnification of the simple microscope. Take the value of D as 25 cm.

(iv) A historical document placed in a museum is framed using a transparent glass plate of 2 cm thickness to protect it. Assume that the inner surface of the glass plate touches the document. Take the refractive index of glass as 1.6. Find the distance to the apparent position of the document from the front surface of the glass plate.

(v) Consider that the same person mentioned in part (i) is reading the document using the simple microscope mentioned in part (iii).

(1) What is the distance from the lens, to the image of the document produced by the lens when the letters are clearly seen by the person?

(2) What is the distance to the document from the lens when the letters in the document are clearly seen?

(*b*) (i) Draw a **complete** ray diagram indicating all relevant lengths for an astronomical telescope in normal adjustment labelling the objective and the eyepiece clearly. Take f_o and f_e as the focal lengths of the objective and the eyepiece respectively.

(ii) Derive an expression for the angular magnification of the telescope when it is in normal adjustment using the ray diagram drawn in part (*b*)(i).

(iii) An astronomical telescope is made using two thin convex lenses of focal lengths 100 cm and 10 cm. Calculate the angular magnification of the telescope in normal adjustment.

(iv) What is the practical advantage of using a convex lens with large aperture area as the objective of an astronomical telescope? Explain your answer.

7. Read the following passage and answer the questions.

Instability of soil that occurs due to the infrastructure developments such as road constructions in mountain regions without proper study, can create problems such as sinking roads and landslides. Landslides are now a common tragedy in many parts of the country during rainy seasons. The stability of sand, a constituent of soil, heavily depends on the amount of water present in the sand. Anyone who has built structures such as 'sandcastles' using wet sand knows that the adhesive properties of wet and dry sand are very different. Wet sand can be used to build sharp-featured sandcastles whereas dry sand just crumbles down in this process. Some of the aspects of these phenomena related to the stability of soil or sand can be explained by fundamental physics concepts such as gravity, friction and surface tension.

Soil is generally a porous medium comprising a mixture of mineral particles such as clay, silt and sand of different sizes, and voids. Voids are filled with either air or water as shown in figure 1(a). The porous nature of soil can create practical problems, such as sinking of heavy structures on the ground. This occurs due to the compression of voids caused by the heavy loads on the ground. Leaning of Pisa tower and sinking of the Meethotamulla dump site and the earth in the vicinity of the Uma Oya tunnel are a few examples. Another important parameter which determines the stability of soil (or sand) is the angle of repose. When a bucket of dry soil is emptied on to a hard levelled floor the soil particles slide easily and form a conical pile due to the friction between grains as shown in figure (2). The angle α of the pile is known as the angle of repose which is the steepest stable slope that a particular substance can form. Removal of soil from the base of a slope, increasing the angle of repose, can create instability on the slope.

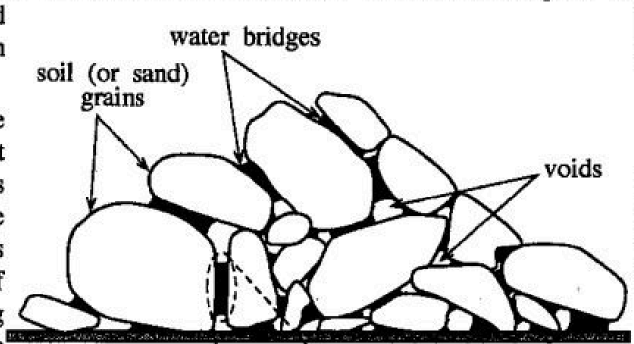


Figure 1(a)

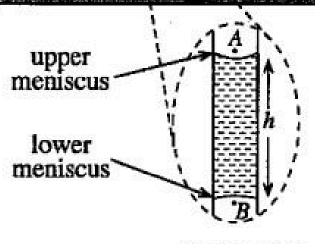


Figure 1(b)

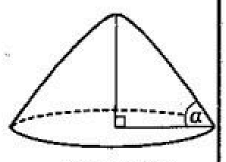


Figure (2)

Sand in soil can be considered as a porous medium. It consists of a system of randomly oriented complex capillary tubes of different sizes similar to the structure shown in figure 1(a). Capillary forces draw water into the sand changing the physical properties of sand medium. Damp sand forms capillary water bridges between its grains (see figure 1(a)). Nanometre-scale water bridges between millimetre-scale grains dramatically increase the attraction between grains. It is due to the adhesive forces associated with the water bridges between grains. Dry sand grains maintain stability due to frictional forces, and in addition wet sand grains attract each other due to adhesive forces. The enhancement of the attraction of the grains due to these capillary forces leads to the increase of the repose angle creating sand clumps. The surface of a water bridge is concave (figure 1(b)), and so generates 'capillary action' which helps to hold the sand grains firmly together due to surface tension.

During rainy season the soil saturated with water creates high pressure on the voids and grains. Gradually increasing the pressure inside voids increases the curvature of the surface of water bridges decreasing the capillary force between the grains. The addition of more water to the soil can decrease friction and strength between the grains, and increase the weight of the soil making an ideal situation for landslides. Damage on the Earth's soil surface due to the addition of large amounts of pesticides and fertilizers decreasing the surface tension force between the grains can also dramatically increase the likelihood of a landslide.

(*a*) Name **three** fundamental physics concepts which can be used to explain some aspect of the stability of soil and sand.

(*b*) Write down **three** main mineral constituents of soil.

(*c*) In a road construction, soil has been removed from a certain section of the slope altering the natural slope as shown in figure (3). This is a vulnerable place for landslides. Explain this using the information given in the passage.

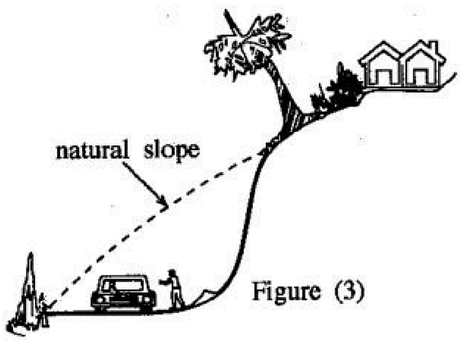


Figure (3)

(*d*) Addition of water into dry sand dramatically increases the stability of sand. Explain the main reason for this.

(*e*) A water bridge between two spherical sand grains is shown in figure (4). Copy the figure (4) to your answer script and draw the **resultant** reaction forces (using arrows) **on each grain** due to the surface tension.

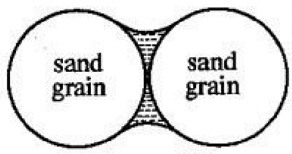


Figure (4)

(*f*) Consider a water bridge formed by two sand grains shown in figure 1(b) where the radii of curvature of the upper and lower miniscii are r_1 and r_2 respectively. Using the expressions for the pressure differences across the upper and lower air-water interfaces, derive an expression for the height h of the water column in figure 1(b). Take surface tension and density of water as T and d respectively. Assume that the pressures at points A and B, shown in the figure, are **equal**.

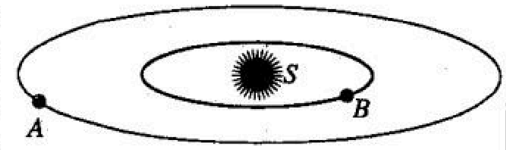
(*g*) Calculate the height h for the situation mentioned in (*f*) above. Take $r_1 = 0.8$ mm, $r_2 = 1.0$ mm, $T = 7.2 \times 10^{-2}$ N m^{-1} and $d = 1.0 \times 10^3$ kg m^{-3}.

(*h*) Consider a situation where the pressures at points A and B are **higher** than the situation shown in figure 1(b). Copy the figure 1(b), **including the two meniscii**, to your answer script and draw the shapes of the two new meniscii and **clearly** label them as X and Y.

(*i*) If the pressures at points A and B, shown in figure 1(b), are continuously increasing, what will happen to the radii of the meniscii, contact angle and the resultant reaction forces due to the surface tension forces between the grains? Explain your answer.

(*j*) Write down **two** human activities mentioned in the passage, which can increase the likelihood of landslides.

8. The main objective of NASA's Kepler exploration is to find habitable planets in other planetary systems in our galaxy, the Milky Way. A large number of planets which orbit around stars have been detected by the exploration. One such observation was a planetary system consisting of two planets, planet A and planet B of orbital periods T_A = 300 earth days and T_B = 50 earth days, respectively. Assume that the planets are uniform spheres and moving in circular orbits around a star S of mass M as shown in the figure. Neglect the interaction between the planets.



(*a*) (i) Derive an expression for the orbital speed (v_B) of the planet B in terms of M, the orbital radius R_B of the planet B and universal gravitational constant G.

(ii) Write down an expression for the period T_B of the planet B in terms of R_B and v_B.

(iii) Derive an expression for the mass M of the star at the centre in terms of T_B, R_B and G.

(iv) If $R_B = 0.3\,\text{AU}\ (1\text{AU} = 1.5\times10^{11}\,\text{m})$, calculate the mass M of the star. Take $G = 6.7\times10^{-11}\,\text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2}$ and $\pi^2 = 10$.

(*b*) (i) Using the expression obtained in (*a*)(iii) above, derive an expression relating orbital radii R_A, R_B and periods T_A and T_B of planets A and B.

(ii) Calculate the orbital radius R_A of planet A using given values.

(*c*) The mass and the radius of the outer planet A are found to be $23\,m_E$ and $4.6\,r_E$ respectively, where m_E and r_E are the mass and the radius of the earth respectively.

(i) Derive an expression for the gravitational acceleration, g_A, at a point on the surface of planet A, in terms of m_E, r_E and G.

(ii) Obtain an expression for the g_A in terms of the gravitational acceleration g_E at a point on the surface of the earth.

(iii) If a space landing module of mass 100 kg is landed on planet A, calculate the weight of the landing module after landing.

(iv) The outer planet A is located within the habitable zone when compared with our solar system. Obtain an expression for the average density d_A of the planet A in terms of the average density d_E of earth.

9. Answer either part (A) or part (B) only.

(A) (*a*) Explain briefly how the back electromotive force (e.m.f.) is produced in a direct current motor. Name the laws in physics which determine (i) the magnitude and (ii) the direction of the back e.m.f. respectively.

(*b*) Write down an expression for the back e.m.f. E produced by a direct current motor when it draws a current of I from a battery. The internal resistance of the motor coil is r and the terminal voltage of the battery is V.

(*c*) If $V = 80\,\text{V}$ and $r = 1.5\,\Omega$ calculate the following quantities when the motor operates with full load drawing a current of 4.0 A.

(i) Back e.m.f. (E) produced by the motor.

(ii) Power given to the motor.

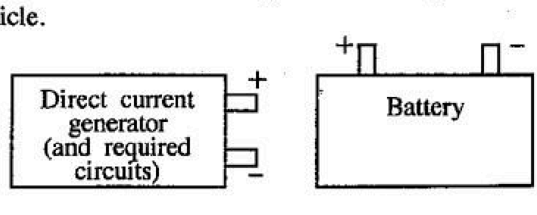
(iii) The mechanical power output and the efficiency of the motor. (Neglect any energy losses due to friction.)

(*d*) Assume that the values given for r and the current (4.0A) in (*c*) above for the motor are the values when the coil is at the room temperature of 30 °C. After running the motor for several hours it was found that the current in the coil had dropped to 3.6 A with voltage V remaining unaltered at 80 V. Calculate the new temperature of the coil. Temperature coefficient of resistance of the material of the coil is $0.004\,°\text{C}^{-1}$ at 0 °C.

(*e*) In electric motor vehicles, direct current motors driven by batteries are used to rotate the wheels of the vehicles. During the application of brakes, the same motor in such vehicles is made to operate as a direct current generator, and part of the kinetic energy of the vehicle is used to drive the generator. The generator output is then used to recharge the battery of the same vehicle.

(i) How do you operate a direct current motor as a direct current generator?

(ii) Copy the two diagrams in the figure to your answer script and show how you would connect the direct current generator output to charge the battery.



(B) (*a*) Write down the expression for the relationship among I_C, I_E and I_B of an *npn* transistor. All symbols have their usual meaning.

(*b*) The *npn* transistor connected as shown in figure (1), is operating in the active mode. Assume that the current gain of the transistor is 100, and when it is forward biased, the voltage across the base and the emitter, V_{BE} = 0.7V.

(i) Calculate the base current I_B necessary to produce a collector voltage of 5V.

(ii) Calculate the value of R_2 if R_1 = 12kΩ. (Assume I_B is negligible for this calculation).

(iii) Modify the given circuit shown in figure (1) so that it could be operated with a negative power supply voltage of –10V. Correctly re-label, the modified circuit using R_1, R_2, 10kΩ, and the labels *A* and *B* given for the points in the **appropriate** manner. Indicate the direction of the collector current, and the direction of the current through R_1 and R_2 with arrows.

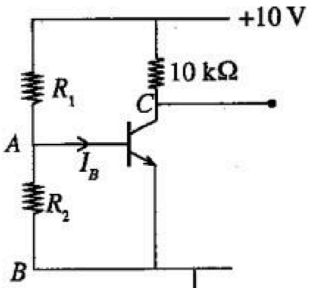


Figure (1)

(*c*) A photodiode is to be connected across the base and the emitter of the transistor in the **modified circuit** that you have drawn under (*b*)(iii).

(i) When connecting a photodiode to a circuit, it is done in such a way that the photodiode is reverse biased. Using the circuit symbol of the photodiode show how you would connect it correctly across the base and the emitter of the transistor in the **modified circuit**.

(ii) When the photodiode is connected to the modified circuit correctly, will it alter the resistance across base and emitter appreciably? Explain your answer.

(iii) When a rectangular light pulse of short duration is incident on the photodiode,

(1) show the direction of the current through the photodiode in the circuit using an arrow.

(2) draw the waveform of the **voltage** pulse appearing at the base relative to emitter, and the waveform of the **voltage** pulse at the collector relative to the earth due to the light pulse at appropriate places on the circuit.

10. Answer either part (A) or part (B) only.

(A) A certain house consumes 100 kg of hot water at 50 °C per one hour for washing purposes at the kitchen and bath rooms. Hot water generated at 70 °C by an electrical boiler is mixed outside the boiler with water at 30 °C to produce water at 50 °C.

Take specific heat capacity, and the density of water as 4200 J kg^{-1} K^{-1} and 1000 kg m^{-3} respectively.

Assume that the heat loss to surroundings and the heat capacity of the boiler are negligible for all the calculations.

(*a*) Calculate the mass of hot water to be needed from the boiler at 70 °C to produce 100 kg of water at 50 °C.

(*b*) The boiler is designed so that when the amount of hot water at 70° C calculated in (*a*) is taken out of the boiler it is refilled with the same amount of water at 30 °C in such a way that the temperature of the water inside the boiler does not go below 66 °C. Calculate the minimum capacity of water of the boiler in terms of (i) kilograms and (ii) litres needed to fulfil this condition.

(*c*) At the beginning of the day, the boiler is filled with the same amount of mass of the water calculated in (*b*) as the capacity, and heated at a constant rate from 30 °C to 70 °C using an electrical heater. If the heating is to be completed in one hour, calculate the power of the heater needed for this purpose.

(*d*) After the initial heating has been done according to (*c*), refilling of water at 30 °C is done continuously to compensate for the hot water taken out of the boiler according to the requirement (*a*) above. The boiler is designed so that another small electric heater provides heat to maintain the average temperature of the boiler at 70 °C throughout the period of one hour. Calculate the power of the small heater needed.

(B) (*a*) (i) The diagram given in figure (1) is a rough sketch of an X-ray tube. Name the parts marked as A and B.

(ii) Name the part marked as D and explain the purpose of using it.

(iii) Name the part marked as C in the diagram and explain the purpose of using it.

(iv) Explain how X-rays are produced.

(v) Give a reason for using an evacuated tube.

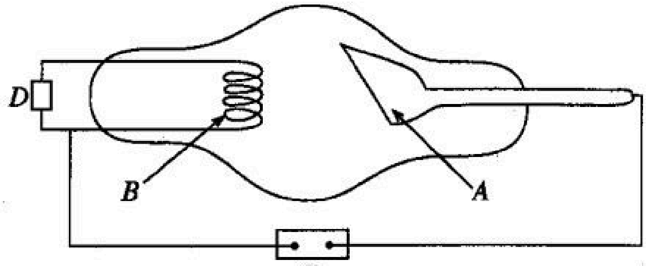


Figure (1)

(*b*) The supply voltage of an X-ray tube is 100 000 V.

(i) Calculate the maximum energy of an electron reaching A in units of keV.

(ii) An electron carrying the maximum energy calculated in (*b*)(i) above produces an X-ray photon spending half of its energy, and the rest of the energy is completely absorbed. Explain what will happen to the absorbed energy.

(iii) Calculate the wavelength of the X-ray photon produced in part (*b*)(ii).
[$h = 6.6 \times 10^{-34}$ J s, $c = 3 \times 10^{8}$ m s^{-1} and 1 eV = 1.6×10^{-19} J]

(*c*) When γ-rays pass through a material, a certain fraction of the γ-ray photons are absorbed by the material. Consider a beam of γ-rays of intensity I_0 incident perpendicular to a sheet of material of thickness t as shown in the figure (2). As a result of the absorption the transmitted intensity of the γ-ray beam is decreased, and it is denoted by I.

The relationship between I_0 and I is given by $\log\left(\frac{I_0}{I}\right) = 0.434\mu t$, where μ is a constant for the material at the given γ-ray energy. All data given below are for 2 MeV γ-rays. Take value of μ for lead as 51.8 m^{-1} for 2 MeV γ-rays.

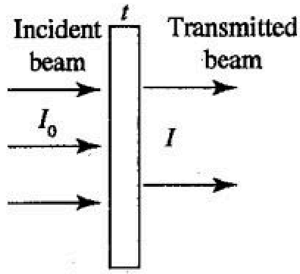


Figure (2)

(i) Calculate the thickness of lead required to reduce the intensity of the above γ-rays by half.

(ii) The maximum permissible annual dose for a radiation worker is 20 mSv. When a person is exposed to the above γ-ray beam of intensity 10^{10} m^{-2} s^{-1}, the annual dose received is 2.5×10^{6} mSv. Determine the maximum intensity of the above beam of γ-rays that a radiation worker can be exposed without exceeding the maximum permissible dose.

(iii) Consider a radiation therapy room in a hospital, in which a 2 MeV γ-ray source is installed to treat patients. Radiation workers work in the adjacent room. The two rooms are separated by a lead wall. In case of a radiation leak in the source the maximum intensity of the γ-rays incident normal to the lead wall is 2.56×10^{6} m^{-2} s^{-1}. Determine the minimum thickness of the lead wall required in order for the radiation workers to work safely in their room.

***