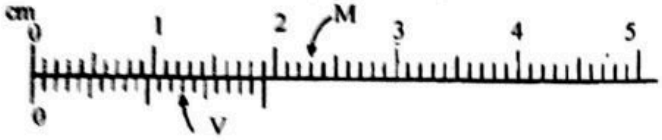
G.C.E. (Advanced Level) Examination - April 2002

PHYSICS - II

Three hours

Answer all four questions. **PART A - Structured Essay** $[g = 10\ N\ kg^{-1}]$

01. Figure shows a part of the main scale (M) and vernier scale (V) of a certain vernier calliper when their respective zero marks coincide. (Note that the figure is enlarged.)



(a) (i) What is the length of a vernier division in mm?

.....

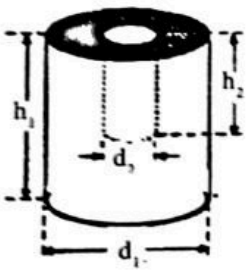
(ii) Hence or otherwise determine the least count of the instrument.

.....

(iii) According to the above figure, what is the **least distance** (in mm) of the vernier scale that has to be moved in order to make a vernier scale mark coincide once again with a main scale mark?

.....

(b)



A cylindrical metal piece has a cylindrical hole as shown in the figure.
In order to determine accurate values of the following measurements which part of the vernier calliper (out of external jaws, internal jaws and depth bar) would you use?

(i) For the measurement of d_1 .....

(ii) For the measurement of h_1.....

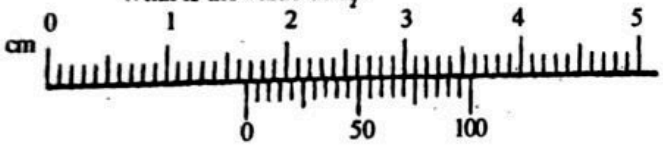
(iii) For the measurement of d_2 .....

(iv) For the measurement of h_2.....

(c) Write down an expression for the volume V of the metal in terms of d_1, h_1, d_2, and h_2.

.....

(d) (i) When d_2 was measured using the vernier calliper mentioned above, the position of the vernier scale obtained relative to the main scale is shown below. What is the value of d_2?

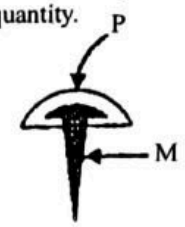


.....

(ii) What is the fractional error of this d_2 measurement? (Simplification is **not** expected.)

.....

02. You are provided with metal (M) naild studded with plastic (P) caps as shown in the figure, and asked to find the specific heat capacity (C_P) of the plastic using the method of mixtures without separating the plastic part. The plastic content of each nail is 30% of its total mass. Specific heat capacity (C_M) of the metal is a known quantity.



(a) If the nails at 100 °C, a calorimeter, and water are provided what other apparatus would you require to carry out this experiment? (Assume that the plastic can be heated to 100 °C without affecting its properties.)

.....

(b) Write down the list of mesurements that you would take in this experiment. Make sure to list them in the order you take the measurements. (Select the appropriate symbols given.)

(i) ..... (m_1 say)

(ii) .....(m_2 say)

(iii) .....(θ_1 say)

(iv) .....(θ_2 say)

(v) .....(m_3 say)

(c) Write down an expression relating C_P, C_M, C_W (specific heat capacity of water) and the quantities measured in (b). Assume that the calorimeter and the metal part of nails are made of the same metal.

.....

.....

.....

(d) State a main experimental error that can affect the result of the experiment in addition to errors associated with the above measurements.

.....

(e) Suggest a suitable measure to minimize the error that you have stated under (d).

.....

.....

(f) Would you expect to obtain a more accurate value for C_p if a relatively large quantity of nails and a small quantity of water are used in this experiment? (Yes or No)
Give reasons for your answer.
.....
.....
.....

(g) Give a valid reason as to why the value obtained for C_p in this experiment is more accurate than the value that would have been obtained had a large lump of plastic been used instead of nails.
.....
.....

03. You are provided with a uniform glass tube open at both ends, a tuning fork of frequency (f) 512Hz and a tall vessel containing water. An experimental arrangement has to be set up to determine the speed (V) of sound in air by the method of resonance.

(a) Draw a diagram to illustrate the experimental set up.

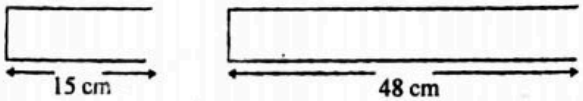
(b) State the correct procedure that you would follow in this experiment to obtain the resonance **states** of the air column properly.
.....
.....
.....

(c) What are the two readings that you would take to find a resonance length of the air column?
.....

(d) Write down a general expression for the resonance length (l) in terms of the wavelength (λ) of the sound wave and an integer n (n = 1 , 3, 5, ...). Neglect the end correction of the tube.
.....

(e) Using quantities l, V, f and n write down a suitable expression to find the speed (V) of sound in air using a graphical method.
.....

(f) The first two resonance lengths of such an experiment are found to be 15 cm and 48cm respectively. Draw the wave patterns for the above two modes of vibrations in the figures shown below.



(g) What is the type of wave persent inside the tube at resonance; travelling or standing?
.....

(h) Rewrite the expression in part (e) to accommodate the end correction (ϵ).
.....

(i) Use the values given in part (f) above to find the speed of sound in air.
.....
.....
.....
.....

04. A resistor S, a milliammeter A and a battery E are connected in series across the points X and Y as shown in figure 1. The milliammeter has an iternal resistance of 25Ω and it requires a current of 1 mA for full scale deflection.

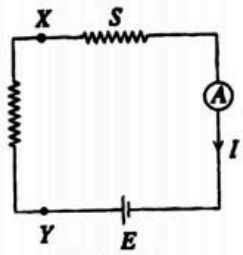


Figure 1

The dial of the milliammeter is shown in figure 2. The battery has an e.m.f of 10 V and negligible internal resistance. R is any resistor connected externally across the points x and Y. Let I be the current through the milliammeter.

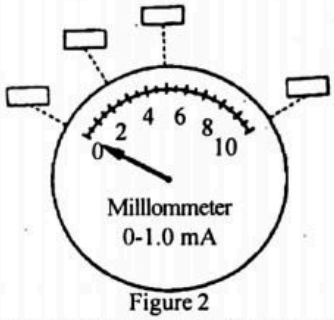


Figure 2

(a) When R = 0, the milliammeter reads a full scale deflection (I = 1.0mA).

(i) Find the value of the resistance S.
.....
.....

(ii) Practically how do you achieve R = 0?
.....

Write the above value of R (i.e. 0) in the box corresponding to the pointer position of the deflection of the milliammeter in figure 2.

(b) (i) When $R = \infty$ (infinity), what is the current (I) through the milliammeter?
.....
Write the value of R (i.e. ∞) in the corresponding box in figure 2.

(ii) Practically how do you achieve $R = \infty$?
.....

(c) What resistances of R give the following deflections of the milliammeter?

Half the full scale deflection :
.....
.....

Quarter of the full scale deflection :
.....
.....

Write the above values of R also in the corresponding boxes in figure 2.

(d) If the section of the **circuit with the milliammeter** (i.e. section of the circuit to the right of XY) shown in figure1 is calibrated also for other values marked in the dial of the milliammeter, this set up can be used to measure an unknown resistance. The unknown resistance is connected across X and Y and the value of the resistance can be read from the calibrated scale.

(i) Propose a suitable standard name for this set up.

.....

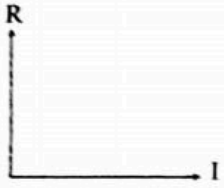
(ii) Is the milliammeter scale linear or non-linear?

.....

Is the scale calibrated to measure the resistance linear ot non-linear?

.....

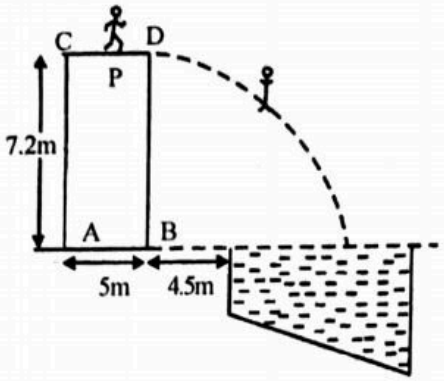
(iii) Draw a rough sketch to show the variation of R with I. **[Hint:** You may look at the values marked in the boxes in figure 2.]



PART - B Essay

Answer four questions only. $[g = 10\ N\ kg^{-1}]$

01.



A shown in the figure a fun game involves running along the top of a platform P and falling into a pool below.

Astudent of mass 50 kg accelerates uniformly from rest at one end (C) of the platform to the other end (D) and leaves the platform in the horizontal direction at a speed of $5ms^{-1}$ without any rotational motion. The length of the platform is 5m. (Neglect air resistane.)

(i) (a) Calculate the acceleration of the student while he is running on the platform.

(b) How long does he take to reach the other end (D) of the platform?

(c) State clearly how does the student obtain the required external force in order to achieve his acceleraton.

(d) Mark clearly the forces acting on the student while he is running on the platform (copy the diagram given here  on your answer sheet for this purpose).

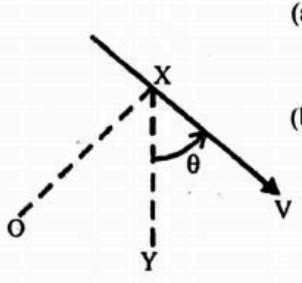
(ii) (a) How loge does he take to touch the water after leaving the platform?

(b) Determine the horizontal distance from the point B to the point at which he lands on water.

(c) Mark clearly the force/forces acting on the student while he is falling in air (copy the diagram give here  on your answer sheet for this purpose.)

(iii) Sketch the velocity (V) - time (t) curve for the horizontal component of the velocity of the student from the start (C) until he touches water.

(iv) The figure shows the direction of the instantaneous velocity vector (V) of the student when he has fallen a vertical distance of 1.25m from the platform.



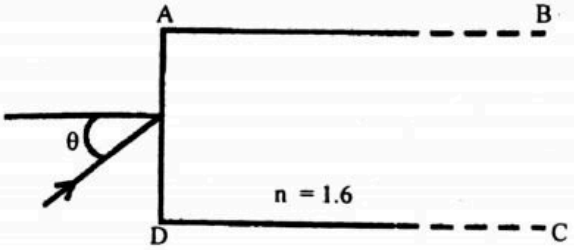
(a) Calculate the magnitude, and direction (i.e. angle between V and vertical line XY) of velocity V.

(b) At this instant the motion of the student can be treated as a part of a circular motion around a point O. Determine the centripetal acceleration of the student at this moment.

(c) Hence calculate the radius of the corresponding circle.

02. A monochromatic ray of light is falling with an angle of incidence θ on a long glass block *ABCD* of refractive index $n = 1.6$ placed in air as shown in the figure. Consider only the rays falling on the surface *AB* after the refraction at the suface *AD* in answering follwing questions.

(Disregard $\theta = 0$ situation)



(i) Find the critical angle for the glass.

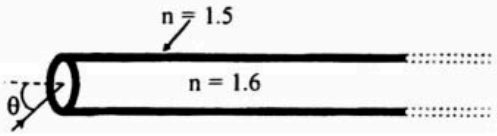
(ii) Show that the ray must undergo total internal reflection at the surface AB for all possible values of θ.

(iii) When $\theta = 30^0$ calculate the angle of refraction at the surface *AD*, and the angle of incidence at the surface *AB*.

(iv) If the space above the surface *AB* is filled with a transparent material of refractive index 1.7, then draw the ray diagram after calculating the relevant angles for $\theta = 30^0$.

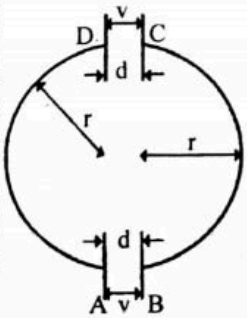
(v) (a) If the space above the surface *AB* is filled with a transparent material of refractive index 1.5, find the maximum value of angle θ, (i.e. θ_m) that the ray could undergo total internal reflection at *AB*. What happens if is greater than θ_m?

(b)



An optical fiber is made as shown in the figure. A monochromatic ray of light enters the fiber from air at an angle θ which is slightly less than θ_m. Dreaw the path of the ray in the fiber.

03. A proton of charge *q* and mass m is set up to travel along the path *ABCDA* through small holes on parallel plates as shown in the diagram. It has been done by applying uniform electric fields between the plates and uniform magnetic fields outside the plates. *AB* and *CD* are straight paths of length *d* and *BC* and *DA* are semicircular paths of radius *r*.



Each pair of plates is subjected to a potential difference of V. Neglect gravity. Answer the questions in terms of given symbols.

(i) (a) Write down expressions for the electric fields between the plates. Indicate their directions.

(b) The proton is initially released from rest at the hole *A*. Obtain expressions for the energy and the speed of the proton at *B*.

(ii) (a) Derive an expression for the magnetic flux density along the path *BC*. Indicate its direction.

(b) What is the speed of the proton when it enters the hole *C*? Give the reason for your answer.

(iii) (a) Obtain expressions for the new energy and the speed of the proton when it leaves the hole *D*.

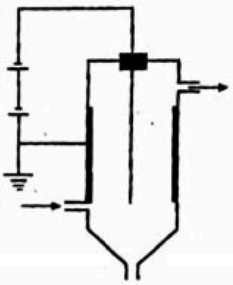
(b) Will the magnetic flux density obtained in (ii) (a) sufficient to guide the proton along the path *DA*? (Yes/No). If not, obtain an expression for it.

(iv) Explain briefly how this set up can be used to accelerate the proton to a higher energy without changing the magnitude of *V*.

(v) Can this process be done in air? If not, suggest a suitable solution?

04. Read the following passage carefully and answer the questions given below.

One important application of electrical discharge in gases is a device called an electrostatic precipitator. This device is used to remove particulate matter from combustion gases, thereby reducing air pollution. They are especially useful in coal power plants and industrial plants that generate large quantities of smoke.



Modern precipitators are able to eliminate more than 99% of the ash and dust (dy weight) from the smoke. Figure shows an arrangement which gives the basic idea of the electrostatic precipitator.

A conducting wire running down the centre is maintained at a high potential relative to the grounded outer cylindrical conductor. Polluted gases enter at the bottom and pass through the electric field around the wire. The strong electric field near the wire causes a corona discharge around the wire and the formation of positive ions, electrons and negative ions, such as O_2^-, .

As the electrons and negative ions are accelerated towards the outer wall, the impurity particles in the streaming gas become charged by collisions and ion capture. Since these impurity particles become negatively charged they are drawn to the outer wall, where they stick. By periodically shaking or flushing the cylinder the impurity particles fall loose and are collected at the bottom.

The phenomenon known as corona discharge is often observed near sharp points of a conductor or thin conducting wires reised to a high potential. If the electric field intensity near the conductor is high enough (about 3×10^6 Vm^{-1} for dry air) it can cause an electrical discharge (breakdown) in air. This breakown is initiated by the molecular ions and electrons present in air produced for example by cosmic rays. These ions and electrons accelerate rapidly towards the conductor under the action of the

electric field. On their way to the conductor they collide with other molecules, and thereby create more ions and electrons.

$$\left[\frac{1}{2\pi\varepsilon_0} = 18 \times 10^9 \text{ Nm}^2\text{C}^{-2}\right]$$

(i) (a) What is the purpose of using this device in coal power plants?

(b) Do modern precipitators fulfil the purpose that you have mentioned above? Justify your answer.

(ii) Is the wire maintained at positive or negative potential?

(iii) What is the advantage of grounding the outer cylinder?

(iv) Draw the electric lines of force in the vicinity of the wire.

(v) Is there a current between the wire and the outer wall when the precipitator is in operation? explain your answer.

(vi) Why are the polluted gases sent in at bottom rather than at the top of the device?

(vii) What is the reason for mainataining the polarity as mentioned in (ii) above?

(viii) If an O_2^- ion and an electron are at a same distance from the wire, which one has the higher acceleration?

Give reasons for you answer.

(ix) State two methods whereby some molecules in the air get ionized naturally. (One method is given in the paragraph)

(x) If the magnitude of the potential of the wire relative to the outer wall is V volts, and the charge per unit length on the wire is λC m^{-1}, V is related to λ by the following equation.

$$V = \frac{5}{2\pi\varepsilon_0}\lambda$$

Calculate λ for V = 90kV.

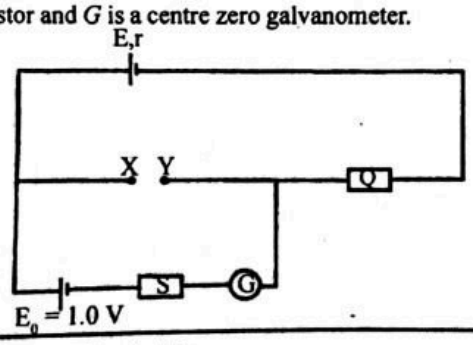
(xi) (a) Assuming the wire to be very long, use Gauss' theorem to show that the electric field intensity E at a distance r from the wire is given by $E = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{r}$

[**Hint** : Select a cylindrical Gaussian surface of radius r and unit length of height that is coaxial with the wire.]

(b) Determine E at a distance r = 1 mm. Show that this value is greater than the breakdown electric field intensity for dry air.

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

(a) The standard cell E_0 in the circuit shown below has an e.m.f of 1.0 V. The other cell has an unknown e.m.f. E and internal resistance r. Q is a resistance box. S is another resistor and G is a centre zero galvanometer.



(i) A resistance box P is now connected across X and Y. When $P = 20\Omega$ it is found that the deflection of the galvanometer is zero for $Q = 17\Omega$. When $P = 40\Omega$, again it was found that the deflection is zero for $Q = 35\Omega$. Find the e.m.f. E and the internal resistance r of the cell.

(ii) Instend of the resistane box P, a Nichrome wire of cross-sectional area 3×10^{-7} m^2 and length 10m is now connected across X and Y. it is found that the galvanometer deflection becomes zero when $Q = 53\Omega$. Find the resistvity of Nichrome. Find also the current through the Nichrome wire.

(iii) What is the necessity of having a resistances?

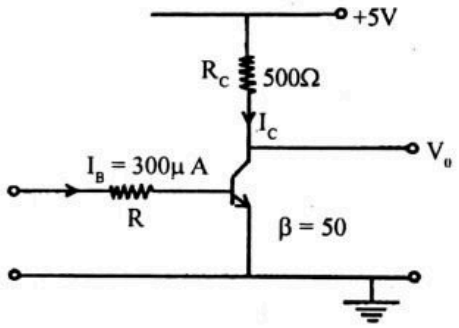
What apparantus is used for S?

How do you use S in order to find the balance condition (zero deflection) accurately?

(b) (i) Draw the output characteristic (I_C vs V_{CE}) of an npn transistor operating in the common emitter configuration, and clearly label the saturation and cut-off regions.

(ii) When plotting the curves in (*i*), one parameter is kept constant for each curve. What is it?

(iii) Considering the current (I) - voltage (V) characteristics for open and closed mechanical switches, show that an *npn* transistor can be operated as a switch.



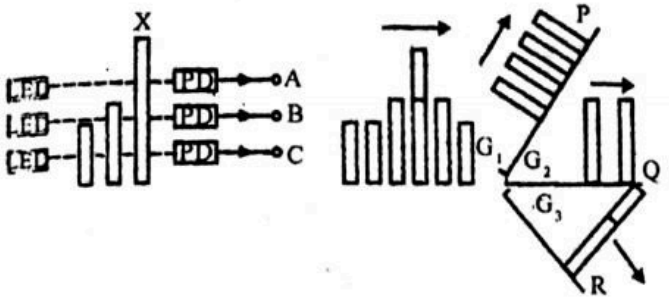
(iv) Assume that the transistor in the circuit given above operates in the saturation mode. What are the output voltage (V_0) and the collector current (I_C) of the circuit?

(v) Also using the data given, verify that $I_C < \beta I_B$ for the above transistor which is opreating in the saturation mode ($\beta = 50$)

(vi) What is the relationship between I_C and I_B if a transistor operates in the active mode? If I_B in the above circuit is maintained at 300μA and the R_C value is reduced to 200Ω, show that the operation mode of the transistor is shifted from saturation to active mode.

(vii) Three LED - photodiode circuit (PD) combinations are to be used to sort out two types of metal cans coming down a production line according to their heights and put them in two different lines P and Q by opening mechanical gates G_1 and G_2. See the figure. Rare occurrences of sitting one can on top of the other, such as X in the diagram shown have to be detected and put them into the third line R by opening the gate G_3.

The arrangement is shown below.



Assuming that PD circuit output A, B and C produce voltage signals correcponding to binary '1' when light beams emitted from LEDs are interrupted by cans, propose three logic circuits which provide binary '1' output signals to open the mechanical gates G_1, G_2 and G_3 at appropriate occasions.

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

(a) Thermal conductivity K is defined by the expression

$$\frac{Q}{t} = KA \frac{(\theta_1 - \theta_2)}{d}$$

(i) Identify the quantities $\frac{Q}{t}$ and $\frac{\theta_1 - \theta_2}{d}$ given in the expression.

(ii) State the condition under which the expression is valid.

(iii) Suppose the average temperature of the surface of an ice layer of thickness 50 m floating on the Arctic ocean is -50°C throughout the year. If the ice layer continues to grow due to the difference of temperatures at its top and bottom surfaces, find the time taken in hours to grow its thickness by another 1mm. Assume that the temperature at the bottom of the ice layer is 0°C.

Thermal conductivity of ice = 2 W m^{-1} K^{-1}

Specific latent heat of fusion of ice at 0°C = 3.6 x 10^5 Jkg^{-1}

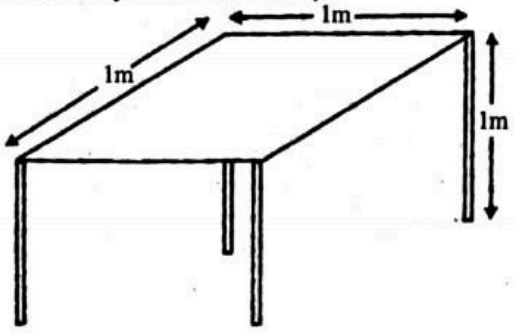
Density of ice at 0 °C = 900 kg m^{-3}

(iv) Continuous growth of such ice layers is however hampered by the presence of warm water currents underneath the layres.

(1) Calculate the minimum rate at which the heat should be provided per unit area of the ice layer by such currents to stop the growth of the above mentioned ice layer at 50m.

(2) If the warm currents provide heat at the rate of 0.5 Wm^{-2} for 2 days what would be the thickness of the 50 m ice layer after the two days.

(b)



One leg of a four-legged square stand used to place a sensitive instrument is found to be longer by 0.1 mm than the other three legs of length 1.0 m each causing the stand to wobble slightly. Each cylindrical leg has a cross sectional area of 1.0cm^2, and they are made of a material having Young's modulus 2.0 x 10^{11} Nm^{-2}. The stand-top consists of a uniform square board of side 1.0 m long. The four legs are fixed at the corners of the board as shown in the figure. Assume that the stand has **negligible mass.**

(i) Keeping a weight at a suitable location on the stand, the stand-top can be made horizontal by compressing the **long leg alone** so that the stand on longer wobbles.

(1) Where do you keep the necessary weight on the stand?

(2) Find the weight thus required.

(ii) Instead of the weight used in (i) another weight of 4000N is placed on the stand to compress **all four legs** so that the stand-top becomes horizontal and the stand does not wobble.

(1) Find the decrease in length of each leg.

(2) Find the reaction on each leg by the floor.

(3) Where do you keep the weight?