G.C.E. (Advanced Level) Examination - April 2004

PHYSICS - II

Three hours

PART A - Structured Essay

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

01.

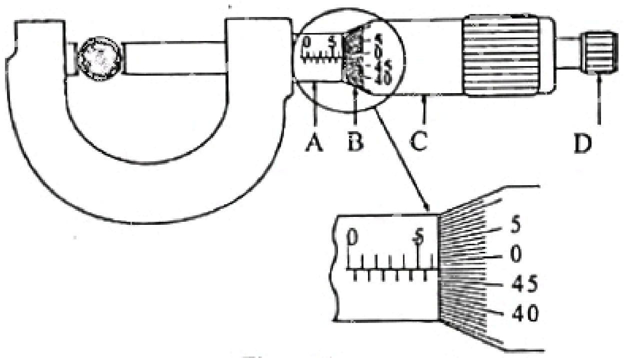


Figure 1

(a) Name the parts of the micrometer screw gauge labelled as *A, B, C*, and *D* in figure 1.

(i) A .... (ii) B ....
(iii) C .... (iv) D ....

(b)(i) What is the least count of the above micrometer screw gauge in mm?

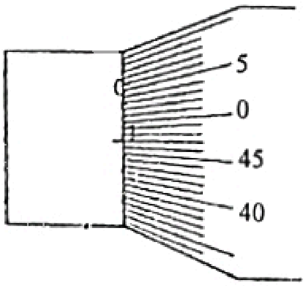
.... mm

(ii) Write down the scale reading for the diameter of the ball shown in figure 1 in mm.

.... mm

(iii) Figure 2 shows a situation in which the micrometer screw gauge is adjusted to determine the zero error.

Figure 2



State the correct value for the diameter of the ball in mm

.... mm

(iv) Write down the fractional error of the measurement for the diameter of the ball (numerical simplification is **not** neces sary.)

....

(v) What is the precaution taken in the micrometer screw gauge to avoid over-pressing the object?

....

....

(c) A wire of circular cross section (length $l \simeq 55$ cm and diameter $d_1 \simeq 4$mm) is fixed to a disk (diameter $d_2 \simeq 5$cm and thickess $t \simeq 3$mm) as shown in figure 3. Magnitudes given in parentheses are approximate values.

(i) Of the measuring instruments, metre rule, spherometer, vernier callipers, and the micrometer screw gauge, write down the most suitable instrument for the measurement of each of the above quanitites.

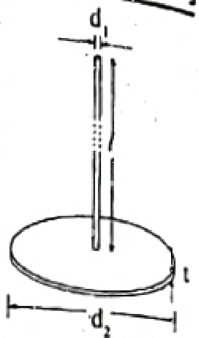


Figure 3

Measurement	**Instrument**
l	....
d_1	....
d_2	....
t	....

(ii) What experimental procedure would you follow to obtain a better value for the thickness of the disk?

....

....

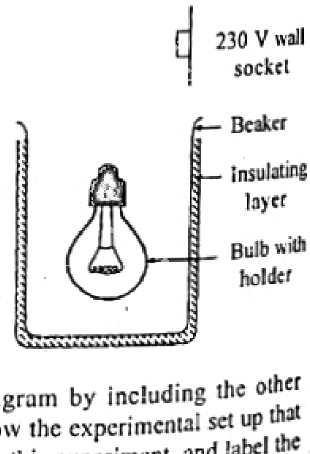
(d) The thickness of a certain type of polythene sheet is much smaller than the least count of a micrometer screw gauge. Propose a method to estimate the thickness of a sheet using a micrometer screw gauge.

....

....

....

02. Figure showe some of the appartus provided to you to experimentally determine the electric power dissipated as heat from a 230V, 25W fila ment bulb. You are asked to use water to collect heat given out by the bulb.



(a)(i) Complete the above diagram by including the other required apparatus, to show the experimental set up that you would use to perform this experiment, and label the items.

(ii) Mark on the diagram the level up to which you fill water.

(b) Give **two** reasons as to why it is advantageous to use a small beaker in this experiment.

(1) ....

(2) ....

(c) Give a list of apparatus needed to take measurements in this experiment.

....

....

(d) When this experiment was performed with a 230V, 25W filament bulb, the temperature of water was found to increase from 28°C to 37°C in 10 minutes. Mass of the water used was 240g. Estimate the electrical power that was transferred to water as heat (specific heat capacity of water = 4200 J kg^{-1} K^{-1})

....

....

....

(e) The value obtained in (*d*) above may not be exactly equal to the power dissipated as heat from the bulb. Give two possible modes of heat loss which are not taken into account in this experiment.

(1) ....

(2) ....

(f) Certain manufacturers indicate a maximum power rating for electric lamp shades. Briefly explain the reason for this.

03.

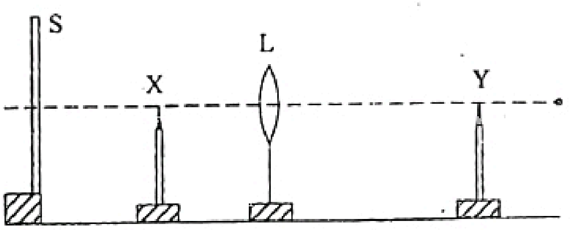


Figure 1

Figure 1 shows a schematic diagram of a **properly** arranged experimental set up used by a student to determine the focal length of a convex lens *L*. In this experiment the position of the real image of pin *X* is found with the help of pin *Y*.

(a) What is the advantage of having the screen *S*?

....

(b) (i) Figure 2 shows the field of view (with the pin *Y*) that the student sees when he keeps his eye at point *E* on the principal axis of the lens to observe the real image of *X*. (The image of *X* is not shown.) Draw the image of *X* on figure 2.

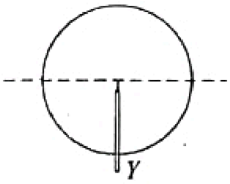


figure 2

(ii) If the student moves his eye sideways observing the movements of *Y* and the image of *X*, what will he see when

(I) the image of *X* is **not** formed at the position of *Y*?

....

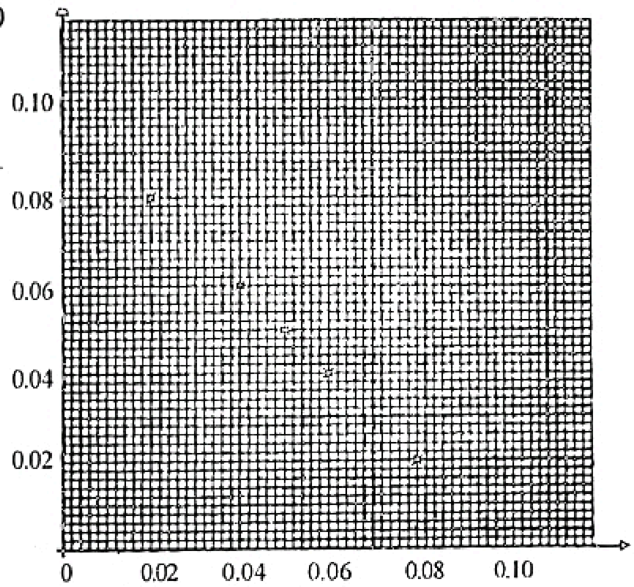
(II) the image of *X* is formed at the position of *Y*?

....

(c) Write down the relationship among the object distance *U*, image distance *V* and the focal length *f* of the lens, for this experiment, after applying the sign convention to the lens equation.

....

(d)



The student recorded *U* and *V* in cm and plotted the graph shown, with properly selected axes, to determine the focal length of the lens. Note that the student used the values recorded in cm to draw the graph.

(i) Label the axes of the graph.

(ii) Detemine the focal length of the lens *L*.

....

(*e*) For a certain position of *X*, a virtual image is observed by the student. He decided to find the position of this virtual image using a plane mirror.
By drawing in fiure 1, show how he should place the plane mirror and the pin *Y* for this. Label the plane mirror as *M* and the new position of *Y* as *Y'*.

04.

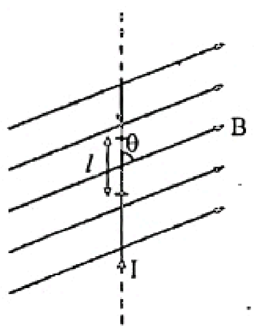


Figure 1

A straight wire carrying a current *I* is placed in a uniform magnetic field of flux density *B*, as shown in figure *1*. The angle between the dirctions of the magnetic field and current is θ.

(a) (i) Write down an expression for the magnitude of the magnetic force *F* acting on a length *l* of the wire in terms of *I*, *B*, *l* and θ.

....

(ii) Write down the rule that gives the direction of the magnetic force (for the case θ = 90°).

....

....

....

....

(b) Now the above wire is bent to form a rectangular coil *PQRS* of *N* turns and of length *a* and breadth *b*. This coil is placed in a uniform magnetic field of flux density *B* as shown in figure 2. The angle between the plane of the coil and the direction of *B* is *a*. *A* current *I* is passed through the coil.

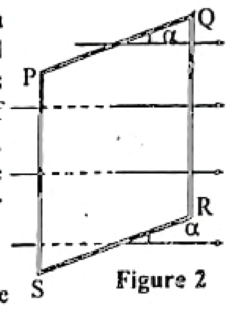


Figure 2

(i) Write down expressions for the magnetic forces acting on the arms *PS* and *QR* of the coil at the instant shown in figure 2. and hence derive an expression for the magnitude of the couple acting on the coil in terms of N, I, B, a, and the area A of the coil.

....

....

....

(ii) The couple due to the magnetic forces on the arms. PQ and RS is zero. Explain the reason for this.

....

....

(c) Figure 3 shows a schematic diagram of a moving coil galva nometer in which the magnetic field in not shown.

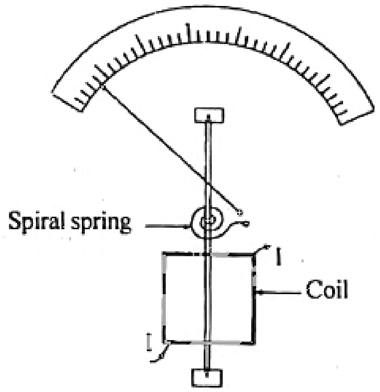


Figure 3

(i) How is the dependence of the couple on a, [mentioned in (b) (i) above] avoided in this instrument?

....

....

(ii) The galvanometer coil has N turns and area A. The flux density of the magnetic field is B and the spiral spring has a torsion constant C. When a current I is flowing through the galvanometer, the deflection of the pointer is θ.

Write down an expression relating I and θ.

....

(iii) this galvanometer has a full scale deflection of 5 mA. How would you connect an external resistor to convert this instrument into an ammeter having a full scale deflection of 5A?

....

....

(iv) If the resistance of the galvanometer coil is 20Ω, calculate the value of the resistor needed in c (iii).

....

....

....

(v) Propose a method to modify this instrument internally to measure currents in the range of μA.

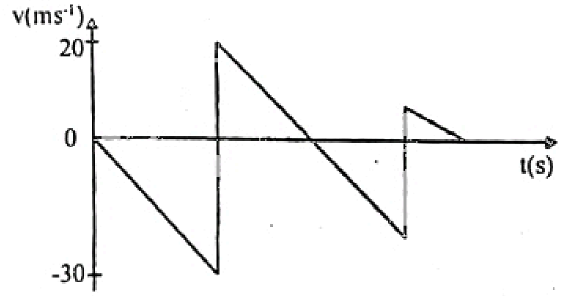
....

....

PART B - Essay

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

01. A small ball of mass 0.1 kg is dropped from rest at t = 0 onto a horizontal floor. The ball was initially at a height H from the floor, and it bounces back vertically after each and every collision. Figure shows a portion of the velocity (v) - time (t) graph of the ball.



(i) Neglecting air resistance and the upthrust, calculate the fol lowing for the ball.
   (a) The initial height H.
   (b) The change in momentum of the ball, and the momen tum transferred to the floor at the first collision.
   (c) The value of t at which the second collision occurs.

(ii) If the collision between the ball and the floor is perfectly elastic, draw the v - t graph for this motion.

(iii) A paricle of mass 6×10^{-26}kg in an empty cubical box of side length 1m is made to move back and forth, while making collisions with tow opposite walls of the box normally. The collisions between the particle and the walls are perfectly elastic, and the speed of the particle is 2×10^{3} ms^{-1} (As sume that the gravitaitonal force on the particle is negligible.)
   (a) Calculate the rate at which the particle collides with one of the tow wals.
   (b) What is the rate at which the particle transfers momentum to that wall?
   (c) Suppose that the box contains 2×10^{23} such particles performing the same motion mentioned above. Assume also that these particles do not make collisions among themselves, and that the collisions are uniformly distributed over the entire area of the wall.
   Calculate the pressure exerted by the particles on one of the two walls.

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

The source of any sound, including musical notes, is a vibrating object. A sound is characterized by its louderss, its pitch and also by a third property called quality. Quality of sound enables us to distinguish a given type of musical instrument from others. For example, when a note is played separately in a violin and in a flute with the same loudness and pitch, there is a clear difference between the two sounds heard. This is due to the difference in quality of sound of these two instruments. Just as loudness and pitch can be related to measurable physical quantities of the sound wave, so too can quality. Generally, when a note is played in a musical instrument, overtones are present in addition to the fundamental frequency of the sound. Quality of sound depends on the number of these overtones and their relative amplitudes.

Figure 1 shows a sound pattern of a note produced by a violin. It indicates the variation of the total amplitude of the sound produced by this instrument with time. Figure 2 shows the 'Fourier spectrum' of this sound patterm giving the frequencies of its fundamental and the overtones, and their relative amplitudes. The Fourier spectrum is generated from the sound pattern using a mathematical technique called Fourier Analysis. In contrast to the musical notes, sounds which are normally called noise have nearly continuous Fourier Spectrum than discrete specter.

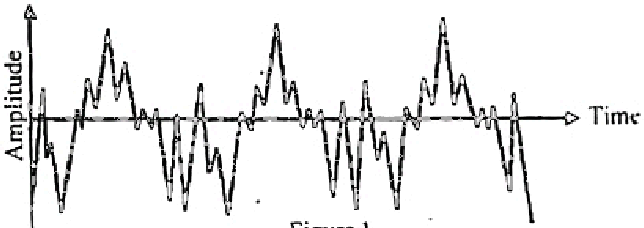


Figure 1

Today we have electronic organs that can reconstruct music produced by any musical instrument available to us. For such reconstructions, first the Fourier spectra of the musical notes must be obtained. After that, it is possible to electronically generate an electric wave pattern for each note by mixing electrical signals having fréquencies and their corresponding rela tive amplitudes present in the fourier spectrum. These electrical wave patterns can then be converted to sound wave patterns. All these can be done with near perfection using digital tech niques.

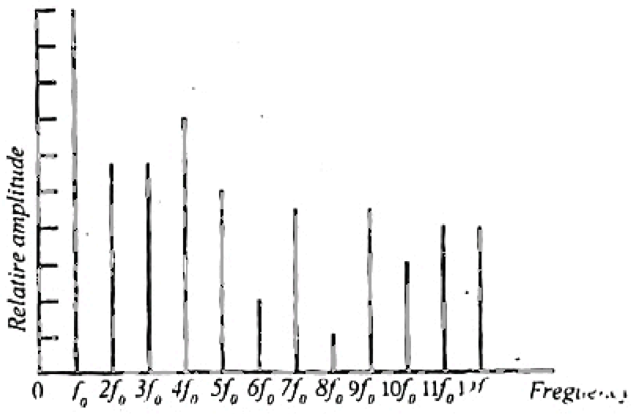


Figure 2

In standard musical instruments, the source is set into vibration by striking, blowing, plucking or bowing. Among the common musical instruments, the drum has a membrane that vibrtes when struck. The flute and trumpet make use of vibrating columns of air to produce musical notes. Flute can be considered as a tube with both ends open. When the flute is played the air inside it resonates.

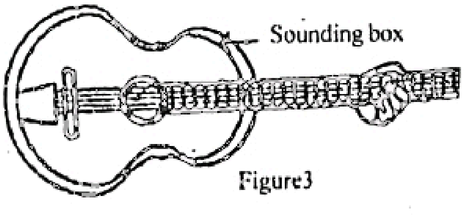


Figure3

Violin, guitar and piano all have vibrating stretched strings. In guitar, different musical notes are obtained by varying the vibrating length of a string fingers, and the guitar has several such strings to produce all required notes. In piano, there is a separate string for each note. In general, the mechanical vibrations in thin strings do not produce sounds loud enough to be heard directly. In stringed instruments, therefore, a sounding box is used (figure 3) to amplify the sound. When steings are set into vibration, the sounding box resonates with the same sound pattern producing a much stronger sound. However, in electric guitars, mechanical vibration of a string is converted to an electrical signal which is subsequently amplified electronically.

(i) What physical property of the sound wave determines the loudness of a sound?

(ii) What physical property of a sound wave is associated with the pitch of the sound?

(iii) The fundamental frequency f_0 of the Fourier spectrum of the violin, shown in figure 2, is 400Hz.

(a) What is the frequency of the 3rd overtone produced of the violin?

(b) What is the value of $\frac{\text{amplitufe of the 5th overtone}}{\text{amplitude of the fundamental frequency}}$?

(iv) A note produced by a musical instrument has a fundamental frequency at 420Hz, and the first and second overtones each having an amplitude equal to one half of that of the fundamental. Assuming that no other overtones are present, draw the Fourier spectrum of the note.

(v) State the steps that should be taken to electronically generte the sound described in (iv) above.

(vi) Electronic guitars have no sounding boxes. Give the reason.

(vii) Write down an expression relating the length l, tension T, mass per unit length m and the fundamental frequency f_0 of a vibrating stretched string.

(viii) A 0.68 m long guitar string is tuned to play a note of fundamental frequency 330Hz when unfingured. How far from the end of this string must the finger be placed to play a note of fundamental frequency 440Hz.

(xi) A flute is designed to produce a note of fundamental frequency 262Hz when played at a temperature of 27°C, with all the holes closed.

(a) If the speed of sound in air at 27°C is $340 ms^{-1}$, calculate the approximate length of the flute.

(b) If this fiute is platyed, with all holes closed, in a place where environmental temperature is -30°C, what will be the fundamental frequency of the sound?

03. A particle of charge $+q$ and mass m is moving along the positive x direction in a vacuum where the electric field is zero. This particle then enters at $x = 0$ a uniform electric field of intensity E extended over a large region, with velocity v as shown in figure 1. The electric field is directed along the negative x direction. Describe qualitatively the motion of the particle after entering the electric field. (Neglect the effects of gravity.)

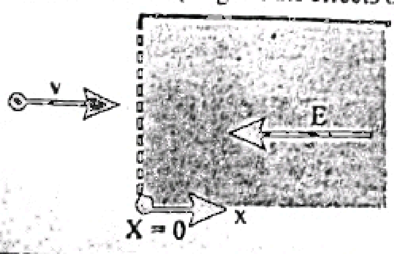


Figure 1

Two particles P and Q each of charge $+q$ and mass m, start to move at time $t = 0$ in a vacuum simultaneously with two initial velocities v_1 and v_2 respectively, ($v_1 > v_2$) along the positive x direction from two points corresponding to $x = 0$ as shown in figure 2.

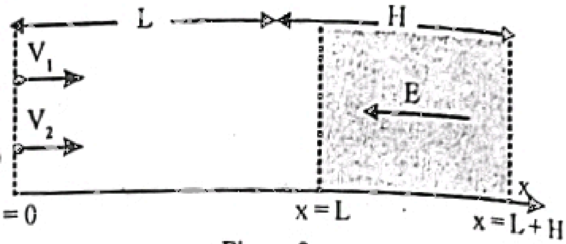


Figure 2

(i) If the two particles travel in a field free region from $x = 0$ to $x = L$, obtain an expression for the separation d between the two particles, at the instant when the faster particle reaches $x = L$.

(ii) At $x = L$, the two particles enter a uniform electric field of intensity E directed along the negative x direction. If the electric field is extended from $x = L$ to $x = L + H$, as shown in figure 2, obtain an expression for the minimum value E_M of the intensity of the electric field required to turn both particles back and make them travel in the negative x direction.

(iii) Now consider a situation where E is greater than E_M

(a) Obtain expressions for the times, t_P and t_Q, spent by the particles P and Q respectively in the electric field.

(b) When the intensity of the electric field E is equal to a certain value E_0, both particles P and Q, which had entered the electric field at different times due to the difference in initial velocities at $x = 0$, leave the electric field at $x = L$ simultaneously. Write down an expression relating E_0 to other relevant parameters given above.

04. Write down poiseuille's equation for the flow of a viscous liquid through a tube, identifying the symbols.

(i) State two of the conditions under which Poiseuille's equation is valid.

(ii) Suppose that the radius of cross section of the tube is r, the pressure difference across the tube is ΔP, and the volume rate of flow is Q.

(a) Write down an expression for the resultant force acting on the liquid in the tube due to this pressure difference ΔP.

(b) The average speed v of the liquid through the tube is given be $v = h \frac{\theta}{\pi r^2}$. Show that this equation is dimensionally correct.

(c) Hence show that the rate of work done by the pressure difference against the viscous force is $Q\Delta P$.

(iii) Poiseuille's equation is often used for approximate calculations of blood flow in human body.

(a) State two reasons why Poiseuille's equation is not strictly valid for blood flow through vessels in human body.

(b) If the average rate of blood flow through a horizontally situated artery with uniform cross section having radius 2mm, and length 20cm is $2.5 cm^3 s^{-1}$, calculate the pressure difference between its two ends. (Average viscosity of blood at body temperature is $4 \times 10^{-3} Nsm^{-2}$)

(c) Suppose the radius of cross section of the above artery has decreased to half the original value due to fat deposition.

(1) By how many times will the pressure difference across the artery have to be increased in order to maintain the same rate of blood flow mentioned in (iii) (b) above?

(2) by how many times will the rate of work done by the heart against viscous force have to be increased to maintain the same rate of blood flow as mentioned in (c) (1)?

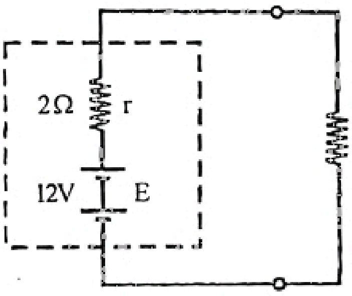
(d) Sometimes doctors prescribe drugs that reduce blood viscosity, to patients having high blood pressure. Briefly explain how such drugs bring relief to patients.

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

(a) The battery in the circuit shown has an e.m.f. (E) of 12v and an internal resistace (r) of 2Ω.

(i) Find the power (P) transferred by the battery to the resistance R in each of the following cases.

(a) $R = 1Ω$ (b) $R = 2Ω$, (c) $R = 3Ω$,
(d) $R = 0$ and (e) R is infinite.



(ii) Hence draw a rough sketch to show how power P varies with resistance R.

(iii) Write down the relationship between r and R when the power transfer from the battery to R is maximum.

(iv) The above mentioned battery is used to light a set of 6V, 0.36W bulbs at the recommended rating.

(a) find the maximum number of bulbs that can be connected to the battery for this purpose.

(b) Draw a circuit diagram to show how you would connect the bulbs to teh battery.

(v) (a) The battery is rated as 90 ampere-hours. This indicates that when it is fully charged, it can deliver a current of 1A for 90 hours, or 2A for 45 hours, and so forth.

For how long the above mentioned battery can provied power to the maximum number of bulbs calculated in part (iv) (a)?

(b) If the mass of the battery is 15kg and its average specific heat capacity is $900 Jkg^{-1 0}C^{-1}$, find the maximum possible increase in temperature of the battery after lighting the set of bulbs for 30 minutes.

(b) (i) Draw a circuit diagram of a *NOT* gate built using a single npn transistor, indicating its input, output, and the power supply connection.

(ii) The circuit shown in figure 1 is made using two germanium diodes and a 1kΩ resistor.

The table under (a) below shows combinations of voltages connected to the inputs A and B of the circuit. All voltages are indicated telative to the point G. (Voltage across a forward biased germanium diode is 0.2V)

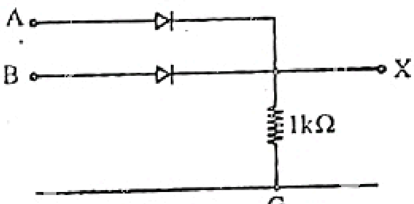


Figure 1

(a) Determine the corresponding output voltages at X and complete the following table. (**Important** : Copy the table on to your answer script.)

A (volts)	B (volts)	X (volts)
0.0	0.0	
0.0	5.0	
5.0	0.0	
5.0	5.0	

(b) Hence identify the gate and writre down its turn table.

(iii) A Student wants to design a digital circuit to turn on a battery powered lamp automatically when there is a mains electricity failure at night. In addition, the circuit must have a facility for it to be turned on at any time by pressing a button.

A block diagram of his circuit, having three inputs and one output, is shown in figure 2.

Assume that he has the means to generate the three inputs A, B and C with logic values (0 and 1) as follows.

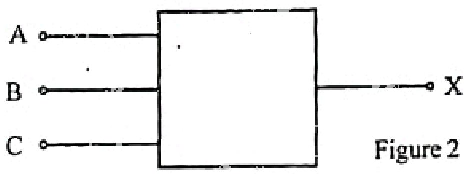


Figure 2

A = 0 when the button is **not** pressed

A = 1 when the button is pressed

B = 0 during day time

B = 1 at night

C = 0 when there is a mains electricity failure

C = 1 when mains electricity is available

The circuit is to be desined so that the lamp will be on when $X = 1$ and off when $X = 0$.

(a) Write down a logic expression for X in terms of A, B and C.

(b) Draw a circuit diagram for your expression, using basic logic gates, and label A, B, C and X.

(c) You are given a Light Dependent Resistor (LDR) having a resistance 10MΩ at dark and 100Ω at bright light, a 5V battery and an additional 100kΩ resistor.

(1) Using these items draw a suitable circuit diagram to generate the logic. values for the input B.

(2) Calcuate the voltage provided by this circuti, for B when dark.

(b) Will the lamp function properly if the circuit is installed in a place where the light dependent resistor is exposed to the lamp itself? Briefly explain your answer.

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

(a) A rubber balloon is filled upto a volume of $4.2 \times 10^{-2} m^3$ with helium gas at 7^0C. The balloon is then held until the tem perature of the gas inside the balloon reaches the outside temperature, which is at 27^0C.

(i) Assuming that the pressure inside the balloon remains the same, find the final volume of the balloon.

(ii) When the balloon is released, it climbs to a height at which the **outside** temperature is 2^0C, when the inside temperature of the ballon reaches 2^0C its inside pressure becomes $\frac{2}{3}$ of that at the groind level. Find the new volume of the balloon.

(iii) While remaining at this height, the balloon enters into a region of low pressure (air pocket) which is also at 2°C. Consider the balloon entering this region under following conditions.

(a) Very slowly (b) Suddenly

Answer the following questions *separately* for the above two situations (*a*) and (*b*).

(1) What happens to the temperature of the gas inside the balloon?

(2) During this process, does the gas inside the balloon absord heat from the surrounding or give out heat to the surrounding?

(3) How does the gas inside the balloon get energy to do work?

(c) In the situation (iii) (a) above, if the pressure inside the balloon reduces to $\frac{1}{3}$ of that at the ground level, find the new volume of the balloon.

(d) Sketck a *P* - *V* diagram for the process in part (iii) (*c*) above.

(b) The intensity (*I*) of the radiation emitted by a black body at a temperature $T = 4000K$ as a funcition of wavelength (λ) is shown in figure 1. The peak of the distribution is at a wavelength (λ_p) = 724.5nm.

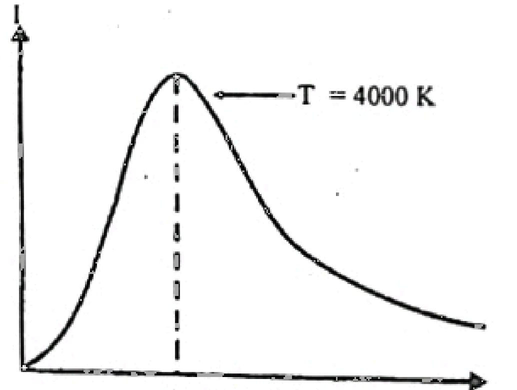


Figure 1

(i) What does the area under the curve shown in figure 1 represent?

(ii) Calculate the energy of a photon having a wavelength $\lambda = 724.5nm$.
Planck's constant $h = 6.63 \times 10^{-34}Js$ and speed of light $c = 3.0 \times 108ms^{-1}$.

(iii) (a) The wavelength λ_p corresponding to the radiation emitted by the sun is 500nm. Considering the sun to be a black body, determine its surface temperature.

(b) The radius of the sun is 7.0×10^8 m. Calculate the total energy radiated per second by the sun. Stefan constant $\sigma = 5.67 \times 10^{-8}Wm^{-2}K^{-4}$.

(c) Consider a distant star, barely visible to the naked eye at night and having properties similar to those of the sun. If the threshold of dark-adapted vision of the eye at wavelengths near 500nm is $4.0 \times 10^{-11}Wm^{-2}$, and 40% of the total radiation emitted by the star is in the near 500nm region, calculate the approximate distance to the star from the earth.

(iv) Figure 2 shows the intensity distribution of the light emitted by a firefly. The wavelength λ_p corresponding to the peak of the distribution is 570nm. Determine the temperature of a black body that would emit the radiation peaked at the same wavelength.
Hence conclude, giving reasons, whether the radiation emitted by the firefly can be considered as black body radiation.

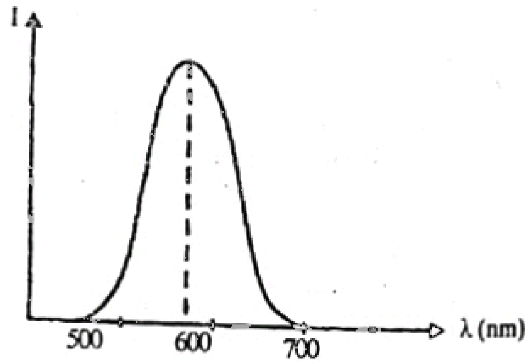


Figure 2