G.C.E. (Advanced Level) Examination - August 2013

PHYSICS - II

Three hours

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

01. You are asked to determine the density of a given oil experimentally using Archimedes' principle. A set-up consisting of a **thin walled** glass test tube containing the oil, and a transparent glass vessel with water as shown in figure is provided to perform the experiment.

The test tube floats in up-right position in water as shown in the figure. A coloured ring is clearly marked around the wall of the tube at P and it can be used as a reference to measure heights. The following symbols are assigned to various parameters relevant to the set-up and use these symbols to answer the questions.

A - Area of cross-section of the tube above the ring

V - Volume of the tube below the ring

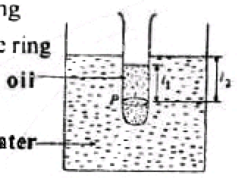
l_1 - Height of the oil column above the ring

l_2 - Height of the water column above the ring

M - Mass of the empty test tube

d - Density of the oil

d_w - Density of water (given)



(a) Writr down an expression for the weight of the oil inside the tube in terms of V, A, l_1, d, and g.

....

(b) Write down an expression for the total weight W of the test tube with the oil.

W = ...

(c) Write down an expression for the upthrust U acting on the test tube.

U = ...

(d) (i) What relationship holds between W and U?

....

(ii) In the relationship you have given in (*d*) (*i*) above, arrange the parameters in W and U, to obtain a relationship in the form $l_2 = ml_1 + c$.

....

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(iii) If a suitable graph is plotted using the relationship obtained in (*d*) (*ii*) above, how would you determine the density of oil, d, using the graph?

....

(e) The following measuring instruments are at your disposal. A half metre ruler, a vernier calliper, and a travelling microscope.

(i) Of the given instruments what is the most suitable instrument to measure l_1 and l_2? You are not allowed to change the position of the test tube.

....

(ii) How do you abtain the relevant readings to measure l_1 and l_2 using the instrument that you have mentioned under (*e*) (*i*)?

....

....

....

(*f*) If the wall of the test tube is thick instead of thin, the corresponding expression for m in the expression that you have obtained in (d) (ii) above will yield $m = \frac{A_i d}{A_e d_w}$, where A_i and A_e are internal area of cross-section and external area of cross-section, respectively of the tube above the ring.

(i) To determine A_i and A_e what measurements do you have to take?

For A_i .... (say x_i)

For A_e .... (say x_e)

(ii) How do you use proper instrument selected out of the measuring instruments given in (*e*) above, to obtain the measurements x_i and x_e?

To measure x_i : ....

To measure x_e : ....

02. An experiment has been designed to find the linear expansivity of lead by using a thin perforated lead tube, closed at both ends. The temperature of the tube is increased in steps by pumping hot air at different temperatures. The temperature of the tube is measured by means of a thermocouple. In this experiment, a student is expected to measure the increase in length that occurs in the length of the tube, with the increase of temperature, by designing and implementing a suitable methodology.

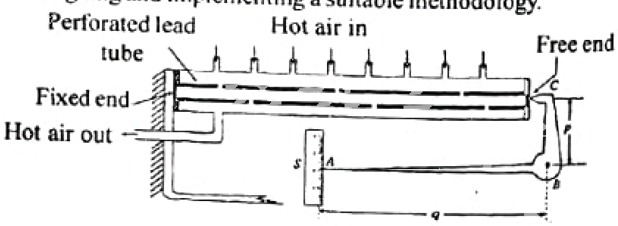

Figure (1)

(a) Let the length of the lead tube at the room temperature be l_0. The new length of the tube, when the temperature of the tube is increased by an amount θ°C from the room trmperature, is l_1. Write down an expression for the linear expasivity a of lead in terms of l_0, l_1 and θ.

....

....

(b) Student proposes to use a metre ruler for the measurement of length l_0. What is the minimum length l_0 must have in order for the percentage error of the l_0 measurement to be less than or equal to 0.2%?

....

....

....

(c) State two advantages of using a thin perforated tube in this experiment?

(1) ....

(2) ....

(d) For the measurement of increase in length $(l_1 - l_0)$ of the tube, student has designed the arrangement shown in the figure (1) above. One end of the tube touches a rigid support. ABC is a lever system pivoted at B. The end C of the lever system firmly touches the movable end of the tube and the ABC structure can rotate about the fixed pivot at B. Scale S is calibrated in **millimetres.**

Let X_0 = Reading indicated by the pointer A, on the scale S, at the room temperature, and

X = Reading indicated by the pointer A, on the scale S, when the temperature of the tube is increased by an amount θ.

Then the relationship between $(l_1 - l_0)$ and $(X - X_0)$ is given by the equation.

$$(l_1 - l_0) = \frac{p}{q}(X - X_0) \text{ ..... (1)}$$

For this arrangement, $P = 2$ cm and $q = 10$ cm.

(i) What is the minimum value of increase in length $(l_1 - l_0)$, that can be measured using this arrangement?

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....

(ii) Substitute the expression for $(l_1 - l_0)$ given is equation l in the expression you have written down for a in part (a) above and obtain a suitable equation to plot a graph of X with θ.

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(e) A graph of X plotted with θ from the reading obtained when the leneth $L = 80.0$ cm is shown in the fieur (2).

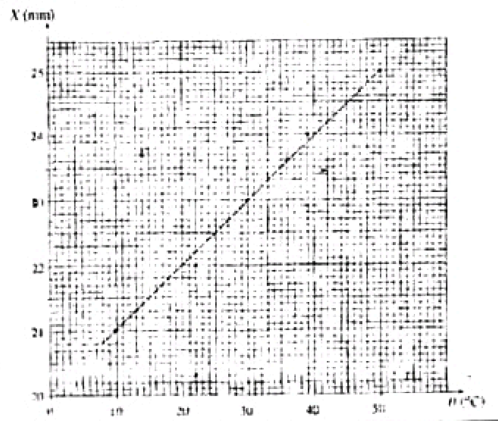

Figure (2)

(i) Find the gradient of the graph.

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....

(ii) Hence determine the linear expansivity of lead.

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....

(f) Student has chosen a material with very low thermal conductivity to construct the arm ABC. Do you agree with his choice? Give reasons.

....

....

(g) In order to reduce the error in taking readings from the scale S, student proposes to fix a narrow strip of a plane mirror (M) colse to the scale S as shown in the figure (3). After this modification, what is the step that must be followed in taking readings from the scale S?

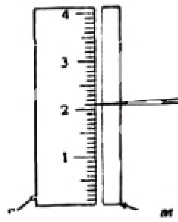

figure (3)

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03. A glass tube, a measuring cylinder with water, a metre ruler and a tuning fork of frequency (f) 512 Hz are provided to determine the speed of sound (v) in air and the end correction of the tube (e). When the glass tube is completely immersed in water and then raised gradually, resonances can be heard when the heights of the tube above the water level are l_1 = 0169 m and l_2 = 0.509 m, respectively.

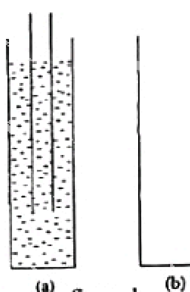


figure 1

(a) (i) Draw the wave form for the resonance heard for the first time in figure 1 (a).

(ii) Draw the tube, water level and the wave form for the resonance heard for the second time in figure 1 (b).

(iii) Clearly mark the height l_2 that you would measure in figure 1 (b).

(b) (i) Obtain an expression for the speed of sound v in terms of e, f and l_1 by considering the resonance heard for the first time.

....

....

(ii) Write down an expression for the speed of sound v in terms of e, f and l_2, considering the resonance heard for the second time.

....

....

(iii) Using the resulte obtained in (b) (i) and (b) (ii) above, obtain an expression for v in terms of l_1, l_2 and f.

....

....

....

....

(iv) Hence calculate v and e.

(c) A student suggested to use a graphical method to determine v and e taking measyrements of several resonance states of the tube with the tuning fork. Write down **two** difficulaties of different nature in preforming such an experiment to obtain sufficient number of measurements.

(1) ......

(2) ......

04. In the circuit shown in figure (1) R_1, R_2, R_3 and R_4 represent resistances and E represents the e.m.f of the cell.

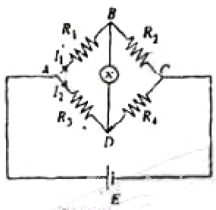


figure 1

(a) If the potential at B is same as that at D, **derive** and expression relating R_1, R_2, R_3 and R_4.

(b) The above circuit can be used to measure the value of an unknown resistor (say R_2) by replacing resistors corresponding to R_3 and R_4 with a uniform resistive wire as shown in figure (2).

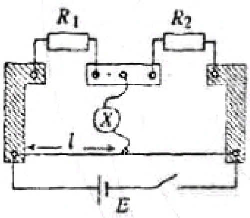


figure 1

All resistors and the resistive wire are connected using wide copper strips. The length of the resistive wire is **exactly 1m**.

What is the main reason for using wide copper strips instead of connecting wires when connecting the components?

(c) Identify the item X in the circuit **precisely**.

(d) If the unknown value of R_2 is to be determined by plotting a graph, state whether you would use a resistance box or a rheostat for R_1. Give reasons for your answer.

(e) (i) Write down an expression relating R_1, R_2 and balanced length l.

(ii) Rearrange the variables in expression given under (*e*) (*i*) above so that it is suitable to plot a graph with the reciprocal $\left(\frac{1}{R_1}\right)$ of the indepndent variable R_1 as X-axis.

(iii) How do you find R_2 from the graph?

(*f*) Give **two** reasons for not selecting R_1 values which produce small values for l.

(1) ......

(2) ......

PART B

Answer four questions on this paper itself.

$[g = 10\ N\ kg^{-1}]$

05. The vertical force (lift) required for the taking off of an airplane is provided by two forces, one arises due to the Bernoulli effect and the other due to the hitting of air molecules on the wings of the airplane. The orientation and the cross sectional view of a wing of an airplane when it is travelling along the runway for taking off are shown in the figure (1). Here the bottom surface of the wing makes an angle θ with the horizontal direction.

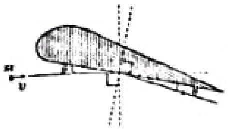


Figure (1)

Figure (2)

Figure (3)

(a) Take the speed of the airplane on the runway to be (ms^{-1}) at a certain instant and assume that air molecules remain still relative to the earth. Also assume that each air molecule has the same mass m. Consider a complete elastic collision of an air molecule with the wing. [see figure (1).] The speed of the air molecule relative to the airplane is shown in the figure.

(i) Write down an expression for the change in momentum of the air molecule in the direction **perpendicular** to the bottom surface of the wing in terms of m, υ and θ.

(ii) If the number of air molecules hitting the witg during one second is N, using the result in (a) (i) above obtain an expression for the **vertical** force generated by collisions of air molecules on the with in terms of m, υ, θ and N.

(b) When the airplane is moving, a wing sweeps an effective cross-sectional area A [figure (2)], and therefore molecules in a volume $A\upsilon$ hit the wing during one second period. Let the density of air be d.

(i) Write down the total mass of air molecules hitting the wing during one second in terms of A, υ and d.

(ii) Hence express N in terms of A, υ, d and m.

(iii) Obtain an expression for the total vertical force (take as F_c), generated due to the collisions of air molecules on **both wings** in terms of A, υ, d and θ.

(iv) If $\theta = 10^o$, $A = 25\ m^2$ and $d = 1.2\ kg\ m^{-3}$ obtain the value of F_c in terms of υ.
(Take $\sin\theta = 0.2$ and $\cos\theta = 1$ for $\theta = 10^o$)

(c) (i) Assume that, because of the shape of the wing, the average speeds of the air streams relative to the airplane just above and just below the wing are $\frac{7\upsilon}{6}$ and $\frac{5\upsilon}{6}$ respectively. Taking P_1 to be the pressure just above the wing and P_2 to be the pressure just below the wing [figure (3)], show that the pressure difference across the wing due to the Bernoulli effect is given by

$$(P_2 - P_1) = \frac{2}{5}\upsilon^2.$$

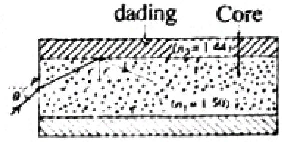
(ii) If the effective surface area of one wing is $120\ m^2$, find the total vetical force on both wings (Say F_b) due to the above pressure difference, in terms of υ.
(Assume $\cos 10^o = 1$)

(d) If the mass of the airplane is 4.32×10^4 kg, calculate the minimum speed required for the plane to take off.

(e) The maximum possible acceleration of the airplane on the runway is $0.9 m\ s^{-2}$. Assuming that the airplane accelerates uniformly, calculate the minimum length the runway must have for taking off.

(f) Pilots take off airplanes by accelerating against the direction of wind, whenever possible. Explain the reason for this.

06. In modern world optical fibres are used in numerous fields such as telecommunication and medicine. Figure (1) shows a crosssection of an optical fibre known as a 'step-index' fibre.



The inner part of the fibre known as the core in made of a transparent material of refractive index 1.50 and the outer layer of th fibre known as the cladding is made of another transparent material of refractive index 1.44.

(a) As shown in figure (1) a monochromatic ray of light travelling in air and entering one end of the fidre with an angle of incidence θ is refracted into the core. Then the ray is incident on the core-cladding interface at an angle corresponding to the critical angle C of that interface.
[sin 160 = 0.28; sin 25° = 0.42, sin74° = 0.96]

(i) Calculate the value of C

(ii) Hence calculate the value of θ

(iii) Find the range of values θ must have for the ray to be totally internally reflected from the core-cladding interface and transmit along the fibre.

(iv) Write down an important advantage of using such fibres in telecommunication.

(v) Draw the paths of emergent rays from the other end of the fibre for (1) odd number of reflections and (2) even number of reflections.

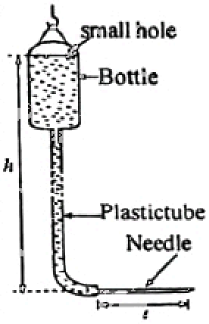
(vi) Copy the figure (1) onto your answer sheet with the existing incident ray and show the complete path of a ray incident at P and subsequently falls at the core-cladding interface but **does not** undergo total internal reflection.

(b) Two short red and blue light pulses are sent into one end of a straight optical fibre of 3km length simultaneously and perpendicular to it. Calculate the time interval between the red blue light pulses when emerging at the other end. The speed of light in air is $3.00 \times 10^8\ m\ s^{-1}$ and the refractive indices for blue and red light are 1.53 and 1.48 respectively.

(c) (i) To transmit light signals more efficiently some optical fibers are made so as to decrease its refractive index gradually and continuously from the middle (axis) of the fibre to the outer surface of the fibre. This type of optical fibre is called a 'graded-index' fibre. Draw the path of a monochromatic light ray transmitting along such a fibre in a span of two total internal reflections.

(ii) If the incident ray consists of blue and red colours instead of being monochromatic, will they travel along the same path inside the fibre? Explain your answer with a help of a diagram.

07. Treatment procedures adapted in hospitals very often require infusion of fluids such as saline, antibiotics, insulin, etc. into the venous sxstem of patients, over a long period of time. A common method used for this is to allow the fluid to be infused to the patient under the gravity. Here, the fluid to be infused is included in a bottle, and a metal needle in the form of a thin tube is connected to the bottle by a plastic tube as shown in figure (1). The fluid is allowed to be infused by inserting the needle to a vein of the patient.



(a) Suppose that it is required to infuse a saline solution to a patient using the set-up shown in figure (1).

(i) If r = Internal radius of the needle; l = Length of the needle; Q = Volume flow rate of the saline solution through the needle; η = Viscosity of the saline solution; ΔP = Pressure difference across the needle, write down an expression for ΔP in terms of r, l Q and η, when the needle is placed horizontally.

(ii) When a needle with $r = 2 \times 10^{-4}$m and $l = 3 \times 10^{-2}$ m is used, the volume flow rate through the needle, before it is inserted into the patient is $Q = 1.5 \times 10^{7}$ m^3 s^{-1}. Calculate the height h shown in figure (1) under these conditions. You are also provided with the following data.

Density of the saline solution
$= 1.2 \times 10^3$ kg m^{-3} ; $\eta = 2 \times 10^{-3}$ Pa s. Take $\pi = 3.0$.

(iii) If it is desired to maintain the **initial** volume flow rate through the needle at the same value given in (a) (ii) above, after inserting the neelde into a place where the venous blood pressure of the of the patient is 3×10^3 N m^{-2} over and above the atmospheric pressure, by how much the height h must be increased?

(iv) If the length of the saline bottle is 0.2 m, by how much the volume flow rate through the needle will change when a completely filled saline bottle becomes almost empty?

(v) Hence, find the average value of the volume flow rate through the needle.

(vi) If a saline bottle contains $1.10^4 \times 10^{-3}$ m^3 of saline solution, using the result obtained in (a) (v) above, find the time taken for the infusion of one bottle of saline completely to the patient.

(b) Infusion under the gravity is not a very good method when it is crucial to maintain a constant rate of infusion. In this situation use of infusion machines is appropriate. A schematic diagram of the relevant section of such an infusion machine is shown in the figure (2).

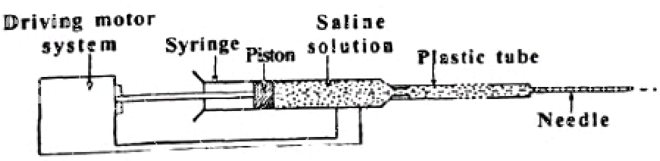


figure (2)

Here the fluid is filled to a syringe and is pressed using a piston which can be moved very slowly by a controllable motor system. Consider that the needle described in (a) (ii) above is connected to this machine horizontally as shown in the figure. The machine is used to infuse the saline solution to the patient as described in (a) (iii) above with the same volume flow rate of $Q = 1.5 \times 10^{-7}$ m^3 s^{-1}.

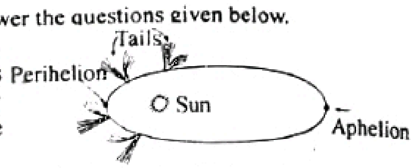
(i) If the internal cross-sectional area of the syringer is 1.2×10^{-3} m^2, how fast the piston must be moved?

(ii) Assuming that the pressure differences of the saline solution across the syringe and the plastic tube [see figure (2)] are negligibly small calculate the constant force exerted by the piston on the saline solution.

(iii) calculate the rate of work done by the driving motor systen on the piston.

08. Read the passage and answer the questions given below.

Comets are small astronomical objects typically moving in highly elliptical ordits around the sun. [see figure (1).]



Some orbits extend roughly one light-year beyond the planetary system. The main force acting on the comet is the gravitational attraction to the sun. The main components of a comet are the nucleus, coma and tails. While the solid body of the comet, the nucleus, is generally less than 50 km in extent, the coma may be larger than the sun, and the tails can extended over 150 million kilometres.

Comets mainly, compose of frozen carbon dioxide, methane, water (ice) with dust, and various types of minerals. When the comet reaches the inner planets and moving closer to the sun, its outer layer gets evaporated due to the radiation pressure from the sun. The dust and gases released from it form the extended atmosphere of the comet around its nucleus and is called the coma. The solar radiation pressure and the solar wind acting on the coma produce a bluish colour tail of ions which is straight and directed away from the sun as the gas is more strongly affected by the solar wind. The dust released from the comet forms another white coloured and slightly curved tail behind the comet.

The speed of the comet varies from its minimum value at furthest point from the sun (aphelion) to the maximum value at the closest point to the sun (perihelion). For example, the Halley's comet of mass 2.0×10^{14} kg at the aphelion which is at adistance of 5.0×10^{12} m from the sun, acquires its lowest speed of 12.0 km s^{-1}.

Debris those enter the atmosphere from the outer space are known as meteoroids. Most meteoroids burn out emitting light in the atmosphere due to heat generated through the friction with the expense of their kinetic energies, both linear and rotational. They are called meteors. When the Earth's atmosphere crosses the debris left along the path of a comet, meteor showers could be observed. Some meteoids fall onto the Earth's surface and they are called meteorites.

When a meteoroid is rapidly reaching its melting point, it becomes incandescent. When the surrounding atoms become ionized and rapidly recombined with the electrons causing the emission of light, the meteoroid produces a huge spherical air mass, appearing as a fire ball. Some meteoroids seen as fire balls could explode into several pieces of meteors. Seconds after seeing the explosion, the shock waves produced by the fragments of the meteoroid could reach the ground making ground-breaking sonic booms as heard in the recent event in Russia.

(*a*) What are the main components of a come?

(*b*) Write down three main differences between the two types of tails of a comet.

(*c*) Calculate the gravitational force acting on the Hallry's comet when it is at aphelion.

(Mass $\frac{3}{5}$ of the Sun = 2×10^{30} kg, $G = 6.7 \times 10^{11}$ N m^2 kg^{-2})

(*d*) Find the speed of the Halley's comet when it is located at perihelion where its distance from the sun is 8.0×10^{10}m.
Note : The velocity of the comet is perpendicular to radial direction at both perihelion and aphelion. Assume that the mass remains undhanged.

(*e*) Why meteor showers are produced when the Earth's atmosphere crosses an orbit of a comet?

(*f*) What is the difference between meteors and meteorites?

(*g*) What energies are converted to heat energy in burning meteorids?

(*h*) What is the mechanism that generates the light for a meteoroid to appear as a fire ball?

(*i*) A meteoroid falling vertically downward with a speed of 200 m s^{-1} explodes into two pieces. If one piece having a mass of the meteoroid travels in the horizontal direction with the speed of 600 m s^{-1}, find the speed of the other piece.

(*j*) What should be the condition that must be satisfied by the speed of a piece of meteoroid to create a shock wave?

(*k*) Explain the formation of a shock wave using a diagram.

09. Answre either part (A) or part (B) only.

(A) The box P shown in the figure (1) comprises a complex electrical circuit containing only cells and resistances.

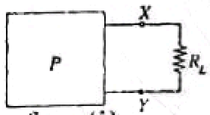


figure (1)

Assume that the entire circuit inside the box can be replaced with a series combination of a single cell with an e. m. f. E and a single resistance R_0 as shown in figure (2).

(a) Write down an expression for the current I drawn from the circuit in P when an external resistance R_L is connected across the terminals XY in figure (2) in terms of E, R_0, and R_L.

Values of E and R_0 mentioned above can be determined exprimentally be using the two methods indicated under (b) and (c) below.

(b) After removing the resistance R_L the voltage across the terminals XY is measured with a voltmeter having an internal resistance very much greater than R_0. Let the voltmeter reading be V_0.

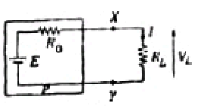


figure (2)

Then the terminals XY are short circuited for a short time and the current in the circuit is measured by an ammeter with negligible internal resistance. Let the ammeter reading be I_s.

Use the results obtained above to write down expressions for E and R_0.

(c) In order to find values of E and R_0 using the second method, two resistors having different values are used for R_L in figure (2), and the voltages V_L across R_L are measured with a voltmeter having an extremely high internal resistance compared to R_L values. Set of values obtained in such a measurement is given below.

When R_L = 1 kΩ, V_L = 75 mV
When R_L = 100kΩ V_L = 5 V

Use the above measurements and calculate E and R_0.

(d) (i) In general if R0 is extremely large compared to R_L, show that the current I in the circuit is almost independent of the value of R_L and it depends only on E and R_0. You may use the expression obtained for I under part (*a*) above for this. (Under this condition the circuit in P consisting of E and R_0 can be treated as a constant currant source)

(ii)If the voltage appearing across R_L under the conditions mentioned in (d) (i) above is V_L, draw a rough sketch to show how the current I varies with V_L. (Use V_L for x - axis.)

(e) Part of the output I - V characterictic of an npn transistor [see figure (3)] connected in the common emitter mode is almost similar to the rough sketch that you have drawn in (*d*) (ii).

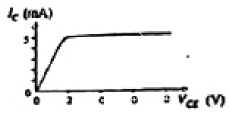


figure (3)

From this what can you infer about the magnitude of the resistance between the collector and the emitter of the transistor? Briefly explain your answer.

(B) A step-down transformer produces an output voltage of 18 V (peak value) from a 240 V, 50 Hz ac mains voltage.

(a) Draw a circuit diagram of a bridge rectifier connected to the appropiate terminals of the above transformer.

(b) Draw the voltage waveforms formed across a resistor connected across the outputs at the following output stages. Label the axes of the graphs and clearly mark the peak values of the voltage (in volts) and the period of the waveforms (in seconds). Assume that silicon restifier diodes used in the rectifier have a forward bias voltage of 1 V.

(i) Transformer output

(ii) Rectifier output (without smoothing capacitor)

(iii) Rectifier output with the smoothing capacitor. Show the capacitor connection in the circuit, that you have drawn under (*a*).

(iv) Output after connecting a zener diode to regulate the voltage. Show the zener diode connection in the circuit that you have drawn under (*a*).

(c) (i) What is the advantage of choosing a large capacitance value for the smoothing capacitor than a small value?

(ii) When the smoothing capacitor is in place what is the maximum reverse-bias voltage that can appear across a diode?

(d) If the zener diode used in (b) (iv) above has following specifications, colculate the value of the safety resistor that has to be used in order to safeguard the zener diode.

Zener voltage = 10 V

Maximum permissible current through the zener diode = 200 mA

(Use the relevant peak values for your calculations.)

(e) A student has decided to use the rectifier sircuit with the smoothing capacitor (but without zener regulation) as the dc power supply which is necessary to operate a common emitter amplifier.

(i) Draw a circuit diagram of a common emitter amplifier.

(ii) State changes that you would expect in voltages at the base and at the output of the amplifier due to the voltage variation (ripple voltage) of the power supply.

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

(A) Starting from ideal gas equation derive an expression for the density (ρ) of an ideal gas in terms of pressure (P), molar mass (M), absolute temperature (T) and universal gas constant (R).

As shown in figure (i) a volume of 1.0 m^3 of air at atmospheric pressure (1.0×10^5 Pa) and temperature 27^{0}C (point A of the P - V curve). is compressed adiabatically to a pressure of 1.5×10^5 Pa and temperature of 64.5 ^{0}C (point B of the P-V curve).

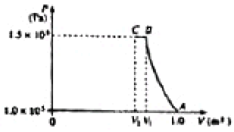


figure (1)

Then the air is cooled to the initial temperature of 27 ^{0}C under a constant pressure of 1.5×10^5 Pa (point C of the P - V curve).

[Assume that air behaves as an ideal gas; the molar mass of air $= 3.0 \times 10^{-2}$ kg mol^{-1}; R = 8.31 J k^{-1} mol^{-1}; take $\frac{1}{8.31} = 0.12$]

(a) Calculate the densities of air (i) at point A, (ii) at point B, and (iii) at point C.

(b) Calculate (i) volume V_1 of air at point B, (ii) volume V_2 of air at point C. (Give your answers to the nearest second decimal place.)

(c) Assuming the adiabatic curve to be linear, the above P - V diagram could be redrawn as shown in figure (2). During the compression process of air from A to B, calculate the following.

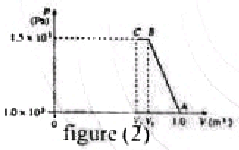


figure (2)

(i) Work done by air

(ii) The change in the internal energy

(d) During the compression process of oir from B to C, calculate the following.

(i) Work done by air.

(ii) The amount of heat given out from air.

(e) A process similar to the process shown in figure (1) takes place in some vehicle engines. The power output of an automobile engine is directly proportional to the mass of air that can be drawn into the engine to mix with a given mass of fuel. These vehicles have a unit called 'turbocharger' which compresses the air before it enters the engine, giving a greater mass of air per unit volume. This rapid, adiabatic compression heats the air. [Process A to B shown in figure (1).] To compress it further, the air is then passed through a unit called 'intercooler' in which the air gives out heat at constant pressure. [Process B to C shown in figure (1).] The air is then drawn into the engine.

Compared to the power output of an engine that takes in air at a pressure 1.0×10^5 Pa at 27^{0}C, what percentage increase in power output can be obtained by using the 'turbocharger' and 'intercooler'?

[Hint : use the results obtained in (a) (i) and (a) (iii) above.]

(B) A photosensitive surface is illuminated by radiations of wavelength λ.

(a) (i) Write down the Einstein's photoelectric equation relating the maximum kinetic energy (K_{max}) of the ejected photoelecrons to λ and the work function (ϕ) of the photosensitive material.

(ii) Obtain an expression for ϕ in terms of the threshold wavelength (λ_0) of the photosensitive material.

(b) Intensity

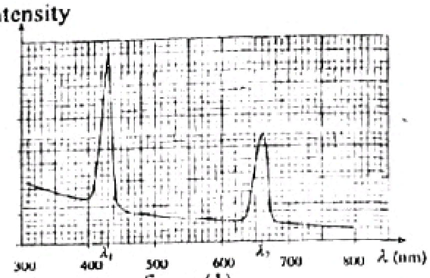


figure (1)

Plants can convert solar energy directly to chemical energy. This process is known as photosynthesis. In order to absord light, plants use pigments known as chlorophyll. A typical chlorophyll molecule absorbs two wavelengths (one of blue colour and the other of red colour) from sunlight. The wavelengths absorbed by chlorophyll are shown in the figure (1).

(i) Determine the two wavelengths, λ_1 and λ_2 absorbed by a chlorophyll molecule.

(ii) Which wavelength corresponds to blue colour?

(c) Chlorophyll molecules absorb the photons of the corresponding wavelengths shown in figure (1) above and get transferred to excited states. The minimum energy needed to excite the molecules is known as the excitation energy (ϕ) of the molecule. This excitation energy can be evaluated by the same expression obtained for the work function ϕ in (a) (ii) above. Determine the two excitation energies, ϕ_1 and ϕ_2 of the chlorophyll molecule, corresponding to the excitations occur due to the two absorptions, λ_1 and λ_2 respectively.
(Take hc = 1290 eV nm)

(d) (i) During the day time average rate of solar radiation incident on a unit area of the Earth's surface in Sri Lankd is 1200W m^{-2}. Assuming that out of this rate of energy, only 0.1% belongs to the energy of the photons corresponding to the wavelength λ_1 determined in (b) (i) above, calculate the rate of energy incident on a unit surface area of the Earth, which belongs to wavelength λ_1.

(ii) (1) If the effective surface area of chlorophyll molecules on a leaf of a plant is 4.0×10^{-4} m^2, determine the rate of energy incident on chlorophyll molecules, which belongs to wavelength λ_1.

(2) What is the rate of photons corresponding to the rate of energy in (ii) (1) above?

(1 eV = 1.6×10^{-19} J)

(iii) If only one chlorophyll molecule is excited for every 10^{14} photons incident on chlorophyll molecules, how many molecules are excited due to the incident photons calculated in (ii) (2) above?

(iv) If such six excited chlorophyll molecules are needed to make one glucose molecule, hoq much time is needed to make one glucose molecule?