Part B – Essay
Answer four questions only.
(g = 10 N kg^{-1})

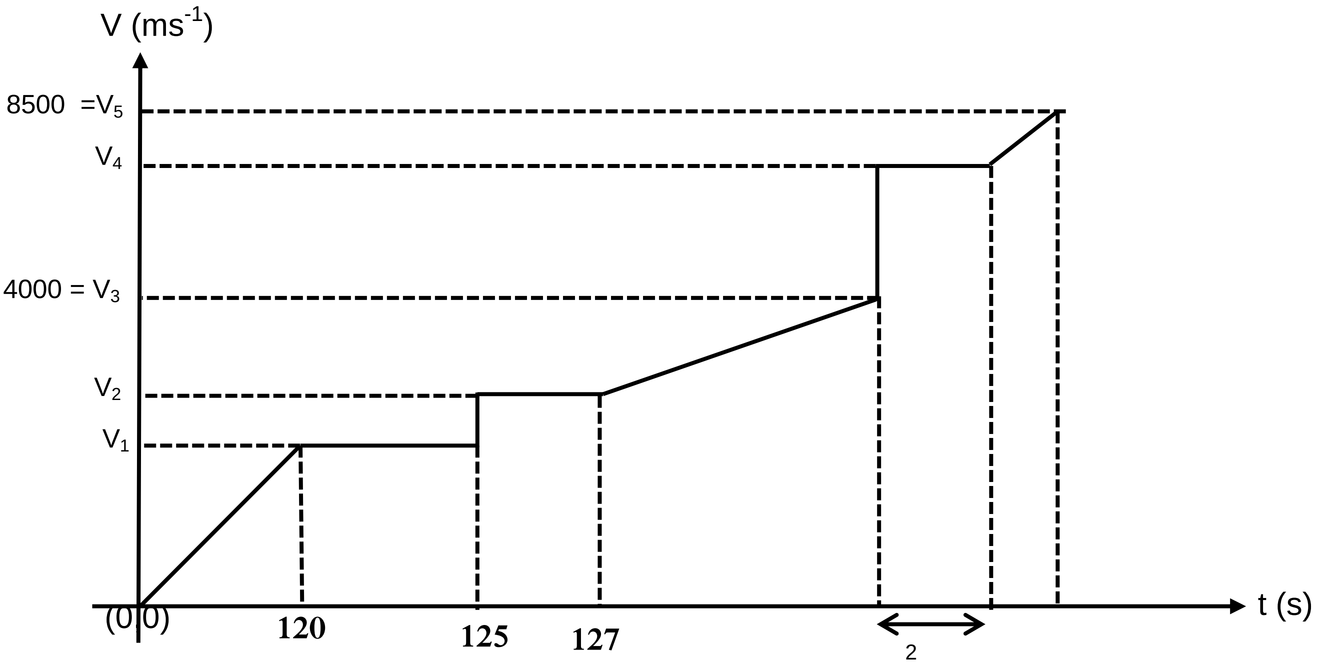
5. a) A space station has been established in space at an altitude of 400 km above the Earth and it rotates around the Earth.

A rocket carrying astronauts travels towards this space station. This rocket consists of a section with two primary combustion engines, a center section with four secondary combustion engines and a pre- shuttle with lateral balancing engines.

This rocket will launch from a platform created on earth. The rocket, with only the primary combustion engine firing, is carried up to a distance of 90 km to the thermosphere, which is considered the edge of the Earth's atmosphere. The time taken for that is 120 s. At the same time the primary combustion engine is turned off and the rocket travels at a constant speed for 5 s.

Here, a planned explosion in the thermosphere causes the booster to separate from the rocket and travel upward at a velocity of 800 ms^{-1} relative to the ground. The primary combustion engine has a mass of 4000 kg, and this primary and secondary engine will provide the necessary thrust force for the rocket. The rocket then moves at a constant speed for another 2 s and operate all four secondary combustion engines simultaneously. This secondary engine takes the rocket to a distance of 350 km above the Earth's surface. The center section also then separates from the rocket with an explosion and becomes stationary relative to the ground.This engine also has a mass of 4000 kg. After traveling at a uniform velocity for another 2 s, the lateral balancing engines are activated and the shuttle reaches orbit. Mass of the shuttle is 24 000 kg. This engine operates to reach the required orbital velocity of 8500 ms^{-1}. The lateral balancing engines then move along the orbit, maintaining a speed of 8500 ms^{-1}, with control as needed, until they reach the space station.

A velocity-time graph can be created for the entire motion of the shuttle, ignoring the change in velocity caused by mass loss due to fuel combustion as the rocket accelerates. It is given below.



i. If the velocity is V_1 when it reaches the thermosphere , what is it's value?
ii. What is the acceleration given to the rocket by the two primary combustion engines ?
iii. If the velocity of the shuttle after support is removed is V_2, what is the value of it?
iv. What is the acceleration given to the rocket by secondary combustion engines?
v. Calculate the velocity (V_4) of the shuttle after the secondary combustion engine is released.
vi. Calculate the acceleration given to the rocket by pre- shuttle with lateral balancing engines.
vii. Calculate the time taken for the rocket to reach the orbit.

b) The rocket builds thrust by releasing gas produced by a reaction between liquid O_2 and liquid H_2 at high speed through a nozzle. When a rocket of mass m is moving upwards with a velocity u, a mass of air Δm is thrown downwards with a velocity V relative to the rocket in a very small time Δt. Thus the rocket obtains a velocity V_0 relative to earth. (Ignore the effect of gravity during the time Δt)

i. What is the velocity at which the air moves downward relative to the ground? ($V > V_0$)
ii. Obtain an equation for the velocity change of rocket using the conservation of linear momentum.
iii. If m >>> Δm , Write an expression for the thrust force exerted on the rocket using Newton's second law of motion,.

6.

a) Angular magnification and linear magnification are important in optics. But angular magnification is most commonly used when considering the images of objects formed by optical instruments. Therefore, when compared to linear magnification, angular magnification is considered as a better measurement of the magnification provided by an optical instrument.

i. What is "linear magnification" ?
ii. As mentioned above, explain why the angular magnification is considered as a better measurement than linear magnification.
iii. When considering the image formed by an optical instrument, the most suitable position to place the eye to observe a sharp and clear image is eye ring. Define the eye ring.

b) A compound microscope is an optical instrument used to magnify and observe a very small object.

i. Write down an expression for the magnifying power (M) of a compound microscope as an optical instrument.
ii. Take the focal length of eyepiece lens as f_e and focal length of objective lens as f_o. Derive an expression for the magnifying power or angular magnification for a compound microscope at normal adjustment by taking the least distance of distinct vision as D (D=25cm).

iii. A compound microscope uses two convex lenses of focal lengths 2.0 cm and 2.0 mm. Here, an object placed 2.5 mm from the objective lens is expected to be observed during normal adjustment.

1) What is the image distance (v_0) for the image formed by objective lens?
2) Find the object distance (u_e) for objective lens.
3) Calculate the linear magnification of the objective and the linear magnification of the eyepiece for this situation.
4) What is the angular magnification for the compound microscope?
5) What is the length of the microscope tube?
6) Find the location of the eye ring.

7.

When a solid spherical particle moves downward in a viscous fluid, the fluid will oppose its motion by a force called fluid friction. This force is described by Stokes' law.

a) i. Write an equation for the viscous force acting on a solid spherical particle in a viscous fluid. Identify it's all terms.

ii. There are several assumptions used in deriving the equation you presented above. Write two of them.

iii. A spherical particle of density d and radius r is submerged in a liquid of density ρ and then released. $\rho > d$. The coefficient of viscosity of the liquid is η. The terminal velocity acquired by this particle as it rises through the liquid is V_0. Derive an equation for the terminal velocity. (Ignore the change in pressure as the particle rises)

b) After reaching the free liquid surface, this particle will move vertically under gravity. Consider that the viscous force exerted by the atmosphere is negligible.

i. The particle moves under gravity after released from liquid surface. Derive an expression for the maximum height it travels.

ii. Calculate the time taken for this particle to return to the liquid surface.

iii. Show the variation of velocity with time for a particle rising up through the liquid using a graph.

iv. If the spherical particle, which falls back to the liquid surface as mentioned in (b)(ii) above, repeatedly undergoes several such motions in the liquid and floats on the liquid surface, plot the displacement-time graph related to its motion.

c) If the average radius of an air bubble coming up through the above liquid is r = 0.1 mm, density of the liquid ρ =900 kgm^{-3}, density of air inside the bubble = 1.25 kgm-3 and coefficient of viscosity of the liquid is η = 7.5 x 10^{-2} Nsm^{-2} , obtain a value for the terminal velocity. (g = 10 ms^{-1})

8. A capacitor is a device that can store electric charges. Here, the electric field is the mechanism by which the capacitor stores energy. Capacitors are widely used in electric circuits. Because the electrical energy stored in capacitors can release very quickly.

Conductors are used to store electric charges, and also this device is designed to store a large amounts of electric charges in a very small space.

The flash lamp in a camera is activated by the rapid discharge of electrical energy stored in a capacitor.

Applications of capacitors are providing a backup power to the computers during power outages, used in tuning circuits in radio, used in motor vehicles for managing voltage spikes.

A capacitor made of two conducting plates placed parallel to each other is called a parallel plate capacitor. Such a capacitor can be charged using a battery.

When the capacitance of the capacitor is C, the distance between the plates is d, and the area of a plate A, the capacitance of the capacitor is expressed as $C = \frac{\varepsilon A}{d}$. Here ε is the permittivity of the medium between plates. When the medium between the plates is air or a vacuum, the permittivity of the medium is denoted by ε_0. The charge (q) on one plate of such a capacitor is inversely proportional to the potential difference between the plates.

a)

i. What is the reason for using capacitors in electric circuits?

ii. State two situations where capacitors used in practice.

iii. Draw a circuit you have designed to charge a capacitor.

iv. Name the items you used there.

v. Plot a graph to show the amount of charge stored in a capacitor when charging with time.

b)

i. Write down the gauss law.

ii. Write down an expression for the capacitance of a capacitor using potential difference and charge.

iii. Derive an expression for the electric field intensity (E) in the space between the plates of a capacitor using the gauss law.

iv. Thus, Show that the capacitance of a parallel plate capacitor is given by the expression $C = \frac{\varepsilon A}{d}$.

v. Derive an expression for the potential energy stored in a capacitor .

c) A parallel plate capacitor is created by placing two circular metal plates of radius 9 cm and 9 mm apart. This is charged by a potential difference of 100 V. The space between the plates is filled with air. ($permitivity\ of\ air, \varepsilon_0 = 8.85 \times 10^{-12}\ Fm^{-1}$)

i. Find the capacitance of capacitor. ($\pi = 3$)

ii. What is the charge of a capacitor?

iii. Find the electrical potential energy of a capacitor.

9. Answer only Part **A** or Part **B.**

A.

a)

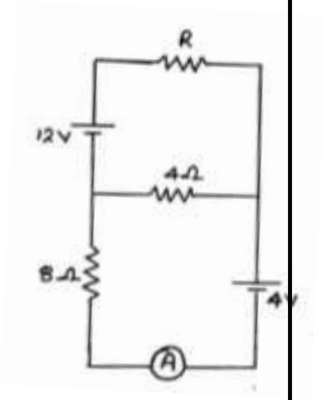
i. Write down the kirchhoff's law of electicity.

ii. This law express the conservation of charges and conservation of energy . Explain.

iii. A compound cell is formed by connecting two cells of electromotive force E_1 and E_2 with internal resistance r_1 and r_2 respectively, in parallel. If the equivalent internal resistance of this compound cell is r, write an expression for r in terms of r_1 and r_2. From that, write an equation for the equivalent electromotive force (E).

iv. When using cells for electrical circuits, it is preferable to use a large number of similar cells connected in parallel to each other instead of using a single cell. Explain this.

b) Here R is a temperature sensitive resistor. The ammeter is perfect. The internal resistance of the cells is zero.



i. If the room temperature is 27 ^{0}C , the ammeter reading is zero. Calculate the value of R here.

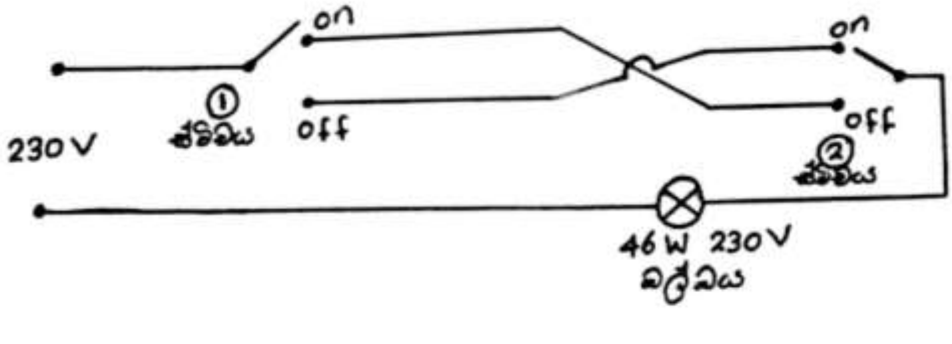
ii. A student wants to find the temperature of an oven using this setup. For this the variation of value of R with current (I) is important. Show that,

$R = \frac{8(I+1)}{(1-3I)}$ by using kirchhoff's law.

iii. Find the value of R when the reading of the ammeter is 0.25 A.

iv. If the ammeter reading is 0.25 A when the temperature of the oven measured by R is 535 ^{0}C , find the temperature coefficient of resistance of the material of which R is made.

c) Electricity is used in the home to make everyday tasks easier. Both simple and complex electrical circuits are used in the home. The use of substandard fuses, wires, and switches in these electrical circuits can even cause fires and extensive property damage.
The circuit shown below is a two-way switch bulb circuit used to illuminate a staircase in a house. This circuit uses one switch above the staircase and another switch below the staircase. Both of these switches are two-way switches.



OFF - open

ON - closed

situation	Switch 1	Switch 2	Bulb lights up / does not light up
1	OFF	OFF	
2	OFF	ON	
3	ON	OFF	
4	ON	ON	

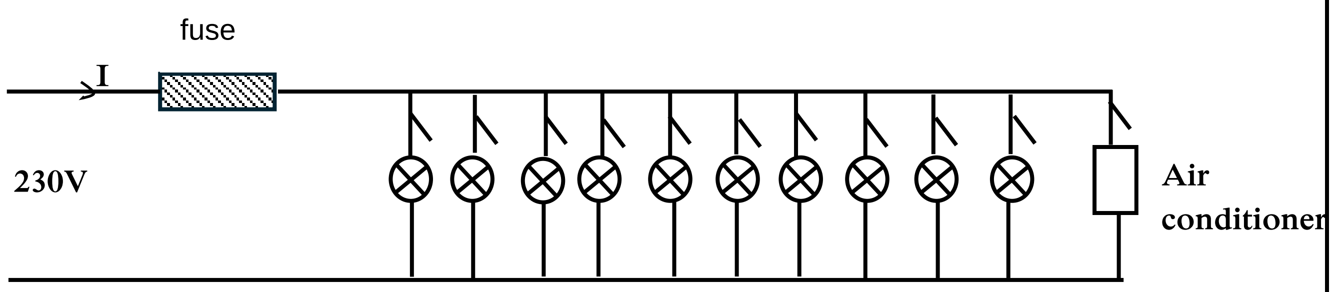
i. Copy the table above and indicate whether the bulb will light up/not light up depending on the conditions of the two switches.

ii. Write the dimensions of [potential difference X charge] .

iii. Find the resistance using the values of 46W, 230V shown on the bulb.

iv. Find the current flowing through the bulb when it is light up.

d) A room in a house lights up by 10 bulbs of 46W, 230V and cooled by a 2300W, 230V air conditioner. All these electrical devices are connected in parallel as shown in the figure below.



i. Find the current passing through the fuse used here while protecting it.

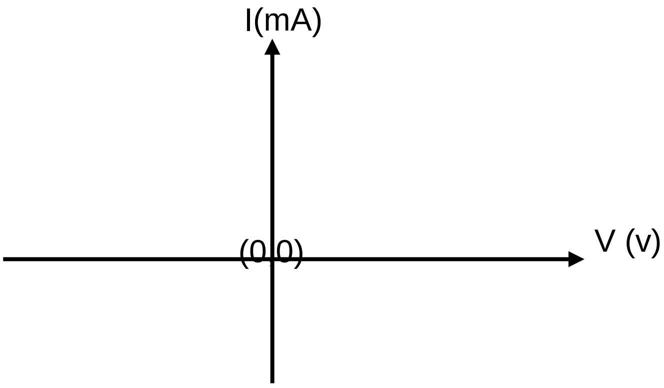
ii. The fuse is available in 5A, 10A, 15A . Write down the maximum current of the fuse suitable for this circuit.

iii. If the 10 bulbs and the air conditioner in this room were operated for five hours, find the total energy consumed in kWh.

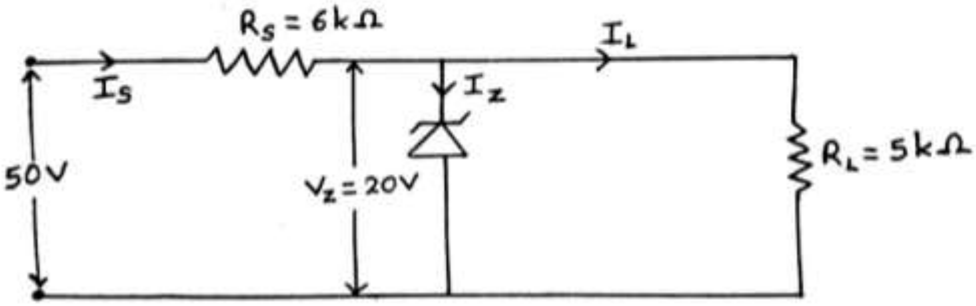
iv. If the charge for 1 kWh is Rs.30 , find the total cost.

B.

a) Copy the graph below and create the forward and reverse bias characteristic curve of a diode.



b)



The figure shows a voltage regulator circuit that uses a Zener diode to obtain a constant voltage of 20 V across a load from a 50 V voltage supply.

i. Find the current I_S flowing through R_S .

ii. Find the current I_L flowing through R_L .

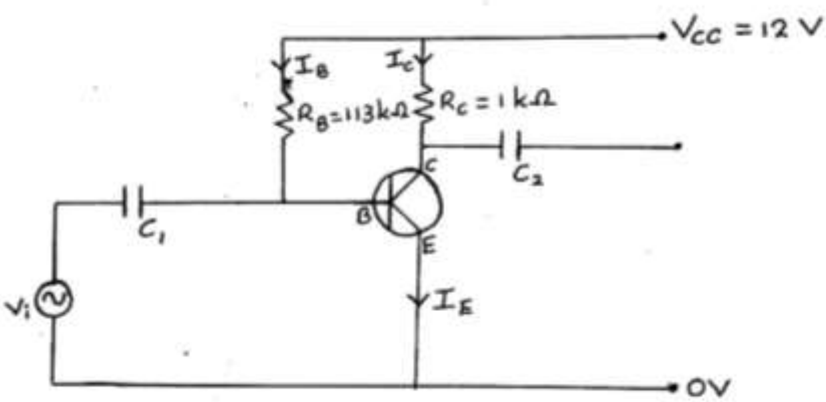
iii. Find the current I_Z flowing through zenor diode.

iv. Find the power dissipation of the zenor diode.

c)

i. State the two main functions performed using a transistor in a circuit.

ii. The circuit shown in the figure contains an npn silicon transistor in a common emitter configuration. Current gain $\beta = 100$ ($V_{BE} = 0.7$ V)



1) Find the current I_B flowing through R_B .

2) Find the current I_C flowing through R_c.

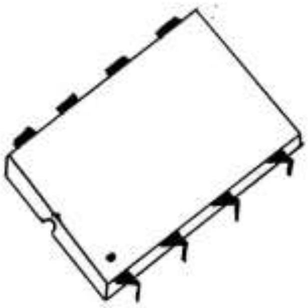
3) Find the current I_E.

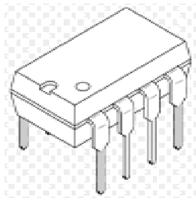
4) Find the potential difference V_{CE}.

d)

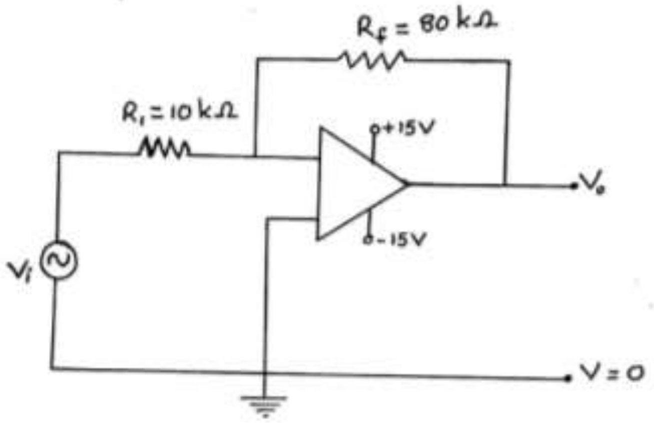
i. The creation of a large circuit on a small piece of Si is done by the integrated circuit (IC). Nowadays, these integrated circuits are widely used in electrical appliances. Mention three advantages of these integrated circuits.

ii. The figure shows how an integrated circuit looks when viewed from above. Copy this figure and number the pins of the integrated circuit.





iii.



Consider the operational amplifier given above. In that $R_f = 80\ k\Omega$ and $R_1 = 10\ k\Omega$. A sinusoidal voltage signal with a maximum value of 20 mV is applied to V_i.

1) What type of operational amplifier is shown above?
2) Find the voltage gain of this circuit.
3) Find the maximum value of output voltage V_0 .
4) What is the phase difference between V_i and V_o .

10.

Considering the expansion of liquids with heat, the density of the liquid decreases as the temperature increases. But when heat is supplied to water , it's density also increases as its temperature increases within the range of 0 ^oC to 4 ^oC. This is known as the anomalous expansion of water. Hence maximum density of water exists at 4 ^0C .

a)

i. When heat is supplied to a liquid of volume V_1 , it's volume changes to V_2. Consider the temperature change as $(\Delta\theta)$, and taking the volume expansion as γ , write down an equation for the expansion in volume.

ii. When the temperature of a liquid was increased by $\Delta\theta$, its density changed from d_1 to d_2. Derive an equation for the new density of the liquid.

iii. Define the real expansion and the apparent expansion of a liquid .

iv. Derive an equation for the relationship between the real expansion and the apparent expansion by considering the expansion of the vessel that contains the liquid.

v. A glass block at room temperature is placed inside a brass vessel. The remaining space in the pot was completely filled with oil and the pot was gradually heated. The volume of thevessel in room temperature is 100 cm^3. If the volume of oil is sufficient to fill the remaining space of the container without spilling the liquid at each temperature, calculate the volume of the glass block at room temperature.

Volume expansiviy of brass = $60 \times 10^{-6}\ {}^0C^{-1}$

Volume expansiviy of oil = $100 \times 10^{-6}\ {}^0C^{-1}$

Volume expansiviy of glass = $25 \times 10^{-6}\ {}^0C^{-1}$

b)

i. As mentioned above, draw a suitable graph for the variation of density with temperature of water, considering the anomalous expansion that occurs within the range of (0 – 4) ^0C. (Must have the temperature below 0 ^oC)

i. Draw a graph for the variation of volume within the temperature range mentioned in (b) (i).

ii. Even though European countries experience snowfall for an extended period of the year, aquatic life survives safely throughout that period. Explain that using anomalous expansion of water.