२. भौतिक विज्ञान (Physics)

Test Specification Chart 2078

Grade : 12 **Subject : Physics Theory (Phy. 102)**

<table>
<tr><th rowspan="4">SN</th><th rowspan="4">Content Area</th><th rowspan="4">Working hour</th><th colspan="22">Competency level</th><th rowspan="4">Unit wise Marks</th></tr>
<tr><th colspan="4">Remembering</th><th colspan="6">Understanding</th><th colspan="6">Applying</th><th colspan="6">Higher Ability</th></tr>
<tr><th colspan="2">MCQ</th><th colspan="2">SAQ</th><th colspan="2">MCQ</th><th colspan="2">SAQ</th><th colspan="2">LAQ</th><th colspan="2">MCQ</th><th colspan="2">SAQ</th><th colspan="2">LAQ</th><th colspan="2">MCQ</th><th colspan="2">SAQ</th><th colspan="2">LAQ</th></tr>
<tr><th>No. of Questions</th><th>Marks</th><th>No. of Questions</th><th>Marks</th><th>No. of Questions</th><th>Marks</th><th>No. of Questions</th><th>Marks</th><th>No. of Questions</th><th>Marks</th><th>No. of Questions</th><th>Marks</th><th>No. of Questions</th><th>Marks</th><th>No. of Questions</th><th>Marks</th><th>No. of Questions</th><th>Marks</th><th>No. of Questions</th><th>Marks</th><th>No. of Questions</th><th>Marks</th></tr>
<tr><td>1</td><td>Mechanics</td><td>22</td><td rowspan="5">2</td><td rowspan="5">2</td><td rowspan="5">2</td><td rowspan="5">10</td><td rowspan="5">5</td><td rowspan="5">5</td><td rowspan="5">1</td><td rowspan="5">5</td><td rowspan="5">1</td><td rowspan="5">8</td><td rowspan="5">3</td><td rowspan="5">1</td><td rowspan="5">2</td><td rowspan="5">10</td><td rowspan="5">1</td><td rowspan="5">8</td><td rowspan="5">1</td><td rowspan="5">1</td><td rowspan="5">3</td><td rowspan="5">15</td><td rowspan="5">1</td><td rowspan="5">8</td><td>13</td></tr>
<tr><td>2</td><td>Heat and Thermodynamics</td><td>12</td><td>7</td></tr>
<tr><td>3</td><td>Wave and Optics</td><td>26</td><td>15</td></tr>
<tr><td>4</td><td>Electricity and Magnetism</td><td>35</td><td>21</td></tr>
<tr><td>5</td><td>Modern Physics</td><td>33</td><td>19</td></tr>
<tr><td colspan="2">Total Marks</td><td>128</td><td colspan="4">12</td><td colspan="6">18</td><td colspan="6">21</td><td colspan="6">24</td><td>75</td></tr>
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<table>
<tr><th colspan="6">Item format plan</th></tr>
<tr><th>S.N.</th><th>Type of item</th><th>Score per item</th><th>Total item</th><th>Total score</th><th>Time</th></tr>
<tr><td>1</td><td>Multiple Choice Questions</td><td>1</td><td>11</td><td>11</td><td>25 minutes</td></tr>
<tr><td>2</td><td>Short Question Answer</td><td>5</td><td>8</td><td>40</td><td rowspan="2">155 minutes</td></tr>
<tr><td>3</td><td>Long Question Answer</td><td>8</td><td>3</td><td>24</td></tr>
<tr><td colspan="2">Grand Total</td><td></td><td>22</td><td>75</td><td>3 hours</td></tr>
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Remarks:

- Item format in composite should be met as per the specification grid.
- Designated weightage in the combined cell should be met, but ±3 marks variation will be allowed within a unit/content area. But no unit can be nil.
- In the case of SAQ and LAQ, these should ensure that 1 mark will be assigned per element expected as correct response.
- The distribution of cognitive domain of questions should be nearly 15% knowledge/remembering, 25% understanding, 30% applying and 30% higher ability level, but ±5percent variation will be allowed in overall question set.
- SAQ and LAQ can be structured (have two or more sub-items). SAQ and LAQ can be distributed to two or more cognitive behaviors.
- In such case these will be added to their respective cognitive behavior. In sum the distribution of cognitive behavior should be approximately to the required distribution. Incase of SAQ there will be 2 "OR" questions and in case of LAQ there will be 2 "OR" question.

MODEL QUESTION

SCHOOL LEAVING CERTIFICATE

2078

Grade: 12 Subject: Physics Subject Code: 102

Full marks: 75 (11 marks Objective + 64 marks Subjective) Time: 3 Hours

Group A: Multiple Choice Questions ($11 \times 1 = 11$) **Time: 25 minutes**

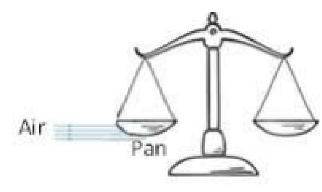
Tick the correct answers.

1. Which of the following is a correct formula for calculating radius of gyration of a rotating object?

A) $k^2 = I/m$ B) $k = I/m$ C) $k = m/I$ D) $k = (I/m)^2$

→ A

2. A horizontal steam of air is blown under one of the pans of a beam balance as shown in the figure. What will be the effect of this on the pan?



A) Goes up. B) Goes down. C) Remains unaffected D) rotates

→B

3. What will be the height of a capillary on the surface of the Moon if it is 'h' on Earth?

A) h B) h/6 C) 6h D) zero

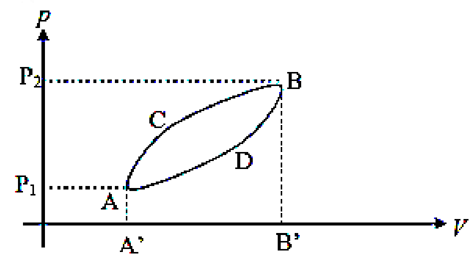
→ C

4. What is the coefficient of performance of an ideal refrigerator working between ice point and room temperature (27℃)?

A) 0 B) 0.1 C) 1 D) 10

→ D

5. A thermodynamic system is taken from A to B via C and then returned to A via D as shown in the p-V diagram. The area of which segment of the graph represents the total work done by the system?



A) $P_1ACBP_2P_1$ B) ACBB'A'A   C) ACBDA   D) ADBB'A'A

→ C

6. Which one of the following directly affects the quality (timbre) of sound?

A) Shape of the source   B) frequency   C) intensity   D) wave form

→ D

7. A diffraction pattern is obtained using a beam of red light. What will be the effect on the diffraction pattern if the red light is replaced with white light?

A) All bright fringes become white.

B) All bright fringes, except the central one, become white.

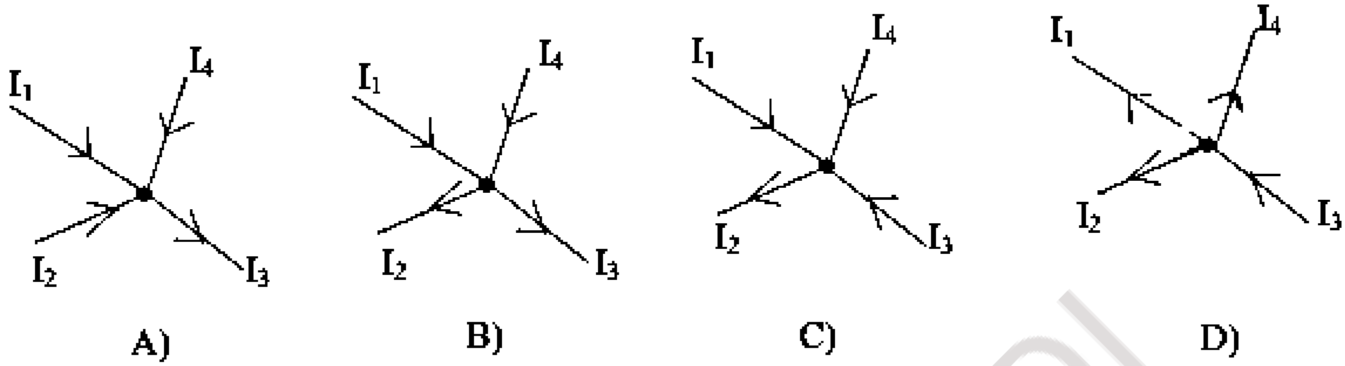
C) All bright fringes become colourful.

D) All bright fringes, except the central one, become colourful.

→ D

8. In which one of the following diagrams the currents are related by the equation

$I_1 - I_2 = I_3 - I_4$?



→ B

9. A coil having N turns and cross-section area A carries current I. Which physical quantity does the product NIA represent?

A) Magnetic flux of the coil

B) magnetic flux density of the coil

C) Magnetic moment of the coil

D) magnetic susceptibility of the coil

→ C

10. What happens to the neutral temperature, if the cold junction of a thermocouple is decreased?

A) Increases

B) decreases

C) remains the same

D) Approaches inversion temperature

→ C

11. What is the point where the seismic waves start called?

A) Epicentre

B) hypocentre

C) metacentre

D) seismic centre

→ B

MODEL QUESTION

SCHOOL LEAVING CERTIFICATE

2078

Grade: 12 Subject: Physics Subject Code: 102

Full marks: 75 (11 marks Objective + 64 marks Subjective) Time: 3 Hours

Attempt all the questions.

Group B: Short Answer Questions (8×5 = 40)

1. (i) Define 'surface tension'. [1]

→ The property of a liquid under which it occupies the minimum surface area is called surface tension.

(ii) Establish a relation between surface tension and surface energy of a liquid. [2]

→ Relation between surface energy (σ) and surface tension (T)

To find the relation between the surface energy of a liquid and its surface tension, we consider a rectangular frame of wire PQRS in which the wire PQ is moveable. If we dip the frame in a soap solution, a thin film is formed which pulls the wire PQ inward due to surface tension. The force on wire PQ due to the surface tension is given by

$F = T \times 2l$

Where T is the surface tension of the film and l is the length of the wire SR. The length is taken twice because the soap film has two free surfaces on two sides of the wire.

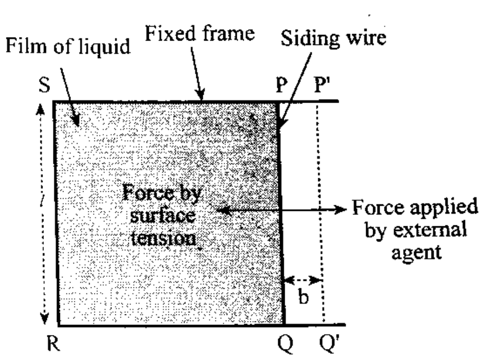


Fig. Surface Energy

If the film is stretched outward by a small distance b to the new position P'Q' against the force due to surface tension T, the work done is given by

W = force · displacement

$= F \cdot b = (T \times 2l) \cdot b = T \cdot (2l\, b)$

$\therefore W = T \cdot A$ ……… (ii)

Here, $A = (2l\, b)$ is the total increase in area of the soap film on both sides. From the definition of surface energy, we can write

Surface energy = $\frac{work\ done\ in\ increasing\ surface\ area}{increase\ in\ surface\ area} = \frac{W}{A}$

Or, $\sigma = T \cdot A$

$\therefore \sigma = T$ ……… (iii)

Thus, the surface tension of liquid T numerically equals its surface energy σ.

(iii) Two spherical rain drops of equal size are falling vertically through air with a certain terminal velocity. If these two drops were to coalesce to form a single drop and fall with a new terminal velocity, explain how the terminal velocity of the new drop compares to the original terminal velocity. [2]

→ Solution:

Let r be the radius of smaller rain drop & F, V, W be the viscous force, terminal velocity, weight of the smaller rain drop respectively.

Let R be the radius of larger rain drop & F', V', W' be the viscous force, terminal velocity, weight of the larger rain drop respectively. Then,

Volume of larger rain drop = 2 × Volume of smaller rain drop

$$\text{or,} \quad \frac{4}{3}\pi R^3 = 2 \times \frac{4}{3}\pi r^3$$

$$\text{or,} \quad R^3 = 2\, r^3$$

$$\text{or,} \quad R = 2^{\frac{1}{3}}\, r$$

For smaller rain drop,

$F = 6\pi\eta r v$, W = mg

We know that,

$$F = W$$

$$\text{or,} \quad 6\pi\eta r V = mg$$

$$\text{or,} \quad 6\pi\eta r V = \rho v g$$

$$\text{or,} \quad 6\pi\eta r V = \rho \times \frac{4}{3} \times \pi r^3 g$$

$$\therefore 6\pi\eta r V = \frac{4}{3}\pi r^3 \rho g \qquad \dots\dots\dots \text{(i)}$$

Similarly for larger rain drop,

$$\therefore 6\pi\eta R V' = \frac{4}{3}\pi R^3 \rho g \qquad \dots\dots\dots \text{(ii)}$$

Now, dividing equation (ii) by (i) we get,

$$\frac{RV'}{rV} = \frac{R^3}{r^3}$$

$$\text{or,} \quad \frac{V'}{V} = \left(\frac{R}{r}\right)^2$$

$$\text{or,} \quad \frac{V'}{V} = 2^{\frac{2}{3}}$$

$$\text{or,} \quad V' = 2^{\frac{2}{3}}\,V$$

The terminal velocity of the new larger rain drop will be $2^{\frac{2}{3}}$ times the terminal velocity of the original terminal velocity.

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2. Angular speed of a rotating body is inversely proportional to its moment of inertia.

(i) Define 'moment of inertia'. [1]

→ The moment of inertia of a rigid body about a particular axis is defined as the sum of the products of masses of all the particles contains on that rigid body and the square of their respective distances from the axis of rotation.

(ii) Explain why angular velocity of the Earth increases when it comes closer to the Sun in its orbit. [2]

→ When the earth comes closer to the sun, its moment of inertia about the axis through the sun decreases. To conserve the angular momentum (L=Iω), the angular velocity of the earth increases.

(iii) If the Earth were to shrink suddenly, what would happened to the length of the day? Give reason. [2]

→ If the Earth were to shrink suddenly, its radius R would decrease. The moment of inertia of earth $I = \frac{2}{5}MR^2$ would decrease. As no external torque is acting on earth, its angular momentum $L = I_{\omega} = I\frac{2\pi}{T}$ remains constant. As I decreases, T must decrease. Hence the length of the day will decrease.

OR

(i) State Bernoulli principle. [1]

→ Bernoulli's principle states that for the steady flow of an incompressible and non-viscous fluid, the total energy (i.e. the sum of pressure energy, kinetic energy, and potential energy) per unit volume remains constant throughout the flow.

(ii) Derive Bernoulli's equation. [2]

→ Suppose an incompressible and non-viscous fluid flowing steadily between the two sections X and Y of a pipe of varying cross-section area as shown in the figure. Suppose A_1, v_1 and P_1 be the area of cross-section, the velocity of the fluid, and pressure of the fluid at section X respectively at a height h_1 above the horizontal line.

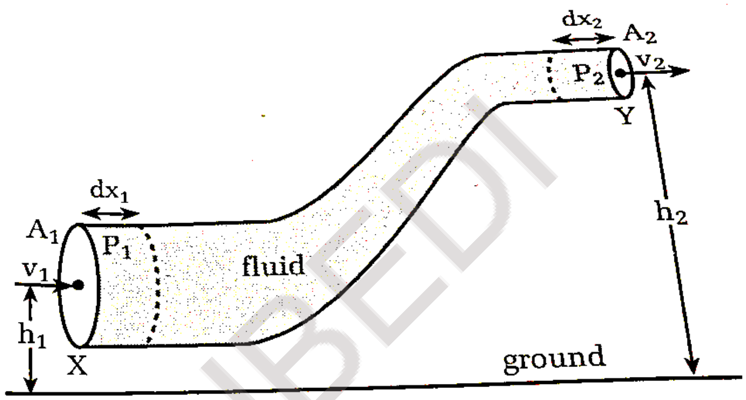

Fig. Bernoulli's principle

Suppose A_2, v_2 and P_2 are the values of corresponding quantities at section Y respectively at a height h_2 above the horizontal line.

In a steady flow, the mass of fluid entering the pipe at section X in time Δt is equal to the mass of the fluid that flows out from section Y at the same time Δt. Here,

Force acting on the liquid at point X $(F_1) = P_1A_1$

Distance travelled by the liquid in time Δt $(dx_1) = v_1\Delta t$

Work done on the liquid at X due to the force F_1 (W_1) = force × displacement = $F_1 \times dx_1$

$= P_1A_1v_1\Delta t$

Similarly, the work done by the liquid at Y due to the force F_2 $(W_2) = P_2A_2v_2\Delta t$

Thus, net work done on the fluid by the pressure energy in moving the fluid from the pipe in time Δt is

ΔW = work done on the fluid at X − work done by the fluid at Y

$$= F_1dx_1 - F_2dx_2 = P_1A_1 \times v_1\Delta t - P_2A_2 \times v_2\Delta t$$

From the equation of continuity, we have

$$A_1v_1\Delta t = A_2v_2\Delta t = V = \frac{m}{\rho}$$

So, net work done on the fluid becomes

$\Delta W + (P_1 - P_2)\frac{m}{\rho}$ ....(i)

This work done by the pressure energy on the fluid increases so that the kinetic energy and potential energy of the fluid when it flows from X to Y.

Now, the change in kinetic energy of fluid is

$\Delta KE = KE \text{ at } Y - KE \text{ at } X = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = \frac{1}{2}m(v_2^2 - v_1^2)$ .... (ii)

Also, the change in gravitational potential energy is

$$\Delta PE = PE \text{ at } Y - PE \text{ at } X = mgh_2 - mgh_1$$

$$= mg\,(h_2 - h_1) \qquad \text{......... (iii)}$$

From the principle of conservation of energy, we can write

net work done on the fluid = change in KE of the fluid + change in PE of the fluid

$$\text{or,}\quad (P_1 - P_2)\frac{m}{\rho} = \frac{1}{2}m(v_2^2 - v_1^2) + mg(h_2 - h_1)$$

$$\text{or,}\quad (P_1 - P_2) = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 + \rho g h_2 - \rho g h_1$$

$$\text{or,}\quad (P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 \qquad \text{......... (iv)}$$

In general, we can write

$$P + \frac{1}{2}\rho v^2 + \rho g h = \text{constant} \qquad \text{......... (v)}$$

This is the mathematical form of Bernoulli's principle (Bernoulli's Equation).

(iii) You can squirt water from a garden hose a considerably greater distance by partially covering the opening with your thumb. Explain how this works. [2]

→ From the equation of continuity,

$$A_1V_1 = A_2V_2$$

$$\text{or,}\qquad AV = \text{constant}$$

$$\text{or,}\qquad A = \frac{1}{V}$$

From above it is clear that the speed of flow of water is inversely proportional to the cross-sectional area. So, when the thumb is placed at the opening, the cross-sectional area is decreased which increases the speed of the flow of the water. So, it covers a greater distance.

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3. (i) Define ‘harmonics’ in music. [1]

→ Vibrations having frequencies, which are simple multiples of a fundamental vibration, are known as harmonics.

(ii) Calculate the frequency of a monotonous sound produced by a 30 cm long flute open at both ends and being played in the first harmonic. [Velocity of sound in air= 330ms^{-1}] [2]

→ Solution:

Length of open pipe (l) = 30 cm = 0.3 m

Speed of sound (v) = 330 ms^{-1}

First harmonic (f_1) = ?

We know that,

$$f_1 = \frac{v}{2l} = \frac{330}{2 \times 0.3} = \frac{330}{0.6} = 550 \text{ Hz}$$

Hence, the frequency of the monotonous sound is 550 Hz.

(iii) The flute mentioned in question (ii) was being played by a passenger on a stationary bus. The bus then moves uniformly. Explain what change in the pitch of the flute sound, if any, a person sitting on a bench at the bus park will feel when the bus starts moving. [2]

→ When the bus moves away from the person with uniform velocity ‘V’ then the apparent frequency of sound received by the listener is,

$$f' = \frac{V}{V+V_S} \times f$$

This shows that the pitch of the sound received by the listener decreases as the bus moves from the bus park.

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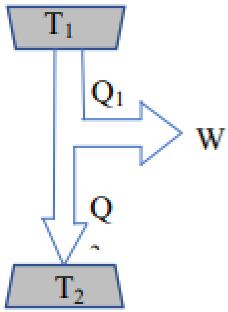
4. (i) State the second law of thermodynamics. [1]

→ The second law of thermodynamics states that, “it is impossible to construct a device operating in a cycle that can transfer heat from colder body to a hot body without consuming any work.”

(ii) A refrigerator transfers heat from a cold body to hot body. Does this not violate the second law of thermodynamics? Give reason. [2]

→ No, it doesn’t violate the second law of thermodynamics. According to Clausius statement, “heat can’t be transferred from a cold body to hot body without doing work on it.” But in refrigerator heat produced in it is taken out to the surrounding & the work is done with a constant supply of electrical energy.

(iii) In the given figure, a heat engine absorbs Q_1 amount of heat from a source at temperature T_1 and rejects Q_2 amount of heat to a sink at temperature T_2 doing some external work W.



(a) Obtain an expression for the efficiency of this heat engine. [1]

→ Solution:

Efficiency (η) = $\dfrac{\text{work done by engine in 1 cycle (W)}}{\text{Heat absorbed from the source }(Q_1)}$

$$\eta = \frac{Q_1 - Q_2}{Q_1}$$

$$\eta = 1 - \frac{Q_2}{Q_1}$$

$$\eta = \left(1 - \frac{Q_2}{Q_1}\right) \times 100\%$$

Also,

$$\eta = \left(1 - \frac{T_2}{T_1}\right) \times 100\%$$

$$\left[\begin{array}{c} As\ Q \propto T \\ \frac{Q}{T} = constant \\ i.e. \frac{Q_1}{T_1} = \frac{Q_2}{T_2} \\ \rightarrow \frac{Q_2}{Q_1} = \frac{T_2}{T_1} \end{array}\right]$$

Which is the required expression for the efficiency of this heat engine.

(b) Under what condition does the efficiency of such engine become zero percentage, if at all? [1]

→ For, η = 0

$$1 - \frac{T_2}{T_1} = 0$$

or, $\dfrac{T_2}{T_1} = 1$

or, $T_2 = T_1$ --- (i)

Also,

$$1 - \frac{Q_2}{Q_1} = 0$$

or, $\dfrac{Q_2}{Q_1} = 1$

or, $Q_2 = Q_1$ --- (ii)

(i) & (ii) are the required conditions for efficiency of such engine to be zero.

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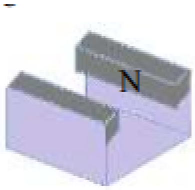
5. A student wants to measure the magnetic flux density between the poles of two weak bar magnets mounted on a steel yoke as shown in the figure. The magnitude of the flux density is between 0.02T and 0.04T.



(i) Define Magnetic flux density. [1]

→ The strength of the magnetic field at a point is called magnetic flux density.

(ii) One way of measuring the magnetic flux density could be the use of a Hall probe. Suggest one reason why Hall probe is not a suitable instrument to measure the magnetic flux density for the arrangement shown in the above figure. [1]

→ Hall probe is sensitive enough to measure which could even measure the Earth's magnetic flux density, resulting in inaccurate magnetic flux density. Therefore, it is not suitable to measure the magnetic flux density for the arrangement below.

(iii) Another method of measuring the magnetic flux density for the arrangement shown in the above figure is to insert a current-carrying wire between the poles of the magnet. Explain how the magnetic flux density can be determined using this method. You are allowed to use any additional apparatus. [3]

→ We have added electric balance to measure force between them which is in downward direction & is calculated as,

F = (Reading shown in balance in kg) × g

Also an electric ammeter is added to measure the amount of current flowing through the wire.

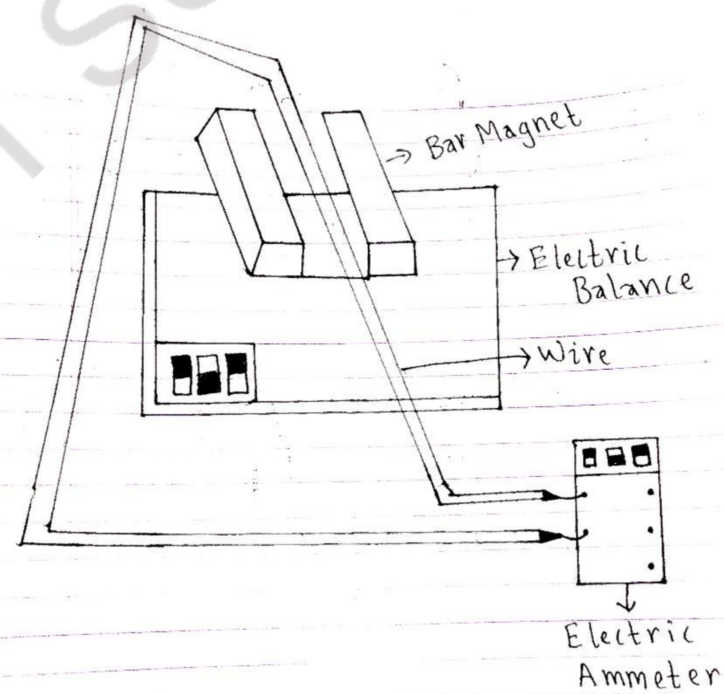


Fig: Required Apparatus.

Here,

$F \propto L$ ('L' is the length of bar magnet)

$F \propto I$ ('I' is the current flowing)

$F \propto N$ ('N' is the number of turns in wire)

$F \propto B$ ('B' is the magnetic flux density)

$F \propto \sin\theta$ ('θ' is the angle between 'L' & 'B')

Combining all,

$F = k\,B\,I\,N\,L\sin\theta$ (k is in S.I. system) or, F = B I N L $(\theta = 90°)$

or, $B = \frac{F}{I N L}$

Hence F, I, N, L can be determined by observation & B can be calculated by using the formula above.

6. (a) Law of electromagnetic induction can be expressed mathematically as

$\in = -N \frac{d\varphi}{dt}$.

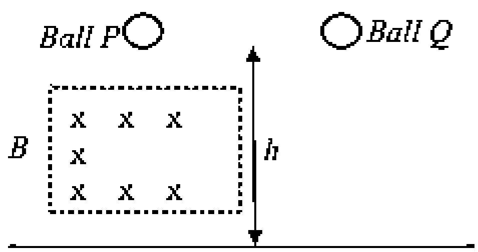
(b) (i) State what the symbols $\in$ and $\frac{d\varphi}{dt}$ represent in the equation. [2]

→ Here, $\in$ represents the induced e.m.f. and $\frac{d\varphi}{dt}$ represents change in magnetic flux with respect to time.

(ii) Explain the significance of the negative sign. [1]

→ The negative sign indicates that the direction of the induced e.m.f. is opposite to any change of magnetic flux in the circuit.

(iii) Two identical copper balls are dropped from the same height as shown in the figure. Ball P passes through a region of uniform horizontal magnetic field of flux density B. Explain why ball P takes longer than ball Q to reach the ground. [2]



→ When the ball P passes through a region of uniform horizontal magnetic field of flux density B, there is change in magnetic field. So, flux changes (∵ flux = BA) so due to change in the flux, e.m.f. is induced and by Lenz's law, current flow in the direction which opposes the change in magnetic field.

So, the force due to this current induces magnetic field which opposes the motion of the ball P. Therefore, making the fall acceleration to be less than gravity. Hence, ball P takes more time to reach the ground than ball Q.

7. Ultraviolet radiation of frequency 1.5×10^{15} Hz is incident on the surface of an aluminium plate whose work function is 6.6×10^{-19} J.

→ Given, Frequency of radiation (f) = 1.5×10^{15} Hz

Work function of metal (φ) = 6.6×10^{-19} J

(i) Show that the maximum speed of the electrons emitted from the surface of the aluminium is $8.6 \times 10^5\ \mathrm{ms^{-1}}$. [3]

→ From Einstein's photoelectric equation,

$$\mathrm{hf} = \varphi + \frac{1}{2}\mathrm{mv_{max}^2}$$

$$\text{or,}\qquad 6.62 \times 10^{-34} \times 1.5 \times 10^{15} = 6.6 \times 10^{-19} + \frac{1}{2}\mathrm{mv_{max}^2}$$

$$\text{or,}\qquad \mathrm{v_{max}^2} = \frac{6.6 \times 10^{-19}}{9.1 \times 10^{-31}}$$

$$\text{or,}\qquad \mathrm{v_{max}^2} = 7.3 \times 10^{11}$$

$$\therefore\ \mathrm{v_{max}} = 8.6 \times 10^5\ \mathrm{ms^{-1}}$$

Hence, the maximum speed of the electrons emitted from the surface of the aluminium is $8.6 \times 10^5\ \mathrm{ms^{-1}}$.

(ii) State and explain what change, if any, occurs to the maximum speed of the emitted electrons when the intensity of the ultraviolet radiation is increased. [2]

→ When the intensity of ultraviolet radiation is increased, there is no change in the speed of emitted electrons because increasing intensity means to increase the number of photons and the change in that number can emit more electron but can't affect the kinetic energy of the emitted electrons.

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8. (i) State Bohr's postulates of atomic model. [3]

→ According to Bohr's theory of atomic model, the following are the postulates:

(a) The electrons move around the nucleus in a circular path under the electrostatic force of attraction.

$$\frac{\mathrm{mv^2}}{\mathrm{r}} = \frac{1}{4\pi\epsilon_o} \times \frac{\mathrm{Ze.e}}{\mathrm{r^2}} \qquad \ldots\ldots\ldots (i)$$

Where $\frac{1}{4\pi\epsilon_o} = 9 \times 10^9\ \mathrm{Nm^2C^{-2}}$ and $\epsilon_o = 8.85 \times 10^{-12}\ \mathrm{C^2N^{-1}m^{-2}}$ is permittivity of free space (or air or vacuum).

(b) An electron can occupy only those orbits in which the angular momentum is equal to an integral multiple of $\frac{h}{2\pi}$, where h is the Planck's constant. If an electron of mass m is moving with a constant velocity v in a stable orbit of radius r, then

$$\mathrm{mvr} = \mathrm{n}\frac{\mathrm{h}}{2\pi}, \qquad (\text{where } \mathrm{n} = 1, 2, 3, \ldots\ldots \text{ are integers}) \quad \ldots\ldots\ldots \text{(ii)}$$

This is called Bohr's quantization condition. The orbits given by the above equation are known as stationary orbits.

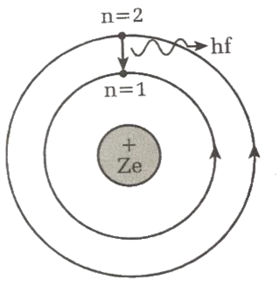


Fig.: Emission of radiation

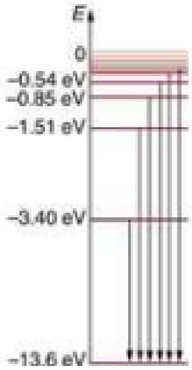
(c) An electron revolving in any stationary orbit doesn't radiate energy at all. The electron emits energy when it jumps from outer orbit to inner orbit. Similarly, it absorbs radiation energy when it jumps from the inner orbit to the outer orbit.

If E_n and E_o are the energies associated with excited and ground state energy levels respectively, the energy released during the transition of an electron is given by

$$\mathrm{h}f = \mathrm{E_n} - \mathrm{E_o} \qquad \ldots\ldots\ldots \text{(iii)}$$

Where *f* is the frequency of radiation.

(ii) The figure shows Lyman series of energy transmission in hydrogen atom. Calculate the frequency of a photon emitted by an electron jumping from the second excited state to the ground level. [2]



→ Solution:

$n_1 = 1$

$n_2 = 2$

R = $1.097 \times 10^7\ \mathrm{m^{-1}}$

c = $3 \times 10^8\ \mathrm{m/s}$

We know that,

$$\frac{1}{\lambda} = \mathrm{R}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(1 - \frac{1}{4}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{3}{4}$$

$$\frac{\mathrm{f}}{\mathrm{c}} = 1.097 \times 10^7 \times \frac{3}{4}$$

$$f = 3 \times 10^8 \times 1.097 \times 10^7 \times \frac{3}{4}$$

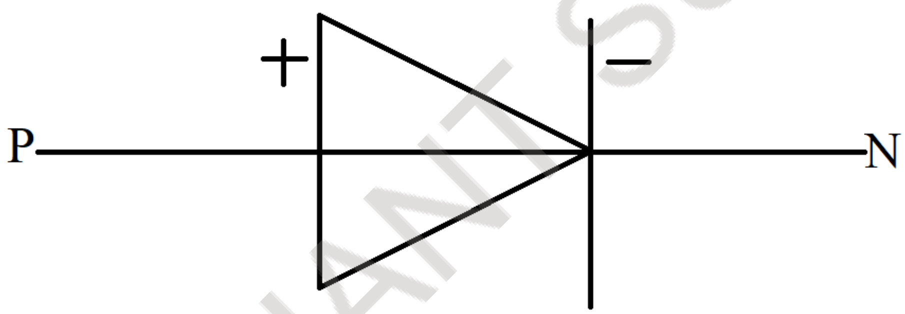
$$f = 2.46 \times 10^{15}\ \text{Hz}$$

Hence, the frequency of a photon emitted by an electron jumping from second excited state to the ground level is 2.46×10^{15} Hz.

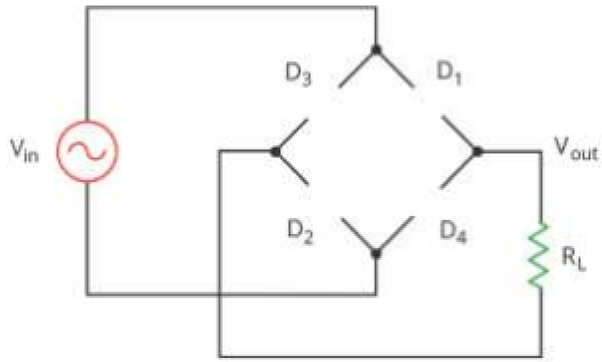
OR

(i) Sketch the symbol of a p-n junction diode and indicate the polarity of its ends. [1]

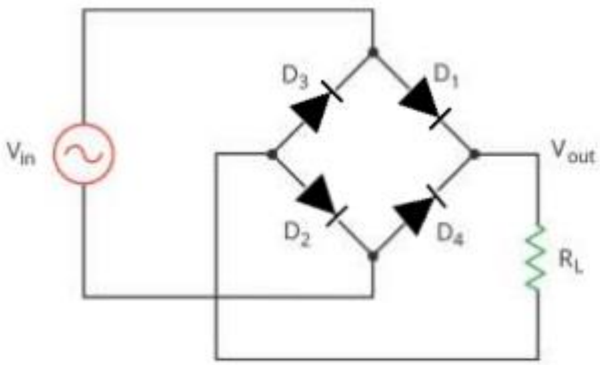
→ The symbol of p-n junction diode is,



(ii) Copy the outline of a diode bridge rectifier and complete it by adding diodes in the gaps. [2]



→ The outline of diode bridge rectifier with complete diodes is,



(ii) Explain what will happen if one of the four diodes is damaged so that it stops conducting totally in any direction. Sketch a graph to show how the pd across the Load R_L would vary with time in this situation. [2]

→ Full wave bridge rectifier consists of 4 diodes in which two diodes operates during positive (+) half cycle and other two during negative (-) half cycle.

Assume that D_1 diode is damaged, so during positive (+) half cycle D_1 & D_3 are forward biased. Thus no current will pass through load resistance as forwarded diode D_1 is damaged and D_2 & D_4 are reverse biased. Thus no current will pass through load resistance as forwarded diode D_1 is damaged & D_2 & D_4 are reverse biased.

Now, during negative (-) half cycle D_1 & D_3 are reverse biased & D_2 & D_4 are forward biased. Thus current will pass through D_2& D_4 to load resistance.

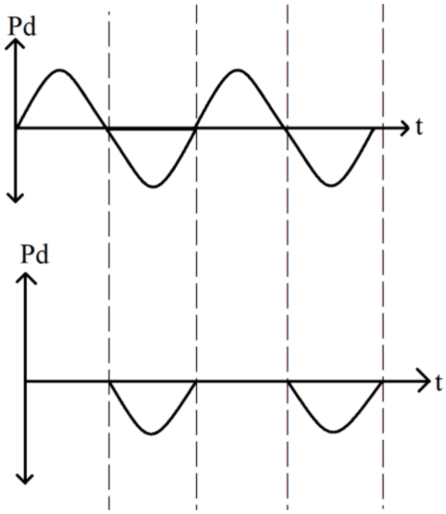


Figure: Variation of P.d across load R_1 with time

Section C: Long Answer Questions. (3 × 8 = 24)

9. Earthquake sets rocks and buildings in motion. When a rock is subjected to compression, a restoring force develops inside it. This restoring force is given by an equation F= -Ax where x is displacement and A is a constant.

(i) Prove that this force will make the rock vibrate with simple harmonic motion. [2]

→ Solution:

Given, $f = -Ax$

Where, f is restoring force

A is a constant

& x is displacement.

So,

$ma = -Ax$

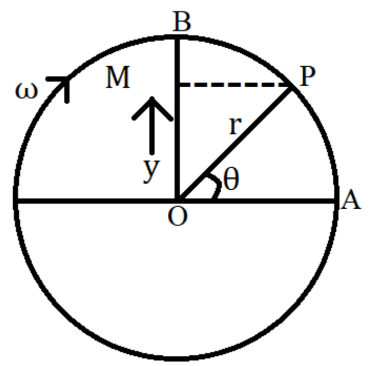
$a \propto -x$ ……… (i)

This shows that acceleration is directly proportional to the displacement & negative (-) sign shows that direction of restoring force is opposite to the direction of displacement, which is the required condition for simple harmonic motion.

Thus from above it is proved that the rock will vibrate with simple harmonic motion.

(ii) Show that the speed of an object undergoing simple harmonic motion is given by the expression $v = \pm\omega\sqrt{(A^2 - x^2)}$ where the symbol carry standard meanings. [2]

→ Consider a particle moving around a circle of radius 'r' with angular velocity 'ω' in anti-clockwise direction.



In ΔPOA,

$$\sin\theta = \frac{PA}{OP} = \frac{OM}{OP} = \frac{y}{r}$$

or, $r\sin\theta = y$

or, $y = r\sin\omega t$ ……… (i) $[\because \theta = \omega t]$

Now, we know that,

$$v = \frac{dy}{dt}$$

$$\text{or,} \quad v = \frac{d(r \sin \omega t)}{dt}$$

$$\text{or,} \quad v = r\omega \cos \omega t$$

$$\text{or,} \quad v = r\omega\sqrt{1 - \sin^2 \omega t}$$

$$\text{or,} \quad v = r\omega\sqrt{1 - \left(\frac{y}{r}\right)^2} \qquad \text{from (i) } \sin \omega t = \frac{y}{r}$$

$$\text{or,} \quad v = r\omega\sqrt{\left(\frac{r^2 - y^2}{r^2}\right)}$$

$$\text{or,} \quad v = \pm r\omega\frac{\sqrt{r^2 - y^2}}{r}$$

$$\text{or,} \quad v = \pm\omega\sqrt{r^2 - y^2}$$

For maximum amplitude (r = A)

$$\therefore v = \pm\omega\sqrt{A^2 - y^2}$$

Thus, the speed of object undergoing simple harmonic motion is given by the expression $v = \pm\omega\sqrt{A^2 - y^2}$.

(iii) Calculate the maximum speed of a building shaken by S-waves of 21Hz and amplitude 0.05m. [2]

→ Solution:

Frequency (f) = 21 Hz

Amplitude (A) = 0.05m

Maximum Speed (v_{max}) = ?

We know that, $v = A\omega \cos \omega t$

For maximum velocity, ($\cos \omega t = 1$)

Thus,

$$v_{max} = A\omega$$

$$= A \times 2\pi f = 0.05 \times 2\pi \times 21 = 6.6 \text{ m/s}$$

Thus, the maximum speed of a building shaken by this wave is 6.6 m/s.

(iv) Explain why tall buildings are more susceptible to damage by S-waves which generally have low frequency. [2]

→ A seismic wave have low frequency and tall buildings also have low natural frequency, when these two low frequencies match then resonance phenomenon takes place which tends in vibration with maximum amplitude and hence may destroy the building. Thus, tall buildings are more susceptible to damage by S-waves which generally have low frequency due to resonance phenomenon.

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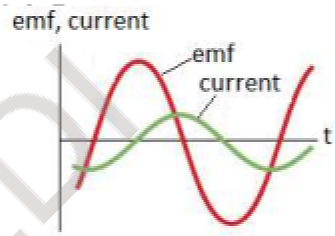
10. The figure below shows the variation of e.m.f. and current with time in a typical LRC circuit.

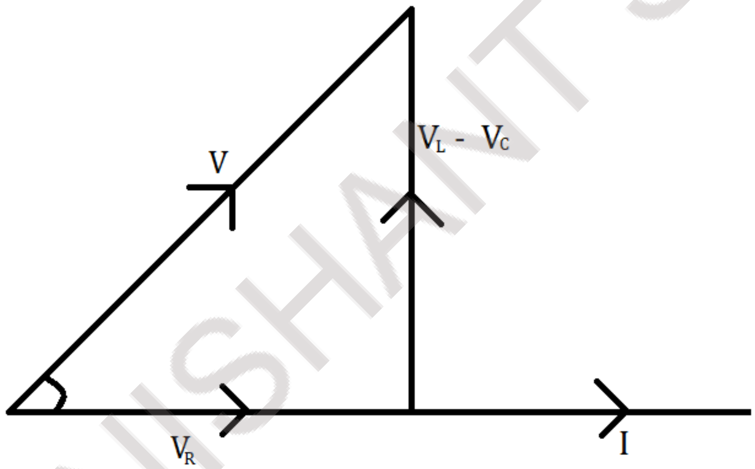


(i) Explain whether the phase constant is positive or negative. [2]

→ Here current lags applied e.m.f. or we can say e.m.f. leads current ($\emptyset > 0$) so phase constant is positive.

(ii) Sketch a phasor diagram for the given case. [2]

→



(iii) Is the circuit more inductive or capacitive? Explain. [2]

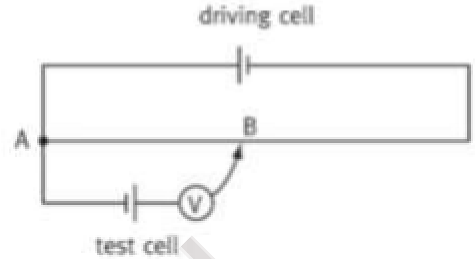
→ Since the phase constant is positive, the circuit is more inductive.

(iv) To increase the rate at which energy is transferred to the resistive load, should the inductance be increased or decreased? Justify your answer. [2]

→ Here $X_L > X_C$, to increase rate at which energy is transmitted to load X_L must be equal to X_C which can be done by decreasing X_L to X_C or increase X_C to X_L.

OR

A student sets up a circuit as shown in the figure given below to measure the e.m.f. of a test cell.



(a) Explain why he is unable to find a balance point and state the change he must make in order to achieve the balance. [2]

→ He is unable to find balance point because of

i) Terminal of cell is joined incorrectly.
ii) Voltmeter is used.

To achieve balance point below mentioned faults should be removed by him

i) Joining the positive terminal of cell with point A.
ii) Using galvanometer instead of voltmeter.

(b) State how he would recognize the balance point. [1]

→ When the jockey connected to galvanometer is slid over the potentiometer wire at a point in the wire he will find galvanometer showing no deflection and that point would be called balance point.

(c) He obtained the balance point for distance 37.5cm using standard cell of e.m.f. 1.50V. And for the test cell, the balance distance AB was 25.0 cm. Calculate the e.m.f. of the test cell. [2]

→ Solution:

Standard Cell	Test Cell
$E_1 = 1.5$ V	$E_2 = ?$
$L_1 = 37.5$ cm	$L_2 = 25$ cm

We know that,

$E \propto L$

⇨ $\frac{E_1}{E_2} = \frac{L_1}{L_2}$

⇨ $\frac{1.5}{E_2} = \frac{37.5}{25}$

⇨ $E_2 = 1$ V

Hence, the e.m.f. of the test cell is 1V.

(d) He could have used an ordinary voltmeter to measure the e.m.f. of the test cell directly. The student, however, argues that the above instrument is more precise than an ordinary voltmeter. Justify his logic. [2]

→ Yes, the above instrument (potentiometer) is more precise then an ordinary voltmeter. Since a voltmeter has certain value of its internal resistance and when it is connected in parallel with cell to measure P.d across it, it will measure the P.d less than the actual value and potentiometer uses null deflection method to measure e.m.f. and does not draw any current and thus measures e.m.f. more precisely.

---

11. (a) Explain what is meant by quantization of charge? [2]

→ Quantization of charge means charge only exists discrete amount rather than continuous value. Positive charge is always found in integral multiple of charge of an electron/proton. i.e. $q = \pm ne$

Where, n is an integer

For electron charge is $-e$ & for proton charge is $+e$.

(b) In a Millikan's oil drop experiment, an oil drop of weight 1.5×10^{-14}N is held stationary between plates 10mm apart by applying a P.d of 470V between the plates.

(i) State the condition necessary for the drop to remain stationary. Also, sketch the forces acting on the oil drop. [2]

→ When the oil drop remains stationary,

$F_e + U = W$

Since, the density of air is very small, so the upthrust on the oil drop can be neglected i.e. U = 0.

$F_e = W$

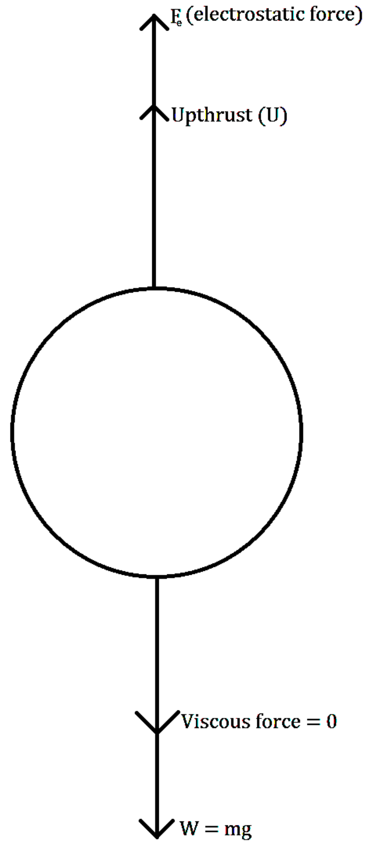


FIGURE: Stationary condition of oil drop.

(ii) Calculate the charge on the oil-drop. [2]

→ Solution:

Weight of oil drop (mg) = 1.5×10^{-14}N

Distance between plates (d) = 10mm

= 10×10^{-3}m

Potential difference (P.d or V) = 470 V

Since, the oil drop remains stationary,

$$f_e + U = W$$

$$f_e = W - U$$

$$qE = mg - U$$

$$q = \frac{mg - U}{E}$$

Since, the density of air is very small, so the upthrust on the oil drop can be neglected i.e. U = 0.

So,

$$q = \frac{mg}{E}$$

$$\text{or,} \qquad q = \frac{mg}{\frac{V}{d}}$$

$$\text{or,} \qquad q = \frac{dmg}{V}$$

$$\text{or,} \qquad q = \frac{10^{-3} \times 1.5 \times 10^{-14} \times 10}{470}$$

$$\text{or,} \qquad q = 3.19 \times 10^{-19}\ \text{C}$$

Hence, the charge on the oil drop is 3.19×10^{-19} C.

(iii) Explain what would happen if the above oil drop is suddenly struck by a stray alpha particle. [2]

→ Since the oil drop is negatively charged & alpha particle is positively charged, they will attract each other.

If ‘f’ be the force of attraction between them, q_1 is the charge of oil drop & q_2 be the charge of alpha particle, then

$$F = \frac{q_1 q_2}{4\pi\epsilon_o r^2}$$

Where r is the distance between them.

OR

(a) Derive an expression $N = N_o e^{-\lambda t}$ for a radioactive process where the symbols carry their standard meanings. [3]

→ According to law of disintegration or radioactivity.

$$-\frac{dN}{dt} \propto N$$

Let N_o be the initial number of atom

$$-\frac{dN}{dt} = \lambda N \quad (\therefore \lambda = \text{decay constant})$$

$$\text{or,} \quad -\frac{dN}{N} = \lambda\, dt$$

$$\text{or,} \quad \int_{N_o}^{N} -\frac{dN}{N} = \int_{t=0}^{t} \lambda\, dt$$

$$\text{or,} \quad -[\log(N)]_{N_o}^{N} = \lambda\, [t]_0^t$$

$$\text{or,} \quad -[\log(N) - \log(N_o) = \lambda\, t$$

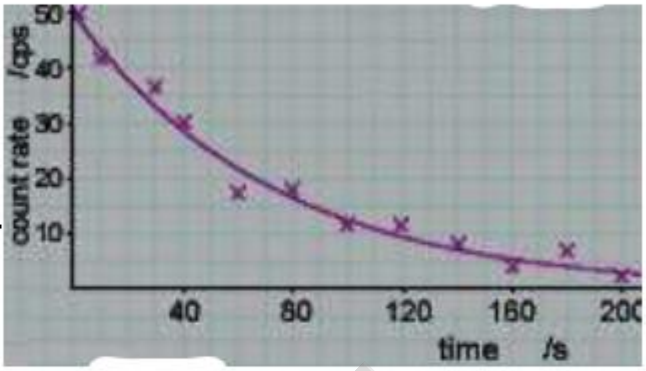
$$\text{or,} \quad -\log\left(\frac{N}{N_o}\right) = \lambda\, t$$

$$\text{or,} \quad \frac{N}{N_o} = e^{-\lambda t}$$

$$\therefore N = N_o\, e^{-\lambda t}$$

Hence, this is the required equation of decay law.

(b) A student measured the activity of a sample of radioactive rock. Her results are presented in the graph.



(i) Explain why the data are scattered. [1]

→ Since the count rate is not exactly correlated with time, so the data are scattered.

(ii) Determine the half-life of this sample. [2]

→ Solution:

From the above graph;

$$\frac{dN}{dt} = \lambda\, t$$

or, $$\frac{50}{50} = \lambda$$

$$\therefore \lambda = 1$$

$$\therefore T_{\frac{1}{2}} = \frac{0.693}{1} = 0.693$$

Hence, the half-life of this sample is 0.693 sec.

(iii) How will the shape of this curve will change if she repeats the experiment with a sample with a larger decay constant? Give reason to your answer. [2]

→ The curve will be steeper than the initial one.

As we know, $T_{\frac{1}{2}} = \frac{0.693}{\lambda}$, if λ (disintegration constant) will increase then $T_{\frac{1}{2}}$ will decrease which means it will decay in short time making the curve quickly decreasing (steeper).