CLASS XII (2019-20)

PHYSICS (042)

MOCK TEST -1

Time : 3 Hours **Maximum Marks : 70**

General Instructions :

(i) All questions are compulsory. There are 37 questions in all.

(ii) This question paper has four sections: Section A, Section B, Section C, Section D.

(iii) Section A contains twenty questions of one mark each, Section B contains seven questions of two marks each, Section C contains seven questions of three marks each and Section D contains three questions of five marks each.

(iv) There is no overall choice. However, internal choices has been provided in two question of one marks each, two question of two marks, one question of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.

(v) You may use the following values of physical constants wherever necessary.

$c = 3 \times 10^8$ m/s, $h = 6.63 \times 10^{-34}$ Js, $e = 1.6 \times 10^{-19}$ C, $\mu_0 = 4\pi \times 10^{-7}$ TmA^{-1},

$\varepsilon_0 = 8.854 \times 10^{-12}$ C^{2}N^{-1}m^{-2}, $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ Nm^{2}C^{-2}, $m_e = 9.1 \times 10^{-31}$ kg,

Mass of neutron $= 1.675 \times 10^{-27}$ kg,

Mass of proton $= 1.673 \times 10^{-27}$ kg, Avogardro's number $= 6.023 \times 10^{23}$ per gram mole,

Boltzmann constant $= 1.38 \times 10^{-23}$ JK^{-1}.

Section-A

DIRECTION : (Q 1-Q 10) Select the most appropriate option from those given below each question

1. When a body is connected to the earth, then electrons from the earth, flow into the body. It means that the body is
(a) unchanged
(b) an insulator
(c) positively charged
(d) negatively charged

Ans : (c) positively charged

We know that when a positively charged body is connected to the earth, then electrons from the earth flow into the body.

2. The energy stored in a capacitor is actually stored
(a) between the plates
(b) on the positive plate
(c) on the negative plate
(d) on the outer surfaces of the plates

Ans : (a) between the plates

We know that energy stored in a capacitor is in the form of electrostatic energy. It is actually stored between the plates of the capacitor.

3. A charge moving with uniform velocity produces
(a) only an electric field
(b) only a magnetic field
(c) electromagnetic field
(d) none of these

Ans : (c) electromagnetic field

A moving charge is produces electric and magnetic field. Hence, a electromagnetic field is present around a moving charge.

4. The image formed by objective lens of a compound Microscope is
(a) Virtual and diminished
(b) Real and diminished
(c) Real and large
(d) Virtual and Large

Ans : (c) Real and large

The image formed by objective lens of a compound microscope is real and large.

5. The magnifying power of a magnifying glass of power 12 dioptre is
(a) 4 (b) 1200
(c) 3 (d) 25

Ans : (a) 4

Given,Magnifying power of glass,

$$m = 12$$

Power of the lens, $$P = \frac{1}{f}$$

$$f = \frac{1}{P} = \frac{1}{12}\,\text{m}$$

$$= \frac{100}{12}\,\text{cm}$$

Magnifying lower of simple microscope is given by,

$$m = 1 + \frac{D}{f} = 1 + \frac{25 \times 12}{100}$$

$$= 1 + 3 = 4$$

6. In a closed circuit of resistance $10\,\Omega$, the linked flux varies with time according to relation $\phi = 6t^2 - 5t + 1$. At $t = 0.25$ second, the current (in Ampere) flowing through the circuit is

(a) 0.4 (b) 0.2

(c) 2.0 (d) 4.0

Ans : (b) 0.2

Given, $$\phi = 6t^2 - 5t + 1$$

We know that, $$e = \frac{-d\phi}{dt} = \frac{-d(6t^2 - 5t + 1)}{dt}$$

$$= -12t + 5$$

Here, $$t = 0.25$$

$$= -12 \times 0.25 + 5$$

$$= -3 + 5 = 2\,\text{V}$$

Now, Current, $$I = \frac{e}{R}$$

Here, $$R = 10\,\Omega$$

$$= \frac{2}{10} = 0.2\,\text{A}$$

7. In an oscillating LC circuit, maximum charge on the capacitor is Q. The charge on this capacitor, when the energy is stored equally between the electric and magnetic fields is

(a) Q (b) $\frac{Q}{2}$

(c) $\frac{Q}{\sqrt{3}}$ (d) $\frac{Q}{\sqrt{2}}$

Ans : (d) $\frac{Q}{\sqrt{2}}$

Given, Maximum charge on capacitor,

$$q_{max} = Q$$

We know that maximum energy stored in the capacitor,

$$E_{max} = \frac{q_0^2}{2C}$$

And energy stored in capacitor at any time,

$$E_1 = \frac{q^2}{2\,C}$$

where $q =$ Charge at on capacitor

Therefore, magnetic energy stored in the inductor at any time,

$$E_2 = (E_{max} - E_1) = \frac{q_{max}^{\ 2}}{2\,C} - \frac{q^2}{2\,C}$$

Since, both the energies are equal, therefore,

$$E_2 = E_1$$

or $$\frac{q_{max}^{\ 2}}{2C} - \frac{q^2}{2C} = \frac{q^2}{2C}$$

or $$\frac{q_{max}^{\ 2}}{2C} = \frac{q^2}{C}$$

or $$q^2 = \frac{q_{max}^{\ 2}}{2}$$

or $$q = \frac{q_{max}}{\sqrt{2}} = \frac{Q}{\sqrt{2}}$$

8. A parallel plate capacitor consists of two circular plates each of radius 2 cm separated by distance of 0.1 mm. If rate of change of potential difference is 5×10^{13} V-s^{-1}, then displacement current will be

(a) 5.6 A (b) 5.6×10^2 A

(c) 5.6×10^3 A (d) 5.6×10^4 A

Ans : (c) 5.6×10^3 A

Given, Radius of each plates, $r = 2\,\text{cm}$

$$= 0.02\,\text{m}$$

Distance between the plates, $d = 0.1\,\text{mm}$

$$= 0.1 \times 10^{-3}\,\text{m}$$

and rate of change of potential difference,

$$\frac{dV}{dt} = 5 \times 10^{13}\,\text{V-s}^{-1}$$

We know that area of circular plate,

$$A = \pi r^2 = \pi(0.02)^2$$

$$= 1.26 \times 10^{-3}\,\text{m}^2$$

Therefore displacement current,

$$I_d = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}(EA)$$

$$= \varepsilon_0 \frac{d}{dt}\left(\frac{V}{d} \times A\right)$$

$$= \frac{\varepsilon_0 A}{d}\,\frac{dV}{dt}$$

$$= \frac{(8.85 \times 10^{-12})(1.26 \times 10^{-3})}{0.1 \times 10^{-3}} \times (5 \times 10^{13})$$

$$= 5.6 \times 10^3 \text{ A}$$

where, $\varepsilon_0 =$ Absolute electric permittivity of free space equal to 8.85×10^{-12} C^2-N^{-1}-m^{-2}

9. Light of two different frequencies, whose photons have energies of 1 eV and 2.5 eV successively illuminate a metal whose work function is 0.5 eV. The ratio of maximum velocities of the emitted electrons will be

(a) 1 : 5 (b) 1 : 4
(c) 1 : 2 (d) 1 : 1

Ans : (c) 1 : 2

Given, Energy of first photon,

$$E_1 = 1 \text{ eV}$$

Energy of second photon,

$$E_2 = 2.5 \text{ eV}$$

and work function of the metal,

$$\phi_0 = 0.5 \text{ eV}$$

We know that maximum kinetic energy of an electron,

$$K_{max} = \frac{1}{2} m v_{max}^2$$

We also know that maximum kinetic energy of the emitted electron,

$$\frac{1}{2} m v_{max}^2 = E - \phi_0$$

or $$v_{max} = \sqrt{\frac{2(E-\phi_0)}{m}} \propto \sqrt{(E-\phi_0)}$$

Therefore, $$\frac{v_{max_1}}{v_{max_2}} = \sqrt{\frac{E_1 - \phi_0}{E_2 - \phi_0}}$$

$$= \sqrt{\frac{1-0.5}{2.5-0.5}}$$

$$= \sqrt{\frac{0.5}{2}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

or $$v_{max_1} : v_{max_2} = 1:2$$

10. In the nuclear fusion reaction $_1H^2 + _1H^3 \rightarrow _2He^4 + n$, the repulsive potential energy between the two nuclei is 7.7×10^{-14} J. The temperature at which the gases must be heated to initiate the reaction is nearly (Boltzmann's constant $k = 1.38 \times 10^{-23}$ J-K^{-1})

(a) 10^9 K (b) 10^7 K
(c) 10^5 K (d) 10^3 K

Ans : (a) 10^9 K

Given, Repulsive potential energy between two nuclei,

$$u = 7.7 \times 10^{-14} \text{ J}$$

and Boltzmann's constant,

$$k = 1.38 \times 10^{-23} \text{ J-K}^{-1}$$

We know that kinetic energy of gas molecules,

$$\text{K.E.} = \frac{3}{2} kT$$

We also know that to initiate the reaction, kinetic energy (K.E.) of gas molecules should be equal to the repulsive potential energy between two nuclei to overcome the repulsive electrostatics force (u).

Therefore, $$\frac{3}{2} kT = u$$

or $$T = \frac{2 \times u}{3k}$$

$$= \frac{2 \times (7.7 \times 10^{-14})}{3 \times (1.38 \times 10^{23})}$$

$$= 3.78 \times 10^9 \text{ K}$$

Thus, temperature, at which the gases must be heated, to initiate reaction is nearly 10^9 K.

DIRECTION : (Q11-Q15) Fill in the blanks with appropriate answer.

11. The net charge on a current carrying conductor is ....

Ans : zero

We know that number of protons in a current carrying conductor at any instant is equal to the number of free electrons.

Therefore, the net charge on a current carrying conductor is zero.

12. If a bar magnet of length 10 cm and pole strength 40 A-m is placed at an angle of 30° in a uniform magnetic field of intensity 2×10^{-4} T, then torque acting on it is ....

Ans : 4×10^{-4} N-m

Given, Length of bar magnet, $2l = 10$ cm

$$= 0.1 \text{ m}$$

Pole strength, $$m = 40 \text{ A-m}$$

Angle between bar magnet and magnetic field,

$$\theta = 30°$$

and intensity of magnetic field,

$$B = 2 \times 10^{-4} \text{ T}$$

We know that magnetic moment,

$$M = m \times 2l$$

$$= 40 \times 0.1$$

$$= 4 \text{ A-m}^2$$

Therefore, torque acting on the bar magnet in uniform magnetic field

$$\begin{aligned}\tau &= MB\sin\theta \\ &= 4 \times (2 \times 10^{-4}) \times \sin 30° \\ &= (8 \times 10^{-4}) \times 0.5 \\ &= 4 \times 10^{-4} \text{ N-m.}\end{aligned}$$

or

When the intensity of magnetic field is increased four times, the time period of suspended magnetic needle becomes ....

Ans : half

The time period of suspended magnetic needed is given by.

$$T = 2\pi\sqrt{\frac{I}{mB}}$$

i.e., $$T \propto \frac{1}{\sqrt{B}}$$

Hence, $$\frac{T_1}{T_2} = \sqrt{\frac{B_2}{B_1}}$$

$$\frac{T_1}{T_2} = \sqrt{\frac{4B_1}{B_1}}$$

$$T_2 = \frac{T_1}{2}$$

The time period of suspended magnetic needed become half.

13. The value of maximum amplitude produced due to interference of two waves is given by $y_1 = 4\sin\ \omega t$ and $y_2 = 3\cos\omega$t is ....

Ans : 7

Given, $$y_1 = 4\sin\omega t \qquad ...(1)$$

$$y_2 = 3\cos\omega t$$

$$y_2 = 3\sin\left(\tfrac{\pi}{2} + \omega t\right) ...(2)$$

Compare equation.(1) and (2) with a standard equation, we get

$$A_1 = 4$$

$$A_2 = 3$$

Initial phase difference, $\phi = \dfrac{\pi}{2}$

Resultant amplitude,

$$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos\phi}$$

$$\cos\phi = 1$$

For maximum amplitude,

Hence, $$\phi = 0°$$

$$A = \sqrt{(A_1 + A_2)^2}$$

So, $$\begin{aligned}A_{\max} &= A_1 + A_2 \\ &= 3 + 4 = 7\end{aligned}$$

14. Excitation energy of a hydrogen-like ion, in its first excitation state is 40.8 eV. The energy needed to remove the electron from the ion in ground state, is ....

Ans : 54.4 eV

Given, Excitation energy in first excitation state,

$$E_2 = 40.8 \text{ eV}$$

We know that energy level of first excitation state,

$$n_2 = 2$$

and energy level of ground state,

$$n_1 = 1$$

We also know that excitation energy of hydrogen-like ion in its first excitation state,

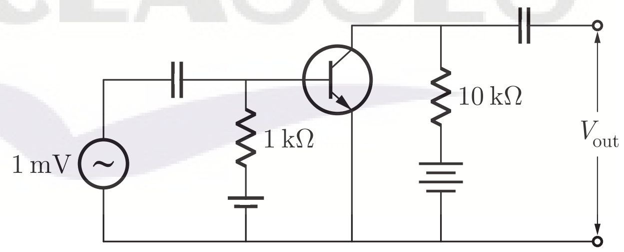
$$E_2 = E_1\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

or $$\begin{aligned}40.8 &= E_1\left(\frac{1}{1^2} - \frac{1}{2^2}\right) \\ &= \frac{3E_1}{4}\end{aligned}$$

or $$\begin{aligned}E_1 &= \frac{40.8 \times 4}{3} \\ &= 54.4 \text{ eV}\end{aligned}$$

(where $E_1 =$ Energy needed to remove an election from the ion in ground state)

15. In the following common-emitter configuration an n-p-n transistor with current gain $\beta = 100$ is used. The output voltage of the amplifier will be .... V.



Ans : 1.0 V

Given, Current gain for common-emitter,

$$\beta = 100$$

Input voltage of common-emitter,

$$V_{in} = 1 \text{ mV} = 10^{-3} \text{ V}$$

Load resistance, $$\begin{aligned}R_L &= 10 \text{ k}\Omega \\ &= 10 \times 10^3\ \Omega\end{aligned}$$

and base-emitter resistance,

$$R_{BE} = 1 \text{ k}\Omega = 10^3\ \Omega$$

We know that the output voltage of the

amplifier,

$$V_{out} = \frac{\beta V_{in} R_L}{R_{BE}}$$

$$= \frac{100 \times 10^{-3} \times (10 \times 10^3)}{10^3}$$

$$= 1.0 \text{ V}$$

DIRECTION : (Q16-Q20) Answer the following

16. A concave mirror is held in water. What should be the change in focal length of the mirror?

Ans :

No change is focal length as the focal length of mirror f is independent of medium and depends only on radius of curvature R, i.e.

$$f = \frac{R}{2} \qquad \textbf{(1)}$$

17. Magnetic field lines can be entirely confined within the core of a toroid but not within a straight solenoid, why?

Ans :

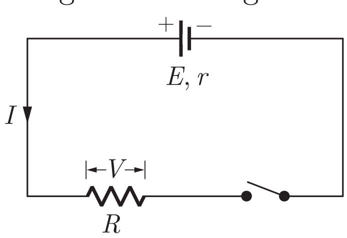
A toroid is formed by current loops placed along a circle. Field lines thus formed by these closed loops remain inside the toroid producing a net dipole moment zero.

But in a solenoid current loops are placed along a straight line and so their field lines resemble that of a bar magnet with a non-zero dipole moment. **(1)**

18. A cell of emf E and internal resistance r is connected across a variable resistor R. Plot a graph showing the variation of terminal potential V with resistance R. Predict from the graph, the condition under which V becomes equal to E.

Ans :

According to given conditions in the question, the circuit diagram can be given as,



From the above diagram,

$$V = IR = \frac{E}{R+r} \cdot R$$

$$= \frac{E}{\frac{R+r}{R}} = \frac{E}{1+\frac{r}{R}}$$

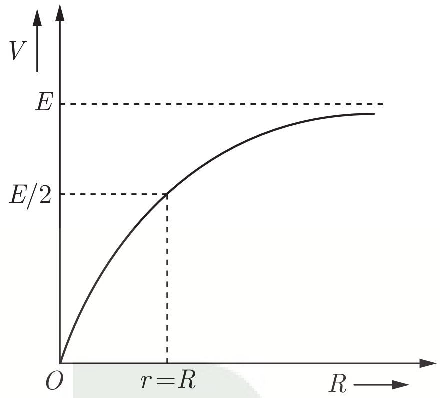
$$\therefore \qquad V = \frac{E}{1+\frac{r}{R}}$$

When $R = 0$, $V = 0$

When $R = r$, $V = \frac{E}{2}$

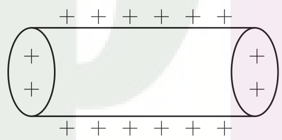
When $R = \infty$, $V = E$ **(1)**

The plot showing variation of V versus R is given below.



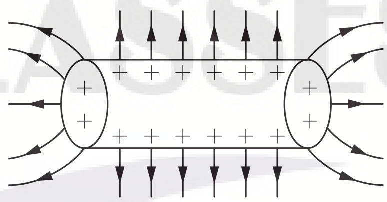
From the above graph, it is clear that V becomes equal to E when $R \to \infty$ **(1)**

19. Sketch the electric field lines for a uniformly charged hollow cylinder as shown in the figure.



Ans :

The field lines for a uniformly positive charged hollow cylinder as shown in the figure.



(1)

20. Write any two properties of X-rays.

Ans :

1. The range of wavelength of X-ray is 1 mm to 10^{-3} nm.
2. They gives the luminous effect on photo graphic plates. **(1)**

or

Write down two properties of electromagnetic wave.

Ans :

Properties of electromagnetic waves are following:

1. Electromagnetic waves are produced due

to oscillating and accelerating charge.

2. These waves do not require any medium to propagate. They can also travel in vacuum also.

Section-B

21. Usually it has been seen in offices choke coil is needed in the fluorescent tubes with AC mains. Also, an ordinary resistor can not used instead of choke coil. Why? What is the value hidden in the question?

Ans :

We use the choke coil instead of resistance because the power loss across resistor is maximum, while the power loss across choke is zero.

For resistor, $\phi = 0^\circ$,

$$P = I_{rms} V_{rms} \cos 0^\circ$$
$$= I_{rms} \cdot V_{rms} = \text{maximum}$$

(choke coil)

For inductor, $\phi = 90^\circ$,

$$P = I_{rms} V_{rms} \cos 90^\circ = 0$$

Value hidden in the question is 'electricity saving'. **(2)**

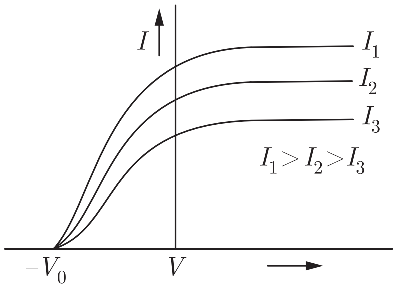
22. Draw suitable graphs to show the variation of photoelectric current with collector plate potential for

1. A fixed frequency but different intensities $I_1 > I_2 > I_3$ of radiation.
2. A fixed intensity but different frequencies $f_1 > f_2 > f_3$ of radiation.

Ans :

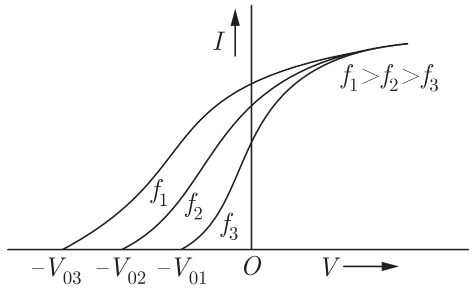
Graphs showing variation of photoelectric current I with collector plate potential V for

1. A fixed frequency but different intensities of radiation.



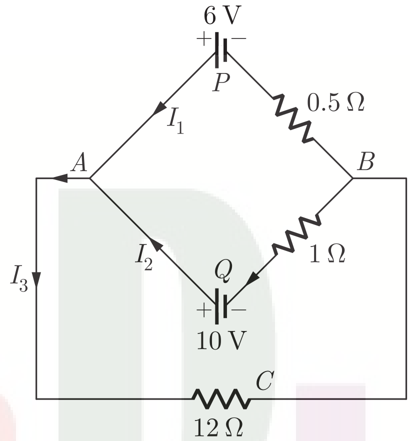
(1)

2. a fixed intensity but different frequencies of radiation.



(1)

23. Apply Kirchhoff's laws to the loops $ACBPA$ and $ACBQA$ to write the expressions for the current I_1, I_2 and I_3 in the network.



Circuit diagram of loops

Ans :

Apply Kirchhoff's 1st law,

$$I_3 = I_1 + I_2 \qquad \textbf{(1/2)}$$

Applying Kirchhoff's lind law to loop $ACBPA$,

$$-12I_3 - 0.5I_1 + 6 = 0$$
$$0.5I_1 + 12I_3 = 6 \qquad \textbf{(1/2)}$$

Applying Kirchhoff's second law to loop $ACBQA$

$$-12I_3 - 1I_2 + 10 = 0$$
$$I_2 + 12I_3 = 10 \qquad \textbf{(1)}$$

24. What kinetic energy of a neutron will be associated by the de-Broglie wavelength 1.32×10^{-10}m ? Given that mass of a neutron $= 1.675 \times 10^{27}$kg.

Ans :

Given:

Wavelength, $\lambda = 1.32 \times 10^{-10}$ m

Mass of neutron, $m_n = 1.675 \times 10^{-27}$ kg

As, we know that $\lambda = \dfrac{h}{\sqrt{2m_n K}}$

$$\therefore \qquad K = \frac{h^2}{2m_n\lambda^2} \qquad \textbf{(1)}$$

$$= \frac{(6.63 \times 10^{-34})^2}{2 \times 1.675 \times 10^{-27} \times (1.32 \times 10^{-10})^2}$$

$$= 7.53 \times 10^{-21}\,\text{J} \qquad \textbf{(1)}$$

25. Answer the following questions:

1. The angle of dip at a location in southern India is about 18°. Would you except a greater or smaller dip angle in Britain?
2. Geologists claim that besides the main magnetic N-S pole, there are several local poles in the earth's surface oriented in different directions. How is such a thing possible at all?

Ans :

1. We can expect a greater value of angle of dip in Britain because Britain is located close to North pole. The value of angle of dip in Britain is about 70°. **(1)**
2. 'The earth's magnetic field is only due to the dipole field. As there are several local N-S poles that may exist oriented in different direction, so they may nullify the effect of each other. These local N-S poles may occur due to the deposition of magnetised minerals. **(1)**

26. Define magnifying power of a telescope. Also, write its expression.

Ans :

The magnifying power of a telescope is equal to the ratio of the visual angle subtended at the eye by final image formed at least distance of distinct vision D to the visual angle subtended at the naked eye by the object at infinity.

When final image is at D,

Magnifying power, $M = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$

In normal adjustment, $M = -\frac{f_o}{f_e}$ **(2)**

or

Show that linear magnification of an image formed by a curved mirror may be expressed as ,

$$m = \frac{f}{f-u} = \frac{f-v}{f}$$

Where, letters have their usual meanings.

Ans :

We know that linear magnification of an image formed by a curved mirror is given by

$$m = \frac{h'}{h} = \frac{-v}{u} \qquad \text{...(i)}$$

However, from mirror formula,

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{u-f}{uf}$$

$$v = \frac{uf}{u-f}$$

Hence, $m = \frac{-v}{u} = -\frac{1}{u}\left(\frac{uf}{u-f}\right)$

$$= \frac{f}{f-u} \qquad \text{...(ii)}$$

(1)

Again, as per mirror formula

$$\frac{1}{u} = \frac{1}{f} - \frac{1}{v}$$

$$= \frac{v-f}{fv}$$

$\therefore$ $m = -\frac{v}{u}$

$$= -v\left(\frac{v-f}{fv}\right) = \frac{f-v}{f} \qquad \text{...(iii)}$$

From equation (ii) and (iii), we get

$$m = \frac{f}{f-u}$$

$$= \frac{f-v}{f} \qquad \textbf{(1)}$$

27. Define mean value and root mean square value of alternating current.

Ans :

Mean Value of alternating current(AC)- It is defined as the value of AC which would send same amount of charge through a circuit in half cycle that is sent by steady current in the same time. It is denoted by I_m or I_{av} **(1)**

Root mean square value of AC- It is defined as that average value of alternating current (AC) over a complete cycle which would generate same amount of heat in a given resistor that is generated by steady current in the resistor and in the same time during a complete cycle. **(1)**

or

What is transformer? What do you mean by its efficiency?

Ans :

Transformer- It is a device, which is used to increase or decrease the alternating voltage. **(1)**

Efficiency of transformer- The ratio of output power to input power is known as efficiency of transformer

$$\eta = \frac{\text{Power output}}{\text{Power input}}$$

The efficiency, $\eta = \dfrac{\text{Power output}}{\text{Power input}} \times 100\%$

The efficiency of real transformers is fairly high (90-99%) through not 100%. **(1)**

Section C

28. (i) An electrostatic field line is a continuous curve, i.e. a field line cannot have sudden break. Why not?

(ii) Explain, why two field lines never cross each other at any point?

(iii) A proton is placed in a uniform electric field directed along the positive X-axis. In which direction will it tend to move?

Ans :

(i) Electric field is continuous and exists at all points around a charge distribution. Hence, an electrostatic field line is a continuous curve and cannot have sudden break. **(1)**

(ii) Two field lines never cross each other, because if they do so, then at the point of intersection, there will be two possible directions of electric field, which is impossible. **(1)**

(iii) Proton will tend to move along the positive X-axis in the direction of uniform electric field. **(1)**

29. (i) Two slits are made 1 mm apart and the screen is placed 1 m away. What is the fringe separation, when blue-green light of wavelength 500 nm is used?

(ii) What should be the width of each slit to obtain 10 maxima of the double slit pattern within the central maximum of the single slit pattern?

Ans :

(i) Given: $d = 1\,\text{mm} = 10^{-3}\,\text{m},\ D = 1\,\text{m}$

$$\lambda = 500\,\text{mm} = 5 \times 10^{-7}\,\text{m}$$

$\therefore$ Fringe separation, $\beta = \dfrac{\lambda D}{d}$

$$= \frac{5 \times 10^{-7} \times 1}{10^{-3}}$$

$$= 5 \times 10^{-4}$$

$$= 0.5\,\text{mm} \quad \textbf{(1)}$$

(ii) Let width of each slit be a , then the width is given by,

$$x = \frac{2\lambda D}{a}$$

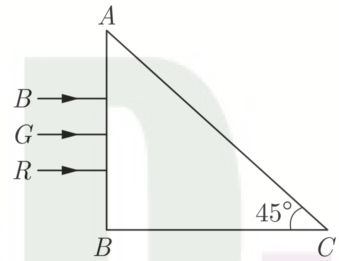
and as per condition Given:

$$x = 10\beta = \frac{10\lambda D}{d}$$

$$\frac{2\lambda D}{a} = \frac{10\lambda D}{d}$$

$$a = \frac{d}{5} = \frac{1}{5} = 0.2\,\text{m} \quad \textbf{(2)}$$

30. Three light rays, red R, green G and blue B are incident on a right angled prism ABC at face AB. The refractive indices of the material of the prism for red, green and blue wavelengths are 1.39, 1.44 and 1.47, respectively. Our of the three, which colour of ray will emerge out of face AC? Justify your answer. Trace the path of these rays after passing through face AB.



Ans :

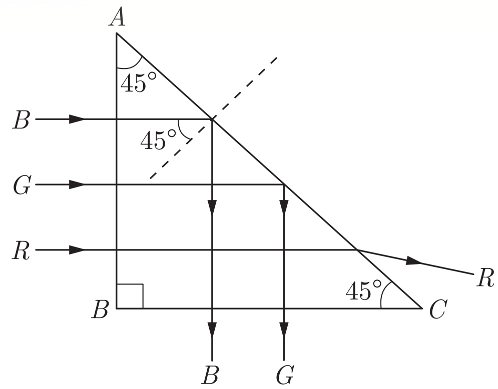
By geometry, angle of incidence i at face AC for all three rays is 45°. Light suffers total internal reflection for which this angle of incidence is greater than critical angle.

$$i > i_C \Rightarrow \sin i > \sin i_C \quad \textbf{(1)}$$

or $\sin 45^\circ > \sin i_C$ or $\dfrac{1}{\sin 45^\circ} < \dfrac{1}{\sin i_C}$

$$\sqrt{2} < \mu \quad \textbf{(1)}$$

Total internal reflection takes place on AC for rays with $\mu > \sqrt{2} = 1.414$, i.e. green and blue colours suffer total internal reflection whereas red undergoes refraction.



(1)

31. Obtain the first Bohr's radius and the ground state energy of a muonic H-atom [i.e. an atom in which a negatively charged muon (μ) of mass about 207 m_e orbits around a proton].

Ans :

Muonic hydrogen is the atom in which a negatively charged muon of mass about 207 m_e revolves round a proton. **(1)**

In Bohr's atom model, $r \propto \frac{1}{m}$

$$\frac{r_{\text{muon}}}{r_{\text{electron}}} = \frac{r_\mu}{r_e} = \frac{m_e}{m_\mu} = \frac{m_e}{207 m_e}$$

$$= \frac{1}{207} \qquad [\because m_\mu = 207 m_e]$$

Here, r_e is the radius of orbit of electron in H-atom $= 0.53\,\text{Å}$

$$r_\mu = \frac{r_e}{207} = \frac{0.53 \times 10^{-10}}{207}$$

$$= 2.56 \times 10^{-13}\,\text{m} \qquad \textbf{(1)}$$

Again in Bohr's atomic model,

$$\because \qquad E \propto m$$

$$\therefore \qquad \frac{E_\mu}{E_e} = \frac{m_\mu}{m_e} = \frac{207\, m_e}{m_e}$$

$$E_\mu = 207\, E_e$$

For ground state, energy of electro in H-atom

$$E_e = -13.6\ \text{eV}$$

$$E_\mu = 207(-13.6)$$

$$= -2815.2\,\text{eV}$$

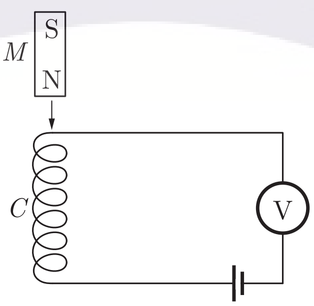
$$= -2.8152\ \text{keV} \qquad \textbf{(1)}$$

32. (i) A current is set up in a long copper pipe. Is there a magnetic field

(a) inside

(b) outside the pipe

(ii) Figure shown below shows a bar magnet M falling under the gravity through an air cored coil C.



(a) Plot a graph showing variation of induced emf E with time t.

(b) What does the area enclosed by the $E-t$ curve depict?

Ans :

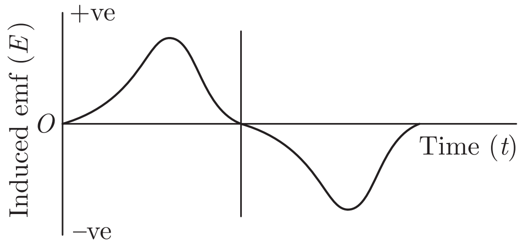
(i)

(a) There is no magnetic field inside the pipe.

(b) There is a magnetic field outside the pipe. **(1)**

(ii)

(a) The graph showing variation of induced emf E with time t is given below. **(1)**



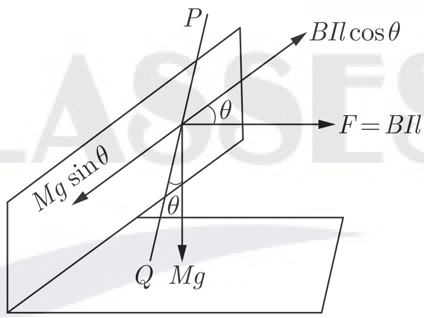
(b) The area enclosed by the $E-t$ curve depicts the total change in magnetic flux linked with the coil during that time. **(1)**

or

On a smooth plane inclined at 30° with the horizontal, a thin current carrying metallic rod is placed parallel to the horizontal ground. The plane is located in a uniform magnetic field of 0.15 T in the vertical direction. For what value of current can the rod be stationary? The mass per unit length of the rod is $0.03\,\text{kg m}^{-1}$.

Ans :

Let a rod PQ be horizontally placed on an inclined plane as shown in the figure.



Inclined plane

Following forces act on the current carrying rod PQ:

1. Weight (Mg) (vertically downward)
2. Horizontal force, $F = IBl$ (due to magnetic field B) **(1)**

Resolving Mg and BIl along and perpendicular to incline plane.

For rod to be stationary,

$$Mg \sin\theta = BIl \cos\theta \qquad ..(i)$$

If, l is the length of rod and m is mass per unit length.

i.e. $$\frac{M}{l} = m$$

$$M = ml \quad \textbf{(1)}$$

From equation.(i), we have

$$(ml)\, g\sin\theta = BIl\cos\theta$$

$$I = \frac{mg\tan\theta}{B}$$

$$= \frac{0.03 \times 9.8 \times \tan 30^\circ}{0.15}$$

$$= 1.132\text{ A} \quad \textbf{(1)}$$

33. A beam of light consisting of two wavelengths 560 nm and 450 nm, is used to obtain interference fringes in a Young's double slit experiment. Find the lest distance from the central maximum, where the bright fringes due to both the wavelengths coincide. The distance between the two slits is 4mm and the screen is at a distance of 1 m from the slits.

Ans :

To find the point of coincidence of bright fringes, we can equate the distance of bright fringes from the central maxima, made by both the wavelengths of light.

Given:

$$D = 1\text{ m},\ d = 4\text{ mm} = 4 \times 10^{-3}\text{ m}$$

$$\lambda_1 = 560\text{ nm},\ \lambda_2 = 420\text{ nm}$$

Let n the order bright fringe of λ_1 coincides with $(n+1)$th order bright fringe of λ_2.

$$\therefore \quad \frac{Dn\lambda_1}{d} = \frac{D(n+1)\lambda_2}{d} \ [\lambda_1 > \lambda_2] \quad \textbf{(1)}$$

$$n\lambda_1 = (n+1)\lambda_2 \Rightarrow \frac{n+1}{n} = \frac{\lambda_1}{\lambda_2}$$

$$\therefore \quad 1 + \frac{1}{n} = \frac{560 \times 10^{-9}}{420 \times 10^{-9}} \Rightarrow 1 + \frac{1}{n} = \frac{4}{3}$$

$$\therefore \quad n = 3 \quad \textbf{(1)}$$

Least distance form the central fringe, where bright fringe of two wavelengths coincide

= Distance of 3rd order bright fringe of λ_1

$$\therefore \quad y_n = \frac{3D\lambda_1}{d} = \frac{3 \times 1 \times 560 \times 10^{-9}}{4 \times 10^{-3}}$$

$$= 0.42 \times 10^{-3}\text{ m}$$

$$= 0.42\text{ mm}$$

3rd bright fringe of λ_1 and 4th bright fringe of λ_2 coincide at 0.42 mm from central fringe. **(1)**

34. Calculate the binding energy (BE) per nucleon of ${}_{20}\text{Ca}^{40}$ nucleus. Given:

$$m({}_{20}\text{Ca}^{40}) = 39.962589\text{ u}$$

$$m_n = 1.008665\text{ u}$$

$$m_p = 1.007825\text{ u}$$

(Take, 1 amu = 931 MeV).

Ans :

In a nucleus of ${}_{20}\text{Ca}^{40}$,

Number of protons, $P = 20$

Number of neutrons, $N = 40 - 20 = 20$

Total mass of 20 protons and 20 neutrons

$$= 20m_p + 20m_n$$

$$= 20(m_p + m_n)$$

$$= 20(1.007825 + 1.008665)$$

$$= 40.3298\text{ u}$$

$$\text{Mass defect, } \Delta m = 40.298 - 39.962589$$

$$= 0.367211\text{ u}$$

Total Binding energy,

$$B_e = 0.367211 \times 931$$

$$= 341.873441\text{ MeV}$$

$$\text{BE/nucleon} = \frac{341.873441}{40}$$

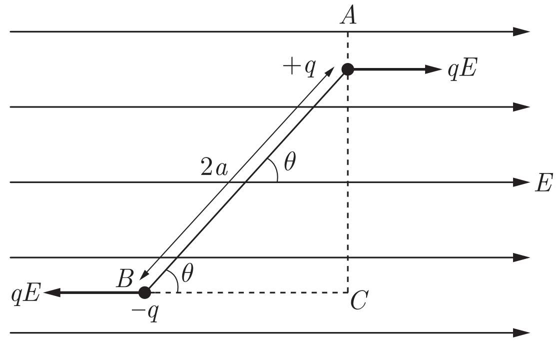
$$= 8.547\text{ MeV/nucleon} \quad \textbf{(3)}$$

Section D

35. Find an expression for the torque acting on an electric dipole placed in uniform electric field. A system of two charges, $q_A = 2.5 \times 10^{-7}$ C and $q_B = 2.5 \times 10^{-7}$C located at points $A(0, 0, -15\text{ cm})$ and $B(0, 0, +15\text{ cm})$, respectively. Find the electric dipole moment of the system and the magnitude of the torque acting on it, when it is placed in a uniform electric field $5 \times 10^4\text{ NC}^{-1}$ making an angle 30°.

Ans :

Consider an electric dipole AB consisting of two point charge $+q$ and $-q$ separated by a distance $2a$. It is placed in a uniform electric field E, making an angle θ.



Force acting on charge $+q$,

$$F_1 = qE \quad \text{[along the direction of E]}$$

Force acting on charge $-q$,

$$F_2 = qE \quad \text{[opposite to the direction of E]}$$

Forces F_1 and F_2 are equal in magnitude, opposite in direction having different lines of action of force.

Therefore, it forms a couple of force. **(1)**

Torque acting on dipole

=Force× Perpendicular distance between the forces

$$\tau = qE \times AC \quad \textbf{(1)}$$

From ΔACB,

$$\sin\theta = \frac{AC}{AB}$$

$$AC = AB\sin\theta$$

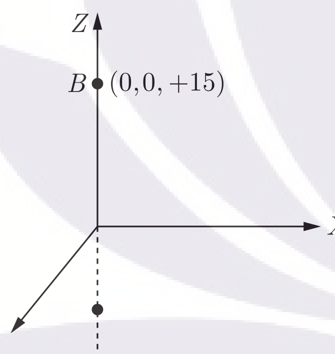
or $$AC = 2a\sin\theta$$

$$\tau = qE \times 2a\sin\theta$$

But, $q \times 2a = p$ [electric dipole moment]

$\therefore$ $$\tau = pE\sin\theta \quad \textbf{(1)}$$

Charge, $q_A = q_B = 2.5 \times 10^{-7}\,\text{C}$



Length of dipole $= 2a = 30\,\text{cm} = 0.30\,\text{m}$

We know that,

$\therefore$ Electric dipole moment

$$(p) = q(2a)$$

$$p = 2.5 \times 10^{-7} \times 0.30$$

$$= 7.5 \times 10^{-8}\,\text{C}-\text{m} \quad \textbf{(1)}$$

Uniform electric field,

$$E = 5 \times 10^4\,\text{NC}^{-1}$$

$\therefore$ Torque acting on electric dipole,

$$\tau = pE\sin\theta$$

$$= 7.5 \times 10^{-8} \times 5 \times 10^4 \times \sin 30^\circ$$

$$= 37.5 \times 10^{-4} \times \frac{1}{2}$$

$$= 18.75 \times 10^{-4}$$

$$= 1.88 \times 10^{-3}\,\text{N}-\text{m} \quad \textbf{(1)}$$

or

A capacitor of capacitance C is charged fully by connecting it to a battery of emf E. It is then disconnected from the battery. If the separation between the plates of the capacitor is not doubled, what will happen to

1. Charge stored by the capacitor?
2. Potential difference across it?
3. Field strength between the plates?
4. Energy stored by the capacitor?
5. Capacitance of the capacitor?

Ans :

1. Charge stored by the capacitor would remains unchanged. **(1)**
2. Potential difference between the plate, $V = \frac{q}{C}$ As, capacitance of the capacitor $\left(C = \frac{KA\varepsilon_0}{d}\right)$ reduces to half and hence, potential difference between the plate becomes twice of the initial value, i.e. 2V. **(1)**
3. Field strength between the plates, $E = \frac{V}{d}$
$$E = \frac{2V}{2d} = \frac{V}{d}\text{(same)} \quad \textbf{(1)}$$
4. Energy stored by the capacitor,
$$U = \frac{1}{2}\frac{q^2}{C}$$
As, capacitance reduces to half and hence energy stored would be doubled. **(1)**
5. Capacitance of the capacitor,
$$C = \frac{KA\varepsilon_0}{d}$$
$$C \propto \frac{1}{d}$$

When separation between the plates is doubled, the capacitance is reduced to half of its initial value. **(1)**

36. Explain with the help of a neat and labelled diagram, the principle, construction and working of a transformer.

Ans :

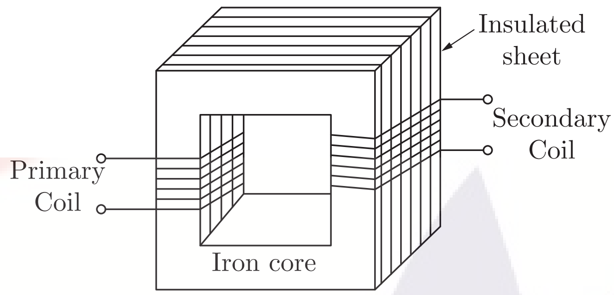
A transformer is a device which is used to convert high alternating voltage to a low alternating voltage and vice-versa, **(1/2)**

Principle

Transformer works on the principle of mutual induction of two coils. When current in the primary coil is changed, the flux linked to the secondary coil also changes. Consequently, an emf is induced in the secondary coil. **(1)**

Construction

It consists of a rectangular core of soft iron in the form of sheets insulated from one another. Two separate coils of insulated wires, a primary coil and a secondary coil are wound on the core. These coils are well insulated from one another and form the core. The coil on the input side is called primary coil and the coil on the output side is called secondary coil.



Transformer

Working

Suppose an alternating voltage source V_p is connected to the primary coil. Current in primary coil produces magnetic flux, which is linked to secondary. When current in primary changes, flux in secondary also changes which results and emf V_s in secondary.

According to Faraday law, emf induced in a coil depends upon the rate of change of magnetic flux in the coil. If resistance of the coil is small, then the induced emf will be equal to voltage applied. **(1)**

According to Faraday law,

$$V_p = N_p \frac{d\phi}{dt} \qquad \text{...(i)}$$

Similarly, for secondary coil,

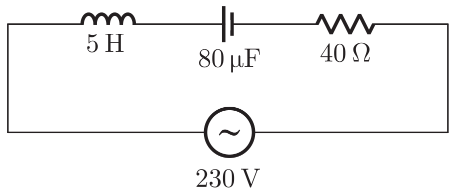
$$V_s = N_s \frac{d\phi}{dt} \qquad \text{...(ii)}$$

From Eqs. (i) and (ii), we have

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} \qquad \textbf{(1/2)}$$

or

The given circuit diagram shows a series L-C-R circuit connected to a variable frequency 230 V source.



1. Determine the source frequency which derives the circuit in resonance.
2. Obtain the impedance of the circuit and the amplitude of current at the resonating frequency.
3. Determine the rms potential drop across the three elements of the circuit.
4. How do you explain the observation that the algebraic sum of the voltage across the three elements in capacitance (C) is greater than the supplied voltage?

Ans :

Given: $L = 5.0\,\text{H}$,

$C = 80\,\mu\text{F} = 80 \times 10^{-6}\text{F}$,

$R = 40\Omega$ and $V_{\text{rms}} = 230\text{ V}$

1. Source frequency for resonance condition,

$$v_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2 \times 3.14\sqrt{5.0 \times 80 \times 10^{-6}}}$$

$$v_0 = 7.96\text{ Hz} \qquad \textbf{(1)}$$

2. At resonating frequency,

$$Z = R = 40\Omega$$

and amplitude of current,

$$I_m = \frac{V_m}{R} = \frac{\sqrt{2}\,V_{\text{rms}}}{R} = \frac{\sqrt{2} \times 230}{40}$$

$$= 8.13\text{ A} \qquad \textbf{(1)}$$

3. $$l_{\text{rms}} = \frac{l_m}{\sqrt{2}} = \frac{8.13}{1.414} = 5.75\text{ A}$$

$$V_R = l_{\text{rms}} \times R$$

$$= 5.75 \times 40 = 230\text{ V}$$

$$V_L = I_{\text{rms}} \times X_L$$

$$= I_{\text{rms}} \times 2\pi v_0 \times L$$

$$= 5.75 \times 2 \times 3.14 \times 7.96 \times 5.0$$

$$= 1437.2\text{ V} \qquad \textbf{(1)}$$

At resonance condition,

$$V_C = V_L = 1437.2\text{ V} \qquad \textbf{(1/2)}$$

4. $V_R + V_L + V_C$ is much greater than V_{rms}, It is because V_R, V_L and V_C are in different phase conditions.

On the basis of phaser method, we find that

$$\sqrt{V_R^2 + (V_L - V_C)^2} = V_{\text{rms}} \qquad (1^{1/2})$$

37. Show that the refractive index of the material of a prism is given by

$$\mu = \frac{\sin\frac{(A+\delta_m)}{2}}{\sin\left(\frac{A}{2}\right)}$$

Where, the symbols have their usual meanings.

Ans :

Consider a prism ABC of refractive index μ. A light ray PQ is incident on face AB at an angel of incidence i and refracted at an angle r_1. It strikes on face AC at an angle r_2 and emerges at an angle e. The angle of deviation is δ. **(1)**

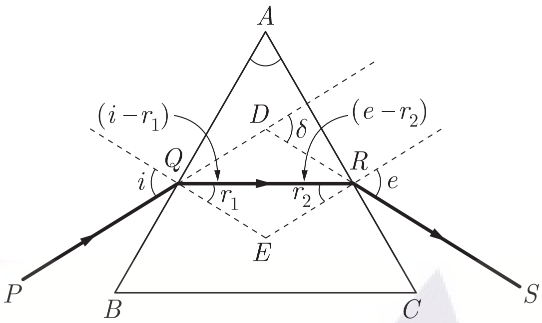


Figure: A prism of refractive index μ

Hence, $\angle DQR = (i - r_1)$ **(1)**

and $\angle DRQ = (e - r_2)$

For $\Delta\, DQR$, δ is exterior angle,

Hence, $\delta = (i - r_1) + (e - r_2)$

or $\delta = (i + e) - (r_1 + r_2)$ ...(i)

In cyclic quadrilateral $AQER$,

Hence, $\angle A + \angle E = 180°$ ...(ii) **(1)**

In $\Delta\, QER$, $r_1 + r_2 + \angle E = 180°$ ...(iii)

From Eqs. (ii) and (iii), we get

$$\angle A = r_1 + r_2 \quad \text{...(iv)}$$

Substituting the value in Eq. (i), we get

$$\delta = (i + e) - \angle A \quad \text{...(v)}$$

For minimum angle of deviation (δ_m),

$$\delta = \delta_m$$

and $i = e$, $r_1 = r_2 = r$ (assume)

From Eq. (iv), we get,

$$\angle A = r + r$$

or $r = \dfrac{\angle A}{2}$ ...(vi)

From Eq. (v), we get

$$\delta_m = i + i - \angle A$$

or $i = \dfrac{\angle A + \delta_m}{2}$ ...(vii)

(1)

If μ is refractive index of the material of the prism, then according to the Snell's law,

$$\mu = \frac{\sin i}{\sin r}$$

Substituting the values of i and r, we get

Hence, $\mu = \dfrac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$ **(1)**

or

Define the term resolving power of an astronomical telescope. How does, it get affected on

1. increasing the aperture of the objective lens?
2. increasing the wavelength of light used?
3. increasing the focal length of the objective lens?

Ans :

Resolving Power of an Astronomical Telescope

The ability of an astronomical telescope to form separate images of two neighbouring astronomical objects, is called its resolving power.

The least distance between two neighbouring objects for which telescope can form separate images is called the limit of resolution. The angular limit of resolution of a telescope is given by,

$$\theta = \frac{1.22\lambda}{d} \quad \textbf{(1)}$$

where, λ = wavelength of light used

d = diameter of aperture of objective lens

Resolving power is the reciprocal of limit of resolution.

Hence, Resolving power $= \dfrac{d}{1.22\lambda}$

1. As, resolving power $\propto d$. Therefore, resolving power of the telescope increase on increasing diameter of the aperture of the objective lens. **(1)**
2. As,

   $$\text{Resolving power} \propto \frac{1}{\lambda}$$

   Therefore, resolving power of the telescope decreases on increasing the wavelength of the light used. **(1)**
3. Resolving power of a telescope is independent of the focal length of the objective lens. Hence, on increasing the focal length of the objective lens, resolving power remains unchanged. **(1)**