2009

Set: I

Set: I

Question: 1

Answer all questions briefly and to the point. [1]

What is the electrostatic potential due to an electric dipole at an equatorial point.

Answer:
Electric potential at any point in the equatorial plane of dipole is zero.

Question: 2

Name the EM waves used for studying crystal structure of solids. What is the frequency range? [1]

Answer:
X-rays are used for studying crystal structure of solids. Their frequency range is 10^{16} Hz to 3×10^{21} Hz.

Question: 3

An electron does not suffer any deflection while passing through a region of uniform magnetic field. What is the direction of the magnetic field? [1]

Answer:
The direction of magnetic field $\vec{B}$ is parallel to the velocity $\vec{V}$ of electron.

As, $F = q(\vec{V} \times \vec{B}) = 0$ since $\vec{V} \parallel \vec{B}$

Question: 4

How the angular separation of interference fringes in Young would's double slit experiment change when the distance between the slits and screen is doubled? [1]

Answer:

Fringe width (β) is given by, $\beta = \frac{\lambda}{d}$

When D is doubles

$\therefore \beta = \frac{2\lambda D}{d} = 2\beta$

Question: 5

Two thin lenses of power +6D and -2D are in contact. What is the focal length of the combination? [1]

Answer:
Since $P = P_1 + P_2$
$\therefore P = +6 + (-2) = +4D$

Since,

$$f = \frac{1}{P} = \frac{1}{4}$$
$= 0.25$ m
$= +25$ cm

Question: 6

The stopping potential in an experiment on photoelectric effect is 1.5V. What is the maximum kinetic energy of the photoelectrons emitted? [1]

Answer:
The maximum kinetic energy of an electron is given by
$K_{max} = eV_0$
$= 1.6 \times 10^{-19} \times 1.5 = 2.4 \times 10^{-19}$

Question: 7

Two nuclei have mass numbers in the ration 1:8. What is the ratio of their nuclear radii? [1]

Answer:
$A_1 : A_2 = 1 : 8$

$$\Rightarrow \frac{A_1}{A_2} = \frac{1}{8}$$

$$\therefore \frac{R_1}{R_2} = \frac{A_1^{1/3}}{A_2^{1/3}}$$

$$= \left(\frac{A_1}{A_2}\right)^{1/3}$$

$$= \left(\frac{1}{8}\right)^{\frac{1}{3}}$$

$$= \frac{1}{2}$$

Question: 8

Give the logic symbol of NOR gate. [1]

Answer:
See topics on ‘NOR gate’.

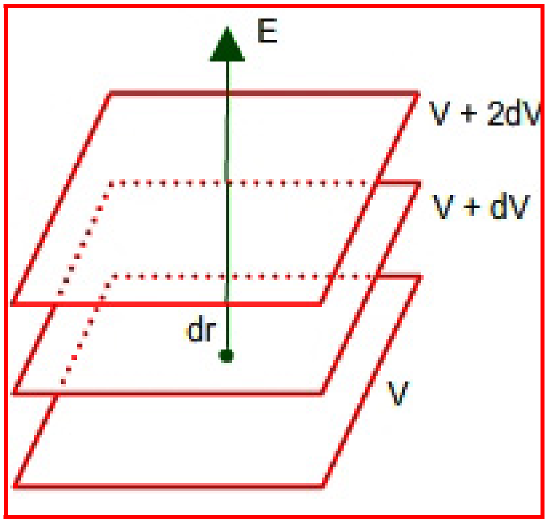
Question: 9

Draw 3 equipotential surfaces corresponding to a field that uniformly increases in magnitude but remains constant along Z-direction. How are these surfaces different from that of a constant electric field along Z-direction? [2]

Answer:
Equipotential surface increase with increase in magnitude

$$\text{Since, } E = \frac{dV}{dr}$$

The negative sign shows that the direction of electric field $\vec{E}$ is the direction of decreasing potential.



Question: 10

Define electric flux. Write its S.I unit. A charge q is enclosed by a spherical surface of radius R. if the radius is reduced to half, how would the electric flux through the surface change? [2]

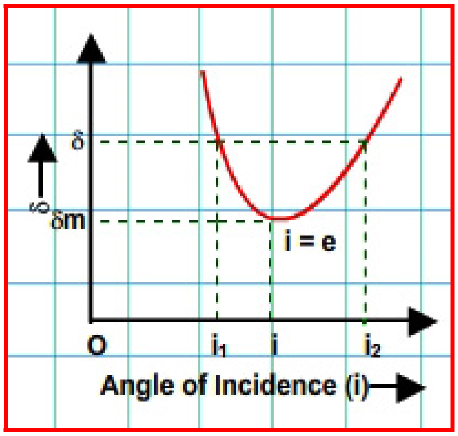
Answer:
See topics on 'Electric flux'.

Question: 11

Define refractive index of a transparent medium. A ray of light passes through a triangular prism. Plot a graph showing the variation of the angle of deviation with the angle of incidence. [2]

Answer:
Refractive index
The ratio of the velocity of light in vacuum to the velocity of light in medium is called absolute refractive index of the medium.

Graph
The plot of angle of deviation (δ) versus angle of incidence (i) for a triangular prism is shown below.



Question: 12 *(**)*

Calculate the current drawn from the battery in the given network. [2]

Question: 13 [2]

Answer the following questions:

a. Optical and radio telescopes are built on the ground while X-ray astronomy is possible only from satellites orbiting the Earth? Why?

Answer:

Since the transmission of signals using ground waves restricted up to a frequency of 1500 Hz to save the loss of energy.

b. The small ozone layer on top of the stratosphere is crucial for human survival. Why?

Answer:

The ultraviolet radiations from the sun is harmful to the living cells and plants. The ozone layer absorbs ultraviolet radiation and prevents it from reaching the earth. It also keeps the earth warm by trapping infra-red radiations.

Question: 14

Define current sensitivity and voltage sensitivity of a galvanometer. Increasing the current sensitivity may not necessarily increase the voltage sensitivity of a galvanometer. Justify. [2]

Answer:

Current sensitivity

It is defined as the deflection produced in the galvanometer on passing unit current through its coil.

Voltage sensitivity

It is defined as the deflection produced in the galvanometer when a unit voltage is applied across its coil. If α be the deflection produced on applying voltage V then,

Voltage sensitivity = $\frac{\alpha}{V}$

$= \frac{nBA}{kR}$

The voltage sensitivity may be increased by (i) increasing n, B, A (ii) decreasing k and (ii) decreasing R and the current sensitivity $= \frac{nBA}{k}$ can be increased by (i) increasing nBA (ii) decreasing k.

Hence increasing the current sensitivity may not necessarily increase the voltage sensitivity of a galvanometer.

Question: 15

Define the term 'linearly polarized light;. When does the intensity of transmitted light becomes maximum, when a Polaroid sheet is rotated between two crossed Polaroid's? [2]

Answer:

Linearly polarized light

The light in which the vibrations of the light are restricted in a particular plane is called plane or linearly polarized light.

According to law of Malus,

$I = I_0 \cos^2\theta$

The intensity of light transmitted from the analyzer will be maximum when, $\theta = 0^0$ i.e., when polarizer and analyzer are parallel.

Question: 16

A wire of 15Ω resistance is gradually stretched to double its original length. It is then cut into two equal parts. These parts are then connected in parallel across a 3.0 volt battery. Find the current drawn from the battery. [2]

Answer:

When any resistor is stretched to double its original length, the new resistance becomes four times of its original resistance.

Here R = 15Ω an dV = 3.0 Volta

∴ New resistance = 4R = 4 x 15 = 60 Ω

∴ $R_1 = 30\ \Omega$, and, $R_2 = 30\ \Omega$

Effective resistance in parallel combination R_p:

$$\frac{1}{R_P}$$

$$= \frac{1}{30} + \frac{1}{30}$$

$$= \frac{2}{30}$$

$$= \frac{1}{15} \left[\because \frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} \right]$$

$\therefore R_P = 15\Omega$

$$I = \frac{V}{R_P}$$
$$= \frac{3.0}{15}$$
$$= 0.2A$$

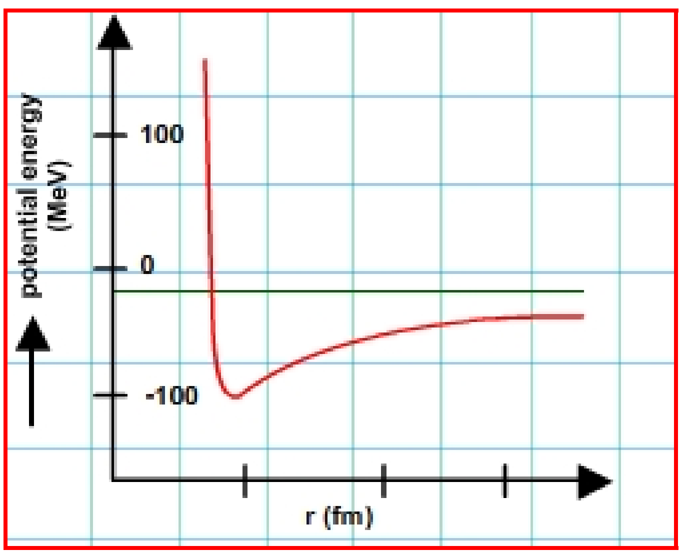
Question: 17 [2]

a. The mass of nucleus in its ground state is always less than the total mass of its constituents, neutrons and protons.

Answer:
Protons and neutrons have to come together within a very small space of the order of 10-14 to make a

b. Plot a graph showing the variation of potential energy of a pair of nucleons as a function of their separation.

Answer:
The graph showing potential energy of a pair of nucleons as a function of their separation is shown as below:



Question: 18 [2]

Write the function of (i) Transducer and (ii) Repeater in the context of communication system.

Answer:
Transducer
A transducer is a device, which converts one form of energy into another.

Repeater
A repeater is a combination of receiver and transmitter placed along the path of signal so as to extend the range of the communication system.

Or

Write two factors justifying the need of modulation for transmission of a signal.

Answer:

Need for modulation

The sound waves cannot be transmitted from a radio transmitter by converting them into electrical wave directly for the following reasons:

i. For efficient transmission and reception, the transmitting and receiving antennas must have a length equal to quarter wavelength of the audio signal. To set up a vertical antenna of this size is practical impossible.

ii. The energy radiated from an antenna is practically zero, when the frequency of the signal to be transmitted is below 15kHz. It also makes the direct transmission of audio signal as impracticable.

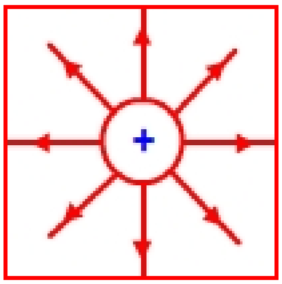
Question: 19 [3]

A positive point charge (+q) is kept in the vicinity of an uncharged conducting plate. Sketch electric field lines originating from the point on to the surface of the plate. Derive the expression for the electric field at the surface of a charged conductor.

Answer:

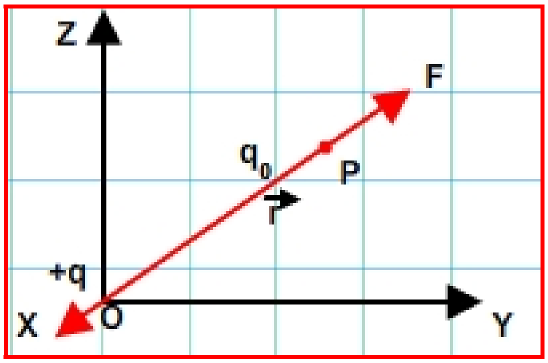
Representation of electric field

The electric field due to a positive charge (+q) is represented as



Electric field due to a point charge

Consider a point charge +q placed at the origin O of the coordinated frame. Let q_0 be any test charge placed at P.



According to Coulomb's law, force on the test charge q0 due to charge q is given by,

$$\vec{F} = \frac{1}{4\pi \epsilon_0} \cdot \frac{qq_0}{r^2} \cdot \hat{r}$$

When $\hat{r}$ is a unit vector along OP. If $\vec{E}$ be the electric field at point P then,

$$\vec{E} = \frac{F}{q_0} \cdot \frac{1}{4\pi \epsilon_0} \cdot \frac{1}{r^2}\hat{r}$$

$$\hat{E} = \frac{F}{q_0} \cdot \frac{1}{4\pi \epsilon_0} \cdot \frac{q}{r^3} \cdot \vec{r} \left[\because \hat{r} = \frac{\vec{r}}{|r|} \right]$$

$\therefore$ The magnitude of the electric field at point P is given by

$$E = \frac{1}{4\pi \epsilon_0} \cdot \frac{q}{r^2} \text{ (Spherical)}$$

The electric field due to a point charge is symmetric about the charge.

Or

A parallel plate capacitor is charged by a battery. After some time the battery is disconnected and a dielectric slab of dielectric constant K is inserted between the plates. How would (i) the capacitance, (ii) the electric filed between the plates and (iii) the energy stored in the capacitor, be affected? Justify your answer.

Answer:
When battery is removed, charge Q remains constant.

i. Capacity C increases
ii. Electric field E = $\frac{V}{d}$

   as $V = \frac{Q}{C}$ decreases
iii. Energy stored = $\frac{1}{2}\frac{Q^2}{C}$ decreases. [$\because$ C = K C_0]

Question: 20 (**) [3]

a. State the principle of working of a meter bridge.
b. Write the basic features of photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based.

Question: 21 [3]

a. State Faraday's law of electromagnetic induction.

***Answer*:**
Faraday's law of electromagnetic induction:

- Whenever magnetic flux linked with a circuit changes, induced e.m.f is produced.
- The induced e.m.f lasts as long as the change in the magnetic flux continues.
- The magnitude of the induced e.m.f is directly proportional to the rate of change of the magnetic flux linked with the circuit.

b. A jet plane is travelling towards west at a speed of 1800 km/h. what is the voltage difference developed between the ends of the wing having a span of 25 m, if the Earth's magnetic field at the location has a magnitude of 5×10^{-4} T and the dip angle is 30^0?

***Answer*:**

u = 1800 km/h = $\frac{1800 \times 1000}{60 \times 60}$ = 500 m/s

δ = 300, H = 5×10^{-4} T

V = H tan δ

= 5×10^{-4} x tan 300

= $5 \times 10^{-4} \times \frac{1}{\sqrt{3}}$

$= \frac{4}{\sqrt{3}} \times 10^{-4}$ T

Question: 22

In Young's double slit experiment, monochromatic light of wavelength 630 nm illuminates the pari of slits and produces an interference pattern in which two consecutive bright fringes are separated by 8.1 mm. another source of monochromatic light produces the interference pattern in from the second source.

What is the effect on the interference fringes if the monochromatic source is replaced by a source of white light? [3]

***Answer*:**

Here,

λ_1 = 630nm = 630×10^{-9} m,

β_1 = 8.1 mm = 8.1×10^{-3} m

λ_2 = ?

β_2 = 7.2 mm = 7.2×10^{-3} m

Let, d be the slit width and D be the distance between slit and screen then

$$\beta_1 = \frac{\lambda_1 D}{d}, \text{and, } \beta_2 = \frac{\lambda_2 D}{d}$$

$$\therefore \frac{\beta_1}{\beta_2} = \frac{\lambda_1 D}{d} \times \frac{\lambda_2 D}{d} = \frac{\lambda_1}{\lambda_2}$$

$$\text{or, } \frac{8.1 \times 10^{-3}}{7.2 \times 10^{-3}} = \frac{630 \times 10^{-9}}{\lambda_2}$$

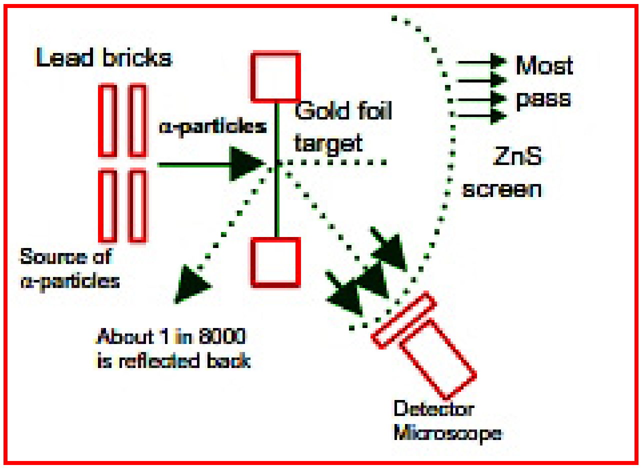
$$\text{or, } \frac{8.1}{7.2} = \frac{630 \times 10^{-9}}{\lambda_2}$$

$$\therefore \lambda_2 = \frac{7.2 \times 630 \times 10^{-9}}{8.1}$$

Question: 23

Draw a schematic arrangement of the Geiger – Marsden experiment. How did the scattering of α particles by a thin foil of gold provide an important way to determine an upper limit on the size of the nucleus? Explain briefly. [3]

Answer:



Schematic arrangement of the Geiger-Marsden experiment:

Observations:

- Since most of the α- particles passed undeviated, the atom has a lot of empty space in it.
- Since 1 in about 8000 α- particles is deflected through 180^0, the size of the nucleus is about $\frac{1}{10000}$ of the size of atom.

Question: 24

Distinguish between sky wave and space wave propagation. Give a brief description with the help of suitable diagrams indicating how these waves are propagated. [3]

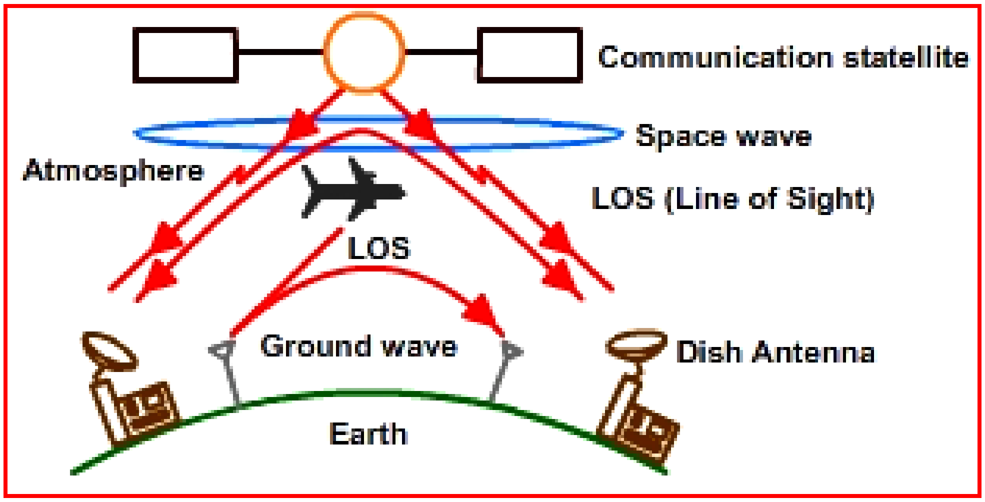
Answer:

Sky waves

A radio wave transmitted towards the sky and reflected by the ionosphere towards the desired location of the earth is called a sky wave.

Space waves

A radiowave that travels directly from a high transmitting antenna to the receiving station is called a space wave.

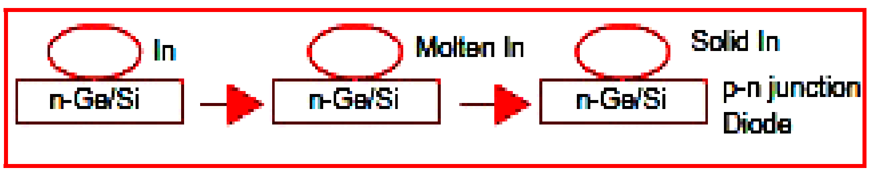


Question: 25

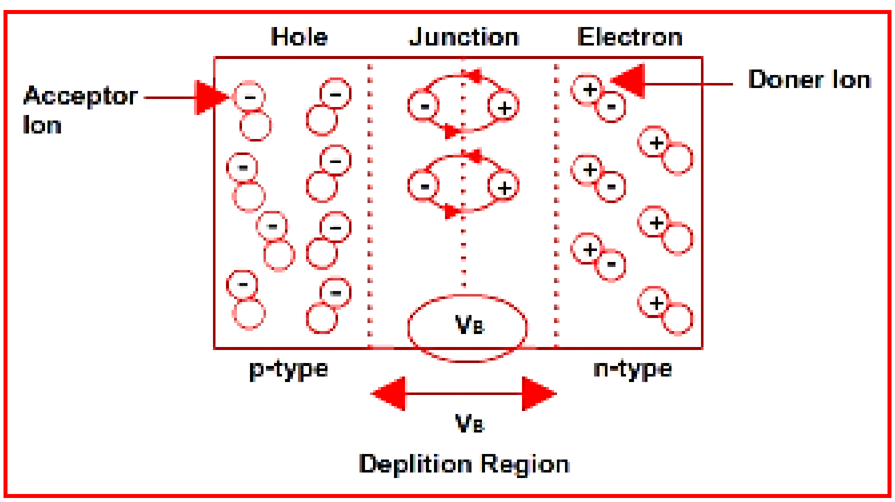
With the help of a suitable diagram explain the formation of depletion region in a p-n junction. How does its width change when the junction is (i) forward biased and (ii) reverse biased? [3]

Answer:

p-n junction: When a small piece of III group metal like In(Indium) is placed over n-Ge or n-Si and melted. The lower portion of molten indium forms alloy with the n-semiconductor and converts its top layer into p-layer to form p-n junction.



Formation of potential barrier and depletion to form p-n junction.



In a p-n junction diode, due higher concentration of holes on p-side and electrons on n-side, the diffusion of holes towards n-side and electrons towards p-side takes place. Hence a region of un-neutralized negative ion on p-side and positive ions on n-side is formed near the junction which is depleted of mobile charges. This region is called depletion region.

In the depletion region, a potential difference VB is created is called potential barrier as it creates an electric field which opposes the further diffusion of electrons and holes.
- In forward biased, the width of depletion region is increased.
- In reverse biased, the width of depletion region is decreased.

Question: 26

Give a circuit diagram of a common emitter amplifier using an n-p-n transistor. Draw the input and output waveforms of the signal. Write the expression for its voltage gain. [3]

Answer:
See topics on 'As an amplifier'.

Question: 27 [3]

a. Draw a ray diagram showing the image formation by a compound the image formation by a compound microscope. Hence obtain expression for total magnification when the image is formed at inifinity.

Answer:
See topics on 'Compound'.

b. Distinguish between myopia and hypermetropia. Show diagrammatically how these defects can be corrected.

Answer:
See topics on 'Defects types and correction'..

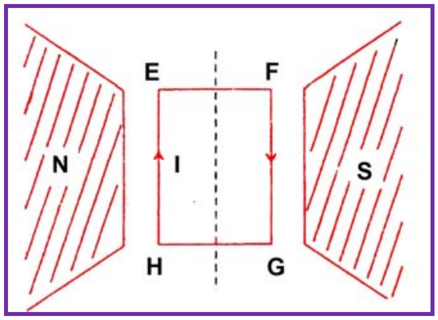
Question: 28 *(**)* [5]

Draw a schematic sketch of a cyclotron. Explain briefly how it works and how it is used to accelerate the charged particles.
i. Show that time period of ions in a cyclotron is independent of both the speed and radius of circular path.
ii. What is resonance condition? How is it used to accelerate the charged particles?

OR

a. Two straight long parallel conductors carry currents I1 and I2 in the same direction. Deduce the expression for the force per unit length between them. Depict the pattern of magnetic field lines around them.

b. A rectangular current carrying loop EFGH is kept in a uniform magnetic field as shown in the figure.



Question: 29 [5]

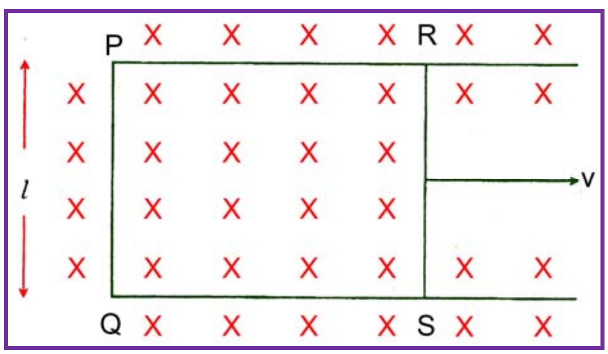
a. What are eddy currents? Write their two applications

Answer:
Eddy currents are the currents induced in the bulk pieces of conductors when the amount of magnetic flux linked with the conductor changes.
Application:

- Eddy current is used in designing dead beat galvanometers.
- Eddy currents are used in deep heat treatment of the human body.

b. Figure shows a rectangular conducting loop PQSR in which arm RS of length 's' is movable. The loop is kept in a uniform magnetic field 'B' directed downward perpendicular to the plane of the loop. The arm RS is moved with a uniform speed 'v'. deduce an expression for,

i. The emf induced across the arm 'RS'.



Answer:
The emf induced across the arm RS: e = B/v

ii. The external force required to move the arm and

Answer:
External force required: F = BI/l

iii. The power dissipated as heat

Answer:

$P = I^2 r = \left(\frac{Blv}{r}\right)^2, r = \frac{B^2 l^2 v^2}{r}$, where, r be the resistance of movable arm PQ of the rectangular conductor.

OR

a. State Lenz's law. Give one example to illustrate this law. "The lenz's law is a consequence of the principle of conservation of energy". Justify the statement.

Answer:

It states that the direction of induced current or emf in a circuit is always such that it opposes the cause which produces it. It gives the direction of current or emf induced in a circuit.

Lenz's law is in accordance with the principles of conservation of energy. In electromagnetic induction, the electrical energy is produced at the expense of mechanical energy.

b. Deduce an expression for the mutual inductance of two long coaxial solenoids but having different radii and different number of turns. *(**)*

Question 30 [5]

a.

i. draw a labeled ray diagram to show the formation of image in an astronomical telescope for a distant object.

Answer:

See topics on 'Astronomical'.

ii. Write three distinct advantages of a reflecting type telescope over a refracting type telescope.

Answer:

See topics on 'Resolving power'.

b. A convex lens of focal length 10cm is placed coaxially 5cm away from a concave lens of focal length 10cm. if an object is placed 30cm in front of the convex lens, find the position of the final image formed by the combined system.

Answer:

f_1 = 10cm,
d = 5cm,
f_2 = -10cm.
u = -30cm,
v = ?

Combined focal length f is

$$\frac{1}{20} - \frac{1}{30} = \frac{1}{v}$$

$$\Rightarrow \frac{3-2}{60} = \frac{1}{v}$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 . f_2}$$

$$\frac{1}{f}=\frac{1}{10}+\frac{1}{-10}-\frac{5}{(10).(-10)}$$

$$\frac{1}{f}=\frac{1}{10}-\frac{1}{10}$$

$$\Rightarrow f=\frac{5}{100}=20cm$$

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

$$\frac{1}{20}=\frac{1}{v}-\frac{1}{-30}$$

$$\Rightarrow \frac{1}{20}=\frac{1}{v}+\frac{1}{30}$$

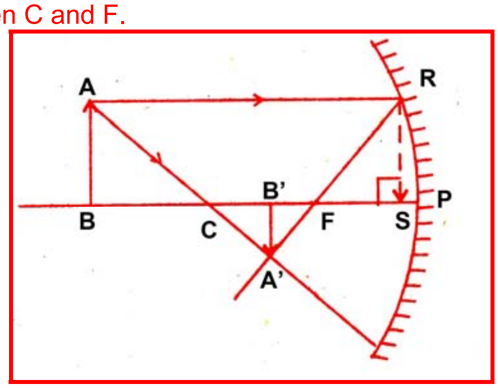
Or

a. With the help of a suitable ray diagram derive the mirror formula for a concave mirror.

Answer:

Mirror formula for a concave mirror

Let, AB be the length of an object placed beyond C in front of a concave mirror. The image A'B' is real, inverted and between C and F.



Applying sign conversions, we have,

Object distance: PB = -u
Image distance: PB' = -v
Focal length: PF = - f, and,
Radius of curvature: PC = -2f

In similar, Δ's ABC and A'B'F

$$\frac{AB}{A'B'}=\frac{BC}{B'C} \qquad \text{(i)}$$

And in similar Δs RSF and A'B'F

$$\frac{RS}{A'B'}=\frac{SF}{B'F}$$

$\because$ RS = AB

$$\frac{AB}{A'B'} = \frac{SF}{B'F} \qquad \text{(ii)}$$

From equation (i) and (ii), we have

$$\frac{BC}{B'C} = \frac{SF}{B'F}$$

Since the aperture of the concave mirror is small so the point S and P coincides.

$$\therefore \frac{BC}{B'C} = \frac{PF}{B'F}$$

$$\frac{PB - PC}{PC - PB'} = \frac{PF}{PB' - PF}$$

$$\frac{-u + 2f}{-2f + v} = \frac{-f}{-v + f}$$

$uv - uf - 2vf + 2f^2 = 2f^2 - fv$

$uv = uf + vf$

Dividing both sides by ‘uvf’, we get

$$\frac{uv}{uvf} = \frac{uf}{uvf} + \frac{vf}{uvf}$$

$$\therefore \frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

b. The near point of a hypermetropic person is 50cm from the eye. What is the power of the [5]

Answer:

Here u = -25cm, v = -50cm, then, f = ?

Using len’s formula,

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

$$= \frac{1}{50} - \frac{1}{25}$$

$$= -\frac{1}{50} + \frac{1}{25}$$

$$= \frac{-1+2}{50}$$

$$= \frac{1}{50}$$

$\therefore$ f = 50cm

$$P = \frac{1}{f(\text{in m})}$$

$$= \frac{100}{f(\text{in cm})}$$

$$\Rightarrow P = \frac{100}{50}$$

= +2D

Hence the corrective lens is convex.

(**) Currently out of syllabus. Answer can be provided up on request.