Studymate Solutions to CBSE Board Examination 2013-2014

Series : OSR/1 | **Code No. 55/1/2**

Roll No. | | | | | | | |

Candidates must write the Code on the title page of the answer-book.

- Please check that this question paper contains 15 printed pages.
- Code number given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.
- Please check that this question paper contains 29 questions.
- **Please write down the Serial Number of the questions before attempting it.**
- 15 minutes time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the student will read the question paper only and will not write any answer on the answer script during this period.

PHYSICS (Theory)

[Time allowed : 3 hours] ***[Maximum marks : 70]***

General Instructions:

(i) *All questions are compulsory.*

(ii) *There are 30 questions in total. Question Nos. 1 to 8 are very short answer type questions and carry one mark each.*

(iii) *Question Nos. 9 to 18 carry two marks each. Question Nos. 19 to 27 carry three marks each and question nos. 28 to 30 carry five marks each.*

(iv) *One of the questions carrying three marks weightage is value based question.*

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

(vi) *Use of calculators is not permitted. However, you may use log tables if necessary.*

(vii) *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

$\mu = 4\pi \times 10^{-7}$ T mA^{-1}

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ Nm}^2 \text{ C}^{-2}$$

1. Define the term 'electrical conductivity' of a metallic wire. Write its S.I. unit.

Sol. Conductivity of a metal is equal to the conductance offered by a wire of unit length and unit cross-sectional area.

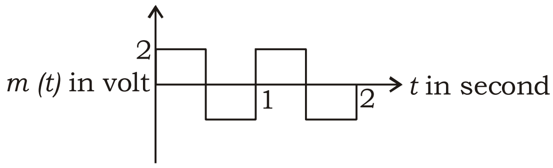
$$\sigma = \frac{1}{\rho}$$

S.I. unit = $\Omega^{-1}\ m^{-1}$

2. The carrier wave is represented by

$C(t) = 5 \sin (10\pi t)$ volt

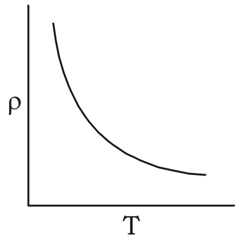
A modulating signal is a square wave as shown. Determine modulation index.



Sol. $\mu = \dfrac{\text{Amplitude of modulating signal}}{\text{Amplitude of carrier wave}} = \dfrac{A_M}{A_C} = \dfrac{2}{5} = 0.4$

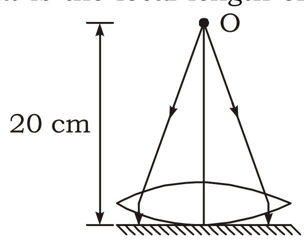
3. Show variation of resistivity of Si with temperature in a graph.

Sol.



Temperature dependence of resistivity for a semiconductor.

4. A convex lens is placed in contact with a plane mirror. A point object at a distance of 20 cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens?



Sol. Since image coincides with object, it implies that ray must be falling normally on the plane mirror. This implies that the ray after passing through lens becomes parallel. So, object must be at the focus of lens.

So, focal length of lens = 20 cm.

5. "For any charge configuration, equipotential surface through a point is normal to the electric field." Justify.

Sol. For any charge configuration, equipotential surface through a point is normal to the electric field at that point.

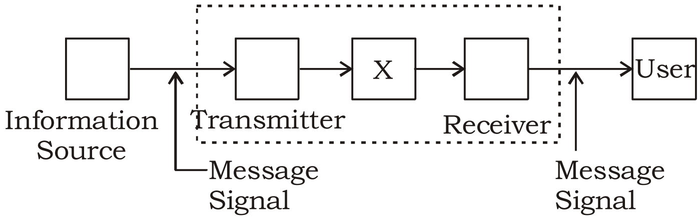
If the field were not normal to the equipotential surface, it would have non-zero component along the surface. This field may move the charge along the surface without any energy supply violating the law of conservation of energy.

6. Write the expression, in a vector form, for the Lorentz magnetic force $\vec{F}$ due to a charge moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$. What is the direction of the magnetic force ?

Sol. $\vec{F} = q(\vec{v} \times \vec{B})$

The direction of magnetic force must be perpendicular to the plane containing $\vec{v}$ and $\vec{B}$ and is given by Fleming's left hand rule.

7. The figure given below shows the block diagram of a generalized communication system. Identify the element labelled 'X' and write its function.



Sol. X $\rightarrow$ Channel

Channel: Medium through which signal travels. The channel is open space in case of radio or TV transmission.

Original signals get mixed or super-imposed by unwanted signal (called noise) as it travels through channel and may lead to loss of energy.

8. Two spherical bobs, one metallic and the other of glass, of the same size are allowed to fall freely from the same height above the ground. Which of the two would reach earlier and why ?

Sol. Due to motion, in metallic bob, eddy current will be produced which will oppose the motion and slows the metallic bob. It will take more time in reaching the ground. So, the glass bob will reach the ground earlier.

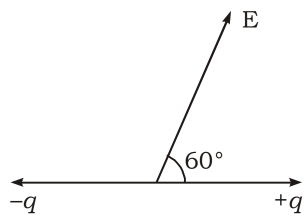
9. A capacitor 'C' a variable resistor 'R' and a bulb 'B' are connected in series to the ac main; in circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if (*i*) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same; (ii) the resistance R is increased keeping the same capacitance ?

Sol. (*a*) When dielectric slab is introduced between the plates of capacitor, its capacitance increases and reactance decreases. This increases the current flowing in bulb and so the bulb glows brighter with resistance unaltered.

(*b*) When resistance increases, current flowing in circuit decreases. Glow of bulb decreases.

10. An electric dipole of length 2 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $8\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if it has a charge of ± 4 nC.

Sol. Torque τ = PE sin θ



$$8\sqrt{3} = 4\times10^{-9}\times2\times10^{-2}\times\frac{\sqrt{3}}{2}(E)$$

$$E = \frac{2}{10^{-11}} = 2 \times 10^{11} \text{ V/m}$$

Potential energy of dipole

$$U = -PE\cos\theta$$

$$U = -4 \times 10^{-9} \times 2 \times 10^{-2} \times 2 \times 10^{11} \times \frac{1}{2} = -8 \text{ J}$$

$$U = -8 \text{ J}$$

11. Out of the two magnetic materials, 'A' has relative permeability slightly greater than unity while 'B' has less than unity. Identify the nature of the materials 'A' and 'B' Will their susceptibilities be positive or negative.

Sol. Material A is paramagnetic. Material B is diamagnetic.

Susceptibility of A is positive and susceptibility of B is negative.

12. State the underlying principle of a cyclotron. Write briefly how this machine is used to accelerate charged particles to high energies.

Sol. Cyclotron : It is a device used to accelerate positively charged particles like protons, deutrons, α-particles etc to very high energies.

Principle : A charged particle can be accelerated to very high energies with the help of smaller values of oscillating electric field. A perpendicular magnetic field which throws the charged particle into a circular motion, repeatedly brings the charge into the oscillating electric field such that repeated acceleration can happen.

Construction :

1. It consists of two D-shaped hollow evacuated metal chambers D_1 and D_2 called the dees.
2. An alternating voltage of the order of 10^4 volts is applied across the gap between the two dees.
3. The dees are placed between the poles of a strong electro-magnet.
4. A source of charged particles or ions is placed near the center of the dees.
5. The whole assembly is evacuated to minimise collisions between the ions and the air molecules.

Working :

1. Suppose the positive ion enters the gap between the two dees & finds D_1 to be negative and it gets accelerated towards D_1.
2. As it enters D_1 it doesn't experience any electric field due to shielding effect of the metallic dee.
3. The perpendicular magnetic field throws it into a circular path.
4. At the instant the ion comes out of D_1, it finds D_1 to be +ve & D_1 –ve. It now gets accelerated towards dee D_2.
5. It now moves faster through D_2 describing a larger semicircle than before.
6. Thus, the +ve ion will go on accelerating every time it comes into the gap between the dees and will go on describing circular path of greater and greater radius with greater speed and finally acquire a sufficiently high energy.
7. The accelerated ion is ejected through a window by a deflecting voltage and hits the target.

Theory: q = charge of particle

m = mass of particle

Magnetic force on charge q = Centripetal force on charge q

$$qvB\sin 90^\circ = \frac{mv^2}{r} \qquad r = \frac{mv}{qB}$$

Period of revolution of the charged particle is given by, $\mathbf{T} = \frac{2\pi r}{v} = \frac{2\pi}{v} \times \frac{mv}{qB} = \frac{2\pi m}{qB}$

Frequency of revolution of the particle is $f_c = \frac{1}{T} = \frac{qB}{2\pi m}$

$$\boxed{f_c = \frac{qB}{2\pi m}}$$

This is called cyclotron frequency or magnetic resonance frequency.

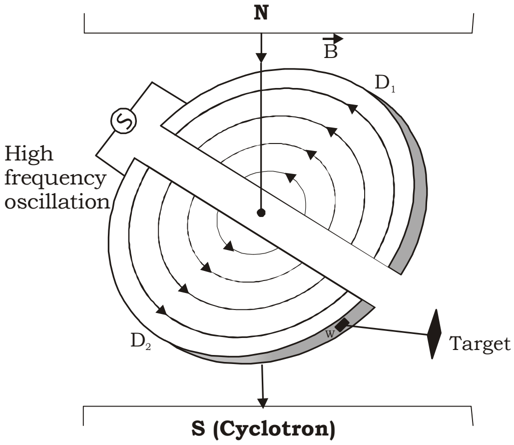
Maximum K.E. of the accelerated ions. The maximum velocity of ions is attained when they are near the periphery of the dees. If v_0 is the maximum velocity acquired by the ions and r_0 is the radius of the dees, then

$$\frac{mv_0^2}{r_0} = qv_0B \quad \text{or} \quad v_0 = \frac{qBr_0}{m}$$

The maximum kinetic energy of the ions will be

$$K_0 = \frac{1}{2}mv_0^2 = \frac{1}{2}m\left(\frac{qBr_0}{m}\right)^2$$

or $\boxed{K_0 = \dfrac{q^2B^2r_0^2}{2m}}$



13. For a single slit of width "a", the first minimum of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of $\frac{\lambda}{a}$. At the same angle of $\frac{\lambda}{a}$, we get a maximum for two narrow slits separated by a distance "a". Explain.

Sol. The condition for minima is single slit is

$$a \sin \theta = n\lambda$$

For first minima and for small angle

$$a\theta = \lambda$$

$$\theta = \frac{\lambda}{a}$$

The minima can be explained by dividing two slits in two equal halves. For every secondary source in upper slit cancels the corresponding contribution of secondary source in second slit which differ's in path length by $\frac{\lambda}{2}$.

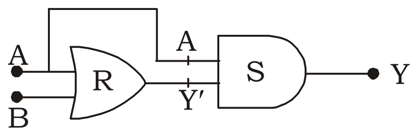
Whereas the condition for maxima in two narrow slits is

$$a \sin \theta = n\lambda$$

for first maxima and for small angle $\theta = \frac{\lambda}{a}$

In this case the path difference between the waves reaching screen is λ and will be contributing to maximum.

14. Write the truth table for the combination of the gates shown. Name the gates used.



Sol. R is OR Gate

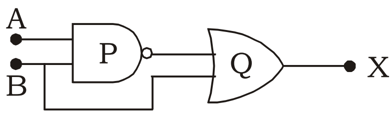
and S in AND Gate

Truth table :

A	B	Y' = A + B	Y = A(A + B)
0	0	0	0
0	1	1	0
1	0	1	1
1	1	1	1

OR

14. Identify the logic gates marked 'P' and 'Q' in the given circuit. Write the truth table for the combination.



Sol. P in NAND Gate

Q is OR Gate

Truth table :

A	B	$\overline{AB}$	$B + \overline{AB}$
0	0	1	1
0	1	1	1
1	0	1	1
1	1	0	1

15. A proton and an alpha particle are accelerated through the same potential. Which one of the two has (*i*) greater value of de-Broglie wavelength associated with it and (*ii*) less kinetic energy. Give reasons to justify your answer.

Sol. V = Accelerating potential

(*i*) Debroglie Wavelength $\lambda = \dfrac{h}{mv} = \dfrac{h}{p}$

since $\dfrac{p^2}{2m} = k$ $\qquad\qquad$ $p = \sqrt{2mk}$

So, $\lambda = \dfrac{h}{\sqrt{2mk}}$

$$\lambda_p = \frac{h}{\sqrt{2meV}} \qquad \text{... (i)}$$

$$\lambda_\alpha = \frac{h}{\sqrt{2(4m)2eV}} = \frac{h}{\sqrt{16meV}} \qquad \text{... (ii)}$$

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{8} = 2\sqrt{2}$$

The de Broglie wavelength for proton is more than debroglie wavelength of α-particle.

(*ii*) Kinetic energy of proton K_p = eV

Kinetic energy of α particle K_α = 2eV

So, kinetic energy of proton is less than K.E. of α-particle.

16. Given a uniform electric field E = 2 x 10^3 $\hat{i}$ N/C, find the flux of this field through a square of side 20 cm, whose plane is parallel to the *y*–*z* plane. What would be the flux through the same square, if the plane makes an angle of 30° with the *x*-axis?

Sol. When plane of square in parallel to YZ-plane, flux of electric field

$\phi_1 = \vec{E}\,.\,\vec{A}$ as area vector is parallel along *x*-axis

$= (2 \times 10^3 \hat{i}) . (20 \times 20 \times 10^{-4} \hat{i})$

$= 8 \times 10$

$\phi_1 = 80$ V-m

When plane make 30° with x-axis

$\phi_2 = EA \cos \theta$

$= 2 \times 10^3 \times 20 \times 20 \times 10^{-4} \times \cos 60°$

$= 2 \times \cancel{400} \times \cancel{10^{-13}} \times \cancel{10^{-4}} \times \frac{1}{2}$

$= 40$ V-m

17. State Kirchhoff s rules. Explain briefly how these rules are justified.

Sol. ***Kirchoff's Current (Junction) rule:*** At any junction, the sum of the currents entering the junction is equal to the sum of current leaving the junction.

When currents are steady, there is no accumulation of charge at any junction or at any point in a line. This is based on the conservation of charge.

Kirchoff loop rule: The algebric sum of changes in potential difference across all the elements in any closed loop involving resistors and cells is zero.

This law is based on the conservation of energy.

18. (*i*) Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2.0×10^{-3} W. Estimate the number of photons emitted per second on an average by the source.

(*ii*) Draw a plot showing the variation of photoelectric current versus the intensity of incident radiation on a given photosensitive surface.

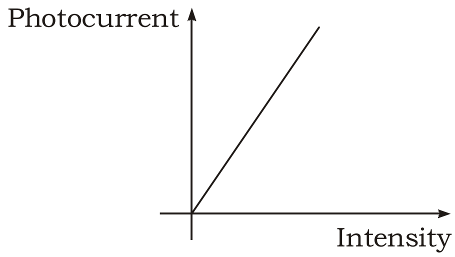
Sol. (*i*) We know energy of photon = $h\nu$

$= 6.63 \times 10^{-34} \times 6 \times 10^{14}$ Joule $= 6 \times 6.63 \times 10^{-20}$

So, No. of photons emitted per second on an average by the source is

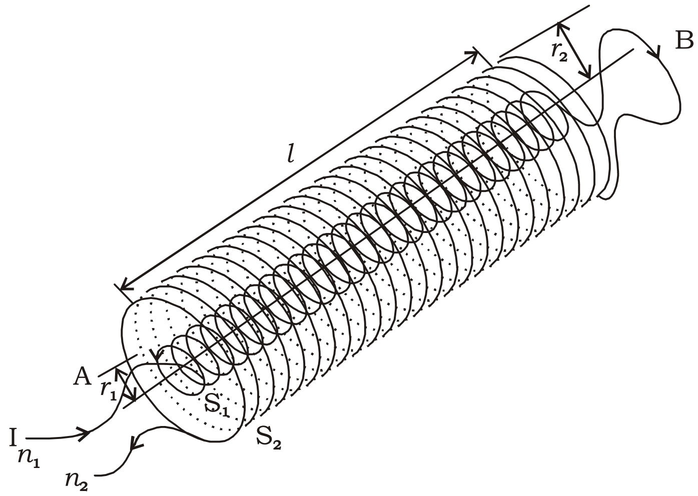
$$= \frac{\text{Power}}{\text{Energy of one photon}} = \frac{2 \times 10^{-3}}{6.63 \times 6 \times 10^{-20}} = \frac{10^{17}}{19.89} = 5.03 \times 10^{15}$$

(*ii*)



19. (*a*) State Ampere's circuital law, expressing it in the integral form.

(*b*) Two long coaxial insulated solenoids, S, and S_2 of equal lengths are wound one over the other as shown in the figure. A steady current "I" flow through the inner solenoid S_1 to the other end B, which is connected to the outer solenoid S, through which the same current "I" flows in the opposite direction so as to come out at end A. If n_1 and n_2 are the number of turns per unit length, find the magnitude and direction of the net magnetic field at a point (*i*) inside on the axis and (*ii*) outside the combined system.



Sol. (*a*) Integral of magnetic field $\left(\oint \vec{B}.\vec{dl}\right)$ around a closed imaginary loop is μ_0 times current encircled by the loop.

$$\oint \vec{B}.\vec{dl} = \mu_0 I$$

(*b*) (*i*) Magnetic field at any point inside the long solenoid is $\mu_0 nI$

Magnetic field due to bigger solenoid = $\mu_0 n_2 I$ towards point 'B'

Magnetic field due to smaller solenoid = $\mu_0 n_1 I$ towards point 'A'

So, net magnetic field = $\mu_0(n_1 - n_2)I$ towards point 'A'

(*ii*) Net field due to long solenoid outside is zero, as the fields due to two diametrically opposite elementary lengths will be zero.

20. A 12.9 eV beam of electrons is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited ?

Calculate the wavelength of the first member of Paschen series and first member of Balmer series.

Sol. (*i*) $\Delta E = 12.9$ eV

Energy in first shell = –13.6 eV

Energy in *n*th shell = $-\dfrac{13.6}{n^2}$

So, drop in energy will be $13.6\left[1-\dfrac{1}{n^2}\right] = 12.9$

$$13.6 - 12.9 = \frac{13.6}{n^2}$$

$$n^2 = \frac{13.6}{0.7}$$

$n^2 = 19.4$

$n = 4$ (Maximum 4th level)

(*ii*) For Paschen series, $\dfrac{1}{\lambda} = R\left(\dfrac{1}{3^2} - \dfrac{1}{4^2}\right) = R\left(\dfrac{16-9}{16\times 9}\right)$

$$\lambda = \frac{144}{7R}$$

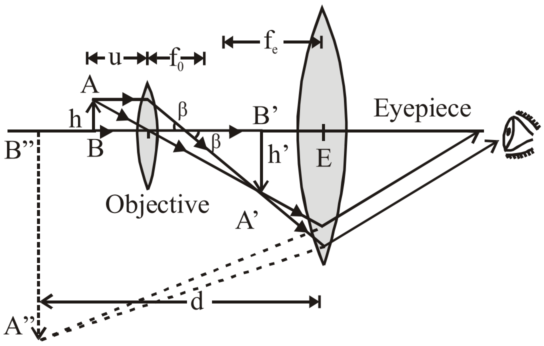
For Balmer series, $n_1 = 2$, $n_2 = 3$

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) \Rightarrow \lambda = \frac{36}{5R}$$

21. (*a*) Draw a labelled ray diagram showing the formation of a final image by a compound microscope at least distance of distinct vision.

(*b*) The total magnification produced by a compound microscope is 20. The magnification produced by the eye piece is 5. The microscope is focussed on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If least distance of distinct vision is 20 cm, calculate the focal length of the objective and the eye piece.

Sol. (a) Compound Microscope :



(b) Magnification produced by eye-piece

$$m_e = \frac{D}{u_e} = 5$$

$$\Rightarrow \quad u_e = \frac{20}{5} = 4cm$$

For eye-piece

$$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$$

$$\frac{1}{-20} - \frac{1}{-4} = \frac{1}{f_e}$$

$$\frac{-1+5}{20} = \frac{1}{f_e}$$

$$\boxed{f_e = \frac{20}{4}\text{cm} = 5\text{cm}}$$

Since $m = m_0 \times m_e = \frac{v_0}{u_0} \times \frac{D}{u_e} = \frac{v_0}{u_0} \times 5$

$$20 = \frac{v_0}{u_0} \times \frac{D}{ue} = \frac{v_0}{u_0} \times 5$$

$$\frac{v_0}{u_0} = 4 \Rightarrow u_0 = \frac{v_0}{4}$$

v_0 = 14 – 4 = 10 cm

For objective

$$\frac{1}{v_0} - \frac{1}{u_0} = \frac{1}{f_0}$$

$$\Rightarrow \quad \frac{1}{10} - \frac{4}{-10} = \frac{1}{f_0}$$

$$\frac{1+4}{10} = \frac{1}{f_0}$$

$$\boxed{f_0 = \frac{10}{5} = 2\text{ cm}}$$

$\Rightarrow \quad f_0 = 2$ cm

22. Answer the following :

(*a*) Name the em waves which are used for the treatment of certain forms of cancer. Write their frequency range.

(*b*) Thin ozone layer on top of stratosphere is crucial for human survival. Why ?

(*c*) Why is the amount of the momentum transferred by the em waves incident on the surface so small ?

Sol. (*a*) γ-rays

Frequency range = 3.0×10^{18} Hz to 3.0×10^{22} Hz

(*b*) It prevents the ultraviolet rays coming from sun in reaching the surface of earth. As these are harmful for human body, the ozone layer is very crucial.

(*c*) For a given em wave of energy E moving with a speed *c*, momentum transfer is $p = \frac{E}{C}$ happens in a very short time with high velocity. So, momentum transfer is small.

23. When Sunita, a class XII student, came to know that her parents are planning to rent out the top floor of their house to a mobile company she protested. She tried hard to convince her parents that this move would be a health hazard.

Ultimately her parents agreed:

(1) In what way can the setting up of transmission tower by a mobile company in a residential colony prove to be injurious to health ?

(2) By objecting to this move of her parents, what value did Sunita display ?

(3) Estimate the range of e.m. waves which can be transmitted by an antenna of height 20 m. (Given radius of the earth = 6400 km)

Sol. (1) Mobile tower requires giant structure at the top level of any building. All through the year it will be an action point where link will be made with mobiles. In case of large scale wind, there is a fear of fall of the structure. Also, the signals wavering around may affect all human life in the neighbourhood.

(2) By objecting to this move of her parents, Sunita displaced the values that

(*i*) She is concerned about large scale damage caused by cyclone/high speed wind with probable loss of life.

(*ii*) She is keeping track (knowledgeable) of the research that is going on in the influence of these signals on human life when exposed for long duration.

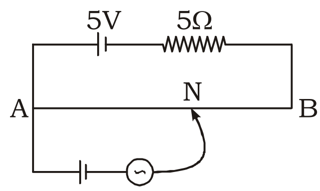
(*iii*) She has foresight of the problems that they may face at large.

(*iv*) She is concerned about the welfare of the community.

(3) Range = R = $\sqrt{2hR_e} = \sqrt{2 \times 20 \times 6400 \times 10^3}$

$= \sqrt{4 \times 64 \times 10^6} = 2 \times 8 \times 10^3 = 16$ Km

24. A potentiometer wire of length 1.0 m has a resistance of 15Ω. It is connected to a 5 V battery in series with a resistance of 5Ω. Determine the emf of the primary cell which gives a balance point at 60 cm.



Sol. At balancing point,

Current flowing in the primary circuit is $i = \frac{5}{5+15} = \frac{1}{4}$A

Potential difference across wire AB

$V = \frac{1}{4} \times 15 = \frac{15}{4}$ volt

Potential gradient = $\frac{V}{L} = \frac{15}{4 \times 1} = \frac{15}{4}$ V/m

At balance point $\varepsilon = \frac{V}{L} . l = \frac{15}{4} \times \frac{60}{100} = \frac{225}{100}$

$\varepsilon = 2.25$ volt

25. (*a*) Deduce the expression, $N = N_0 e^{-\lambda t}$, for the law of radioactive decay.

(*b*) (*i*) Write symbolically the process expressing the β^+ decay of $^{22}_{11}Na$. Also write the basic nuclear process underlying this decay.

(*ii*) Is the nucleus formed in the decay of the nucleus $^{22}_{11}Na$, an isotope or isobar ?

Sol. (*a*) Let N_0 = Total number of atoms present originally in a sample at time $t = 0$

N = Total number of atoms left undecayed in the sample at time t

dN = A small number of atoms that disintegrate in a small interval of time dt

$\therefore$ Rate of disintegration of the element

$R = -\frac{dN}{dt}$ [Minus sign indicates that the number of atoms left undecayed decreases with time]

According to radioactive decay law,

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

$$R = -\frac{dN}{dt} = \lambda N$$

λ = Disintegration constant

$$\frac{dN}{N} = -\lambda dt$$

Integration both side

$$\int \frac{dN}{N} = \int -\lambda dt$$

$$\log_e N = -\lambda t + C$$

C = Constant of integration $t = 0$

$N = N_0$

$\log_e N_0 = \lambda \times 0 + C$

$C = \log_e N_0$

$\log_e N = -\lambda t + \log_e N_0$

$\log_e N - \log_e N_0 = -\lambda t$

$$\log \frac{N}{N_0} = -\lambda t$$

i.e., $\frac{N}{N_0} = e^{-\lambda t}$

$N = N_0 e^{-\lambda t}$

(*b*) (*i*) The basic nuclear process underlying this $+\beta$ decay.

$p \rightarrow n + e^+ + \nu$

The reaction is $^{22}_{11}Na \rightarrow \beta^+ + ^{22}_{10}Ne + \nu$

(*ii*) It is an isobar.

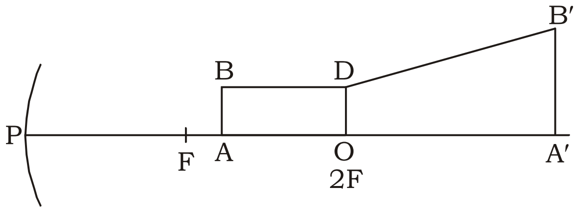
26. (*a*) A mobile phone lies along the principal axis of a concave mirror. Show, with the help of a suitable diagram, the formation of its image. Explain why magnification is not uniform.

(*b*) Suppose the lower half of the concave mirror's reflecting surface is covered with an opaque material. What effect this will have on the image of the object ? Explain.

Sol. (*a*) Image formation of a mobile as an object is shown. Image of one end of the mobile OD is at the same place while the image of the other end AB is A'B'.

The magnification is not uniform along the length and height as, based on the position of the portion of the object, magnification is formed. The portion O of the object and the portion A of the object are separated by a length causing the variation in magnification as

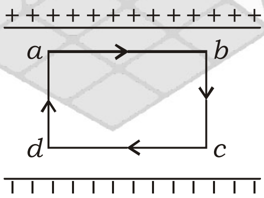
$m = -\frac{v}{u}$



(*b*) We know intensity of image is directly proportional to area of the reflecting surface. When half part is covered reflecting surface area decreases. So, intensity of image decreases. But full image of the object will be formed at the same position as light falls at every point on the mirror from every point of the object.

27. (*a*) Obtain the expression for the energy stored per unit volume in a charged parallel plate capacitor.

(*b*) The electric field inside a parallel plate capacitor is E. Find the amount of work done in moving a charge q over a closed rectangular loop *a b c d a*.



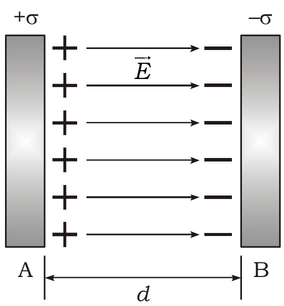
Sol. (a) Assume the capacitor is being charged and, at some moment, has a charge q on it.

The small work needed to transfer a charge dq from one plate to the other: $dW = Vdq = \frac{q}{C}dq$

The **total work** required: $W = \int_0^Q \frac{q}{C}dq = \frac{Q^2}{2C}$

The energy can be considered to be stored in the **electric field** between the plates.

Energy Density



Suppose we have a parallel plate capacitor, as in figure, the field strength between the plates and total charge are given in terms of charge density σ and plate are A by

$E = \frac{\sigma}{\varepsilon_0}$

$Q = A\sigma$

So, energy stored can be expressed in terms of field strength

$U = \frac{1}{2}\frac{Q^2}{C}$

$\therefore \quad U = \frac{1}{2}(A\sigma)^2 \frac{d}{\varepsilon_0 A}$ $\quad \left[\because C = \frac{\varepsilon_0 A}{d}\right]$

$\Rightarrow \quad U = \frac{1}{2} A^2\sigma^2 \frac{d}{\varepsilon_0 A}$

$\Rightarrow \quad U = \frac{1}{2}\frac{\varepsilon_0 \sigma^2}{\varepsilon_0{}^2} dA$

$U = \frac{1}{2}\varepsilon_0 E^2 \times$ (Volume between the plates)

So, ***energy density,*** i.e., energy stored per unit volume (u_E) is

$$u_E = \frac{U}{\text{Volume}} = \frac{1}{2}\varepsilon_0 E^2$$

(b) Since, electrostatic field that exists between the positive and negative plate is a conservative field, the amount of work done in the given path is zero.

OR

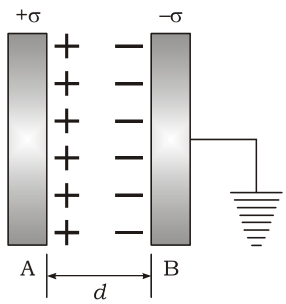
27. (*a*) Derive the expression for the capacitance of a parallel plate capacitor having plate area A and plate separation d.

(*b*) Two charged spherical conductors of radii R_1 and R_2 when connected by a conducting wire acquire charges q_1 and q_2 respectively. Find the ratio of their surface charge densities in terms of their radii.

Sol. (a) Let A = surface area of each plate

d = Separation between the plates

If σ is surface charge density of the plates, then electric field between the plates is given by



$$E = \frac{\sigma}{\varepsilon_0}$$

Since, the field is uniform, the potential difference between the plates is

$$V = Ed = \frac{\sigma d}{\varepsilon_0}$$

The total charge on each plate is = $\pm Q = \pm\sigma A$

∴ Capacitance of a parallel plate capacitor.

$$C = \frac{Q}{V} = \frac{A\sigma}{\frac{\sigma d}{\varepsilon_0}}$$

$$C = \frac{\varepsilon_0 A}{d}$$

(b) Potential on the surface R_1 is $\frac{q_1}{4\pi\varepsilon_0 R_1}$

Potential on the surface of R_2 is $\frac{q_2}{4\pi\varepsilon_0 R_2}$

Since, they are connected, their potentials will be equal,

$$\therefore \quad \frac{q_1}{4\pi\varepsilon_0 R_1} = \frac{q_2}{4\pi\varepsilon_0 R_2}$$

$$\frac{q_1}{q_2} = \frac{R_1}{R_2}$$

Ratio of surface charge densities,

$$\frac{\sigma_1}{\sigma_2} = \frac{\frac{q_1}{4\pi R_1^2}}{\frac{q_2}{4\pi R_2^2}} = \frac{q_1}{q_2}\left(\frac{R_2}{R_1}\right)^2 = \frac{R_1}{R_2} \times \frac{R_2^2}{R_1^2} = \left(\frac{R_2}{R_1}\right)$$

28. (*a*) Describe a simple experiment (or activity) to show that the polarity of emf induced in a coil is always such that it tends to produce a current which opposes the change of magnetic flux that produces it.

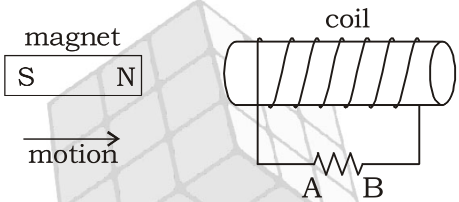
(*b*) The current flowing through an inductor of self inductance L is continuously increasing. Plot a graph showing the variation of

(*i*) Magnetic flux versus the current

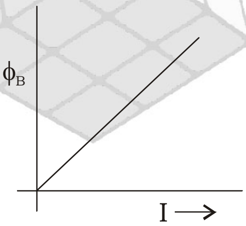
(*ii*) Induced emf versus $\frac{dI}{dt}$

(*iii*) Magnetic potential energy stored versus the current.

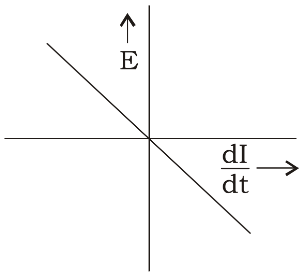
Sol. (a) As shown in the figure, moving the magnetic closer to the coil increases the flux associated with the coil. To oppose the rise in magnetic flux, a north pole is developed in the coil, this causes as induced current in the anti-clockwise direction as seen from the side of the magnet.



(b) (i) Magnetic flux $\phi_B = LI$



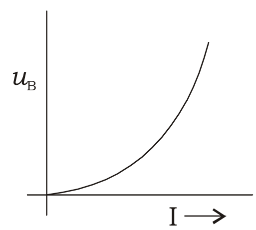
(ii) $\varepsilon = -\frac{LdI}{dt}$



(iii) $u_B = \frac{1}{2\mu_0}B^2 = \frac{1}{2\mu_0}(\mu_0 nI)^2$

$u_B = \frac{\mu_0}{2}n^2I^2$

$u_B \propto I^2$



OR

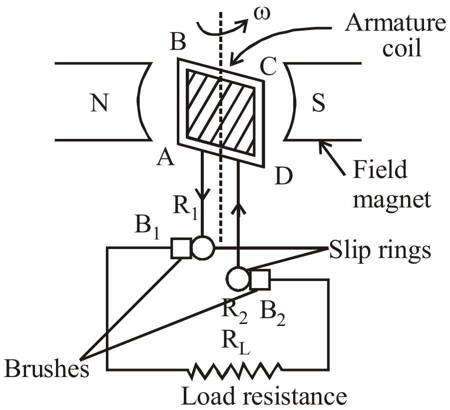
28. (*a*) Draw a schematic sketch of an ac generator describing its basic elements. State briefly its working principle. Show a plot of variation of

(*i*) Magnetic flux and

(*ii*) Alternating emf versus time generated by a loop of wire rotating in a magnetic field.

(*b*) Why is choke coil needed in the use of fluorescent tubes with ac mains ?

Sol. (*a*)



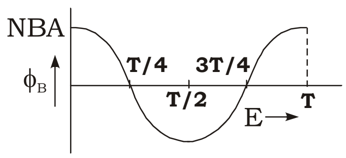
Principle: A dynamo or generator is a device which converts mechanical energy into electrical energy. It is based on the principle of electromagnetic induction. Magnetic flux changes as the coils orientation varies with the rotation ($\phi = BA\cos\theta = BA\cos\omega t$)

Construction: It consists of four main parts-

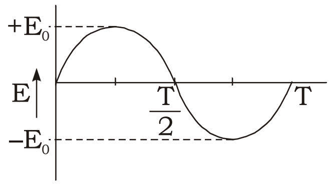
- **Field magnet:** It produces the magnetic field. For a low power dynamo, the magnetic field is generated by a permanent magnet but for a large power dynamo, the magnetic field is produced by an electromagnet.
- **Armature:** It consists of a large number of turns of insulated copper wire on a soft iron core. It can revolve round the axis between the two poles of the field magnet. The soft iron core provides support to the coils and increases the magnetic field through the coil.
- **Slip rings:** The slip rings R_1 and R_2 are two metal rings to which the ends of the armature coil are connected. These rings are fixed to the shaft which rotates the armature coil so that the rings also rotate along with the armature.
- **Brushes (B_1 and B_2):** These are flexible metal plates or carbon rods which are fixed and constantly touch the revolving rings. The output current in external load resistance R_L is taken through these brushes.

(*i*) ϕ_B = NBA cos ωt

$$T = \frac{2\pi}{\omega} \text{ (Time period)}$$



(*ii*) $E = \frac{d\phi}{dt} = NAB\omega\sin\omega t = E_0 \sin \omega t$ making $E_0 = NAB\omega$



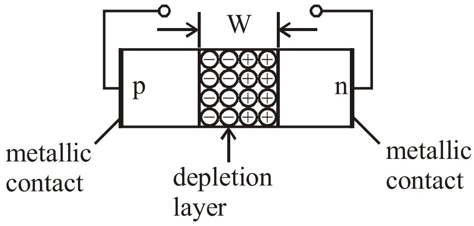
(*b*) Fluorescent tubes require smaller voltage, than AC supplier. A choke coil has some inductive reactance, which causes a fraction of the voltage to drop on itself, thereby reducing the voltage across fluorescent tubes.

29. (*a*) State briefly the processes involved in the formation of p-n junction explaining clearly how the depletion region is formed.

(*b*) Using the necessary circuit diagrams, show how the V-I characteristics of a *p - n* junction are obtained in (*i*) Forward biasing (*ii*) Reverse biasing

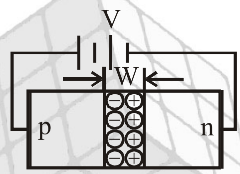
How are these characteristics made use of in rectification ?

Sol. (*a*) **Formation of p – n junction:** Part of p-type can be converted into n – type by adding pentavalent impurity. There is concentration gradient between p and n sides, holes diffuse from p side to n side (p → n) and electrons move from (n → p) creating a layer of positive and negative charges on n and p side respectively called **depletion layer**. External bias is applied to cause charges to flow.



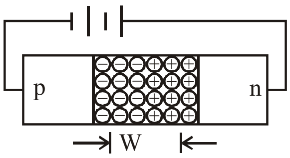
p-n junction

(*b*) **p – n junction under forward bias:** When p – side is connected to positive terminal and n – side to negative terminal of external voltage, it is said to be **forward biased.** The applied voltage V is opposite to built in potential V_0, hence depletion layer width decreases and barrier height is reduced to $(V_0 - V)$. There is minority carrier injection, hence charges begin to flow. Current is in the order of mA.



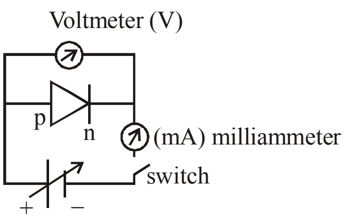
Forward biased p-n junction

p – n junction under reverse bias: The direction of applied voltage is same as direction of barrier potential, so barrier height increases to $(V_0 + V)$. This suppresses flow of electrons from n → p and holes from p → n. Diffusion current decreases but drift of electrons and holes under the electric field affect remains. This drift current is few μA.

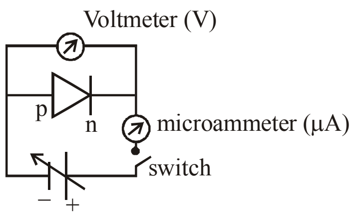


Diode under reverse bias

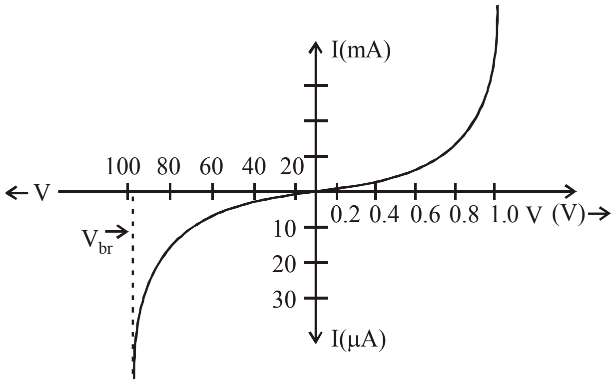
Study of V – I characteristics of a diode: The circuit to study the variation of current as a function of applied voltage is shown. Battery is connected to potentiometer (or rheostat) to change applied voltage. In forward bias we use milliammeter and reverse bias we use microammeter.



p-n junction in FB

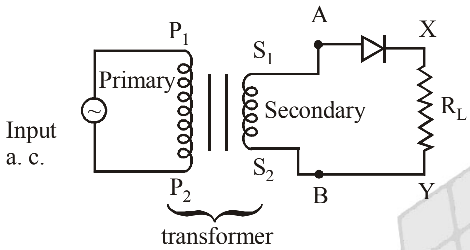


p-n junction in RB

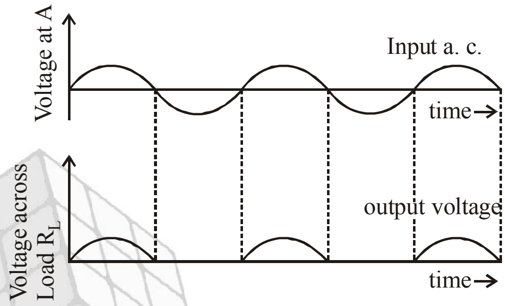


V - I. characteristics graph

Half wave rectifier: Junction diode allows current to pass through only if it is forward biased, hence a pulsating voltage will appear across the load only during positive half cycles when diode is F.B.



(a) Diode rectification Circuit



(b) Input ac and output voltage waveforms

OR

29. (*a*) Differentiate between three segments of a transistor on the basis of their size and level of doping.

(*b*) How is a transistor biased to be in active state ?

(*c*) With the help of necessary circuit diagram, describe briefly how n-p-n transistor in CE configuration amplifies a small sinusoidal input voltage. Write the expression for the ac current gain.

Sol. (a)

	Emitter	**Base**	**Collector**
Doping	Highest doping	Least doping	Moderate Doping
Size	Moderate	Least	Largest

(b) Emitter base junction is forward biased.

Collector base junction is reverse biased.

(c) **Transistor as an amplifier (C E configuration):** Transistor works in active region.

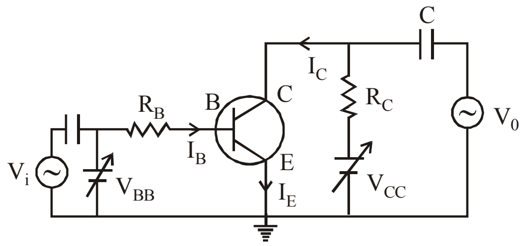
Output, $V_0 = V_{CC} - I_C R_C$ ...(1)

If input voltage increases, output voltage decreases. V_i and V_0 are out of phase.

A_V = small signal voltage gain = $\dfrac{\Delta V_0}{\Delta V_i}$ ...(2)

Since V_{CC} and R_C are constant,

$\Delta V_0 = 0 - R_C \Delta I_C$ (from (1), differentiate)



Amplifier Circuit

Input $V_i = I_B R_B + V_{BE}$

$\Rightarrow \Delta V_i = R_B \Delta I_B + \Delta V_{BE}$ ... (3)

Since ΔV_{BE} = small, neglect it, using (1), (3) in (2),

$A_V = -\frac{R_C \Delta I_C}{R_B \Delta I_B} = -\beta_{ac}\left(\frac{R_C}{R_B}\right)$ where $\beta_{ac} = \frac{\Delta I_C}{\Delta I_B}$ = a.c. current gain

Voltage gain, $A_V = \frac{\Delta V_{CE}}{r \Delta I_B}$

30. (*a*) (*i*) 'Two independent monochromatic sources of light cannot produce a sustained interference pattern'. Give reason.

(*ii*) Light waves each of amplitude "*a*" and frequency "ω", emanating from two coherent light sources superpose at a point. If the displacements due to these waves is given by $y_1 = a \cos \omega t$ and $y_2 = a \cos(\omega t + \phi)$ where ϕ is the phase difference between the two, obtain the expression for the resultant intensity at the point.

(*b*) In Young's double slit experiment, using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is λ/3.

Sol. (a) (i) In independent monochromatic sources phase difference changes at a rate of 10^8 Hz. Hence, the interference pattern obtained also fluctuates with 10^8 Hz and therefore, it is not sustainable as result of peristance of vision.

(ii) The phase difference between two waves arising from slits A and B is ϕ. Then,

$y_1 = a \cos\omega t$ and $y_2 = a \cos(\omega t + \phi)$.

Therefore the resultant displacement will be given by

$y = y_1 + y_2 = a \cos\omega t + a \cos(\omega t + \phi)$

$y = 2a \cos\frac{\phi}{2} . \cos(\omega t + \frac{\phi}{2})$

The amplitude of the resultant displacent is given by

$R = 2a \cos(\frac{\phi}{2})$

As, intensity ∝ $(\text{amplitude})^2$

∴ Resultant intensity, $I = 4a^2 \cos^2(\frac{\phi}{2})$

(b) As the resultant intensity at a point, $I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\phi$

When the path difference = λ, phase difference = 0°

∴ $I_R = I + I + 2\sqrt{I \times I} \cos 0° = 2I + 2\sqrt{I^2} \times 1 = 2I + 2I = 4I = K.$

When the path difference = $\frac{\lambda}{3}$, phase difference $\phi = \frac{2\pi}{3}$

$\therefore \quad I'_R = I + I + 2\sqrt{I.I}.\cos\left(\frac{2\pi}{3}\right) = 2I + 2\sqrt{I^2} \times \left(-\frac{1}{2}\right) = 2I - \frac{2I}{2} = I$

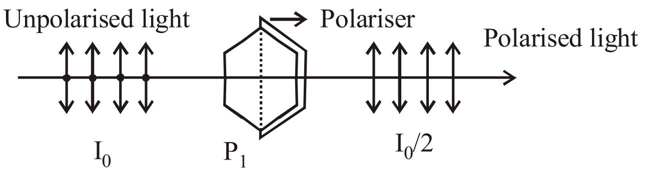
$\therefore \quad I' = \frac{K}{4}$

OR

30. (*a*) How does one demonstrate, using a suitable diagram, that unpolarised light when passed through a Polaroid gets polarised ?

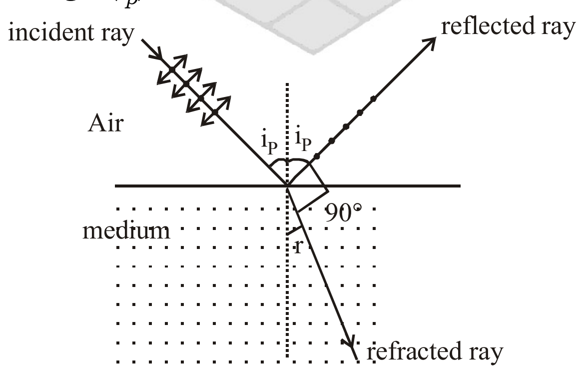
(*b*) A beam of unpolarised light is incident on a glass-air interface. Show, using a suitable ray diagram, that light reflected from the interface is totally polarised, when $\mu = \tan i_B$, where μ is the refractive index of glass with respect to air and i_B is the Brewster's angle.

Sol. (a)



Polariser has a pass axis along which if any electric field vector lies, it will get transmitted to the other side. If an electric field vector which is perpendicular the pass axis, falls on the polariser then, it gets absorbed. We know that an unpolarised light has two components of electric field vector, one of which is parallel to the pass axis and the other which is perpendicular to the pass axis. Since, the perpendicular component gets absorbed, the output light obtained is a polarised light whose electric field vector is parallel to the pass axis.

(b) When unpolarised light is incident on the interface of two transparent media the reflected light is polarised. If the unpolarised light is incident at the angles 0° or 90°, the reflected ray remains unpolarised. When the reflected wave is perpendicular to the refracted wave, the reflected wave is totally polarised. The angle of incidence in this case is called polarising angle or Brewster's angle (i_p).



Brewster's Law says that when an unpolarised light is incident on a transparent surface of refractive index (n) at the polarising angle (i_p) such that the reflected ray and the refracted ray are perpendicular to each other, the reflected light is totally plane polarised and in that condition $n = \tan i_p$. From the diagram,

$i_p + 90° + r = 180°$

$i_p + r = 90°$

$r = 90 - i_p$

$$\mu = \frac{\sin i_p}{\sin r} = \frac{\sin i_p}{\sin(90 - i_p)} = \frac{\sin i_p}{\cos i_p} = \tan i_p$$

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