Series GBM

SET-2

Roll No. | | | | | | | |

Candiates must write code on the title page of the answer – book

- Please check that this question paper contains 21 printed pages with solutions.
- 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 **26** questions.
- Please write down the Serial Number of the question before attempting it.
- 15 minute 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 students will read the question paper only and will not write any answer on the answer-book during this period.

PHYSICS (Theory) & SOLUTION

Time allowed : 3 hours **Maximum Marks :** 70

General Instructions :

(i) All questions are compulsory. There are 26 questions in all.

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

(iii) Section A contains five questions of one mark each, Section B contains five questions of two marks each, Section C contains twelve question of three marks each, Section D contains one value based question of four marks and Section E contains three questions of five marks each.

(iv) 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 the 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 :

$c = 3\times10^{8}$ m/s

$h = 6.63\times10^{-34}$ Js

$e = 1.6\times10^{-19}$ C

$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}

$\varepsilon_0 = 8.854 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}$

$\frac{1}{4\pi\varepsilon_0} = 9\times10^9\ Nm^2C^{-2}$

Mass of electron = 9.1×10^{-31} kg

Mass of neutron = 1.675×10^{-27} kg

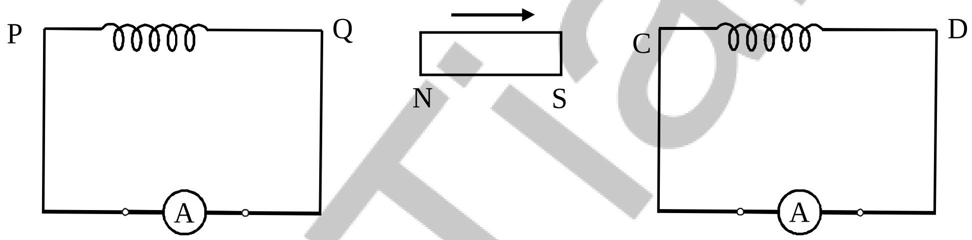
Mass of proton = 1.673×10^{-27} kg

Avogadro's number = 6.023×10^{23} per gram mole

Boltzmann constant = 1.38×10^{-23} JK^{-1}

SECTION A

Q 1. A bar magnet is moved in the direction indicated by the arrow between two coils PQ and CD. Predict the direction of the induced current in each coil.



Ans 1. According to lenz's Law current in both coil PQ and CD will be clock wise direction.

Q 2. Write the relation for the speed of electromagnetic waves in terms of the amplitudes of electric and magnetic fields.

Ans 2. $C = \frac{E_0}{B_0}$

Q 3. Nichrome and copper wires of same length and same radius are connected is series. Current I is passed through them. Which wire gets heated up more ? Justify your answer.

Ans 3. Nichrome wire get heated up more.

because $R_{nichrome} > R_{copper}$ (I are same in both wire so $H = I^2Rt$)

Q 4. How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced by red light ? Give reason.

Ans 4. We know $\delta = A(\mu - 1)$ and $\mu \propto \frac{1}{\lambda}$ For voilet colour $\delta_V = A(\mu_V - 1)$ and For red colour $\delta_R = A(\mu_R - 1)$ so

deviation angle decrease when voilet colour replaced by red colour

Q 5. Name the phenomenon which shows the quantum nature of electromagnetic radiation.

Ans 5. Photoelectric effect shows the quantum nature of electromagnetic radiation.

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SECTION B

Q 6. Find the condition under which the charged particles moving with different speeds in the presence of electric and magnetic field vectors can be used to select charged particles of a particular speed.

Ans 6. qE = qVB

$V = \frac{E}{B}$

Q 7. Identify the electromagnetic waves whose wavelengths lie in the range

(a) 10^{-11} m < λ < 10^{-14} m

(b) 10^{-4} m < λ < 10^{-6} m

Write one use of each.

Ans 7. (a) Gamma rays (b) infrared waves

Uses of Gamma rays → (i) In radiotherapy for the treatment of malignant tumours

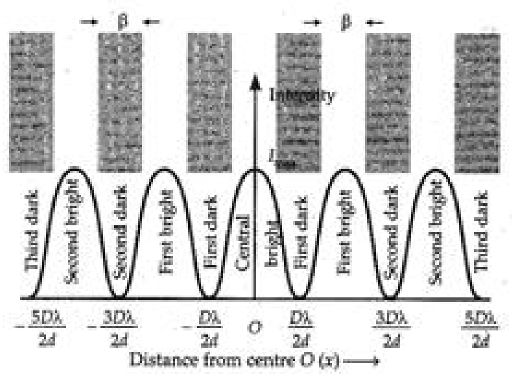
Uses of infrared waves → (i) In the remote control of a TV or VCR.

Q 8. Draw the intensity pattern for single slit diffraction and double slit interference. Hence, state two differences between interference and diffraction patterns.

OR

Unpolarised light is passed through a polaroid P_1. When this polarised beam passes through another polaroid P_2 and if the pass axis of P_2 makes angle θ with the pass axis of P_1, then write the expression for the polarised beam passing through P_2. Draw a plot showing the variation of intensity when θ varies from 0 to 2π.

Ans 8. Intensity distribution curve for interference :→



Intensity distribution curve.

Intensity distribution curve for diffraction :→

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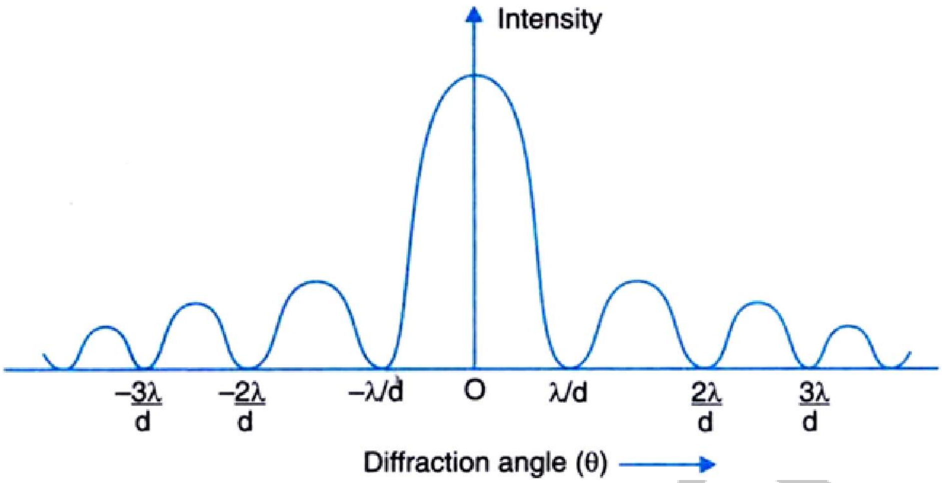


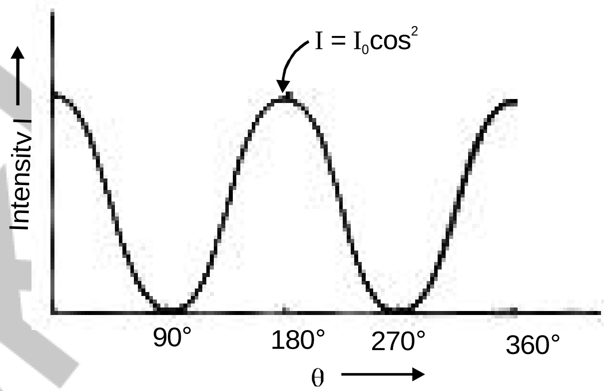
Difference between interference and diffraction pattern

	Interference		diffraction
1.	All bright and dark fringes are of equal width	1.	The width of central bright fringe is twice the width of any secondary maximum
2.	All bright fringes are of same intensity	2.	Intensity of bright fringes decreases as we move away from central bright fringe on either side.

OR

(i) The intensity of beam passing through P_2 is $I = I_0 \cos^2\theta$

(ii)



Q 9. The short wavelength limit for the Lyman series of the hydrogen spectrum is 913.4 A°. Calculate the short wavelength limit for Balmer series of the hydrogen spectrum.

Ans 9. For Lyman series

$$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{n_2{}^2}\right]$$

For shortest wavelength $n_2 = \infty$

$$\frac{1}{913.4} = R\left[\frac{1}{1^2} - \frac{1}{\infty}\right]$$

$R = \frac{1}{913.4\ A°}$

We know for Balmer series

$\frac{1}{\lambda} = R\left[\frac{1}{(2)^2} - \frac{1}{n_2^2}\right]$ For shortest wave length $n_2 = \infty$

$\frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{\infty}\right]$

$\frac{1}{\lambda} = \frac{R}{4}$

$\lambda = 913.4 \times 4 = 3653.6A°$

Q 10. Write two properties of a material suitable for making (a) a permanent magnet, and (b) an electromangnet.

Ans 10. (a) The material used for making permanent magnets must have following properties

(i) High retentivity

(ii) High corecivity

(iii) High permeability

(b) The material used for making electromegnet must have following properties

(i) low retentivity

(ii) high initial permeability.

SECTION C

Q 11. (a) Monochromatic light of wavelength 589 nm is incident from air on a water surface. If μ for water is 1.33, find the wavelength, frequency and speed of the refracted light.

(b) A double convex lens is made of a glass of refractive index 1.55, with both faces of the same radius of curvature. Find the radius of curvature required, if the focal length is 20 cm.

Ans 11. (a) given

λ_a = 589 nm ; , $\mu = \frac{4}{3} = 1.33$

$\lambda_w = ?$

(i) We know $\mu = \frac{\lambda_a}{\lambda_w}$

$$\lambda_w = \frac{\lambda_a}{\mu} = \frac{589}{\frac{4}{3}} = \frac{3 \times 589}{4} = 441.75\ nm$$

(ii) $c = \nu\lambda_a$

$$\nu = \frac{c}{\lambda_a} = \frac{3 \times 10^8}{589 \times 10^{-9}} = \frac{3}{589} \times 10^{17}\text{Hz}$$

$$= \frac{3000}{589} \times 10^{14}\ Hz$$

$$= 5.09 \times 10^{14}\text{Hz}$$

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(iii) $\mu = \dfrac{c}{V_w}$

$V_w = \dfrac{c}{\mu} = \dfrac{3\times10^8}{\frac{4}{3}} = \dfrac{9}{4}\times10^8$

$= 2.25 \times 10^8$ m/s

(b) given

$\mu = 1.55$, f = 20 cm

We know

$\dfrac{1}{f} = (\mu-1)\left(\dfrac{1}{R_1}-\dfrac{1}{R_2}\right)$ (Here $R_1 = R_1$ $R_2 = -R$)

$\dfrac{1}{f} = (\mu-1)\left(\dfrac{1}{R}+\dfrac{1}{R}\right)$

$\dfrac{1}{20} = (1.55-1)\left(\dfrac{2}{R}\right)$

$\dfrac{1}{20} = 0.55\times\dfrac{2}{R}$

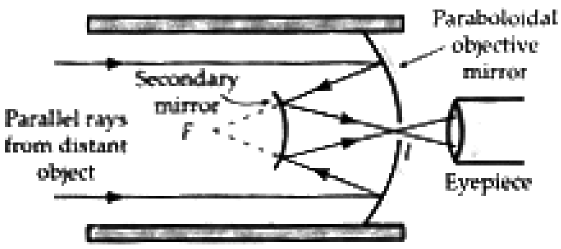
R = 1.10 × 20

= 22 cm.

Q 12. (a) Draw a ray diagram showing the formation of image by a reflecting telescope.

(b) Write two advantages of a reflecting telescope over a refracting telescope.

Ans 12. (a)

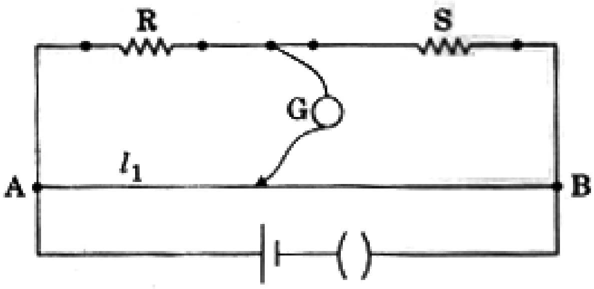


(b) (i) Due to large aperture of the mirror used, the reflecting telescopes have high resolving power.

(ii) As the objective is a mirror and not a lens, it is free from chromatic aberration (formation of coloured image of a white object).

Q 13. (a) Write the principle of working of a metre bridge.

(b) In a metre bridge, the balance point is found at a distance l_1 with resistances R and S as shown in the figure.



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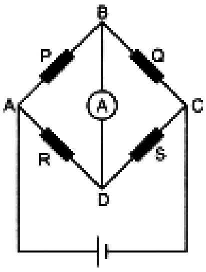
An unknown resistance X is now connected in parallel to the resistance S and the balance point is found at a distance l_2. Obtain a formula for X in terms of l_1, l_2 and S.

Ans 13. (a) Working of metre bridge is based on Wheatstone bridge which is a circuit having four resistances forming four sides of a quadrilateral ABCD as shown.

When there is no current flows between B and D, it is called balance condition and



We have $\frac{P}{Q} = \frac{R}{S}$

(b) Let the resistance per unit length of the metre bridge wire be r then

$$\frac{R}{S} = \frac{r.l_1}{r.(100-l_1)} \qquad ......(1)$$

and $$\frac{R}{\frac{SX}{(S+X)}} = \frac{rl_2}{r(100-l_2)} \qquad ......(2)$$

Dividing (2) by (1)

$$\frac{S}{SX}(S+X) = \left(\frac{100-l_1}{100-l_2}\right)\frac{l_2}{l_1}$$

$$\therefore \quad 1+\frac{S}{X} = \frac{l_2}{l_1}\left(\frac{100-l_1}{100-l_2}\right).$$

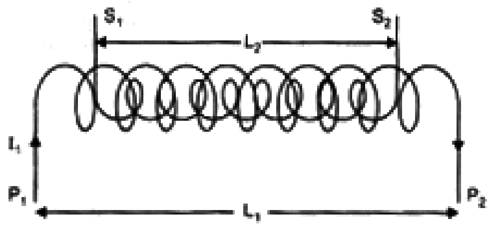
or $$X = \frac{S}{\frac{l_2}{l_1}\left(\frac{100-l_1}{100-l_2}\right)-1} = \frac{S(100-l_2)}{100(l_2-l_1)}$$

Q 14. Define mutual inductance between a pair of coils. Derive an expression for the mutual inductance of two long coaxial solenoids of same length wound one over the other.

OR

Define self-inductance of a coil. Obtain the expression for the energy stored in an inductor L connected across a source of emf.

Ans 14. Mutual inductance of two coils is numerically equal to the induced emf developed in the secondary coil when current in the primary coil changes at the rate of 1 ampere per second.



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Consider two coils primary P_1P_2 and secondary S_1 S_2 with lengths L_1 and L_2 having n_1 and n_2 as number of turns per unit length respectively. Let r_1 denote radius of each turn of primary and r_2 that of the secondary.

For a current I_1 through the primary, magnetic field intensity in the solenoid is given by

$$B = \mu_0 n_1 I_1$$

Magnetic flux through each turn of secondary

$$= B . \pi r_1^2$$

$$= \mu_0 n_1 I_1 \pi r_1^2$$

The area considered πr_1^2 as no magnetic field exists outside the primary coil (solenoid).

Total number of turns in secondary = $n_2 L_2$

$\therefore$ Total magnetic flux through the secondary

$$\phi_2 = \mu_0 n_1 n_2 L_2 I_1 \pi r_1^2$$

or $$\phi_2 = \mu_0 n_1 n_2 \pi r_1^2 L_2 I_1$$

Also $\phi_2 = MI_1$ where M is mutual inductance of the two coils.

$$\therefore \quad M = \mu_0 n_1 n_2 \pi r_1^2 L_2$$

For mutual inductance of the coils both the radius and the total length used in the expression should be the smallar of the two coils.

OR

Self inductance $\rightarrow$ It is define as the magnetic flux linked with the coil when a unit current flow through it

Energy stored in an inductor coil $\rightarrow$

Let I be the current through the inductor L at any instant 't' then induced emf is

$$\varepsilon = -L\frac{dI}{dt}$$

The work done against the induced emf in small time dt is

$$dw = Pdt = -\varepsilon Idt = L\frac{dI}{dt} \times Idt = LIdI$$

the total work done in building up the current 0 to I_0 is

$$w = \int dw = \int_0^{I_0} LIdI$$

$$w = \frac{1}{2}LI_0^2$$

This work done is strored as a magnetic field energy U in the inductor.

$$U = \frac{1}{2}LI_0^2$$

Q 15. Explain giving reasons for the following:

(a) Photoelectric current in a photocell increases with the increase in the intensity of the incident radiation.

(b) The stopping potential (V_0) varies linearly with the frequency (ν) of the incident radiation for a given photosensitive surface with the slope remaining the same for different surfaces.

(c) Maximum kinetic energy of the photoelectrons is independent of the intensity of incident radiation.

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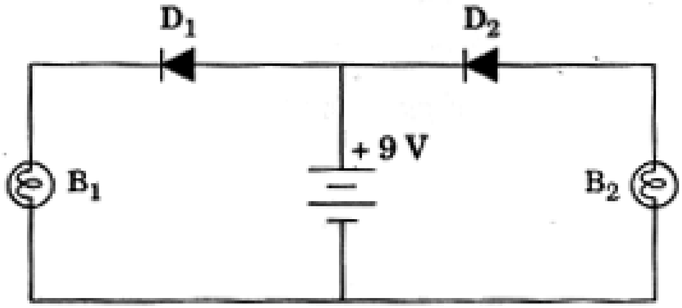
Ans 15. (a) The increase of intensity means the increase in the number of photons striking the metal surface per unit time. As each photon eject only one electron so number of ejected photoelectron increase with the increases in intensity.

(b) Because the slope $V_0 - \nu$ graph gives the value of $\frac{h}{e}$ which is same for different surface.

(c) The increase in intensity increase only the number of incident photon and not their energy. Hence KE of photoelectron is independent of the intensity

Q 16. (a) In the following diagram, which bulb out of B_1 and B_2 will glow and why ?

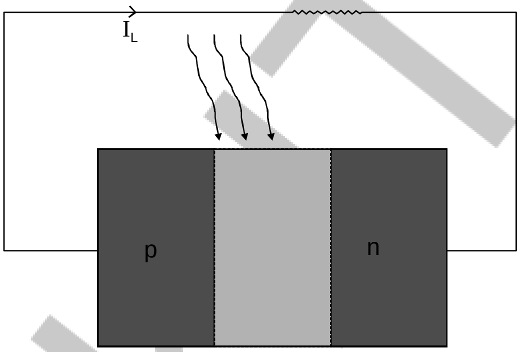


(b) Draw a diagram of an illuminated p-n junction solar cell.

(c) Explain briefly the three processes due to which generation of emf takes place in a solar cell.

Ans 16. (a) bulb B_1 will glow because diode D_1 is in forward biase and diode D_2 is in reverse biase.

(b)



Depletion layer

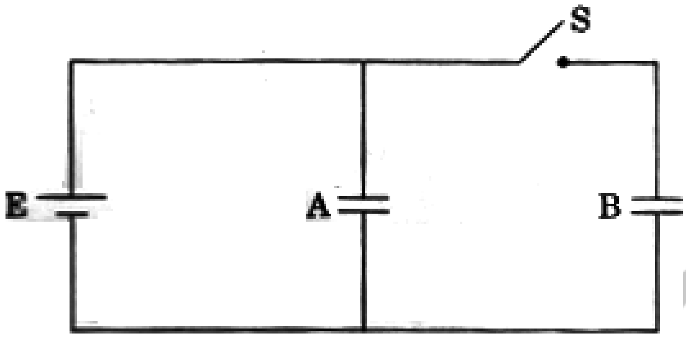
(c) It is due to the following three basic processes: generation. separation and collection–

(i) generation of e-h pairs due to light (with $h\nu > E_g$) close to the junction:

(ii) separation of elecrtrons and holes due to electric field of the depletion region. Electrons are swept to n-side and holes to p-side:

(iii) the electrons reaching the n-side are collected by the front contact and holes reaching p-side are collected by the back contact. Thus p-side becomes positive and n-side becomes negative giving rise to photovoltage.

Q 17. Two identical parallel plate capacitors A and B are connected to a battery of V volts with the switch S closed. The switch is now opened and the free space between the plates of the capacitors is filled with a dielectric of dielectric constant K. Find the ratio of the total electrostatic energy stored in both capacitors before and after the introduction of the dielectric.



Ans 17. Initial electrostatic energy

$$U_i = \frac{1}{2}CV^2 + \frac{1}{2}CV^2 = CV^2$$

Final electrostatic energy

$$U_f = \frac{1}{2}KCV^2 + \frac{1}{2}\frac{KCV^2}{K^2} = \left(\frac{1}{2}KCV^2 + \frac{CV^2}{2K}\right)$$

$$= \frac{1}{2}CV^2\left(K + \frac{1}{K}\right)$$

So,

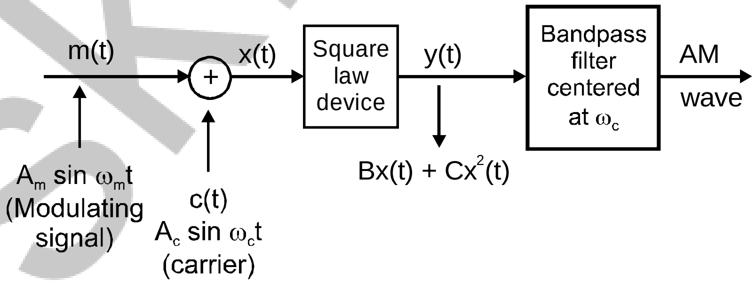
$$\frac{U_i}{U_f} = \frac{CV^2}{\frac{1}{2}CV^2(K + \frac{1}{K})} = \frac{2K}{(K^2+1)}$$

Q 18. (a) How is amplitude modulation achieved?

(b) The frequencies of two side bands in an AM wave are 640 kHz and 660 kHz respectively. Find the frequencies of carrier and modulating signal. What is the bandwidth required for amplitude modulation?

Ans 18. amplitude modulation

(a) Fig. shows a block diagram of a simple square law modulator for obtaining an AM wave.



Here the modulating signal is added to the carrier signal to produce the input signal,

$$x(t) = A_m \sin \omega_m t + A_C \sin \omega_C t$$

This signal is passed through a square law device which gives the output,

$$y(t) = Bx(t) + Cx^2(t)$$

Here B and C are constants. When this signal is passed through a bandpass filter centered at ω_c, the filter rejects the sinusoidal signals of frequencies ω_m, $2\omega_m$ and $2\omega_c$ and retains the frequencies ω_c,

$\omega_c - \omega_m$ and $\omega_c + \omega_m$. The output of the bandpass filter is thus an AM wave.

(b) USB = $f_C + f_M$ = 660 kHz .... (1)

LSB = $f_C - f_M$ = 640 kHz .... (2)

(1) + (2) $2f_C$ = 1300

$f_C = \frac{1300}{2}$ = 650 kHz

Now from eq^n (1)

$650 + f_M = 660$

$f_M = 660 - 650$

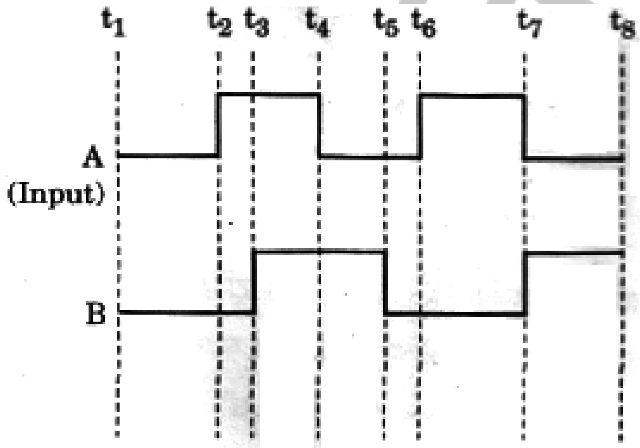
$= 10$ kHz

Bandwidth $= (f_C + f_M) - (f_c - f_M) = 2f_M$

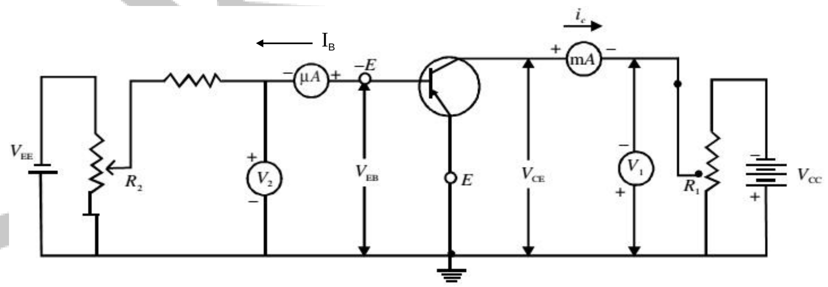
$= 2 \times 10 = 20$ kHz.

Q 19. (a) Draw the circuit diagram for studying the characteristics of a transistor in common emitter configuration. Explain briefly and show how input and output characteristics are drawn.

(b) The figure shows input waveforms A and B to a logic gate. Draw the output waveform for an OR gate. Write the truth table for this logic gate and draw its logic symbol.



Ans 19. (a)

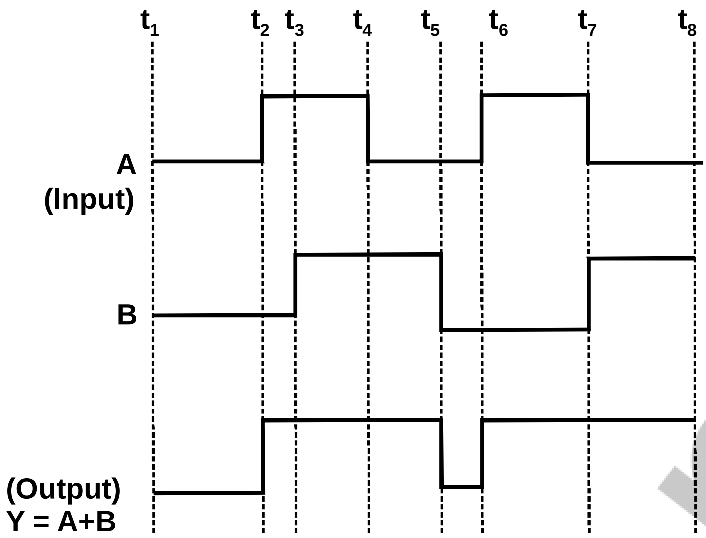


(i) For input characteristics →

By keeping output voltage (V_{CE}) constant with the help of Rh_2 we take four or five observation for input current I_B and input voltage V_{BE} then we plot the graph between I_B and V_{BE}

(ii) By keeping input current I_B constant with the help of Rh_1 then we take four or five observation of output current I_C and output voltage V_{CE} with the help of Rh_2 then we plot the graph.

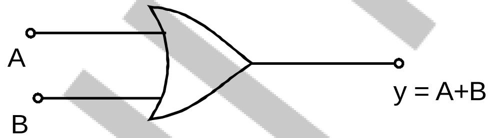
(b)



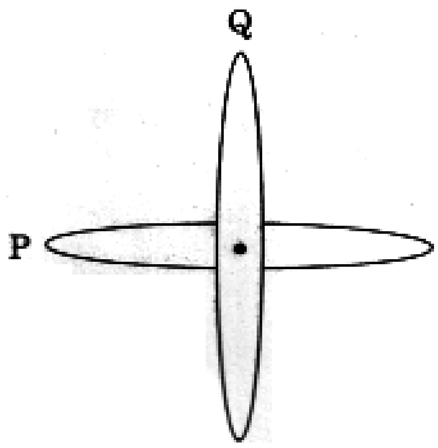
Truth Table

inputs		Output
A	B	y = A+B
0	0	0
0	1	1
1	0	1
1	1	1

logic symbol →



Q 20. Two identical loops P and Q each of radius 5 cm are lying in perpendicular planes such that they have a common centre as shown in the figure. Find the magnitude and direction of the net magnetic field at the common centre of the two coils, if they carry currents equal to 3A and 4A respectively.



Ans 20. B due to loop P, at its centre :

$$B_1 = \frac{\mu_0 I}{2r}$$

$$= \frac{\mu_0 \times 3 \times 100}{2 \times 5} = 30\mu_0$$

B due to loop Q at its centre :

$$B_2 = \frac{\mu_0 \times 4 \times 100}{2 \times 5} = 40\mu_0$$

Since B_1 and B_2 are perpendicular to each other.

$$\therefore \quad \text{Net B} = \sqrt{B_1^2 + B_2^2}$$

$$= \sqrt{(30\ \mu_0)^2 + (40\ \mu_0)^2}$$

$$= 50\mu_0$$

$$= 50 \times 4\pi \times 10^{-7}\ \text{T}$$

$$= 2\pi \times 10^{-5}\ \text{T}$$

and direction $\tan\theta = \frac{B_1}{B_2} = \frac{3}{4}$

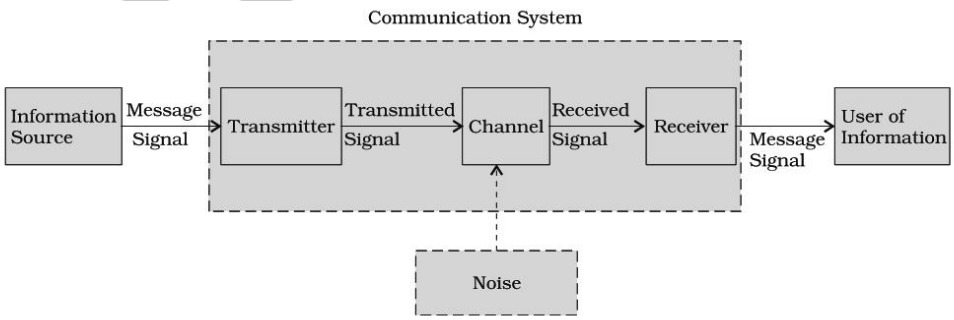
$$\theta = \tan^{-1}\left(\frac{3}{4}\right)$$

= 37° with horizontal (P coil)

Q 21. Draw a block diagram of a generalized communication system. Write the functions of each of the following:

(a) Transmitter
(b) Channel
(c) Receiver

Ans 21.



(i) **Transmitter.** It is a set-up that transmits the message to the receiving end through a communication channel. Its main function is to convert the message signal produced by the information source

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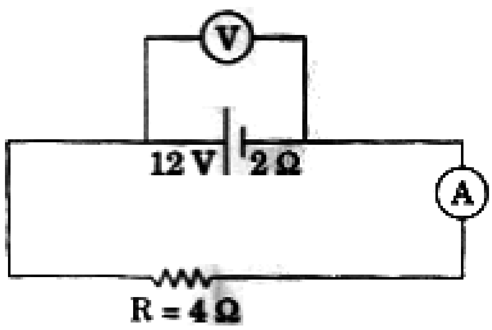
into a form suitable for transmission through the channel and to transmit it. If the information source gives a voice signal, a transducer converts it into an electrical signal before feeding it to the transmitter.

(ii) **Communication channel or transmission medium**. It is the medium or the physical path that connects a transmitter to a receiver. It carries the modulated wave from the transmitter to the receiver. It can be a transmission line, an optical fibre or free space. When the information signal propagates along the channel, some unwanted signals called noise, may interfere with it and thus the receiver receives a corrupted version of the transmitted signal.

(iii) **Receiver.** It is a set-up that receives the transmitted signals from the transmission medium and converts those signals back to their original form. This process of recovering the orginal signal is called demodulation or detector, which is reverse of the modulation process used at the transmitter.

Q 22. (a) The potential difference applied across a given resistor is altered so that the heat produced per second increases by a factor of 9. By what factor does the applied potential difference change?

(b) In the figure shown, an ammeter A and a resistor of 4 Ω are connected to the terminals of the source. The emf of the source is 12 V having an internal resistance of 2 Ω. Calculate the voltmeter and ammeter readings.



Ans 22. (a) Heat = $\frac{V^2}{R} \times t$

Heat per sec (P) = $\frac{V^2}{R}$

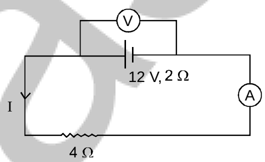
From Question :-

P' = 9P

$\Rightarrow \frac{(V')^2}{R} = 9\frac{V^2}{R}$

V' = 3V

(b)



V = I(R + r)

$I = \frac{V}{R+r} = \frac{12}{4+2} = 2A$

Now from $V = \varepsilon - ir$

$= 12 - (2 \times 2) = 8$ V

So the reading of voltmeter is 8V and reading of ammeter is 2A.

SECTION D

Q 23. Asha's mother read an article in the newspaper about a disaster that took place at Chernobyl. She could not understand much from the article and asked a few questions from Asha regarding the article. Asha tried to answer her mother's questions based on what she learnt in Class XII Physics.

(a) What was the installation at Chernobyl where the disaster took place ? What, according to you, was the cause of this disaster ?

(b) Explain the process of release of energy in the installation at Chernobyl.

(c) What, according to you, where the values displayed by Asha and her mother ?

Ans 23. (a) Nuclear reactor was installation at chernobyl.

Cause → Explosion of core during emergency shutdown of reactor whilst undergoing power failure experiment

(b) Nuclear fission

(c) Concern about mankind, concern about utility of book education.

SECTION E

Q 24. (a) Define wavefront. Use Huygens' principle to verify the laws of refraction.

(b) How is linerarly polarised light obtained by the process of scattering of light ? Find the Brewster angle for air – glass interface, when the refractive index of glass = 1.5.

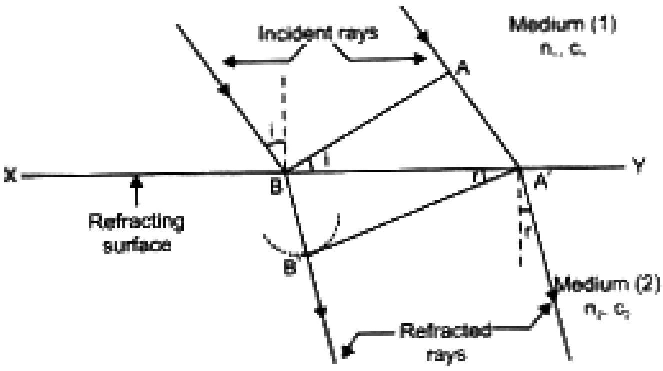
OR

(a) Draw a ray diagram to show the image formation by a combination of two thin convex lenses in contact. Obtain the expression for the power of this combination in terms of the focal lengths of the lenses.

(b) A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is $\frac{3}{4}$th of the angle of prism. Calculate the speed of light in the prism.

Ans 24. (a) **Wave front -** It is the locus point of the light rays which vibrate in same phase.

Verification of laws of refraction



Let AB be the plane wavefront incident on a refracting surface XY at an angle of incidence i. Let medium (1) be the rarer medium where the speed of light is c_1, and medium 2 be the denser medium where the speed is c_2.

First of all, the disturbance from wavefront AB strikes at the point B. By the time $\left(t = \frac{AA'}{c_1}\right)$ disturbance

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from A reaches A', disturbance from B would have spread in the second medium in the form of hemi-spherical wavelet of radius BB' $\left(= c_2 t = c_2 \times \frac{AA'}{c_1}\right)$. Tangent from A' on this wavelet gives refracted wavefront A'B'.

Wavefront A'B' makes an angle r with refracting surface.

In Δ BAA', $\sin i = \frac{AA'}{BA'}$

In Δ BB'A', $\sin r = \frac{BB'}{BA'}$

$$\frac{\sin i}{\sin r} = \frac{AA'/BA'}{BB'/BA'}$$

$$= \frac{AA'}{BB'} = \frac{c_1 t}{c_2 t} = \frac{c_1}{c_2} = \text{constant}$$

$$\frac{\sin i}{\sin r} = \text{constant} = n_{21}$$

= refractive index of second medium with respect of first medium.

This is Snell's law or first law of refraction.

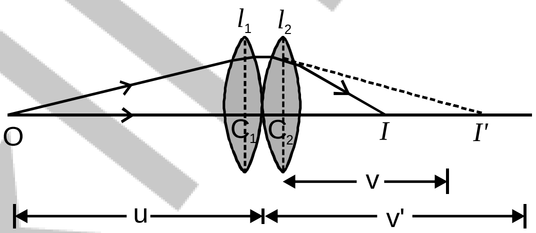
Second law: The incident wavefront AB, the refracting surface XY and the refracted wavefront A'B' are all perpendicular to plane of paper. So the incident ray ($\perp$ AB); the normal ($\perp$ XY) and the refracted ray ($\perp$ A'B') all lie in the plane of the paper i.e., the same plane. This is second law of refraction.

(b) $\tan i_p = \mu$

$i_p = \tan^{-1}(1.5)$

OR

(a) let l_1 and l_2 be two thin lenses of focal length f_1 and f_2 respectively, placed coaxially in contact with one another. Let O be a point object on the principal axis of the lens system.



Let OC_1 = u, In the absence of second lens l_2, the first lens l_1 will form a real image I' of O at distance $C_1 I'$ = v'. Using thin lens formula,

$$\frac{1}{f_1} = \frac{1}{v'} - \frac{1}{u} \qquad ......(1)$$

The image I' acts as a virtual object (u = v') for the second lens l_2 which finally forms its real image I at distance v. Thus

$$\frac{1}{f_2} = \frac{1}{v} - \frac{1}{v'} \qquad ......(2)$$

Adding equations (1) and (2), we get ......(3)

$$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{v} - \frac{1}{u}$$

For the combination of thin lenses in contact, if f is the equivalent focal length, then

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \qquad ......(4)$$

From equations (3) and (4), we find that

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2} \qquad \text{So} \quad P=\frac{1}{f_1}+\frac{1}{f_2}$$

(b) $i=\frac{3}{4}A.$

$i=\frac{3}{4}\times 60^\circ = 45^\circ$

$\therefore\ A = r_1 + r_2\ \&\ r_1 = r_2$

$60^\circ = 2r_1$

$r_1 = 30^\circ = r_2$

$$\mu=\frac{\sin i}{\sin r_2}=\frac{\sin 45^\circ}{\sin 30^\circ}=\sqrt{2}$$

$$\mu=\sqrt{2}=\frac{V_0}{V_g} \quad \Rightarrow V_g = V_0\sqrt{2}$$

$V_g = 3 \times 10^8 \times 0.707 = 2.121 \times 10^8$

$V_g = 2.121 \times 10^8$ m/s

Q 25. (a) Derive an expression for the electric field E due to a dipole of length '2a' at a point distant r from the centre of the dipole on the axial line.

(b) Draw a graph of E versus r for r >>a.

(c) If this dipole were kept in a uniform external electric field E_0, diagrammatically represent the position of the dipole in stable and unstable equilibrium and write the expressions for the torque acting on the dipole in both the cases.

OR

(a) Use Gauss's theorem to find the electric field due to a uniformly charged infinitely large plane thin sheet with surface charge density σ.

(b) An infinitely large thin plane sheet has a uniform surface charge density $+\sigma$. Obtain the expression for the amount of work done in bringing a point charge q from infinity to a point, distant r, in front of the charged plane sheet.

Ans 25. (a) Electric field at an axial point of an electric dipole: →

As shown in Fig. consider an electric dipole consisting of charges + q and –q, separated by distance 2a and placed in vacuum. Let P be a point on the axial line at distance r from the centre O of the dipole on the side of the charge + q.

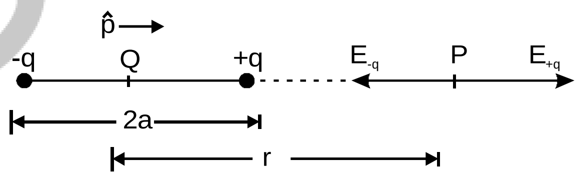


Fig. Electric field at an axial point of dipole.

Electric field due to charge – q at point P is

$$\vec{E}_{-q} = \frac{-q}{4\pi\varepsilon_0 (r+a)^2}\hat{p} \quad \text{(towards left)}$$

where $\hat{p}$ is a unit vector along the dipole axis from – q to +q.

Electric field due to charge + q at point P is

$$\vec{E}_{+q} = \frac{q}{4\pi\varepsilon_0 (r-a)^2}\hat{p} \quad \text{(towards right)}$$

Hence the resultant electric field at point P is

$$\vec{E}_{axial} = \vec{E}_{+q} + \vec{E}_{-q}$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]\hat{p}$$

$$= \frac{q}{4\pi\varepsilon_0}\cdot\frac{4ar}{(r^2-a^2)^2}\hat{p}$$

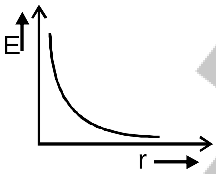
or $$\vec{E}_{qxial} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2pr}{(r^2-a^2)^2}\hat{p}$$

Here p = q × 2a = dipole moment.

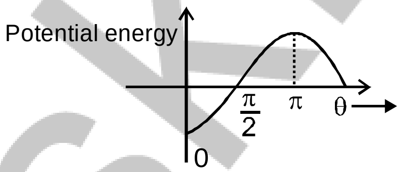
For r >> a, a^2 can be neglected compared to r^2.

$$\therefore \quad \vec{E}_{axial} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2p}{r^3}\hat{p} \quad \text{(towards right)}$$

(b)



(c)



at $\theta = 0$ stable equilibrium

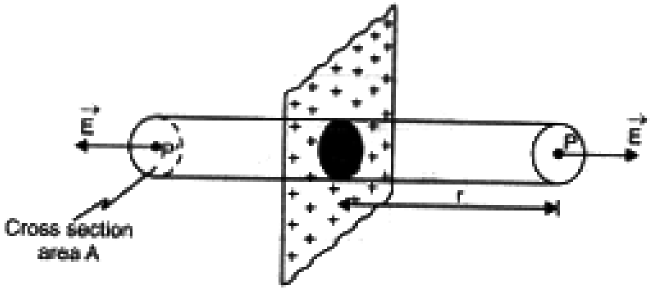
$\theta = \pi$ unstable equilibrium

$\tau = pE_0 \sin 0° = 0$ (at stable equilibrium)

and $\tau = pE_0 \sin 180° = 0$ (at unstable equilibrium)

OR

(a) Consider a thin, infinite plane sheet of charge with uniform surface charge denisty σ Cm^{-2}



Let us consider two points P and P' equidistant from the sheet. By symmetry the electric field $\vec{E}$ has the same magnitude.

Let the dsitance of P and P' from the sheet be r.

Choose a gaussian cylinder of length 2r with its axis perpendicular to the sheet. Since the lines of force are parallel to the curved surface it does not contribute to the electric flux. The total flux through gaussian surface is

$$\phi_E = \oint_{circular\ ends} \vec{E}.d\vec{s} = EA + EA = 2EA$$

Charge enclosed = σA

Therefore 2EA = $\frac{\sigma A}{\varepsilon_0}$ and we get E = $\frac{\sigma}{2\varepsilon_0}$

(b) We know electric field due to infinitely large plane sheet is

$$E = \frac{\sigma}{2\varepsilon_0}$$

and $$V = -\int_{\infty}^{r} Edr$$

So $$V = -\frac{\sigma}{2\varepsilon_0}\int_{\infty}^{r} dr$$

$$V = -\frac{\sigma}{2\varepsilon_0}(r-\infty) = \infty$$

So work done to bring q charge from ∞ to a point

W = qV

= q × ∞ = ∞

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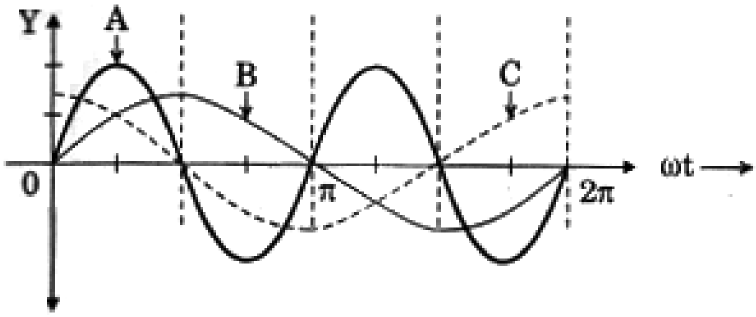
Q 26. A device 'X' is connected to an ac source $V = V_0 \sin \omega t$. The variation of voltage, current and power in one cycle is shown in the following graph:



(a) Identify the device 'X'.

(b) Which of the curves A, B and C represent the voltage, current and the power consumed in the circuit? justify your answer.

(c) How does its impedance vary with frequency of the an source? Show graphically.

(d) Obtain an expression for the current in the circuit and its phase relation with as voltage.

OR

(a) Draw a labelled diagram of an ac generator. Obtain the expression for the emf induced in the rotating coil of N turns each of cross-sectional area A, in the presence of a magnetic field $\vec{B}$.

(b) A horizontal conducting rod 10 m long extending from east to west is falling with a speed 5.0 ms^{-1} at right angles to the horizontal component of the Earth's magnetic field, 0.3×10^{-4} Wb m^{-2}. Find the instantaneous value of the emf induced in the rod.

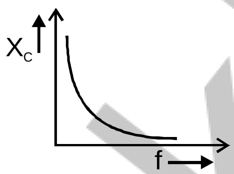
Ans 26. (a) Capacitor

(b) B = Voltage

C = current

A = Power

(c)



(d) $V = V_0 \sin\omega t$

but $V = \dfrac{Q}{C}$

So $Q = CV_0 \sin\omega t$

$$I = \frac{dQ}{dt} = \frac{d}{dt} CV_0 \sin\omega t$$

$$I = \omega CV_0 \cos\omega t$$

$$I = I_0 \sin(\omega t + \frac{\pi}{2})$$

where $I_0 = \dfrac{V_0}{1/\omega C}$

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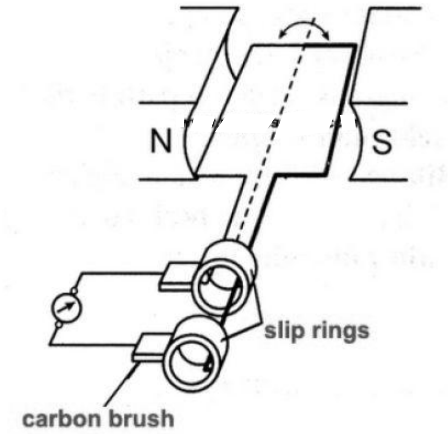
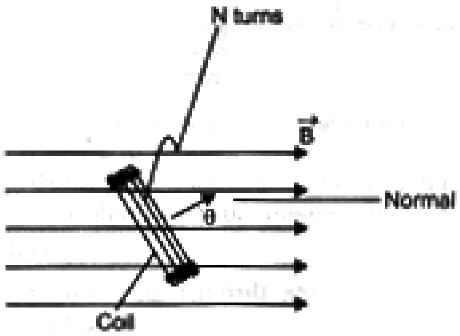
OR

(a) **Ac generator**



Expression for the emf induced in the rotating coil



The magnetic flux through, each loop at any time t is $\phi = BA\cos\theta = BA\cos\omega t$ (at t = 0, θ = 0).

∴ The induced emf is

$$\varepsilon = -N\frac{d\phi}{dt} = -NAB\frac{d}{dt}(\cos\omega t)$$

$= NBA\omega\sin\omega t$.

$\Rightarrow \varepsilon = \varepsilon_0 \sin\omega t$ (where $\varepsilon_0 = NBA\omega$)

(b) induced emf, $\varepsilon = VBl$

$\varepsilon = 5\times10 \times 0.3\times10^{-4}$ volt

$\varepsilon = 15 \times 10^{-4}$

$\varepsilon = 1.5 \times 10^{-3}$ volt

$\varepsilon = 1.5$m volt