Class- XII
Physics

TIME ALLOWED: 3 hours **MAX MARKS:70**

General Instructions:

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

(ii) The 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 questions 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 for 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.

$c = 3\times10^8 \text{ m s}^{-1}$

$h = 6.63\times10^{-34} \text{ J s}$

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

$\mu_0 = 4\pi\times10^{-7} \text{ T m A}^{-1}$

$\varepsilon_0 = 8.854\times10^{-12} \text{ C}^2\text{N}^{-1}\text{m}^{-2}$

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

$m_e = 9.1\times10^{-31} \text{kg}$

mass of neutron = 1.675×10^{-27}kg

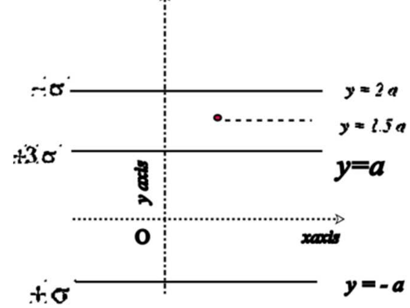
mass of proton = 1.673×10^{-27}kg

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

Boltzmann constant = $1.38\times10^{-23}\text{JK}^{-1}$

SECTION A

1. Three infinitely long uniformly charged sheets are placed as shown below. Find the magnitude and direction of the electric field at P.



2. A glass bead and a steel bead of same mass are dropped into a cardboard cylinder and a magnetic field is applied perpendicular to the axis of the cylinder. Which bead reaches the bottom of the cylinder first? Justify your answer.

3. A device *X* is connected to an a c supply and an ammeter capable of reading a c current is connected in series with it. The frequency of the supply is increased gradually. The a c ammeter shows a steady decline in the value of current as the frequency is increased. Identify the device *X.*

4. Define *Fresnel distance.*

5. What is a solar cell? What kind of semiconductor is ideal for the fabrication of the solar cell?

SECTION B

6. Current flowing through a wire varies with time as $i = 3 + 0.2t$. What is the charge that flows through the conductor in 5 s? If this wire is coiled to form a solenoid of inductance 2mH, find the e m f induced in the coil.

7. An electromagnetic wave of wavelength $\lambda = 0.1\overset{0}{\mathrm{A}}$ is propagating in the +*x* direction. If the electric field oscillates with an amplitude of 20 V/m parallel to the *y axis,* Write the corresponding equation for the oscillating magnetic field.

8. What is Doppler effect? With what speed should a star move with respect to Earth so that an observer on Earth observes a shift of 0.02% in the wavelength of the light received from the star?

OR

Define polarization. Light from a source is passed through a polarizer. The transmitted light is viewed through an analyser which can be rotated between 0° and 90°. Show graphically the variation of transmitted light with the angle of rotation.

9. X rays of wavelength λ fall on a photosensitive surface of negligible work function and electrons are emitted. If the de Broglie wavelength of the electrons is λ_1, prove that $\lambda = \frac{2mc}{h}\lambda_1^2$, where *m* is the mass of the electron, *c* the velocity of light and *h* is the Planck's constant.

10. Define activity of a radioactive sample. How is the instantaneous rate of change of the activity of a radioactive nuclide related to its half-life?

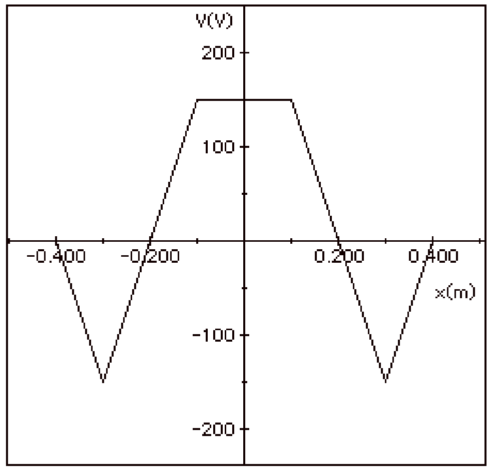
SECTION C

11. Two circular metallic plates each of radius *R,* are placed at a distance *d* apart in air.
(a) Write the expression for its capacitance.
(b) Represent graphically, the variation of capacitance with (i) radius of the plates (ii) distance of separation of the plates.

(c) If the radius is decreased by a factor $\sqrt{3}$ and the distance of separation increased by a factor 3, find the ratio of the new capacitance to the previous one.

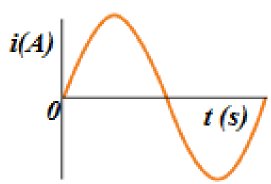
OR

Define electric potential at a point. The potential as a function of *x* is shown below. Plot the corresponding graph of electric field intensity.



12. A particle of charge q enters a uniform magnetic field **B** with a velocity **v.** Find the force acting on the charge if it enters (i) parallel to the direction of **B** (ii) perpendicular to **B** (iii) at an angle θ to the direction of **B**. In all the three cases, show by suitable diagrams, the trajectory of the particle.

13. A rod made of a ferromagnetic material is placed inside a solenoid. The current passing through the solenoid is increased in the manner shown below.



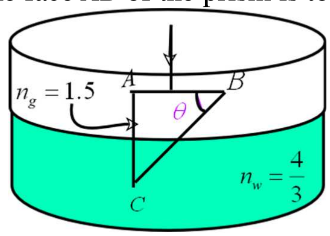
Explain the processes that occur in the rod and graphically represent the variation of the magnetic induction **B** in the material to the magnetizing field **H** of the solenoid.
Explain the significance of the graph and hence define (i) retentivity and (ii) coercivity.

14. A step up transformer at the power generating station has a transformation ratio of 10000 and an efficiency of 60%. It generates a power of 10MW at 220V.Find (i) the output voltage (ii) Output power. Also find the input and output currents. The power is transmitted to a substation and the transmission loss is found to be 40%. Find the power received at the substation.

15. Identify the following electromagnetic radiations and write the use of each.
(i) frequency range 4×10^{14} Hz to 7×10^{14} Hz
(ii) Wavelength range 1 nm to 10^{-3} nm
(iii) Produced from the decay of radioactive nuclei.

16. (a) Derive the relationship between the angle of prism A and the angle of deviation δ for a triangular prism.

(b) A glass prism of refractive index 1.5 is immersed in water of refractive index $\frac{4}{3}$ as shown in the diagram. Find the minimum value of the angle θ such that light incident normally on the face AB of the prism is totally reflected.



17. (a) Draw a ray diagram to show the formation of image by a compound microscope.
(b) Write the expression for its magnification.
(c) Why should the objective of a microscope have a short aperture and small focal length?

18. Derive an expression for the fringe width in Young's double slit experiment.

19. (a) Can photoelectric effect be explained by using the wave nature of light? Give reasons.
(b) Derive an expression for the de Broglie wavelength of an electron accelerated through a potential V.

20. The ground state energy of a hydrogen atom is -13.6eV.
(a) Find the kinetic energy of the electron in the first excited state.
(b) What would be the value of its potential energy in the second excited state?
(c) If an electron makes a transition from the second excited state to the first excited state and the photon emitted be allowed to fall on a cesium plate of work function 2.1eV, will the plate emit photoelectrons? Justify.

21. Explain with the help of a neat circuit diagram the working of a full wave rectifier. Draw the input and output wave forms of the rectifier.

22. What does the process of detection involve? Draw a block diagram to illustrate the process. Draw the wave forms of (i) the AM input wave (ii) rectified wave (iii) output wave.

SECTION D

23. Mohan's father had employed a carpenter to make cupboards at his home. The carpenter had an electric drill and inserted the bare wires into the socket and started the drill. Mohan immediately switched off the supply and advised the carpenter that it was not safe to use the drill in this manner. He convinced the carpenter to connect the wires to a three pin plug and then plug it into the socket.
(a) What possible dangers did Mohan avert by his timely action?

(b) Why is using a three pin plug safer than two pin plug for high power consuming equipment?
(c) If the fuse had a 220V, 5A rating, can the carpenter use a 1kW drill in the circuit?
(d) What values did Mohan display?

SECTION E

24. (a) A thin spherical metallic shell of radius R has a charge Q uniformly distributed over its surface. Use Gauss's law to determine the electric field intensity at a point P located at a distance r from the center of the sphere, when (i) $r > R$ and (ii) $r < R$.
(b) Plot a graph showing the variation of electric field intensity as a function of r.
(c) If the sphere has a charge density of 100 μC/m^2 and a diameter 2 m, find (i) the charge enclosed by the sphere (ii) total flux through the surface.

OR

An electric dipole is of dipole moment $\vec{p}$ is held at an angle θ to the direction of a uniform electric field $\vec{E}$ directed along the positive x direction. If the dipole is released, how will it move? Explain with suitable diagrams, the forces on the dipole when θ varies from 0^o to 180^o. Derive an expression for the energy of the dipole placed in the electric field and discuss the conditions for (i) stable equilibrium (ii) unstable equilibrium. If the electric field is constant in direction but decreases in magnitude along the $+x$ direction, what additional forces would the dipole experience?

25. (a) A rectangular loop ABCD carrying current I is placed between the pole pieces of a strong magnet which produces a uniform magnetic field B. If the normal to the plane of the coil makes an angle θ with the direction of the magnetic field, deduce an expression for the torque experienced by the coil. At what position of the coil, is the torque (i) maximum (ii) minimum?
(b) An ammeter of resistance 100Ω can measure currents up to 1 mA. What adjustments need to be made in the circuit of the ammeter so that it may read currents up to 1 A?

OR

(a) A conductor of length l, area of cross section A carries a current I. It is placed in a magnetic field $\vec{B}$ such that the current element makes an angle θ with the direction of the magnetic field. Find the magnitude and the direction of the force acting on the conductor. Determine the positions of the conductor in the magnetic field when the force on it is (i) maximum (ii) minimum. Represent graphically, the relation between the force and the length of the conductor.
(b) A straight wire of mass 200 g and length 1.5 m carries a current of 2A. It is suspended in mid air by a uniform horizontal magnetic field $\vec{B}$. What is the magnitude of the magnetic field?

26. Explain with a circuit diagram the working of a transistor amplifier in common emitter configuration when a sinusoidal input is applied between the base and the emitter of the transistor. Derive the expression for voltage gain of the amplifier. What is meant by the term power gain? Write an expression for power gain of the amplifier. The values of the a c current gain and voltage gain for a common emitter amplifier is found to be greater than 1. Is a transistor a power generating device? Explain.

OR

What is an oscillator? What kind of feedback process can bring about oscillations? Draw a neat block diagram to explain the feedback in the transistor oscillator. Explain the working of a tuned collector oscillator using a neat circuit diagram.

(Solution)
Class- XII
Physics

TIME ALLOWED: 3 hours **MAX MARKS:70**

SECTION A

1. The electric field at a point due to an infinitely long charged plane sheet is independent of distance.

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{j} + \frac{3\sigma}{2\varepsilon_0}\hat{j} + \frac{\sigma}{2\varepsilon_0}\hat{j} = \boxed{\frac{5\sigma}{2\varepsilon_0}\hat{j}}$$

2. The glass bead reaches first. The magnetic field produces eddy currents in the iron bead which slows it down.

3. The device X is an inductor. The inductive reactance $X_L = L\omega$ increases with increase in frequency; the total impedance of the circuit increases and the current in the circuit decreases.

4. Fresnel distance is the distance beyond which the divergence of a beam of width a becomes significant. $z_F = \frac{a^2}{\lambda}$. Here a is the size of the aperture illuminated by light of wavelength λ.

5. A solar cell is a p –n junction which generated e m f when solar radiation falls on it. Semiconductors with band gap close to 1.5eV are ideal materials for solar cell fabrication.

SECTION B

6. The charge flowing in the circuit is given by

$$dq = idt$$

$$q = \int idt$$

$$= \int_0^5 (3 + 0.2t)dt$$

$$= \left[3t + 0.2\frac{t^2}{2}\right]_0^5$$

$$= 3\times5 + 0.1\times5^2 = 17.5 \text{ C}$$

The e mf induced in the coil is given by

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

$$= -\left(2\times10^{-3}\right)\frac{d}{dt}(3+0.2t)$$

$$= -\left(2\times10^{-3}\right)(0.2)$$

$$= -0.4\times10^{-3}\,\text{V}$$

7. The equation for the electric field oscillating parallel to the y axis in an electromagnetic wave propagating in the x direction is $E_y = E_0 \sin(kx-\omega t)$. The amplitude of the electric field is $E_0 = 20\text{V/m}$.

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{0.1\times10^{-10}} = 2\pi\times10^{11}\,\text{m}^{-1}$$

$$\omega = ck = \left(3\times10^{8}\right)\left(2\pi\times10^{11}\right) = 6\pi\times10^{19}\,\text{rad/s}$$

$$E_y = 20\sin\left[\left(2\pi\times10^{11}\right)x-\left(6\pi\times10^{19}\right)t\right]\text{V/m}$$

The corresponding magnetic field oscillates parallel to the z axis and its equation is given by

$$B_z = B_0 \sin(kx-\omega t)$$

The amplitude of the oscillating magnetic field is

$$B_0 = \frac{E_0}{c} = \frac{20}{3\times10^{8}} = 6.67\times10^{-8}\,\text{T}$$

$$B_z = B_0 \sin(kx-\omega t)$$

$$= \left(6.67\times10^{-8}\right)\sin\left[\left(2\pi\times10^{11}\right)x-\left(6\pi\times10^{19}\right)t\right]\text{T}$$

8. The apparent change in the frequency of the source when there is relative motion between the source and the observer is called Doppler effect.

The Doppler shift is given by $\frac{\Delta\nu}{\nu} = \frac{\Delta\lambda}{\lambda} = \frac{v_{\text{radial}}}{c}$

$$v_{\text{radial}} = c\frac{\Delta\lambda}{\lambda} = \left(3\times10^{8}\right)\left(\frac{0.02}{100}\right)$$

$$= 6\times10^{4}\,\text{m/s} = 60\text{ km/s}$$

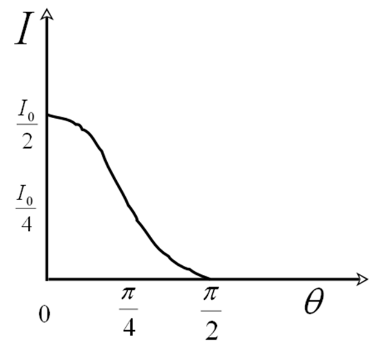
OR

Polarisation is the phenomenon by which vibrations in a wave are limited to one plane.

The transmitted light has the intensity given by

$$I = \frac{I_0}{2}\cos^2\theta$$

The graph between the the intensity and the angle of rotation of the analyser is given below. The intensity varies from maximum $\frac{I_0}{2}$ to zero.



9. If the photosensitive plate has a negligible work function, then the energy of the photon will be completely converted into the kinetic energy of the electron.

$$E = \frac{hc}{\lambda} = \frac{1}{2}mv^2$$

$$v^2 = \frac{2hc}{m\lambda} \qquad \text{......(1)}$$

If the electron has a deBroglie wavelength λ_1, then

$$\lambda_1 = \frac{h}{mv}; v = \frac{h}{m\lambda_1}$$

$$v^2 = \frac{h^2}{m^2\lambda_1^2} \qquad \text{......(2)}$$

Comparing equations (1) and (2)

$$\frac{h^2}{m^2\lambda_1^2} = \frac{2hc}{m\lambda}$$

$$\boxed{\lambda = \frac{2mc}{h}\lambda_1^2}.$$

10. Activity or the total decay rate of a radioactive sample is defined as number of nuclei disintegrating per unit time.

$R = \frac{dN}{dt}$, where, the activity is *R*, the number of nuclei present at the instant of time is *N*.

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

Since $N = N_0 e^{-\lambda t}$, where the number of nuclei present at time $t = 0$ is N_0 and the decay constant is λ.,

$$\frac{dR}{dt} = \frac{d}{dt}\left(\lambda N_0 e^{-\lambda t}\right)$$
$$= -N_0 \lambda^2 e^{-\lambda t}$$

Since $\lambda = \frac{0.693}{T_{1/2}}$

$$\frac{dR}{dt} = -\left(\frac{0.693}{T_{1/2}}\right)^2 \left(N_0 e^{-\lambda t}\right)$$
$$= -\left(\frac{0.693}{T_{1/2}}\right)^2 N$$

Therefore the instantaneous rate of disintegration

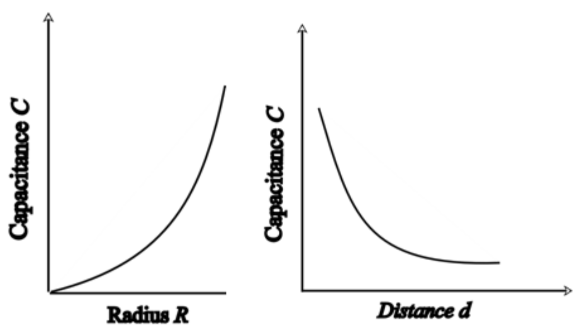
$$\boxed{\frac{dR}{dt} \propto \frac{1}{T_{1/2}^2}}$$

SECTION C

11. The capacitor is a parallel plate capacitor.

(a) The capacitance of the capacitor is $C = \frac{\varepsilon_0 A}{d} = \frac{\varepsilon_0 \left(\pi R^2\right)}{d}$

(b) (i) $C \propto R^2$ (ii) $C \propto \frac{1}{d}$



(c) $C = \frac{\varepsilon_0 \left(\pi R^2\right)}{d}$

$$C_1 = \frac{\varepsilon_0 \left(\pi \left(R/\sqrt{3}\right)^2\right)}{3d} = \frac{\varepsilon_0 \left(\pi R^2\right)}{9d}$$

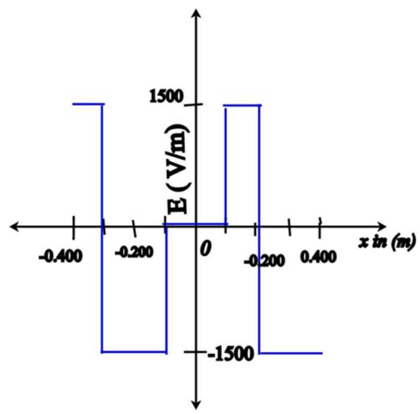
$$C_1 = \frac{C}{9}$$

OR

Electric potential at a point in an electric field is the work done in bringing a unit positive charge from infinity to the point against the electrostatic forces.

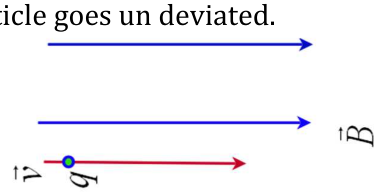
Range of *x (m)*	*dx (m)*	range of *V (V)*	dV (V)	$E = -\frac{dV}{dx}$ V/m
-0.400 to -0.300	0.1	0 to -150	-150	+1500
-0.300 to -0.200	0.1	-150 to 0	+150	-1500
-0.200 to -0.100	0.1	0 to +150	+150	-1500
-0.100 to +0.100	0.2	+150 to+150	0	0
+0.100 to +0.200	0.1	+150 to 0	-150	+1500
+0.200 to +0.300	0.1	0 to -150	+150	-1500
+0.300 to +0.400	0.1	-150 to 0	+150	-1500

The graph is plotted as below.



12. A charged particle with a charge q enters a magnetic field **B** with a speed v at an angle θ to the direction of the magnetic field. It experiences a magnetic Lorentz force given by $\vec{F} = q\left(\vec{v} \times \vec{B}\right)$. The magnitude of the force is given by $\left|\vec{F}\right| = qBv\sin\theta$.

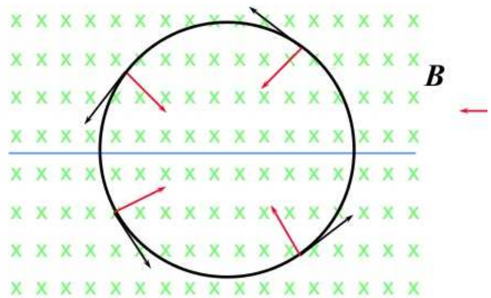
(i) When it enters parallel to the direction of the magnetic field, $\theta = 0° or 180°$ for which $\sin\theta = 0$. The particle goes un deviated.



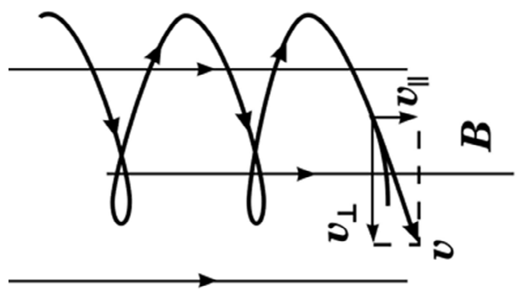
(ii) When the charge enters at perpendicular to the magnetic field, it traces a circular path given by

$$F = qBv = \frac{mv^2}{r};$$

$$r = \frac{mv}{Bq}$$

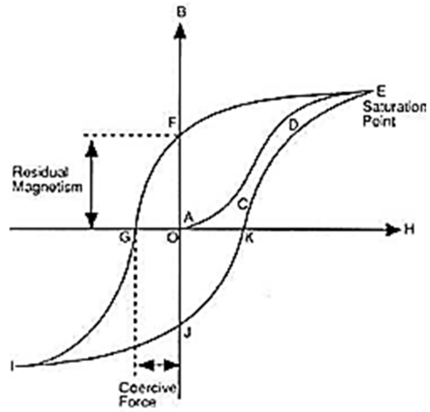


(iii) When the charge enters at an angle θ, it traces a helical path. The velocity has two components- parallel to and perpendicular to the magnetic field. It undergoes a translatory motion due to the component of the velocity parallel to the magnetic field and traces a circular path due to the component perpendicular to the magnetic field.



13. When the current increases in the solenoid, the magnetizing field $H = \mu_0 I$ increases. The magnetic field in the rod increases till it reaches the value of saturation (A to E). When the current falls to zero, the magnetic field decreases but does not retrace the path to zero (E to F). When the magnetizing field is zero, the magnetic field is not zero. This value of magnetic field (AF) is called *retentivity or residual magnetism.* The current and hence the magnetizing field increases in the negative direction. The magnetic field drops to zero at a particular value of the negative magnetizing field. This value of the negative magnetizing field for which the magnetic field intensity is zero is called *coercivity* (OG). The magnetic field increases to attain saturation (GI)and then drops to zero as the field decreases along the path IK.

The magnetic field intensity lags behind the magnetizing field and this effect is called hysteresis. The area of the hysteresis loop measures the amount of energy lost as heat during the process of magnetization- demagnetization- re-magnetization in the opposite direction and the subsequent demagnetization.



14. The transformation ratio is $\frac{V_s}{V_P}$.

(i) The output voltage is

$\frac{V_s}{V_P} = 10000; V_S = 220 \times 10000 = \boxed{2.2 \times 10^6 \text{ V}}$

(ii) Efficiency $\eta = \frac{\text{Output power}}{\text{input power}}$

Output power $= 10 \times 10^6 \times 0.6 = \boxed{6 \times 10^6 W}$

Input power $= V_P \times I_P$

$I_P = \frac{\text{Input power}}{V_P} = \frac{10 \times 10^6}{220} = \boxed{4.54 \times 10^4 A}$

Output power $= V_S \times I_s$

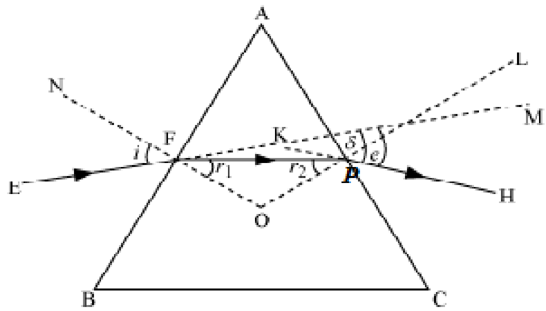
$I_s = \frac{\text{Output power}}{V_S} = \frac{6 \times 10^6}{2.2 \times 10^6} = \boxed{2.73 A}$

Power received at the substation is 60% of the transmitted power.

Power received $= 0.6 \times 6 \times 10^6 = \boxed{3.6 \times 10^6 W}$

15. (i) Visible light.
Use: provides us information about the world.
(ii) X rays.
Use: diagnostic tool in medicine, treatment for cancer.
(iii) γ rays.
Use: In medicine to destroy cancer cells.

16. (a) The figure shows the passage of light through a triangular glass prism.



The ray EF is incident at an angle i to the normal NFO and is refracted into the prism making angles r_1 and r_2 to the normal at AB and AC respectively. The ray emerges out at an angle e to the normal LO.

In the quadrilateral, AFOP,

$\angle A + \angle FOP = 180°, \because \angle AFO = \angle APO = 90°$

In ΔFOP $r_1 + r_2 + \angle FOP = 180°$

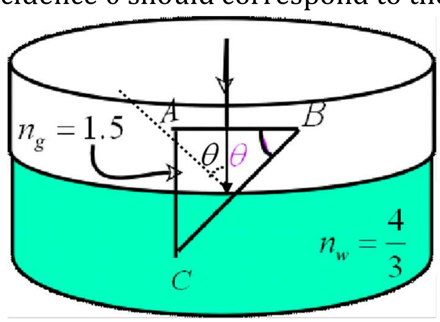
$r_1 + r_2 = A$

The $\angle MKP = \delta$ is the exterior angle to the ΔKFP.

$\delta = (i - r_1) + (e - r_2); \delta = i + e - A$

$\boxed{A + \delta = i + e}$

(b) the ray is incident normally on the face AB, hence passes undeviated. It strikes the face BC of the prism at an angle θ. If the ray has to be totally reflected, the minimum angle of incidence θ should correspond to the angle of refraction $r = 90^0$.



By Snell's law,

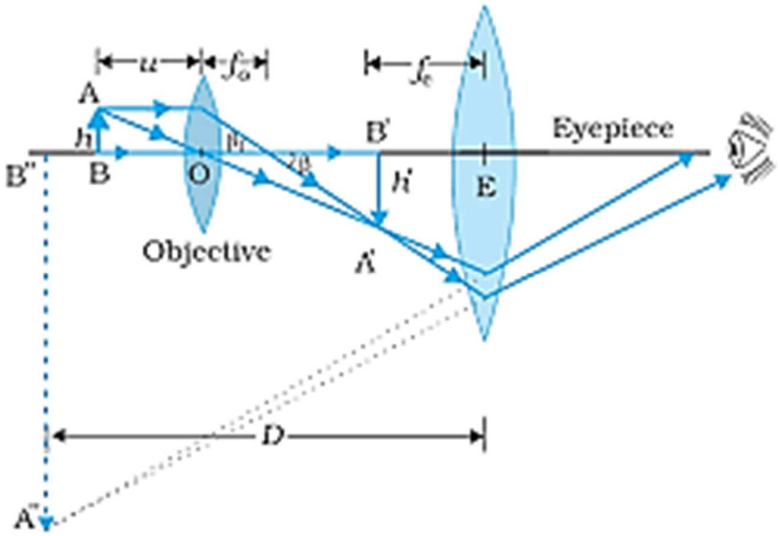
$$\frac{\sin i}{\sin r} = \frac{n_w}{n_g}$$

$\sin i = \sin\theta$ and since $r = 90°, \sin r = 1,$

$$\sin\theta = \frac{4}{3 \times 1.5} = 0.8889$$

$\boxed{\theta = 62.73°}$

17. (a) The ray diagram for a compound microscope is



(b) the magnification of the objective $m_o = \frac{L}{f_0}$ where $L = f_0 + f_e$

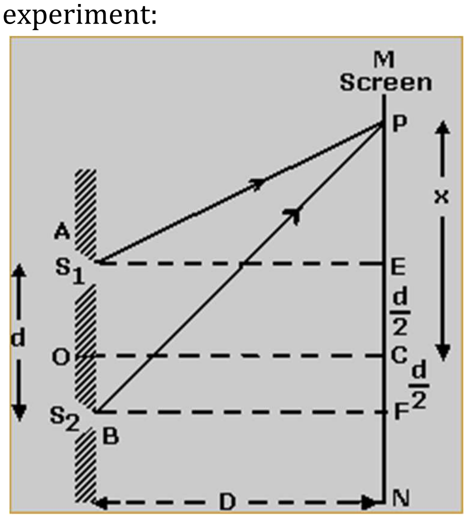
Magnification of the eyepiece when the final image is formed at the near point $m_e = 1 + \frac{D}{f_e}$

Total magnification $m = m_o \times m_e = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$

When the image is formed at infinity, $m_o = \frac{L}{f_0}$ and $m = \frac{L}{f_0}\frac{D}{f_e}$

(c) Small aperture ensures greater intensity of the object and short focal lengths increase the magnification.

18. Young's double slit experiment:



Two coherent sources S_1 and S_2 are at a distance d apart. A screen is placed at a distance D from the sources. At a point P on the screen which is at distance x from the center C.

Two waves S_1P and S_2P meet at P and if the path difference at P is an integral multiple of λ, the wavelength constructive interference occurs at *P.*

The path difference between the waves arriving at P

$$(S_2P)^2-(S_1P)^2=\left[D^2+\left(x+\frac{d}{2}\right)^2\right]-\left[D^2-\left(x+\frac{d}{2}\right)^2\right]=2xd$$

$$S_2P-S_1P=\frac{2xd}{S_2P+S_1P}$$

If $x,d<<D, S_2P+S_1P=2D\,, S_2P-S_1P=\dfrac{xd}{D}$

For constructive interference,

$$\frac{xd}{D}=n\lambda$$

$$x=x_n=\frac{n\lambda D}{d};n=0,\pm1,\pm2,\ldots$$

For destructive interference

$$\frac{xd}{D}=(2n+1)\frac{\lambda}{2}$$

$$x=x_n=\left(n+\frac{1}{2}\right)\frac{\lambda D}{d};n=0,\pm1,\pm2,\ldots$$

The distance between two consecutive bright fringes or two consecutive dark fringes is called fringe width.

$$\beta=x_{n+1}-x_n=\frac{\lambda D}{d}$$

19. (a) Photoelectric effect cannot be explained using the wave picture of light.

(i) According to wave picture, the free electrons at the surface of a metal absorb radiations continuously. So irrespective of the frequency of incident radiation, a sufficiently intense radiation can cause photoelectric emission. But every photosensitive substance is found to have a threshold frequency for photoelectric emission.

(ii) Since in the wave picture, a large number of electrons absorb the incident energy at the same time and hence the time taken for the emission of a photoelectron should be large. But photoelectric emissions are found to be instantaneous.

(b) Consider an electron of mass m charge e accelerated from rest through a potential V. The kinetic energy K of the electron

$$K = \frac{1}{2}mv^2 = eV$$

$$v = \sqrt{\frac{2eV}{m}}$$

The de Broglie wavelength of the electron

$$\lambda = \frac{h}{mv} = \frac{h}{m\sqrt{\frac{2eV}{m}}} = \frac{h}{\sqrt{2meV}} = \frac{h}{\sqrt{2mK}}$$

Substituting the known values,

$$\lambda = \frac{1.227}{\sqrt{V}}\,\text{nm}$$

20. The total energy of the electron in the *n*th orbit is

$$E_n = -\frac{e^2}{8\pi\varepsilon_0 r} = -\frac{13.6}{n^2}eV$$

The kinetic energy in the *n*th orbit is

$$K_n = \frac{e^2}{8\pi\varepsilon_0 r} = \frac{13.6}{n^2}eV$$

The potential energy in the *n*th orbit is

$$U_n = -\frac{e^2}{4\pi\varepsilon_0 r} = -\frac{27.2}{n^2}eV$$

(a)The first excited state is the second energy level *n = 2*

$$K_2 = \frac{13.6}{2^2}eV = 3.4eV$$

(b) The second excited state is the third energy level *n = 3*.

$$U_3 = -\frac{27.2}{3^2}eV = -3.022eV$$

(c) Energy released when the electron falls from the second excited state to the first excited state corresponds to the transition from *n = 3* to *n=2*

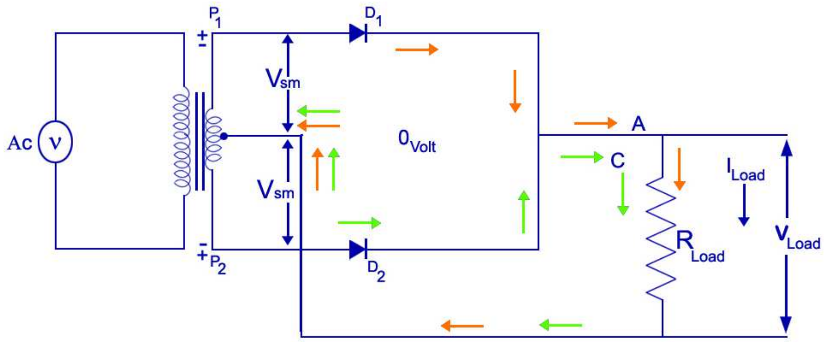
$$E = E_3 - E_2 = -\frac{13.6}{3^2} - \left(-\frac{13.6}{2^2}\right) = 3.4 - 1.51 = 1.89eV$$

If this photon falls on the plate with work function 2.1eV, photoelectric emission will not occur since the energy of the incident photon is less than its work function.

21. The circuit diagram of a full wave rectifier is shown below.

A rectifier is a circuit that converts an a c input voltage into d c.

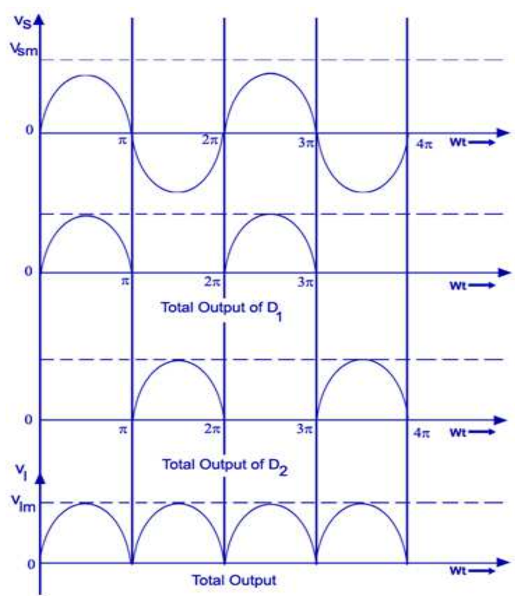
Principle: A diode conducts only when it is forward biased and does not conduct when it is reverse biased. It behaves as a closed switch when forward biased and a open switch when reverse biased. A diode which gives an output during both positive and negative half cycles of the ac input is called a full wave rectifier.



Construction: The P side of the two diodes is connected to the ends of the secondary of a step-down transformer and the N ends of the diodes are connected together. The output is taken from the common point of this connection and the centre tap of the transformer.

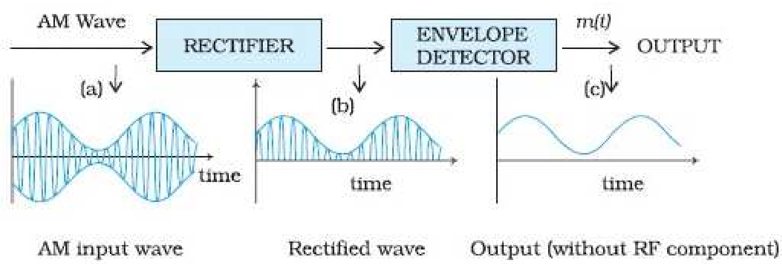
Working: An ac voltage of the form shown in the graph below, is applied across the primary of the transformer. If at the instant, the end P_1 of the secondary is positive with respect to the centre tap and the end P_2 is negative, then the diode D_1 is forward biased and the diode D_2 is reverse biased. The diode D_1 conducts, while D_2 does not. The output is obtained across the load resistance R_{Load} for the positive half cycle as shown in the graph.

In the negative half cycle, the end P_2 is positive with respect to the centre tap and the end P_1 is negative. The diode D_1 is reverse biased and the diode D_2 is forward biased. The diode D_1 does not conduct, while D_2 conducts. The output is obtained across the load resistance R_{Load} for the negative half cycle as shown in the graph.



Thus both the half cycles of the input voltage is rectified and the output waveforms are shown above.

22. Detection is the process of recovering the modulating signal from the modulated carrier wave. The block diagram of a diode rectifier with the wave forms is shown below



SECTION D

23. (a) Inserting loose wire into the socket can cause an electrical shock, sparking and short circuiting.

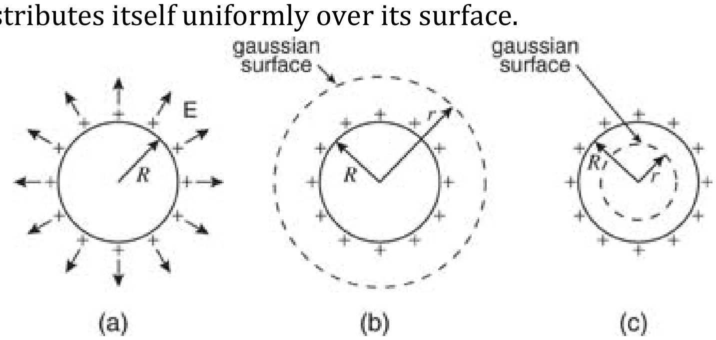
(b) A three-pin plug has an earth connection, which aids in discharging leakage currents into the earth. It prevents shocks.

(c) The current required by the appliance of 1 kW rating is $I = \frac{1000}{220} = 4.55\,\text{A}$. The socket can supply currents up to 5 A. So it is safe to use.

(d) Scientific approach, care for others

SECTION E

24. Consider a spherical metallic shell of radius *R*. It is given a charge +*Q*, and the charge distributes itself uniformly over its surface.



The electric lines of force are radial to the surface and directed outwards.

(i) Consider a point *P* located at a distance *r* from the center of the sphere such that *r* > *R*. A spherical Gaussian surface of radius *r* is constructed such that it passes through the point and is centered at the center of the sphere.

The electric flux through the Gaussian surface is

$$\phi_E = \oint \vec{E} \bullet \vec{A}$$

The flux through the surface is radial, therefore,

$$\vec{E} \bullet \vec{A} = EA = E\left(4\pi r^2\right)$$

By Gauss's law,

$$\phi_E = \frac{Q}{\varepsilon_0} = E\left(4\pi r^2\right)$$

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

Vectorially,

$$\vec{E} = \frac{Q}{4\pi\varepsilon_0 r^2}\hat{r}$$

The field at any point outside the charged shell is as though the entire charge is concentrated at its center.

(ii) Consider a point P located at a distance r from the center of the sphere such that $r < R$. A spherical Gaussian surface of radius r is constructed such that it passes through the point and is centered at the center of the sphere.

The electric flux through the Gaussian surface is

$$\phi_E = \oint \vec{E} \bullet \vec{A}$$

The flux through the surface is radial, therefore,

$$\vec{E} \bullet \vec{A} = EA = E\left(4\pi r^2\right)$$

By Gauss's law,

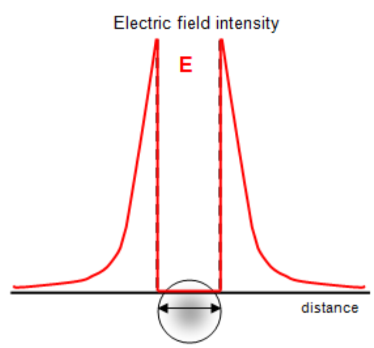
$$\phi_E = \frac{Q}{\varepsilon_0} = E\left(4\pi r^2\right)$$

But the charge enclosed by the Gaussian surface is zero. Therefore,

$$E = 0$$

The field due to an uniform charged shell is zero at all points within the shell.

(b) $E \propto \frac{1}{r^2}$ for all external points and $E = 0$ for all points inside the shell.

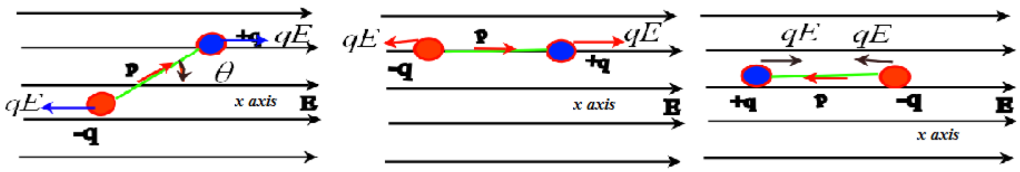


(c) (i) $Q = \frac{\sigma}{4\pi R^2} = \frac{100\times10^{-6}}{4\times3.14\times1^2} = \boxed{7.96\times10^{-6}C}$

(ii) $\phi_E = \frac{Q}{\varepsilon_0} = \frac{7.96\times10^{-6}}{8.854\times10^{-12}} = \boxed{8.99\times10^{7}\,\mathrm{Nm^2C^{-1}}}$

OR

A dipole placed in a uniform electric field experiences a torque and will rotate.



(i) dipole at an angle (ii) stable equilibrium (iii) Unstable equilibrium

Each charge experiences a force qE in the direction shown. The net force on the dipole is zero in a uniform field, whatever be the position of the dipole in the field. The forces on the dipole are depicted in the diagram given above.

Energy of the dipole:

The dipole experiences a torque given by

$\tau = pE\sin\theta$.

If the dipole is rotated by an angle $d\theta$, the work done is given by

$$dW = \tau d\theta$$
$$= pE\sin\theta d\theta$$

The work done in rotating the dipole between two angles θ_1 and θ_2 is stored in the dipole as its potential energy.

$$U = \int dW = \int_{\theta_1}^{\theta_2} pE\sin\theta d\theta$$
$$= \left[-pE\cos\theta\right]_{\theta_1}^{\theta_2}$$
$$= pE\left(\cos\theta_1 - \cos\theta_2\right)$$

Taking the zero of potential energy to correspond to $\theta_1 = \frac{\pi}{2}$ and $\theta_2 = \theta$

$$U = -pE\cos\theta = -\vec{p}\bullet\vec{E}$$

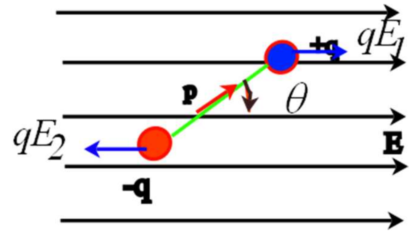
(i) Stable equilibrium corresponds to the least potential energy, which happens when the dipole is aligned with the direction of the field when $\theta = 0$.

$$U = -pE\cos 0 = -pE$$

(ii) Unstable equilibrium is a state of maximum energy, which is when the dipole is aligned antiparallel to the field. $\theta = 180$

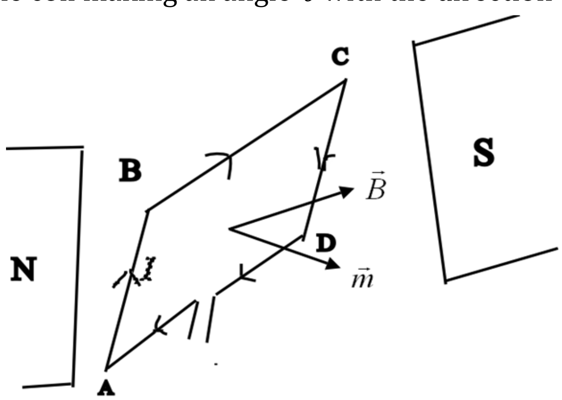
$$U = -pE\cos 180 = -pE(-1) = pE$$

If the electric field decreases along the *x* direction, the force experienced by one charge will be greater than that experienced by the other. Therefore the dipole would experience a force in the –*x* direction in addition to the torque.



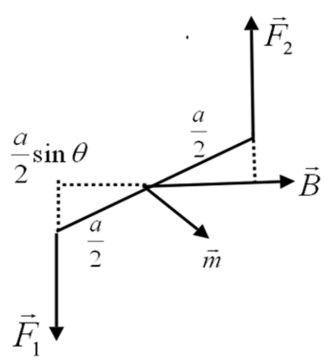
Here, $E_2 > E_1$, so the charge –*q* experiences a greater force than +*q* and there is a net force on the dipole in the –*x* direction.

25. (a) A rectangular coil ABCD carrying current *I,* is placed in a magnetic field $\vec{B}$ with the normal to the coil making an angle θ with the direction of the field.



The arms AB and CD have a length *b* and AD and BC have a length *a.* The forces on the arms BC and DA are equal and opposite and act along the axis of the coil which connects the centres of mass of BC and DA. As the lines of action of these forces are collinear, they cancel each other and there is no resultant force or torque. The forces on the arms AB and CD are $\vec{F}_1$ and $\vec{F}_2$, which are equal and opposite but are not collinear.

$$\left|\vec{F}_1\right| = \left|\vec{F}_2\right| = IbB$$



These two forces result in a couple and the magnitude of the torque is given by

$$\tau = F_1 \frac{a}{2}\sin\theta + F_2 \frac{a}{2}\sin\theta$$
$$= Iab\sin\theta$$
$$= IAB\sin\theta$$

Defining magnetic moment of the coil as $\vec{m} = I\vec{A}$,

$$\vec{\tau} = \vec{m}\times\vec{B}$$

(i) the torque is maximum when $\theta = 90°$ and $\tau = IAB$

(ii) the torque is maximum when $\theta = 0°$ and $\tau = 0$

(b) The resistance R to be connected in shunt is

$$R = \frac{I_G}{I - I_G} G = \frac{10^{-3}\times 100}{1-10^{-3}} = 0.1\Omega$$

OR

(a)Consider a rod of uniform area of cross section A and length l. The number density of mobile charge carriers in the rod is n. The number of mobile charge carriers is

$$N = nAL$$

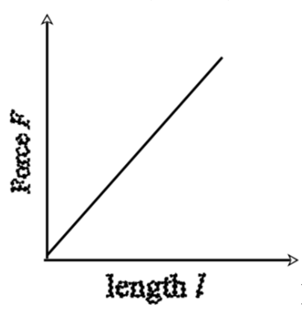
The value of the total mobile charge in the rod is

$$q = N(-e) = -NAle$$

If a steady current I flows in the rod, the electrons in the rod move with a average drift velocity v_d.

The force on the rod

$$\vec{F} = q\left(\vec{v}_d \times \vec{B}\right)$$
$$= -NAle\left(\vec{v}_d \times \vec{B}\right)$$



But

$$I\vec{l} = -NAel\vec{v}_d$$

Therefore

$$\vec{F} = I\vec{l}\times\vec{B}$$

The magnitude of the force is $F = BIl\sin\theta$

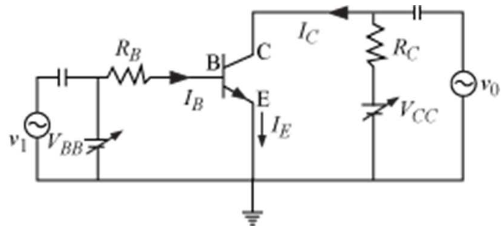
The force is maximum when $\theta = 90°$ and $F = BIl$

The force is minimum when $\theta = 0°$ and $F = 0$
The force $F \propto l$

(b) $F = BIl = mg$

$$B = \frac{mg}{Il} = \frac{0.2 \times 9.8}{2 \times 1.5} = 0.653T$$

26. The circuit for the CE transistor amplifier is given below.



A small sinusoidal voltage with amplitude v_i is superimposed on the dc base bias V_{BB}. The base current, as a result will have sinusoidal variations super imposed on the base current I_B. the collector current I_C will also have sinusoidal variations superimposed on I_C. The output of the amplifier is taken across the collector and the ground.

Applying Kirchhoff's law to the output loop,

$$V_{CC} = V_{CE} + I_C R_C$$

Applying Kirchhoff's rules to the input loop,

$$V_{BB} = V_{BE} + I_B R_B$$

For finite values of v_i,

$$V_{BB} + v_i = V_{BE} + I_B R_B + \Delta I_B \left(R_B + r_i\right)$$

Hence

$$v_i = \Delta I_B \left(R_B + r_i\right)$$

If $r = R_B + r_i$,

$$v_i = r\Delta I_B$$

If the a c current gain is β_{ac} then

$$\beta_{ac} = \frac{\Delta I_C}{\Delta I_B} = \frac{i_C}{i_B}$$

The change in I_C due to a change in I_B causes a change in V_{CE} and the voltage drop across the resistor R_C, because V_{CC} is fixed.

$$\Delta V_{CC} = \Delta V_{CE} + \left(\Delta I_C\right) R_C = 0$$

$$\Delta V_{CE} = -\left(\Delta I_C\right) R_C$$

But $\Delta V_{CE} = v_0$, the output voltage.

$$\Delta V_{CE} = v_0 = -\beta_{ac} R_C \Delta I_C$$

The voltage gain of the amplifier is

$$A_v = \frac{v_0}{v_i} = \frac{\Delta V_{CE}}{r\Delta I_B} = -\frac{\beta_{ac} R_C}{r}$$

Power gain of an amplifier is the product of voltage gain and current gain.

$$A_P = \beta_{ac} \times A_v$$

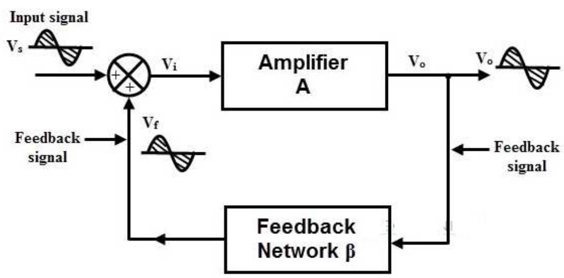
Though β_{ac} and A_v are greater than 1 and ac power gain is obtained, a transistor is not a power generating device. The energy for the higher a c power at the output is supplied by the battery.

OR

An oscillator is a circuit which gives an ac output without any external input.

To attain self-sustained oscillations, a portion of the output power is returned to the input in phase with the starting power. This type of fed back is called positive feedback.

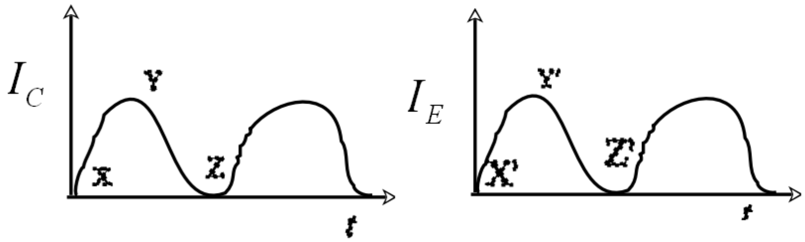
A block diagram of a oscillator with positive feedback is shown below. The feedback circuit can be achieved by the use of inductive coupling or LC or RC networks.



A circuit of tuned collector oscillator is shown below.

In the circuit, feedback is achieved by inductive coupling from one coil winding (T_1) to another coil winding (T_2). The coils T_1 and T_2 are wound on the same core and are inductively coupled through their mutual inductance.

If the switch S_1 is put on, to apply proper bias for the first time, a surge in collector current occurs. This current flows through the coil T_2, where the terminals are numbered 3 and 4. This current increases from X to Y as shown in the graph below.



The inductive coupling between the coil T_2 and the coil T_1 causes a current to flow in the emitter circuit. This is the feedback from input to output. As a result of this positive feedback the emitter current also increases from *X'* to *Y'*. When the collector current attains the value *Y*, the transistor becomes saturated and there is no more increase in the collector current.

The magnetic field around T_2 ceases to grow and there will be no further feedback from T_2 to T_1. Without continued feedback, the emitter current begins to fall. Consequently, the collector current also falls from *Y* to *Z*, which in turn causes the magnetic field around T_2 to decay. This results in further reduction in the emitter current, till it reaches *Z'*, when the transistor is cut-off.

The transistor is therefore restored to its original state and the process of saturation to cut-off to saturation, starts all over again. The time for the change from saturation to cut-off and back is determined by the constants of the tank circuit or tuned circuit. The resonant frequency of the tuned circuit determines the frequency at which the oscillator will oscillate.

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