Answers to RSPL/3

SECTION – A

1. (*a*) $qd = QD \Rightarrow \frac{d}{D} = \frac{Q}{q}$

(*b*) 0°

2. (*a*) Gunn diode

(*b*) *LC* oscillator

3. (*a*) Short wave radio broadcast

(*b*) Satellite communication

4. (*a*) $\frac{r_1}{r_2} = \left(\frac{A_1}{A_2}\right)^{\frac{1}{3}} \Rightarrow \frac{r_1}{r_2} = \frac{1}{2}$

(*b*) 1 : 1

5. $\frac{\lambda_p}{\lambda_\alpha} = \frac{p_\alpha}{p_p} = \frac{\sqrt{2m_\alpha K_\alpha}}{\sqrt{2m_p K_p}} = \sqrt{\frac{m_\alpha}{m_p}} = \sqrt{\frac{4}{1}} = 2 : 1$

SECTION – B

6. (*i*) Rahul's Error: The direction of electric and magnetic fields cannot be the same.

[We have $E \perp B \perp c$]

Correction: E along Y–axis and B along Z–axis or E along Z–axis and B along Y–axis

(*ii*) Rajat's Error: $B_0 = cE_0$

Correction: We have $c = \frac{E_0}{B_0}$. $\therefore$ $B_0 = \frac{E_0}{c}$

7. (*a*) $I_{min} = 0$ $I_{max} = 4I_0$. So the intensity varies between 0 to $4I_0$.

(*b*) (*i*) For constructive superposition $p = n\lambda$

(*ii*) For destructive superposition $p = (2n - 1)\ \lambda/2$

(*c*) As $I_1 = I_2 = I$, we have $a = b = R$

Resultant amplitude $R^2 = a^2 + b^2 + 2ab\cos\phi$

$\therefore$ $R^2 = R^2 + R^2 + 2R^2\cos\phi$

$\Rightarrow$ $R^2 = 2R^2(1 + \cos\phi)$

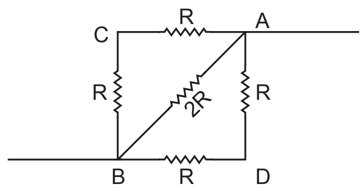
$$\cos\phi = -\frac{1}{2} \text{ or } \phi = 120° = \frac{2\pi}{3}$$

Phase difference = $\frac{2\pi}{3}$.

8. We have $\frac{R_{BC}}{R_{CA}} = \frac{R_{BD}}{R_{AD}} = 1$

$\therefore V_C = V_D$ and no current flows in the branch *COD*.

The circuit can be redrawn as under:

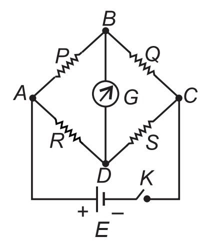


The branches *BCA* (= 2*R*); *BA* (= 2*R*) and BDA (= 2*R*) are joined in parallel.

$$\therefore \quad \frac{1}{R_{eq}} = \frac{1}{2R} + \frac{1}{2R} + \frac{1}{2R} = \frac{3}{2R}$$

$$\Rightarrow \quad R_{eq} = \frac{2R}{3}\,\Omega$$

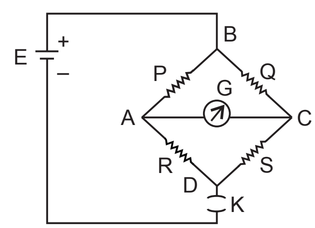
OR



Principle of Wheatstone bridge: In a balanced Wheatstone bridge (No current flows through galvanometer); the product of resistances in opposite arms of the bridge is equal.

i.e., In the figure; if $I_g = 0$; we have

$$P.S = Q.R \quad \text{or} \quad \frac{P}{Q} = \frac{R}{S}.$$



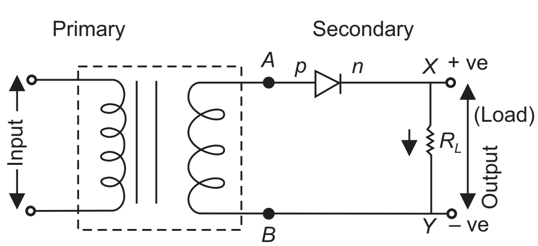
With the battery and the galvanometer interchanged; the condition for balance is $\frac{Q}{S} = \frac{P}{R}$ or $Q.R = P.S$ which is correct. Hence the bridge still remains balanced.

9. The direction of induced current is given by lenz's law. It states that the induced current produced in a circuit due to changing magnetic flux flows in a direction so as to oppose its own cause.

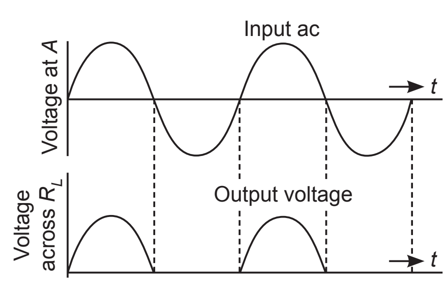
(*a*) Clockwise through the ring [Hint : The magnetic field due to straight conductor through the ring is directed outwards and increases as the ring moves closer].

(*b*) Anticlockwise as seen from the top (because the upper face of the metal ring should become North pole).

10.



A half-wave rectifier

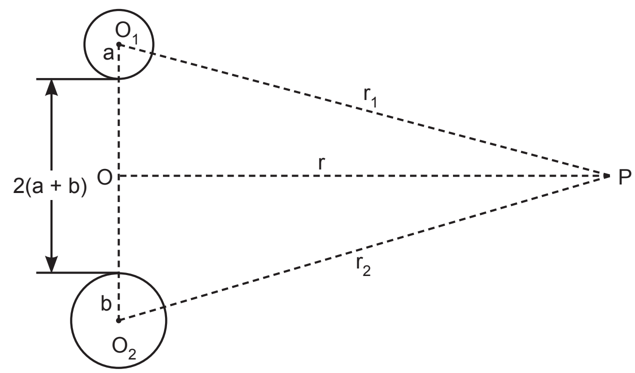


During first half of AC input, suppose terminal 'A' of the secondary in transformer is positive. This makes the *pn* junction forward biased and hence conducting. The current flows through R_L from X to Y providing output.

In second half of AC input; A becomes negative. The *pn* junction is reverse biased and hence non-conducting. Hence no current flows through R_L. So we do not get output in this half.
As we get output only in one-half of the AC cycle; Hence the rectifier is called half-wave rectifier.

SECTION – C

11. The electrostatic potential energy of a system of charges is the amount of work done to assemble the system taking the charges initially at infinite separation.



We have $r_1^2 = OO_1^2 + OP^2$

$= [(a+b)+a]^2 + r^2$

$= (2a+b)^2 + r^2$

$\therefore$ $r_1 = \sqrt{r^2 + (2a+b)^2}$

Similarly $r_2 = \sqrt{r^2 + (a+2b)^2}$

Electrostatic potential at P due to the spheres $= V = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right]$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{[r^2+(2a+b)^2]^{1/2}} + \frac{Q_2}{[r^2+(a+2b)^2]^{1/2}}\right]$$

$\therefore$ *PE* of the charge 'q' at P due to the potential 'V' is

$$U = qV = \frac{q}{4\pi\varepsilon_0}\left[\frac{Q_1}{[r^2+(2a+b)^2]^{1/2}} + \frac{Q_2}{[r^2+(a+2b)^2]^{1/2}}\right].$$

OR

Relaxation time of a free electron is the time elapsed between two successive collisions.
The drift velocity v_d and the relaxation time τ are related as

$$\vec{v}_d = -\frac{e\vec{E}}{m}\tau$$

or speed $$v_d = \frac{eV}{ml}\tau \qquad \ldots(i)$$

Also $$I = ne\,Av_d$$

$\therefore$ From (1) $$\frac{I}{ne\,A} = \frac{eV}{ml}\tau$$

$\therefore$ $$\frac{V}{I} = \frac{ml}{e^2 n\,A\tau}$$

Or $$R = \frac{ml}{e^2 n\,A\tau}$$

Also $$R = \rho\frac{l}{A} \qquad [\rho\text{: Resistivity}]$$

$\therefore$ $$\rho = \frac{m}{e^2 n\tau}$$

Current density $$J = \frac{I}{A} = \frac{e^2\,\tau n V}{ml} = \frac{e^2\,n\,\tau}{m}\,E$$

As $\frac{e^2\,n\,\tau}{m}$ is constant; $J \propto E$

Hence the graph J versus E will be a straight line.

12. The energy of electron in n^{th} orbit is given by

$$E_n = -\frac{13.6}{n^2}\text{ eV}$$

As $$E_n = -\frac{13.6}{n^2} = -3.4;$$

we get $$n^2 = 4 \quad \text{or} \quad n = 2.$$

(*a*) We have: $$E_{\text{Total}} = E_{\text{Kinetic}} + E_{\text{Potential}}$$
$$= E_K - 2E_K \qquad [\therefore\ |E_{\text{Potential}}| = -2E_K]$$
$$-3.4 = -E_K \quad \text{or} \quad E_K = 3.4\text{ eV}$$

(*b*) $$E_p = -2E_K = -6.8\text{ eV}$$

(*c*) Energy released during transition from $n = 2$ to $n = 1$ (Ground state) is

$$E = -3.4 - (-13.6) = 10.2\text{ eV}$$
$$= 10.2 \times 1.6 \times 10^{-19}\text{ J}$$

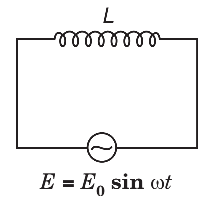
This energy is released as a photon. If λ is wavelength of light emitted; we have

$$E = h\nu = \frac{hc}{\lambda} = 10.2 \times 1.6 \times 10^{-19}$$

$\therefore$ $$\lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{10.2 \times 1.6 \times 10^{-19}} = 1.2423 \times 10^{-7}\text{ m}$$

$$\lambda = 1.2423 \times 10^{3}\text{ Å} = 1242.3\text{ Å}.$$

13. Electrical resistance is the opposition offered to the flow of current through a conductor. It is independent of the frequency of A.C.



The inductive reactance is the opposition offered to the flow of A.C. current by a capacitor or an inductor. The reactance depends on frequency of A.C.

Pure inductive AC circuit: Consider a coil of inductance L having resistance zero, is connected to an A.C. source of emf

$$E = E_0 \sin \omega t \quad \ldots(i)$$

As the alternating current flows; the magnetic flux linked with the inductor changes and a back emf is induced in the coil. If $\frac{dI}{dt}$ is the rate of change of current; we have

$$E_{\text{back}} = -L\frac{dI}{dt} \quad \ldots(ii)$$

Net emf $$E - E_{\text{back}} = E_0 \sin \omega t - L\frac{dI}{dt} = IR = 0 \quad \text{[For pure inductor]}$$

$\therefore$ $$L\frac{dI}{dt} = E_0 \sin \omega t$$

or $$dI = \frac{E_0}{L} \sin \omega t \, dt$$

Integrating $$I = \frac{E_0}{\omega L}(-\cos \omega t)$$

or $$I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right) \quad \ldots(iii)$$

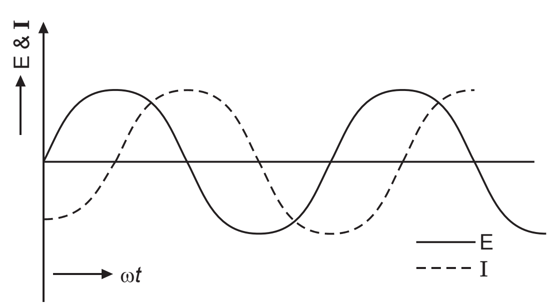
Comparing (i) and (iii), we see that in a pure inductive AC circuit; the current lags behind the emf in phase by $\pi/2$.

Also, $$I_0 = \frac{E_0}{\omega L}$$

$\therefore$ $$\frac{E_0}{I_0} = X_L \text{ (Inductive reactance)}$$

$\therefore$ $$= \omega L = 2\pi\nu L$$

So, $$X_L \propto \nu$$

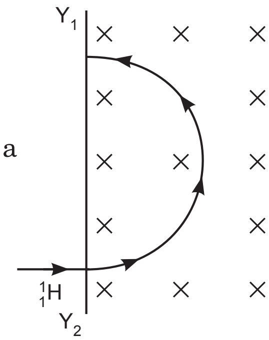


14. (*a*) For the proton; charge $q = 1.6 \times 10^{-19}$ C

$$v = 1 \text{ km/s} = 10^3 \text{ m/s}$$

$$\vec{v} \perp \vec{B} \Rightarrow \theta = 90°$$

$$\text{Force on the proton} = \vec{F} = q(\vec{v} \times \vec{B}) = e(\vec{v} \times \vec{B})$$



As $F \perp \vec{v}$ and $\vec{F} \perp \vec{B}$, the proton follows a circular path completing a semicircle in the field before emerging out.

$$t = \frac{\pi r}{v} = \frac{\pi m}{qB} = \frac{22 \times 1.67 \times 10^{-27}}{7 \times 1.6 \times 10^{-19} \times 10^{-5}} \text{ sec}$$

$$= 3.2 \times 10^{-3} \text{ sec.}$$

(*b*) For the wire to remain suspended, we have

$$mg = BIl$$

$$\therefore \quad \frac{m}{l} = \frac{BI}{g} = \frac{0.65 \times 2}{9.8} = \frac{1.3}{9.8} = \frac{13}{98} \text{ kg/m}$$

$$\simeq 0.133 \text{ kg m}^{-1}$$

15. (*a*) (*i*) **Faraday's laws:** Whenever there is a change in magnetic flux linked with a coil, an induced emf is produced in it lasting as long as the magnetic flux is actually changing.

(*ii*) The magnitude of induced emf produced in a coil is equal to the rate of change of magnetic flux linked with the coil.

$$|E| = \left|\frac{d\phi_B}{dt}\right|$$

(*b*) (*i*)

$$E_0 = NBA\omega \quad \text{(Peak emf)}$$

$$= NBA(2\pi\nu)$$

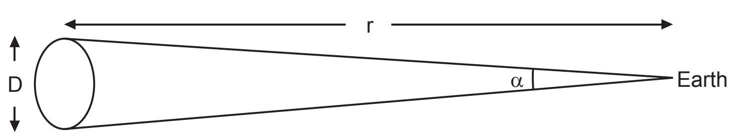
$$= 200 \times 0.01 \times 0.1 \times 2 \times 3.14 \times \frac{50}{60} \text{ volt} = 1.04 \text{ V}$$

(*ii*) E_{av} for half cycle $= \frac{7}{11} E_0 = \frac{7 \times 1.04}{11} = \frac{7.28}{11} = 0.66$ V

(*iii*) For a complete revolution E_{av} = zero.

16. Angular magnification of the telescope $= \dfrac{\text{Focal length of objective '}f_0\text{'}}{\text{Focal length of eyepiece '}f_a\text{'}}$

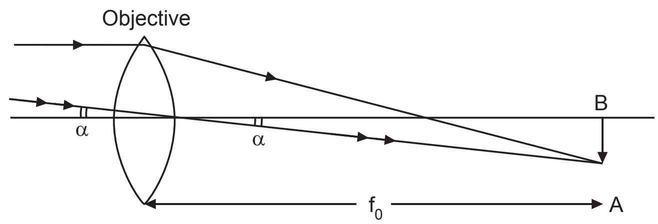
$$= \frac{15 \text{ m}}{1 \text{ cm}} = \frac{1500 \text{ cm}}{1 \text{ cm}} = 1500$$



If the moon subtends an angle α on unaided eye on earth, we have

$$\alpha = \frac{\text{Length of arc}}{\text{Radius}} = \frac{D}{r} = \frac{3.42 \times 10^6 \text{ m}}{3.8 \times 10^8 \text{ m}}$$

$$= \frac{3.42}{3.8} \times 10^{-2} \text{ radian}$$

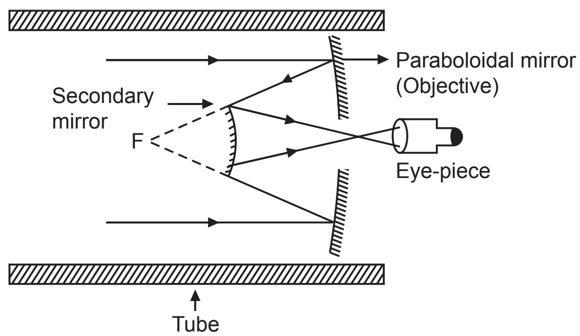


If AB is the image of the moon formed by the objective; we get

$$\frac{AB}{f_0} = \alpha \quad \Rightarrow \quad AB = \alpha . f_0 = \frac{3.42 \times 10^{-2}}{3.8} \times 1500 \text{ cm}$$

$$= 13.5 \text{ cm}$$

17. (*a*)



Ray diagram: reflecting type telescope

(*b*) **Advantages of reflecting type telescope:**

(*i*) The image formed is free from chromatic aberration unlike in refracting type telescope.

(*ii*) The image produced is brighter as the lenses absorb a larger fraction of light when light passes through the lenses.

(*iii*) It is easier to manufacture a defect free mirror of large aperture than a lens.

(*c*) (*i*) We have $m = \frac{f_0}{f_e}$ (Magnifying power)

So the objective should have larger focal length.

(*ii*) Larger aperture of the objective ensures larger light gathering power for brighter image and a higher resolving power.

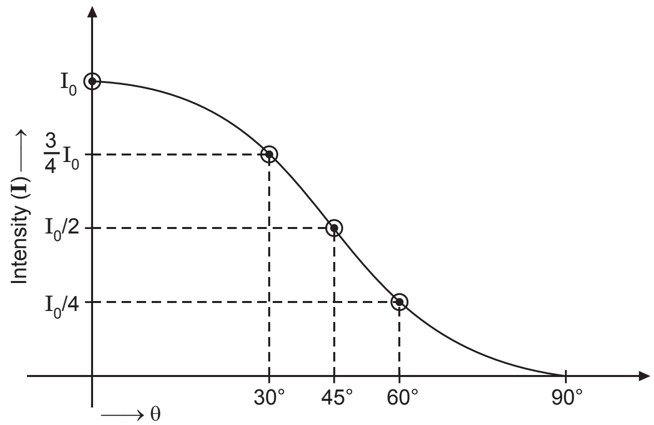
18. Sound wave can't be polarised as it is longitudinal. Heat being a transverse wave can be polarised. The intensity 'I' of the transmitted light is related to I_0 and θ as

$$I = I_0 \cos^2 \theta \qquad \text{[Malu's law]}$$

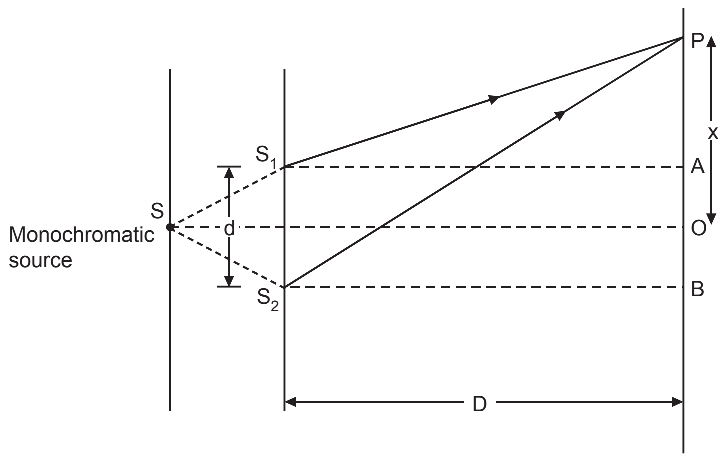
The values of I can be tabulated as under:

θ	**0**	**30**	**45**	**60**	**90**
I	I_0	$\frac{3}{4} I_0$	$\frac{1}{2} I_0$	$\frac{1}{4} I_0$	0

The variation I versus θ is represented below:



19.



Experimental set-up in young's double slit experiment

Expression for separation between successive maxima:

Assumptions: S_1 and S_2 emit light in same phase. O being equidistant from S_1 and S_2 receives light in same phase producing a maxima (central maxima).

The intensity at P depends on the path difference p $(= S_2P - S_1P)$ between light from S_2 and S_1.

We have $$S_2P^2 = S_2B^2 + BP^2 = D^2 + \left(x + \frac{d}{2}\right)^2$$

$$S_1P^2 = S_1A^2 + AP^2 = D^2 + \left(x - \frac{d}{2}\right)^2$$

$\therefore$ $$S_2P^2 - S_1P^2 = \left[x + \frac{d}{2}\right]^2 - \left[x - \frac{d}{2}\right]^2 = 4 \,.\, x. \frac{d}{2} = 2xd$$

or $$(S_2P - S_1P)(S_2P + S_1P) = 2xd$$

We have $$D >> d$$

So $$S_2P + S_1P \simeq 2D$$

$\therefore$ $$p \,.\, 2D = 2xd \quad \Rightarrow \quad p = \frac{xd}{D}$$

For n^{th} maxima at P; $p = n\lambda$ or $x_n = n\frac{D\lambda}{d}$

For $(n + 1)^{th}$ maxima $x_{n+1} = (n+1)\frac{D\lambda}{d}$

$\therefore$ Separation between successive maxima = $x_{n+1} - x_n = \frac{\lambda D}{d}$.

20. We have

$$R_i = 1000\ \Omega;\quad \beta_{ac} = 50$$
$$R_o = 2000\ \Omega;\ V_0 = 2\text{ V}$$

$\therefore$ Collector current $I_C = \frac{V_0}{R_0} = \frac{2}{2000} = \frac{1}{1000}$ A.

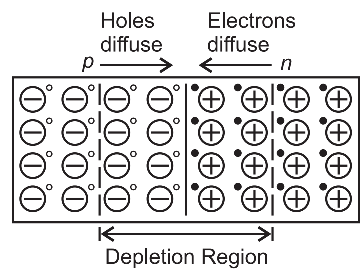
Now $\beta = \frac{I_c}{I_b} = 50$

$\therefore$ $I_b = \frac{\text{I}_c}{50} = \frac{1}{50 \times 1000}$ A = 20 μA

$$V_b = I_b R_i = (20 \times 10^{-6})(1000)$$
$$= 20 \times 10^{-3}\text{ V} = 20\text{ mV}$$

21. (*a*) The processes involved are

(*i*) Diffusion (*ii*) Drift



When a p-type semiconductor is joined to n-type semiconductor; the electrons from electron-rich n region diffuse to electron-deficient p side. This leaves immobile positive ions on the n-side of junction.

Similarly the holes diffuse from p-region to n-region leaving negative immobile ions on p-side.

The accumulation of ions on the two sides creates a barrier potential which prevents further drift of the charge carriers after equilibrium is reached. Hence a thin layer is formed near the junction. This layer is devoid of any free charge carriers and is called depletion layer.

(*b*) D_1 is reverse biased. $\therefore$ I = Zero [$R = \infty$]

D_2 is forward biased; $R = 0$

$\therefore$ $I = \frac{V}{R_{\text{total}}} = \frac{2}{4\Omega + 2\Omega} = \frac{2}{3}$ A

Current through D_1 = 0. Current through $D_2 = \frac{2}{3}$ A.

22. (*a*) A: Square law device to provide an output of the type $y(t) = Bx(t) + Cx^2(t)$ where B and C are constants.

B: Band-pass filter : To allow frequencies ω_c ; $\omega_c + \omega_m$ and $\omega_c - \omega_m$ to pass and block DC components; very low and very high frequencies.

(*b*) X: Intermediate frequency (IF) stage. It changes the high frequency signal to lower frequency for further processing of the signal received.

Y: Audio amplifier: It amplifies the weak signal obtained from the detector before reproduction.

SECTION – D

23. (*a*) (*i*) Scientific temperament

(*ii*) Concern for energy conservation.

(*b*) (*i*) Receptive to good ideas

(*ii*) Desire to improve where possible.

(*c*) (*i*) Replacing electrical lamps/tubelights by CFL's and diode lamps.

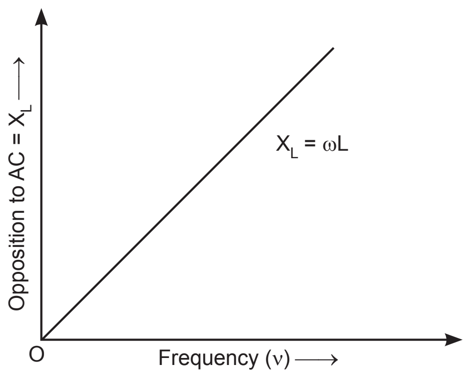
(*ii*) Switching off electrical appliances when not in use.

(*iii*) Optimal use of refrigerators/ACs.

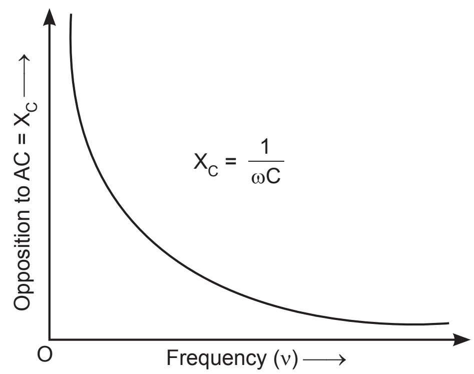
(*d*) $$E = P.t = 2 \times 20 \times 60 \times 60 = 144000 \text{ J}$$
$$= 1.44 \times 10^5 \text{ J.}$$

SECTION – D

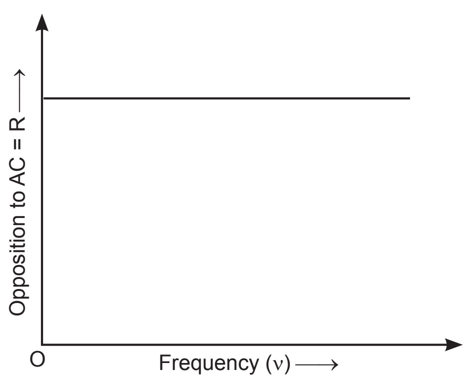
24. (*a*)



(*i*) Inductor



(*ii*) Capacitor



(*iii*) Resistance

(*b*) Given $L = 0.12$ H; $C = 480\ n\text{F} = 4.8 \times 10^{-7}$ F; $R = 23\ \Omega$; $V_{\text{eff}} = 230$ V.

For maximum current; Z should be minimum i.e. the circuit should be in resonance.

Angular frequency at resonance,

$$\omega_r = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.12 \times 4.8 \times 10^{-7}}}$$

$$= \frac{1}{\sqrt{12 \times 12 \times 4 \times 10^{-10}}} = \frac{10^5}{24} s^{-1} = \frac{12500}{3} s^{-1}$$

$$\nu_r = \frac{\omega_r}{2\pi} = \frac{12500}{3 \times 2 \times 3.14} \simeq 663 \text{ Hz.}$$

(*c*) Average power of series LCR circuit is given by

$$P = VI \cos \phi$$

$\therefore$ $P_{\text{max}} = VI$ $[\cos \phi = 1]$

For $P = \frac{1}{2} P_{\text{max}}$; we have $\cos \phi = \frac{1}{2}$

and $\omega = \omega_r \pm \frac{R}{2L}$ and $\nu = \nu_r \pm \frac{R}{4\pi L} = 663 + \frac{23}{4 \times 3.14 \times .12}$

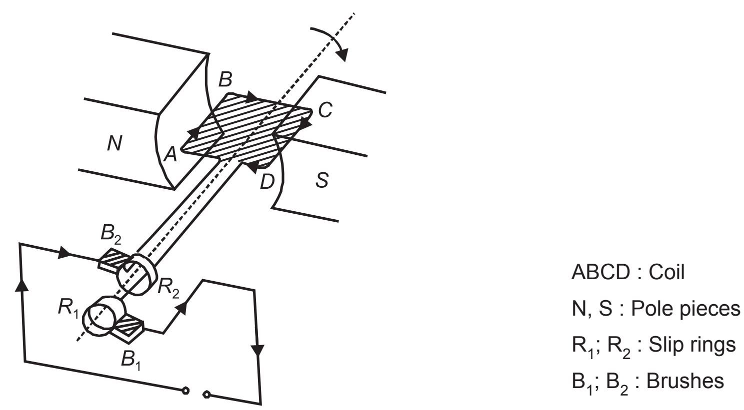
$= 663 \pm 15 = 648$ Hz; 678 Hz.

(*d*) $Q\text{-factor} = \frac{\omega_r L}{R} = \frac{2\pi\nu_r L}{R} = \frac{2 \times 3.14 \times 663 \times .12}{23}$

$= 21.7$

OR

(*a*)



A.C. generator

(*b*) It works on the principle of electromagnetic induction i.e. whenever there is a change in magnetic flux linked with a coil, an induced emf is produced in it.

(*c*) Suppose the coil rotates in magnetic field of intensity B with an angular frequency 'ω'.

Initially plane of the coil is perpendicular to the magnetic field (i.e. At $t = 0$, $\theta = 0$).

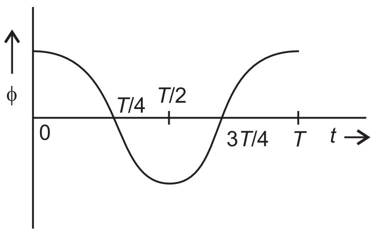
$\therefore$ At time 't'; $\theta = \omega t$

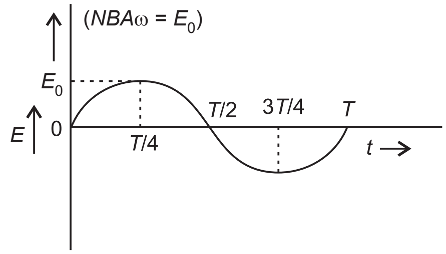
Magnetic flux $\phi_B = NBA \cos \omega t$ [N : Number of turns, A: Area of each turn]

Induced emf $e = \frac{-d\,\phi_B}{dt} = NBA\,\omega \sin \omega t$

$= E_0 \sin \omega t$

(d) Variation ϕ_B and e with time t

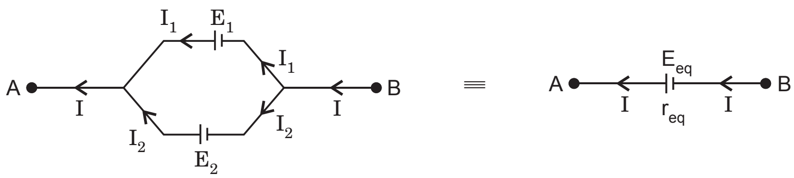




(e) (i) E_{av} = Zero [Over a complete cycle]

(ii) $E_{av} = \frac{7}{11}E_0$ [Over half a cycle].

25. (a) The combination of the cells and the equivalent battery are as under



From the circuit diagram; $I = I_1 + I_2$ ...(i)

For cell 1; potential difference $V = E_1 - I_1 r_1 \Rightarrow I_1 = \frac{E_1 - V}{r_1}$ ...(ii)

For cell 2; potential difference $V = E_2 - I_2 r_2 \Rightarrow I_2 = \frac{E_2 - V}{r_2}$ ...(iii)

Using (ii) and (iii) in (i); we get

$$I = \frac{E_1 - V}{r_1} + \frac{E_2 - V}{r_2} = \frac{E_1 r_2 + E_2 r_1}{r_1 r_2} - V\left[\frac{r_1 + r_2}{r_1 r_2}\right] \quad ...(iv)$$

$\therefore$ $$Ir_1r_2 = (E_1 r_2 + E_2 r_1) - V(r_1 + r_2)$$

$\therefore$ $$V = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} - I\frac{r_1 r_2}{r_1 + r_2} \quad ...(v)$$

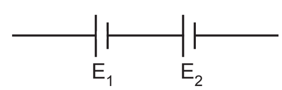
Also $$V = E_{eq} - Ir_{eq} \quad \text{[From equivalent figure]} \quad ...(vi)$$

Comparing, we get $E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$ and $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$ ...(vii)

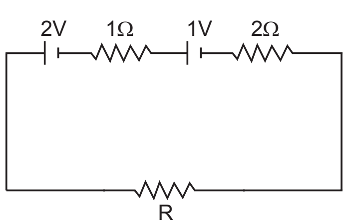
The corresponding formulae for series combination are

$$E_{eq} = E_1 + E_2$$

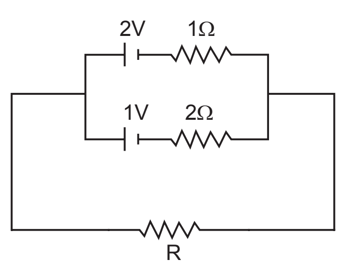
$$r_{eq} = r_1 + r_2$$



(b) (i)



(ii)



In series, $$I_s = \frac{(E_{eq})_{series}}{R + (r_{eq})_s} = \frac{3}{R+3}$$

In parallel, $$(E_{eq})_p = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} = \frac{2 \times 2 + 1 \times 1}{2+1} = \frac{5}{3}\ \text{V}$$

$$(r_{eq})_p = \frac{r_1 r_2}{r_1 + r_2} = \frac{2}{3}\ \Omega$$

$\therefore$ $$I_p = \frac{(E_{eq})_p}{R + (r_{eq})_p} = \frac{5/3}{R + 2/3} = \frac{5}{3R+2}$$

Put $$I_s = I_p$$

$\therefore$ $$\frac{3}{R+3} = \frac{5}{3R+2}$$

$$9R + 6 = 5R + 15$$

$\Rightarrow$ $$\boldsymbol{R = 2.25\ \Omega}$$

As current is the same; the heat dissipated in series combination will be higher due to larger internal resistance.

OR

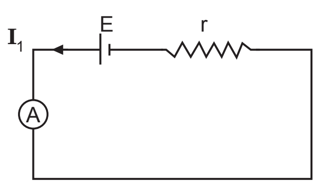
(*a*) **Ohm's law:** It states that for a conductor under fixed physical conditions; the potential difference across the ends of a conductor is directly proportional to the current passing through it.

Conditions for validity

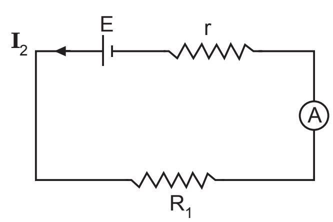
(*i*) The law is applicable only to conductors

(*ii*) The physical condition like temperature of the conductor must be constant.

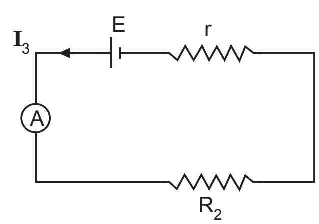
(*b*) The five possible combinations using E, r, R_1 and R_2 are as under:



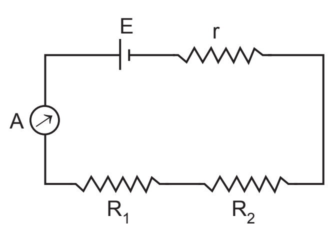
(*i*) $R_{ext} = 0$



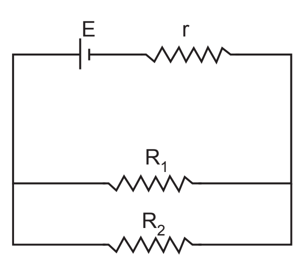
(*ii*) Only R_1



(*iii*) Only R_2



(*iv*) R_1 and R_2 in series



(*v*) R_1 and R_2 in parallel

The total resistances in the five circuits are r, $r + R_{||}$; $r + R_1$; $r + R_2$; $r + R_{series}$ in increasing order.

So the currents are in the order 4.2A, 1.4A, 1.05A, 0.6A and 0.42A for the five cases.

We have $$\frac{E}{r} = 4.2 \quad ...(i)$$

$$\frac{E}{R_{||} + r} = 1.4 \quad ...(ii)$$

$$\frac{E}{R_1 + r} = 1.05 \quad ...(iii)$$

$$\frac{E}{R_2 + r} = 0.6 \quad ...(iv)$$

$$\frac{E}{R_{ser} + r} = 0.42 \quad ...(v)$$

(v) ÷ (ii) gives $$\frac{3}{10} = \frac{r + R_{||}}{r + R_{ser}}$$

or $$3r + 3R_{\text{ser}} = 10r + 10\,R_{||}$$

or $$3R_s - 10\,R_{||} = 7r \quad ...(vi)$$

(i) ÷ (v) gives $$R_s = 9r \quad ...(vii)$$

From (iii) and (iv)

$$r + R_1 = \frac{E}{1.05};\; r + R_2 = \frac{E}{0.6}$$

Adding $$2r + R_S = E\left(\frac{1}{1.05} + \frac{1}{.6}\right)$$

Also $$E = 4.2\,r$$

From (v) and (vii)

$$\frac{4.2\,r}{r + qr} = 0.42 \quad \Rightarrow \quad r = 1\,\Omega$$

∴ $$R_S = 9\Omega;\; R_{||} = 2\Omega.$$

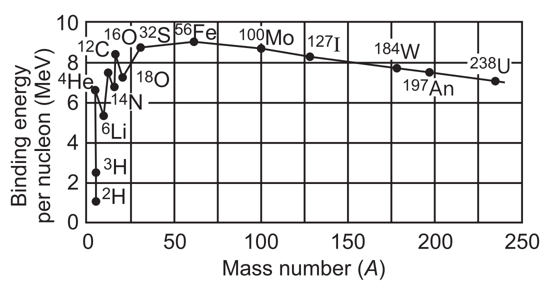
∴ $$R_{||} = \frac{R_1 R_2}{R_1 + R_2} = 2\Omega \quad \text{or} \quad R_1 R_2 = 18$$

Again $$(R_2 - R_1)^2 = (R_2 + R_1)^2 - 4R_1R_2$$

∴ $$R_2 - R_1 = 3\Omega$$

Hence $$R_1 = 3\Omega \quad \text{and} \quad R_2 = 6\Omega;\; E = 4.2\text{ V}.$$

26. (a) The variation of BE/nucleon (in MeV) versus mass number (A) is as shown below:



The graph leads us to following two conclusions:

(*i*) The value of BE/nucleon is very small for lighter nuclei like $_1H^2$, $_1H^3$, $_2He^4$. Its value increases with increase in 'A' and attains a maximum value for $_{26}Fe^{56}$.

(*ii*) The graph has a broad maxima between A = 40 to 200. The BE/A decreases thereafter.

(*b*) Let R denote the radius of a nucleus with mass number A.

We have nuclear density $\rho = \frac{\text{mass}}{\text{volume}} = \frac{mA}{\frac{4}{3}\pi R^3}$ [*m* is mass of each nucleon]

$$= \frac{mA}{\frac{4}{3}\pi (R_0 A^{1/3})^3}$$ [R_0 is a constant]

$$= \frac{3\,m}{4\pi\, R_0^3} = \text{constant.}$$

Hence nuclear density is independent of mass number A.

(*c*) The reaction is

$$^1_0n \longrightarrow {}_1H^1 + {}_{-1}e^{\circ} + \bar{\nu} \text{ (neutrino)}$$

The detection of neutrinos is found difficult because they are uncharged particles, with zero rest mass but carry only energy and momentum.

OR

(*a*) **Postulates of Bohr's theory of hydrogen atoms are:**

(*i*) An electron in an atom revolves around the nucleus in certain orbits called stationary or non-radiating orbits.

(*ii*) The angular momentum of revolving electron in a stationary orbit is an integral multiple of $\frac{h}{2\pi}$.

i.e. $L_n = n \cdot \frac{h}{2\pi}$ or $mv_n r_n = n\frac{h}{2\pi}$ where $n = 1, 2, 3, ...$

(*iii*) An atom emits energy in the form of a photon when electron jumps from a higher energy state to a lower energy state. We have $h\nu = E_{n2} - E_{n1}$ $[n_2 > n_1]$.

(*iv*) The electrostatic attraction of the nucleus on electron provides the necessary centripetal force for the revolving electron.

Expression for frequency:

By Bohr's quantisation condition,

Angular momentum $mv_n\, r_n = n\frac{h}{2\pi}$ ...(*i*)

Also centripetal force $\frac{mv_n^2}{r_n}$ = electrostatic force = $\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n^2}$ ...(*ii*)

or $mv_n^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n}$ ...(*iii*)

$\therefore$ K.E. $= \frac{1}{2}mv_n^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r_n}$

$$PE = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_n} = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n}$$

Total energy of electron in n^{th} orbit = $KE + PE$

or $$E_n = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r_n} - \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n}$$

$$E_n = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{2r_n} \quad ...(iv)$$

Substituting for v_n from (*i*) in (*iii*);

$$m\left(\frac{nh}{2\pi\, mr_n}\right)^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n}$$

or $$\frac{m\, n^2\, h^2}{4\pi^2\, m^2\, r_n^2} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n}$$

∴ $$r_n = (4\pi\varepsilon_0)\frac{n^2\, h^2}{4\pi^2\, me^2}$$

Substituting in (*iv*)

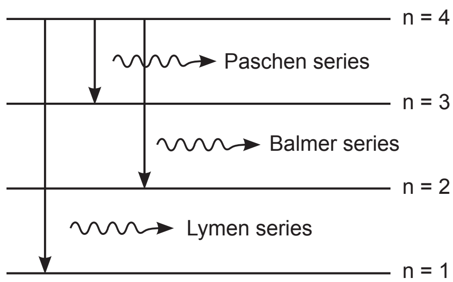
$$E_n = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{2}\frac{4\pi^2\, me^2}{(4\pi\varepsilon_0)\, n^2\, h^2} = -\left(\frac{1}{4\pi\varepsilon_0}\right)^2\frac{2\pi^2\, me^4}{h^2}\cdot\frac{1}{n^2}$$

Using postulate (*iii*) of the theory

∴ $$h\nu = E_{n_2} - E_{n_1} = \left(\frac{1}{4\pi\,\varepsilon_0}\right)^2\frac{2\pi^2\, me^4}{h^2}\left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right]$$

or $$\nu = \left(\frac{1}{4\pi\,\varepsilon_0}\right)^2\frac{2\pi^2\, me^4}{h^3}\left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right]$$

(*b*)



For transition $n_2 = 4$ to $n_1 = 1$; Lyman series belong to UV radiation
For transition $n_2 = 4$ to $n_1 = 2$; Balmer series belong to visible radiation
For transition $n_2 = 4$ to $n_1 = 3$; Paschen series belong to infrared radiation.