1. The liquid drop of charge \( Q \) and mass \( M \) is in equilibrium between the plates of charged parallel plate capacitor of potential difference \( V \) and separation between its plates \( d \), when

\[ QE = Mg \]

where the electric field \( E \) between the plates is given by \( E = \frac{V}{d} \) and mass of liquid drop \( M = \frac{4}{3} \pi r^3 \rho \)

where \( \rho \) is the density of the liquid

So, \( \frac{Q}{d} = \frac{4}{3} \pi r^3 \rho g \) or \( V = \frac{4\pi r^3 \rho g}{3Q} \)

Thus \( V \propto \frac{r^3}{Q} \)

(All other quantities remains unchanged here.)

If \( V' \) is the potential required for the liquid drop of radius \( 2r \) and charge \( 2Q \), then

\[ V' \propto \left( \frac{(2r)^3}{Q} \right) = 4V \]

2. Using Einstein's photoelectric equation,

\[ hv = \phi + KE \]

where \( \phi = hv_0 \) is the work function

In the first case,

\[ \frac{hc}{\lambda} = \phi + E \]

...\( (i) \)

In second case
\[ \frac{hc}{\lambda} = \phi + 2E \] ...(ii)

Subtracting, (ii)-(i)

\[ \frac{hc}{\lambda} - \frac{1}{\lambda} = \frac{E}{\lambda} \]

or

\[ \frac{1}{\lambda} - \frac{1}{\lambda} = \frac{E}{hc} \]

Thus,

\[ \frac{1}{\lambda} < \frac{1}{\lambda} \]

Further from eq. (i)

\[ E = \frac{hc}{\lambda} - \phi \]

when \( \lambda \) changes to \( \lambda /2 \), \( E \) increases to more than \( 2E \). Hence, in order to increase the kinetic energy of electrons to \( 2E \), \( \lambda \) should be decreased to \( \lambda' \)

where,

\[ \lambda' < \lambda /2 \]

Hence, the correct options is (a)

3. \[ \frac{(k.E.)_{\text{photon}}}{(K.E.)_{\text{electron}}} = \frac{hv}{\frac{1}{2}mv^2} = \frac{\frac{hc}{\lambda}}{\frac{1}{2}(m^2v^2)} \] ...(i)

But the de-Broglie wavelength of electron is given by

\[ \lambda = \frac{h}{p} = \frac{h}{mv} \]

\[ \therefore \quad m^2v^2 = \left( \frac{h}{\lambda} \right)^2 \] ...(ii)

On substituting in eq. (i), we get

\[ \frac{E_p}{E_e} = \frac{2mhc/\lambda}{(h/\lambda)^2} = \frac{2m\lambda c}{h} \]

\[ = \frac{2m(h/mv)c}{h} \]

\[ = \frac{2c}{v} \]

4. After a lapse of time \( t \), let the number of atoms of \( x \) element and \( y \) element be respectively \( N_x \) and \( N_y \).

Then,

\[ \frac{N_y}{N_x} = 7 \]

or

\[ \frac{N_y + 1}{N_x} = 8 \Rightarrow \frac{N_y + N_x}{N_x} = 8 \]

or

\[ \frac{N_y}{N_x} = 1 \]

Now the death of an atoms of mother element means the birth of an atoms of daughter element.

\[ \therefore \quad \frac{N_x}{N_x + N_y} = \frac{N}{N_0} = 1 \quad \frac{1}{8} = \left( \frac{1}{2} \right)^n \]

\[ \therefore \quad n = 3 = \frac{t}{T} \]

But \( T = 2 \) hours,

\[ \text{So,} \quad t = 3T = 6 \text{ hr} \]

5. The moment of linear momentum is equal to the angular momentum \( L = mv \)

According to Bohr model

\[ L = \frac{nh}{2\pi} \]

In the second orbit \( n = 2 \)

\[ \therefore \quad L = \frac{h}{\pi} \]

6. \( X^{p+1} \rightarrow \phi^{n+1} + X^p \)

Energy required = B.E. of \( X^{p+1} \) - B.E. of \( X^p \).

\[ = 17 \times 7.25 - 16 \times 7.97 \]

\[ = 4.23 \text{ MeV} \]

7. The given transistor amplifier circuit is in common emitter configuration where the current gain is given by

\[ \beta = \frac{I_c}{I_b} = \frac{1 \times 10^{-3}}{50 \times 10^{-6}} = 20 \]

8. \( \beta = \frac{I_c}{I_b} = 40 \) \( \quad \text{(given)} \)

Also,

\[ I_e = I_b + I_c \]

\[ \frac{I_e}{I_b} = 1 + \frac{I_c}{I_b} = 1 + 40 = 41 \]

9. Length measured with vernier callipers

= reading before the zero of vernier scale + number of vernier divisions coinciding with any main scale division \( \times \) least count

\[ = 10 \text{ mm } + 0 \times 0.1 \text{ mm} \]

\[ = 10 \text{ mm } = 1.00 \text{ cm} \]

10. The figure of merit \( k \) is given as

\[ k = \frac{E}{(R + G)} \]
11. Since the focal length of the lens depends upon the refractive index of the lens material, so there will be two images one at I and the other at I2 when the lens L3 is used.

12. The orbital speed $v_0$ of the satellite is given by

$$v_0 = \sqrt{\frac{gR}{2}}$$

The escape speed $v_e$ is given by

$$v_e = \sqrt{\frac{2gR}{2}}$$

The minimum percentage increase in the speed of the satellite is

$$\left( \frac{v_e - v_0}{v_0} \right) \times 100\% = \left( \frac{\sqrt{2} - 1}{\sqrt{2}} \right) \times 100\% = 0.414 \times 100\% = 41.4\%$$

13. The pressure 'p' at a point P is equal to the sum of pressure $p_1$ exerted due to gravity and $p_2$ exerted due to motion under constant acceleration 'a'.

Here $p_1 = \text{hpg}$

$p_2$ is the pressure necessary to impart an acceleration 'a' to the column of water of length x and area of cross section A.

$\therefore p_2A = xAp_a$

or $p_2 = xpa$

Now, $p_1 + p_2 = \text{hpg} + xpa$

14. Volume strain $= \frac{\Delta V}{V} = 0.001 \times \frac{1}{100} = 1 \times 10^{-5}$

Bulk modulus $K = \frac{\text{Volume stress}}{\text{Volume strain}} = \frac{\Delta P}{\Delta V/V}$

$\therefore$ Increase in pressure,

$$\Delta P = K \cdot \frac{\Delta V}{V} = 2 \times 10^9 \times 1 \times 10^{-5} = 2 \times 10^4 \text{ N/m}^2$$

15. Each block slides down the inclined plane with an acceleration,

From the diagram

$$m_g \sin \theta - R' = m_a$$

$\therefore R' = m_g \sin \theta - m_a$

$$= m_g \sin \theta - m_a$$

= zero

16. $dW = dQ - dU$

At constant pressure, $dQ = C_p dT$ (for 1 gm-mole of the monoatomic gas)

$\therefore dW = C_p dT - C_v dT = (C_p - C_v)dT$

Fraction of heat converted into work is given by

$$\frac{dW}{dQ} = \frac{C_p - C_v}{C_p}dT = 1 - \frac{C_v}{C_p} = 1 - \frac{1}{\gamma}$$

or $\frac{dW}{dQ} = \frac{1}{\gamma}$

$\therefore \gamma = \frac{5}{3}$ for monoatomic gas

17. $y = y_1 + y_2$

$= 2\sin(\omega t - kx) - a\sin(\omega t + kx)$

$= 2a\sin(kx \cdot \cos\omega t)$

Hence, the correct choice is (c)

18. The current in the circuit is given by

$$I = \frac{E + E}{R + r_1 + r_2}$$

Now, the potential difference across the cell of internal resistance $r_1$ is given by,

$$V = E - Ir_1 = 0 \quad \text{ (given)}$$

$\therefore E = Ir_1$

or $E = \frac{2E}{R + r_1 + r_2}$

or $R + r_1 + r_2 = 2r_1$

or $R = r_1 - r_2$
19. Current drawn from the electric motor is given by,

\[ I = \frac{E - e}{R} \]

where \( E \) is the emf of the d.c. source and \( e \) is the back emf.

In the first case

\[ 2 = \frac{12 - e}{1} \Rightarrow e = 10 \text{ V} \]

In the second case, let the back emf is \( e' \).

Since, back emf \( \propto \) speed of the motor

\[ \frac{e}{e'} = \frac{\omega}{\omega'} = 2 \]

\[ e' = \frac{e}{2} = \frac{10}{2} = 5 \text{ V} \]

Now, the current drawn from the motor is

\[ I' = \frac{E - e'}{R} = \frac{12 - 5}{1} = 7 \text{ A} \]

20. The two diametrically opposite edges of the A and B emits irradiations which reach the observer such that the light source A is approaching towards the observer while B is receding away from the observer with the equal velocities \( v \).

Hence, the light radiation from A shifts towards the shorter wavelength side (blue shift) while that from B shifts towards the longer wavelength side (red shift).

Thus for A \( \Delta \lambda = -\frac{v}{c} \lambda \)

and for B \( \Delta \lambda = +\frac{v}{c} \lambda \)

where, \( v = \frac{2\pi R}{T} \)

\( \therefore \) Doppler wavelength shift is

\[ (\Delta \lambda)_D = \pm \frac{2\pi R \lambda}{c T} \]

21. Let the object subtends an angle \( \phi \) at the objective of focal length \( f_0 \) and the final image subtends an angle \( \theta \) at the eye-piece of focal length \( f_e \), then

\[ \frac{\theta}{\phi} = \frac{f_0}{f_e} \]

or \( \theta = \frac{f_0}{f_e} \times \phi \)

\[ = \frac{50}{5} \times 5^\circ = 50^\circ \]

22. The displacement current is given by,

\[ I_d = \varepsilon_0 \left( \frac{d\phi}{dt} \right) \text{ where } \phi = EA \]

\[ = \varepsilon_0 A \frac{dE}{dt} = \varepsilon_0 A \frac{d}{d} \left( \frac{V}{d} \right) \]

\[ I_d = \varepsilon_0 A \frac{dV}{d} \frac{dt}{dt} \]

Hence, the displacement current flows in the capacitor only when the potential difference between the plates of the capacitor is changing with time.

23. \( P = \frac{a - t^2}{b x} = \frac{a}{b x} - \frac{t^2}{b x} \)

From the principle of homogeneity, the dimensions of \( \frac{a}{b x} \) must be same as that of pressure, i.e.,

\[ [P] = \left[ \frac{a}{b x} \right] = [ML^{-1}T^{-2}] \]

\[ \therefore \left[ \frac{a}{b} \right] = [MT^{-2}] \]

24. Initial kinetic energy of the ball

\[ K_1 = \frac{1}{2} m v_1^2 = mgh_1 \]

Final kinetic energy.

\[ K_2 = \frac{1}{2} m v_2^2 = mgh_2 \]

Fractional loss is kinetic energy

\[ \frac{K_1 - K_2}{K_1} = \frac{mgh_1 - mgh_2}{mgh_1} = \frac{h_1 - h_2}{h_1} \]

\[ = \frac{8 - 6}{8} \cdot \frac{2}{8} = \frac{1}{4} \]
25. Without friction the block slides down the incline with an acceleration \( a_1 = g \sin \theta \) and friction the acceleration is \( a_2 = g \sin \theta - \mu g \cos \theta \).

Now if \( t_1 \) and \( t_2 \) be the time taken by the block to slide down the incline without and with friction respectively, then

\[
t_1 = \sqrt{\frac{2S}{a_1}} \quad \text{and} \quad t_2 = \sqrt{\frac{2S}{a_2}}
\]

\[
\therefore \quad \frac{t_1}{t_2} = \sqrt{\frac{a_1}{a_2}} = \sqrt{\frac{g \sin \theta - \mu g \cos \theta}{g \sin \theta}} = \frac{1}{2} \quad \text{(given)}
\]

or \( 1 - \mu \cot \theta = \frac{1}{2} \)

\( \mu \cot \theta = \frac{3}{4} \)

\( \mu = \frac{3}{4} \tan \theta = \frac{3}{4} \tan 45^\circ = 0.75 \)

26. \( 2 \cos^2 \frac{1}{2} = 1 + \cos t \)

we can wrote

\[
y = 2 \times \cos^2 \left( \frac{t}{2} \right) \sin (1000t)
\]

\[
= 2(1 + \cos t) \sin (1000t)
\]

\[
= 2 \sin (1000t) + 2 \cos t \times \sin (1000t)
\]

\[
= 2 \sin (1000t) + \sin (1001t) + \sin 999t
\]

Hence, the given SHM is a resultant of three SH motions of frequencies 999, 1000 and 100 Hz.

27. Here, the effective value of horizontal component of earth's magnetic field is \( B_H \cos 30^\circ \). The real angle of dip \( \theta \) is therefore given by

\[
\tan \theta = \frac{B_V}{B_H} \quad \text{and} \quad \tan 45^\circ = \frac{B_V}{B_H \cos 30^\circ}
\]

\[
\tan \theta = \cos 30^\circ = \frac{\sqrt{3}}{2}
\]

or \( \theta = \tan^{-1} \left( \frac{\sqrt{3}}{2} \right) \)

28. \( \tau = F.R \)

29. The equivalent capacitance \( C \) of the series combination is

\[
\frac{1}{C} = \frac{1}{20} + \frac{1}{30} + \frac{1}{15} = \frac{3}{20}
\]

\[
C = \frac{20}{3} \mu F
\]

Potential difference across this series combination is \((90 - 0) = 90 \text{ V})

Thus charge on the plates of each capacitor is

\[
q = CV = \frac{20}{3} \times 90 \mu C
\]

\[
= 600 \mu C
\]

Potential difference across the plates of 30 \( \mu F \) capacitor

\[
V = \frac{q}{C} = \frac{600 \mu C}{30 \mu F} = 20 \text{ V}
\]

30. For refraction at a single refracting surface

\[
\frac{\mu - 1}{v} = \frac{\mu - 1}{u}
\]

when the object is situated at the first focus, the image will be formed at infinity, i.e., when \( u = f_1 \) then \( v = \infty \)

So,

\[
\mu - \frac{1}{f_1} = \frac{\mu - 1}{R}
\]

\[
\Rightarrow \quad f_1 = -\frac{R}{\mu - 1} \quad \text{(i)}
\]

And for \( u = \infty, \ v = f_2 \)

Therefore,

\[
\frac{\mu - 1}{f_2} = \frac{\mu - 1}{R}
\]

\[
\Rightarrow \quad f_2 = -\frac{\mu R}{\mu - 1} \quad \text{(ii)}
\]

From equations (i) and (ii), we get

\[
f_2 = -\mu f_1 \quad \text{(i)}
\]

31. The constant downward force of pull exerts a torque \( \tau \) on the disc

\[
\tau = F.R \quad \text{(i)}
\]
If I is the moment of inertia of inertia of the disc about its axis of rotation and $\alpha$ is the angular acceleration produced in the disc, then

$$\tau = I \alpha$$

...(ii)

$$F_R = I \frac{a_t}{R}$$

$$I = \frac{1}{2} MR^2$$

$$a_t = \frac{2F}{M}$$

32. The effective value spring constant $k'$ is given by,

$$\frac{1}{k'} = \frac{1}{k} + \frac{1}{2k} + \frac{1}{4k} + \frac{1}{8k} + \ldots \infty$$

$$\frac{1}{k'} = \frac{1}{1 - \frac{1}{2}} = \frac{2}{k}$$

or $\frac{k'}{k} = \frac{1}{2}$

The period of oscillations is

$$T = 2\pi \sqrt{\frac{M}{k'}} = 2\pi \sqrt{\frac{2M}{k}}$$

33. The angular momentum $L$ is directed along the line perpendicular to the plane of the orbit.

34. Since the particle covers the maximum vertical distance in the minimum time, its vertical component of velocity, (i.e., $u \sin \theta$) must be maximum. This is possible when $\theta = 90^\circ$. Here $\theta$ is the angle of projection with the horizontal. Therefore the angle of projection with the vertical is $90^\circ - 90^\circ = 0^\circ$

35. As shown in the adjoining diagram, if the ladder moves down with velocity $u$, then the velocity of the man relative to the ground level is $v-u$. Tension in the rope is same on both sides of the pulley and therefore momentum of both sides will be equal.

36. Let the projectile reaches a height $h$ from the surface of the earth, then its distance from the centre of the earth will be $R+h$.

Using the principle of conservation of energy,

$$\frac{1}{2} mv^2 = \frac{mgh}{1 + \frac{h}{R}}$$

$$\therefore \Delta U = \frac{mgh}{1 + \frac{h}{R}}$$

Given, $v = nv = n\sqrt{2gR}$

$$\frac{1}{2} mn^2 (2gR) = \frac{mgh}{1 + \frac{h}{R}}$$

$$n^2 R = \frac{hR}{h + R}$$
37. \[ PV = \mu RT \]
(for \( \mu \) gm-mole of an ideal gas)
\[ \frac{P}{RT} = \frac{\mu}{V} = \frac{m}{MV} = \frac{\rho}{M} \]
where, \( m \)-mass of the gas and \( M \) its molecular weight.
\[ \therefore \rho \propto \frac{P}{T} \]
\[ \rho_B = \frac{P_B}{P_A} \times \frac{T_A}{T_B} \times \rho_A \]
\[ \rho_B = \frac{2P_B}{P_A} \times \frac{T_0}{3T_0} \rho_A \]
\[ \Rightarrow \rho_B = \frac{2}{3} \rho_A \]

38. For the same field of view,
\[ n_1 \beta_1 = n_2 \beta_2 \]
\[ \Rightarrow n_1 \lambda_1 = n_2 \lambda_2 \]
\[ \therefore n_2 = \frac{\lambda_1}{\lambda_2} n_1 = \frac{5893}{4348} \times 62 = 84 \]

39. The given figure may be shown alternatively as below. The effective capacitance between \( a \) and \( b \) is given by,
\[ C_{ab} = C + \frac{C \times C}{C + C} = C + \frac{3C}{2} \frac{3 \epsilon_0 A}{2 d} \]

40. \[ e^n = \sqrt[n]{\frac{h_n}{h}} \]
where \( h_n \) is height of body it reaches after \( n \)th rebound.
\[ \therefore \]
\[ H = h + 2h e^2 + 2h e^4 + \ldots \]
\[ = h + 2h (1 + e^2 + e^4 + \ldots ) \]
\[ = h + 2h \frac{e^2}{1 - e^2} \]
\[ H = h \left( 1 + \frac{1}{2} \right) = \frac{5}{3} h \]

41. Velocity of efflux \( v = \sqrt{2gh} \)
Time taken by water drops to fall a vertical height of \( (H - h) \)
\[ (H - h) = \frac{1}{2} gt^2 \]
\[ t = \sqrt{\frac{2(H - h)}{g}} \]
Horizontal distance covered by water in time \( t \) with the constant horizontal velocity of \( \sqrt{2gh} \)
\[ R = vt = \sqrt{2gh} \cdot \sqrt{\frac{2(H - h)}{g}} = 2\sqrt{h(H - h)} \]

42. \[ f_1 - f_2 = 4 \]
\[ f_1 = \frac{v}{4 \times 0.45} \]
\[ f_2 = \frac{v}{4 \times 0.46} \]
\[ \frac{v}{4 \times 0.46} - \frac{v}{4 \times 0.46} = 4 \]
\[ v = 331.2 \text{ m/s} \]
\[ f_1 = 184 \text{ Hz} \]
\[ f_2 = 180 \text{ Hz} \]
43. 836 W heater produces \( \frac{836}{4.2} \) cal/s heat.

Let \( t \) be the time taken to heat one litre of water from 10°C to 40°C, then

\[ Q = mS \Delta t \]

\[ \frac{836}{4.2} t = 10^3 \times 1 \times (40 - 10) \] (1 litre = 1000 cm³)

\[ t = \frac{30 \times 4.2 \times 10^3}{836} s \]

\[ = 150 \text{ s} \]

44. \( \frac{0 - 0}{\ell} + \frac{0 - 50}{\ell'} + \frac{0 - 100}{2 \ell} = 0 \)

\( \frac{8K\ell}{4K\ell K\ell} \)

\[ 80 + 4 (\theta - 50) + \frac{0 - 100}{2} = 0 \]

By solving this equation

\[ \theta = 20°C \]

45. \[ i^2 = \int_{t_0}^{t_f} i(t)^2 dt \]

\[ = \frac{4}{2} \left( \frac{t}{2} \right)^4 = 12 \]

\[ i_{\text{rms}} = \sqrt{i^2} = \sqrt{12} = 2\sqrt{3} \text{A} \]

46. In \( \text{CO}_3^2^- \) the oxidation state of C = +4. Which is maximum. So, it will not be oxidised.

47. (A) Poling = Cu, Sn
(B) Cuppellation = Ag
(C) Electrorefining = Cu, Ag, Au, Al, Pb, Sn etc.
(D) Van Arkel Method = Ti, Zr, Si

48. \( \text{H} - \text{C} \overset{\text{O}}{\leftrightarrow} \text{H} - \text{C} \overset{\text{O}}{\leftrightarrow} \), B.O. = \( \frac{2+1}{2} = 1.5 \)

\[ \begin{bmatrix}
  \text{O} & \text{C} & \text{O} \\
  \text{O} & \text{C} & \text{O} \\
  \text{O} & \text{C} & \text{O}
\end{bmatrix}, \]

B.O. = \( \frac{2+1+1}{2} = \frac{4}{2} = 1.33 \)

50. region-1 = unburnt gas & air
region-2 = hottest part of flame (intense combustion)
region-3 = incomplete combustion (reactive gases)
region-4 = complete combustion

53. Yb = [Xe]4f¹⁴ 5d¹⁰6s²
Lu = [Xe]4f¹⁴ 5d¹⁰6s²

55. \( \text{H}^+ \text{PO}_2^- \) (hypophosphorous acid)

57. The structure of \( \text{NO}_3^- \)

58. \( \text{NO} \rightarrow \text{NO}^+ + \text{e}^- \) (charge transfer)
\( \text{Fe}^{2+} + \text{e}^- \rightarrow \text{Fe}^+ \)
\( \text{Fe}^+ [\text{Ar}]3d^6 \)
\( \text{Fe}^+ [\text{Ar}]3d^6 \)

3 unpaired

59. \( \text{I}_2(s) + \text{H}_2\text{O}_2(aq) + 2\text{OH}^-(aq) \rightarrow 2\text{I}^-(aq) + 2\text{H}_2\text{O}^- + \text{O}_2(g) \)

60. \( \text{F} \text{e} \text{Xe} \text{O} \)

BP = 5
\( \ell / p = 0 \)

5 = sp³d = trigonal bipyramidal