PAPER 2

PHYSICS

One or More options Correct Type

This section contains **8 multiple choice questions**. Each question has four choices (A), (B), (C) and (D) out of which **ONE or MORE** are correct.

1. Two bodies, each of mass M, are kept fixed with a separation $2L$. A particle of mass m is projected from the mid-point of the line joining their centres, perpendicular to the line. The gravitational constant is G. The correct statement(s) is(are)

(A) The minimum initial velocity of the mass m to escape the gravitational field of the two bodies is $4\sqrt{\frac{GM}{L}}$.

(B) The minimum initial velocity of the mass m to escape the gravitational field of the two bodies is $2\sqrt{\frac{GM}{L}}$.

(C) The minimum initial velocity of the mass m to escape the gravitational field of the two bodies is $\sqrt{\frac{2GM}{L}}$.

(D) The energy of the mass m remains constant.

Solution

We have

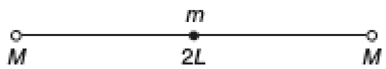
Loss in gravitational P.E. = Gain in K.E.

Therefore,

$$0-\left[-\frac{GMm}{L}\right]\times 2=\frac{1}{2}mv^2-\frac{1}{2}mx0^2$$

$$\Rightarrow \frac{GMm}{L}\times 2=\frac{1}{2}mv^2$$

$$\Rightarrow v^2=\frac{4GM}{L}\Rightarrow v=\sqrt{\frac{4GM}{L}}\Rightarrow v=2\sqrt{\frac{GM}{L}}$$



Also, the energy of mass m keeps on changing as it proceeds towards infinity.

Hence, the correct options are (B) and (D).

2. A particle of mass m is attached to one end of a massless spring of force constant k, lying on a frictionless horizontal plane. The other end of the spring is fixed. The particle starts moving horizontally from its equilibrium position at time $t = 0$ with an initial velocity u_0. When the speed of the particle is $0.5u_0$, it collides elastically with a rigid wall. After this collision,

(A) the speed of the particle when it returns to its equilibrium position is u_0.

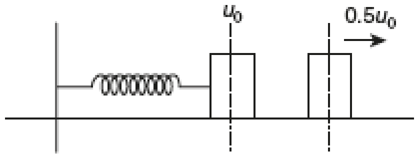
(B) the time at which the particle passes through the equilibrium position for the first time is $t=\pi\sqrt{\frac{m}{k}}$.

(C) the time at which the maximum compression of the spring occurs is $t=\frac{4\pi}{3}\sqrt{\frac{m}{k}}$.

(D) the time at which the particle passes through the equilibrium position for the second time is $t=\frac{5\pi}{3}\sqrt{\frac{m}{k}}$.

Solution

According to conservation of energy, option (A) is correct.



Now, we have the displacement as $x = A\sin\omega t$.

$$v = \frac{dx}{dt} = A\omega\cos\omega t$$

$$\frac{u_0}{2} = u_0\cos\omega t$$

$$\Rightarrow \cos\omega t = \frac{1}{2} \Rightarrow \omega t = \frac{\pi}{3} \Rightarrow t = \frac{\pi}{3\omega}$$

Time taken to reach the wall $= \frac{\pi}{3\omega} = \frac{T}{6}$ as $T = \frac{2\pi}{\omega}$

Time taken to reach the wall and return back = $\frac{T}{6} + \frac{T}{6} = \frac{T}{3} = \frac{2\pi}{3\omega} \Rightarrow \frac{2\pi}{3}\sqrt{\frac{m}{k}}$, as $\omega = \sqrt{\frac{k}{m}}$

Hence, option (B) is wrong.

Maximum compression will occur at time

$$\frac{T}{3} + \frac{T}{4} = \frac{2\pi}{3}\sqrt{\frac{m}{k}} + \frac{\pi}{2}\sqrt{\frac{m}{k}} = \frac{7\pi}{6}\sqrt{\frac{m}{k}}$$

Hence, option (C) is also wrong.

The time at which the particle passes through the equilibrium position for the second time is

$$\frac{T}{3} + \frac{T}{2} = \frac{5T}{6} = \frac{2\pi}{3}\sqrt{\frac{m}{k}} + \frac{2\pi}{2}\sqrt{\frac{m}{k}} = \frac{5\pi}{3}\sqrt{\frac{m}{k}},$$

Hence, option (D) is correct.

Hence, the correct options are (A) and (D).

3. A steady current I flows along an infinitely long hollow cylindrical conductor of radius R. This cylinder is placed coaxially inside an infinite solenoid of radius $2R$. The solenoid has n turns per unit length and carries a steady current I. Consider a point P at a distance r from the common axis. The correct statement(s) is(are)

(A) In the region $0 < r < R$, the magnetic field is non-zero.

(B) In the region $R < r < 2R$, the magnetic field is along the common axis.

(C) In the region $R < r < 2R$, the magnetic field is tangential to the circle of radius r, centred on the axis.

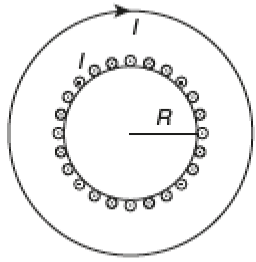
(D) In the region $r > 2R$, the magnetic field is non-zero.

Solution

1. We know that

(i) For a cylinder, $B = 0$ for $0 < r < R$ and $B = \frac{\mu_0}{4\pi} \times \frac{2I}{r}$ for $r > R$.

(ii) For a solenoid, $B = \mu_0 nI$ for $0 < r < R$ and $B = 0$ for $r > R$.



- Assuming that the magnetic induction to be B_C for cylinder and B_S for solenoid.
  In the region $R > r > 0$, $B_S = \mu_0 nI$ while $B_C = 0$. Therefore, the total field is non-zero.

Hence, option (A) is correct.

- In the region $2R > r > R$, the magnetic field is not along the axis of cylinder which is given as

$$B = \sqrt{B_S^2 + B_C^2}$$

Hence, option (B) is wrong.

- For checking option (C), in the region $R < r < 2R$, the magnetic field is tangential to the circle of radius r, centred on the axis. So this statement is wrong because magnetic field is not in the plane of circle.
Hence, option (C) is wrong.

- In the region $r > 2$, $B_S = 0$; while $B_C = \frac{\mu_0}{4\pi} \times \frac{2I}{r}$. Therefore total field is non-zero.

Hence, option (D) is correct.

Hence, the correct options are (A) and (D).

4. Two vehicles, each moving with speed u on the same horizontal straight road, are approaching each other. Wind blows along the road with velocity w. One of these vehicles blows a whistle of frequency f_1. An observer in the other vehicle hears the frequency of the whistle to be f_2. The speed of sound in still air is V. The correct statement(s) is(are)
(A) If the wind blows from the observer to the source, $f_2 > f_1$.
(B) If the wind blows from the source to the observer, $f_2 > f_1$.
(C) If the wind blows from the observer to the source, $f_2 < f_1$.
(D) If the wind blows from the source to the observer, $f_2 < f_1$.

Solution

If the wind blows from the observer to the source, then

$$f_2 = \left(\frac{V - w + u}{V - w - u}\right) f_1$$

we conclude that $f_2 > f_1$, therefore option (A) is correct.

If the wind blows from the source to the observer

$$f_2 = \left(\frac{V + w + u}{V + w - u}\right) f_1$$

Thus, from the above relation, we get $f_2 > f_1$; therefore, option (B) is also correct.
Hence, the correct options are (A) and (B).

5. Using the expression $2d\sin\theta = \lambda$, one calculates the values of d by measuring the corresponding angles θ in the range 0° to 90°. The wavelength λ is exactly known and the error in θ is constant for all values of θ. As θ increases from 0°,
(A) the absolute error in d remains constant.
(B) the absolute error in d increases.
(C) the fractional error in d remains constant.
(D) the fractional error in d decreases.

Solution

Now the given expression is

$$2d\sin\theta = \lambda \Rightarrow d = \frac{\lambda}{2\sin\theta}$$

$$\left|\frac{d}{d\theta}(d)\right| = \frac{\lambda}{2}\left|\operatorname{cosec}\theta \cot\theta\right|$$

$$\Rightarrow |d(d)| = \frac{\lambda}{2}\left|\operatorname{cosec}\theta \cot\theta \, d\theta\right|$$

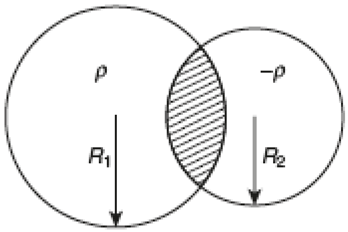
Absolute error in d decreases with increase in θ because cosec θ and cot θ decrease with increase in θ. Hence,

$$\left|\frac{d(d\theta)}{d}\right| = \left|\cot\theta \, d\theta\right|$$

Fractional error decreases with increase in θ.

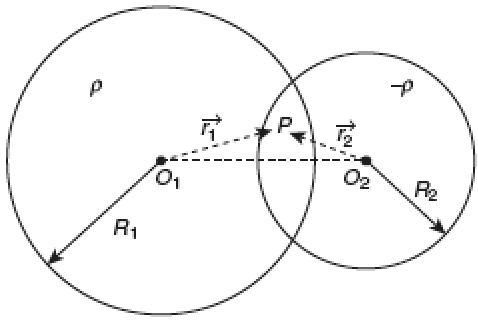
Hence, the correct option is (D).

6. Two non-conducting spheres of radius R_1 and R_2 and carrying uniform volume charge densities $+\rho$ and $-\rho$, respectively, are placed such that they partially overlap, as shown in the figure. At all points in the overlapping region,
(A) the electrostatic field is zero.
(B) the electrostatic potential is constant.
(C) the electrostatic field is constant in magnitude.
(D) the electrostatic field has same direction.



Solution

Let $O_1O_2 = a$ = Constant. Let P be a point in the overlapping region



In ΔO_1PO_2, the triangular law of vector addition gives

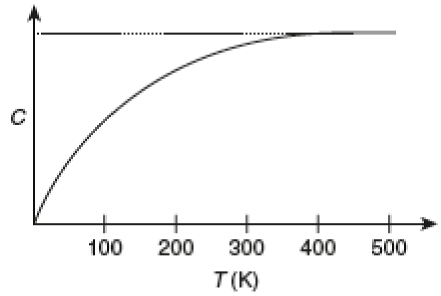
$$\vec{a} + \vec{r}_2 = \vec{r}_1 \Rightarrow \vec{a} = \vec{r}_1 - \vec{r}$$

Also, $$\vec{E}_1 = \frac{\rho \vec{r}_1}{3E_0} \text{ and } \vec{E}_2 = \frac{-\rho \vec{r}_2}{3E_0}$$

Therefore, $$\vec{E}_P = \vec{E}_1 + \vec{E}_2 = \frac{\rho}{3E_0}(\vec{r}_1 - \vec{r}_2) = \frac{\rho \vec{a}}{3E_0} = \text{Constant}$$

Hence, the correct options are (C) and (D).

7. The figure below shows the variation of specific heat capacity (C) of a solid as a function of temperature (T).The temperature is increased continuously from 0 to 500 K at a constant rate. Ignoring any volume change, the following statement(s) is(are) correct to a reasonable approximation.



(A) The rate at which heat is absorbed in the range 0–100 K varies linearly with temperature T.
(B) Heat absorbed in increasing the temperature from 0–100 K is less than the heat required for increasing the temperature from 400–500 K.
(C) There is no change in the rate of heat absorption in the range 400–500 K.
(D) The rate of heat absorption increases in the range 200–300 K.

Solution

Using the relation

$$dQ = mCdT \Rightarrow \frac{dQ}{dT} = mC$$

we can observe that, for 0 K < T < 100 K, the graph is linear

$$\Delta Q = m\int CdT = m \times \text{Area under } C\text{–}T \text{ graph}$$

For 400–500 K, the area is more than that for 0–100 K. Therefore, $\frac{dQ}{dt}$ increases for 200 K < T < 300 K and C increases in this region.

Hence, the correct options are (A), (B), (C) and (D).

8. The radius of the orbit of an electron in a hydrogen-like atom is $4.5a_0$, where a_0 is the Bohr radius. Its orbital angular momentum is $\frac{3h}{2\pi}$. It is given that h is Planck constant and R is Rydberg constant. The possible wavelength(s), when the atom de-excites, is(are)

(A) $\frac{9}{32R}$

(B) $\frac{9}{16R}$

(C) $\frac{9}{5R}$

(D) $\frac{4}{3R}$

Solution

The orbital angular momentum is

$$L = \frac{nh}{2\pi}$$

$$\frac{3h}{2\pi} = \frac{nh}{2\pi} \Rightarrow n = 3$$

The radius of the orbit is

$$4.5(a_0) = a_0\left(\frac{n^2}{Z}\right)$$

$$Z = \frac{n^2}{4.5} = \frac{3^2}{4.5} = \frac{9}{4.5} = 2$$

Thus, the possible transitions are 3→2, 3→1 and 2→1. For the transition 3→2, the wavelength is

$$\frac{1}{\lambda} = R(2)^2\left[\frac{1}{4} - \frac{1}{9}\right] = 4R\left[\frac{9-4}{36}\right] = \frac{5R}{9}$$

$$\Rightarrow \lambda = \frac{9}{5R}$$

For the transition 3 → 1, the wavelength is

$$\frac{1}{\lambda} = R(2)^2\left[1 - \frac{1}{9}\right] = 4R\left(\frac{8}{9}\right) = \frac{32R}{9}$$

$$\Rightarrow \lambda = \frac{9}{32R}$$

For the transition 2→ 1, the wavelength is

$$\frac{1}{\lambda} = R(2)^2\left[1 - \frac{1}{4}\right] = 4R\left(\frac{3}{4}\right) = 3R$$

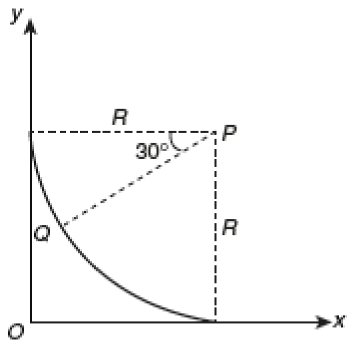
$$\Rightarrow \lambda = \frac{1}{3R}$$

Hence, the correct options are (A) and (C).

Paragraph Type

This section contains **4 paragraphs** each describing theory, experiment, data etc. There are **eight questions** related to four paragraphs with two questions on each paragraph. Each question of a paragraph has **only one correct answer** among the four choices (1), (2), (3) and (4).

Paragraph for Questions 9 and 10: A small block of mass 1 kg is released from rest at the top of a rough track. The track is a circular arc of radius 40 m. The block slides along the track without toppling and a frictional force acts on it in the direction opposite to the instantaneous velocity. The work done in overcoming the friction up to the point Q, as shown in the figure below, is 150 J. (Take the acceleration due to gravity, g = 10 ms^{-2})



9. The speed of the block when it reaches the point Q is

(A) 5 ms^{-1} (B) 10 ms^{-1}

(C) $10\sqrt{3}$ ms^{-1} (D) 20 ms^{-1}

Solution

The loss in potential energy is used in doing work against friction and increasing kinetic energy.

$$mgR\sin 30° = mg\frac{R}{2} = W + \frac{1}{2}mv^2$$

$$1\times 10\times\frac{40}{2} = 150 + \left(\frac{1}{2}\times 1\times v^2\right)$$

$$v^2 = 100$$

$$v = 10 \text{ m/s}$$

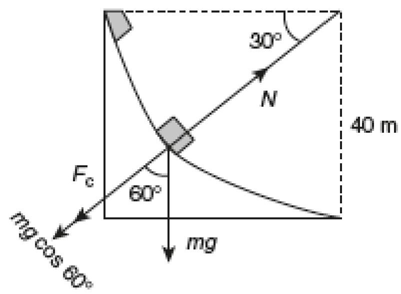
Hence, the correct option is (B).

10. The magnitude of the normal reaction that acts on the block at the point Q is

(A) 7.5 N (B) 8.6 N

(C) 11.5 N (D) 22.5 N

Solution



$$N = mg\cos 60^\circ + \frac{mv^2}{r}$$

$$N = 1\times 10\times\frac{1}{2} + \frac{1\times 100}{40}$$

$$N = 7.5 \text{ N}$$

Hence, the correct option is (A).

Paragraph for Questions 11 and 12: A thermal power plant produces electric power of 600 kW at 4000 V, which is to be transported to a place 20 km away from the power plant for consumers' usage. It can be transported either directly with a cable of large current carrying capacity or by using a combination of step-up and step-down transformers at the two ends. The drawback of the direct transmission is the large energy dissipation. In the method using transformers, the dissipation is much smaller. In this method, a step-up transformer is used at the plant side so that the current is reduced to a smaller value. At the consumers' end, a step-down transformer is used to supply power to the consumers at the specified lower voltage. It is reasonable to assume that the power cable is purely resistive and the transformers are ideal with power factor unity. All the currents and voltages mentioned are rms values.

11. If the direct transmission method with a cable of resistance 0.4 $\Omega\ km^{-1}$ is used, the power dissipation (in %) during transmission is

(A) 20
(B) 30
(C) 40
(D) 50

Solution

Power P = 600 kW
Potential difference V = 4000 V
Total resistance = 0.4 × 20 = 8 Ω

$$P = Vi$$

$$600 \times 10^3 = 4000 \times i$$

$$i = \frac{600}{4} = 150\ \text{A}$$

Now using the relation for power

$$P = i^2 R$$

$$= (150)^2 \times 8 = 22500 \times 8 = 180000\ \text{W} = 180\ \text{kW}$$

$$\%\ \text{loss} = \frac{180}{600} \times 100 = 30\%$$

Hence, the correct option is (B).

12. In the method using the transformers, assume that the ratio of the number of turns in the primary to that in the secondary in the step-up transformer is 1:10. If the power to the consumers has to be supplied at 200 V, the ratio of the number of turns in the primary to that in the secondary in the step-down transformer is

(A) 200:1
(B) 150:1
(C) 100:1
(D) 50:1

Solution

The ratio of the number of turns in the primary to that in the secondary in the step-up transformer is

$$\frac{N_S}{N_P} = 1:10$$

Now, using the relation

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

$$\frac{V_S}{4000} = \frac{10}{1} \quad \Rightarrow V_S = 40,000\ \text{V}$$

Now the required ratio is

$$\frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{40,000}{200} = 200:1$$

Hence, the correct option is (A).

Paragraph for Questions 13 and 14: A point charge Q is moving in a circular orbit of radius R in the x–y plane with an angular velocity ω. This can be considered as equivalent to a loop carrying a steady current $\frac{Q\omega}{2\pi}$. A uniform magnetic field along the positive z-axis is now switched on, which increases at a constant rate from

0 to B in one second. Assume that the radius of the orbit remains constant. The application of the magnetic field induces an emf in the orbit. The induced emf is defined as the work done by an induced electric field in moving a unit positive charge around a closed loop. It is known that, for an orbiting charge, the magnetic dipole moment is proportional to the angular momentum with a proportionality constant γ.

13. The magnitude of the induced electric field in the orbit at any instant of time during the time interval of the magnetic field change is

(A) $\frac{BR}{4}$ (B) $\frac{BR}{2}$

(C) BR (D) $2BR$

Solution

Induced electric field is

$$\oint \vec{E}\cdot d\vec{l} = -\frac{d\phi}{dt}$$

$$\oint \vec{E}\cdot d\vec{l} = -A\frac{dB}{dt}$$

$$\oint \vec{E}\cdot d\vec{l} = AB \qquad \left(\because \frac{dB}{dt} = B \quad \text{given}\right)$$

Therefore, the magnitude of the induced emf is

$$E\times 2\pi R = \pi R^2 \times B$$

$$E = \frac{\pi R^2 \times B}{2\pi R}$$

$$E = \frac{BR}{2}$$

Hence, the correct option is (B).

14. The change in the magnetic dipole moment associated with the orbit, at the end of the time interval of the magnetic field change, is

(A) $-\gamma BQR^2$ (B) $-\gamma\frac{BQR^2}{2}$

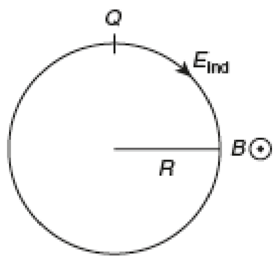
(C) $\gamma\frac{BQR^2}{2}$ (D) γBQR^2

Solution

The magnetic field B is along positive z-axis. Hence

$$M = \gamma L = \gamma m\omega R^2$$

(where m is the mass of charged particle.)



M will change due to change in ω. Change in ω is given by

$$\tau = \frac{dL}{dt} = FR = QER \;= Q\left(\frac{BR}{2}\right)R \qquad \left(\text{we know } E = \frac{BR}{2}\right)$$

$$L = \frac{M}{\gamma}$$

$$\frac{dL}{dt} = \frac{dM}{\gamma}$$

$$dM = \gamma\frac{dL}{dt} = -\gamma Q\left(\frac{BR}{2}\right)R = -\gamma\left(\frac{QBR^2}{2}\right)$$

The negative sign shows change is opposite to direction of *B*.

Hence, the correct option is (B).

Paragraph for Questions 15 and 16: The mass of a nucleus $^{A}_{Z}X$ is less than the sum of the masses of (*A*–*Z*) number of neutrons and *Z* number of protons in the nucleus. The energy equivalent to the corresponding mass difference is known as the binding energy of the nucleus. A heavy nucleus of mass *M* can break into two light nuclei of masses m_1 and m_2 only if $(m_1 + m_2) < M$. Also two light nuclei of masses m_3 and m_4 can undergo complete fusion and form a heavy nucleus of mass M' only if $(m_3 + m_4) > M'$. The masses of some neutral atoms are given in the table below:

$^{1}_{1}$H	1.007825 u	$^{2}_{1}$H	2.014102 u	$^{3}_{1}$H	3.016050 u	$^{4}_{2}$He	4.002603 u
$^{6}_{3}$Li	6.015123 u	$^{7}_{3}$Li	7.016004 u	$^{70}_{30}$Zn	69.925325 u	$^{82}_{34}$Se	81.916709 u
$^{152}_{64}$Gd	151.919803 u	$^{206}_{82}$Pb	205.974455 u	$^{209}_{83}$Bi	208.980388 u	$^{210}_{84}$Po	209.982876 u

(1 u = 932 MeV/c^2)

15. The correct statement is

(A) the nucleus $^{6}_{3}$Li can emit an alpha particle.

(B) the nucleus $^{210}_{84}$Po can emit a proton.

(C) deuteron and alpha particle can undergo complete fusion.

(D) the nuclei $^{70}_{30}$Zn and $^{82}_{34}$Se can undergo complete fusion.

Solution

We have

$$m(^{2}_{1}\text{H}) + m(^{4}_{2}\text{He}) = 2.014102 + 4.002603 = 6.016705\text{ u}$$

$$m(^{6}_{3}\text{Li}) = 6.015123\text{ u}$$

$$m_1 + m_2 > M$$

Thus, option (A) is wrong.

$$m(^{1}_{1}\text{H}) + m(^{209}_{83}\text{Bi}) = 1.007825\text{ u} + 208.980388\text{ u} = 209.988213\text{ u}$$

$$m(^{210}_{84}\text{Po}) = 209.982876\text{ u}$$

$$m_1 + m_2 > M$$

Thus, option (B) is wrong.

$$m(^{2}_{1}\text{H}) + m(^{4}_{2}\text{He}) = 2.014102\text{ u} + 4.002603\text{ u} = 6.016705\text{ u}$$

$$^{6}_{3}\text{Li} = 6.015123\text{ u}$$

$$(m_3 + m_4) > M'$$

Thus, option (C) is correct. Therefore, deuteron and alpha particle can go complete fusion.

$$m(^{70}_{30}\text{Zn}) + ^{82}_{34}\text{Se} = 69.925325\text{ u} + 81.916709\text{ u} = 151.842034\text{ u}$$

$$^{152}_{64}\text{Gd} = 151.919803\text{ u}$$

$$m_3 + m_4 < M'$$

Thus, option (D) is wrong.

Hence, the correct option is (C).

16. The kinetic energy (in keV) of the alpha particle, when the nucleus $^{210}_{84}\text{Po}$ at rest undergoes alpha decay, is

(A) 5319 (B) 5422
(C) 5707 (D) 5818

Solution

When the nucleus $^{210}_{84}\text{Po}$ at rest undergoes alpha decay, the following reaction takes place

$$^{210}_{84}\text{Po} \rightarrow ^{206}_{82}\text{Pb} + ^{4}_{2}\text{He} + \Delta E$$

$$m(^{206}_{82}\text{Pb}) = 205.974455\text{ u}$$
$$m(^{4}_{2}\text{He}) = 4.002603\text{ u}$$
$$m(^{206}_{82}\text{Pb}) + m(^{4}_{2}\text{He}) = 209.977058\text{ u}$$

The mass defect is

$$\Delta m = 209.982876\text{ u} - 209.977058\text{ u} = 0.005818\text{ u}$$
$$\Delta E = 0.005818 \times 932$$
$$= 5.422467\text{ MeV} = 5422.467\text{ keV}$$
$$= 5422.5\text{ keV}$$

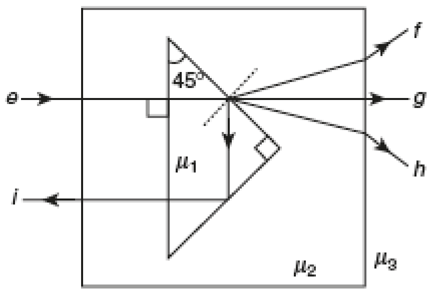
This energy will be shared by recoil nucleus and alpha particle in the ratio $\frac{4}{210}$ for nucleus and $\frac{206}{210}$ for alpha particle $\frac{206}{210} \times 5422 = 5319$ keV.

Hence, the correct option is (A).

Matching List Type

This section contains **4 multiple choice questions**. **Each question has matching lists**. The codes for the lists have choices (A), (B), (C) and (D) out of which **ONLY ONE** is correct.

17. A right-angled prism of refractive index μ_1 is placed in a rectangular block of refractive index μ_2, which is surrounded by a medium of refractive index μ_3, as shown in the figure. A ray of light *e* enters the rectangular block at normal incidence. Depending upon the relationships between μ_1, μ_2 and μ_3, it takes one of the four possible paths '*ef*', '*eg*', '*eh*' or '*ei*'.



Match the paths in List I with conditions of refractive indices in List II and select the correct answer using the codes given below the lists:

List I	List II
(P) $e \rightarrow f$	(1) $\mu_1 > \sqrt{2}\mu_2$
(Q) $e \rightarrow g$	(2) $\mu_2 > \mu_1$ and $\mu_2 > \mu_3$
(R) $e \rightarrow h$	(3) $\mu_1 = \mu_2$
(S) $e \rightarrow i$	(4) $\mu_2 < \mu_1 < \sqrt{2}\mu_2$ and $\mu_2 > \mu_3$

Codes:

	(P)	(Q)	(R)	(S)
(A)	2	3	1	4
(B)	1	2	4	3
(C)	4	1	2	3
(D)	2	3	4	1

Solution

We have the following results:

- For path $e \to f$: $\mu_2 > \mu_1$ and $\mu_3 < \mu_2$. Thus, the correct mapping is (P)→(2).
- For path $e \to g$: $\mu_1 = \mu_2$ (no bending). Therefore, the correct mapping is (Q)→(3).
- For $e \to h$: $\mu_2 < \mu_1$ and $\mu_3 < \mu_2$. Also, $\mu_1 < \sqrt{2}\mu_2$ (no total internal reflection). Thus, the correct mapping is (R) → (4).
- For $e \to i$, the total internal reflection occurs, that is, $\sin 45° > \frac{\mu_2}{\mu_1} \Rightarrow \mu_1 > \sqrt{2}\mu_2$. Therefore, the correct mapping is (S)→(1).

Hence, the correct option is (D).

18. Match List I with List II and select the correct answer using the codes given below the lists:

List I	List II
(P) Boltzmann constant	(1) $[ML^2T^{-1}]$
(Q) Coefficient of viscosity	(2) $[ML^{-1}T^{-1}]$
(R) Planck constant	(3) $[MLT^{-3}K^{-1}]$
(S) Thermal conductivity	(4) $[ML^2T^{-2}K^{-1}]$

Codes:

	(P)	(Q)	(R)	(S)
(A)	3	1	2	4
(B)	3	2	1	4
(C)	4	2	1	3
(D)	4	1	2	3

Solution

The dimensions of Boltzmann constant are

$$[k] = [ML^2T^{-2}K^{-1}]$$

Thus, the correct mapping is (P)→(4).

The dimensions of coefficient of viscosity are

$$[\eta] = [ML^{-1}T^{-2}][T] = [ML^{-1}T^{-1}]$$

Thus, the correct mapping is (Q)→(2).

The dimensions of Planck constant are

$$[h] = [ML^2T^{-2}][T] = [ML^2T^{-1}]$$

Thus, the correct mapping is (R)→(1).

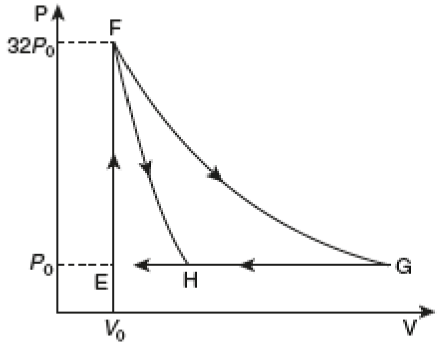
The dimensions of thermal conductivity are

$$[k] = \frac{[ML^2T^{-3}]}{[L][K]} = [ML^1T^{-3}K^{-1}]$$

Thus the correct mapping is (S)→(3).

Hence, the correct option is (C).

19. One mole of a monatomic ideal gas is taken along two cyclic processes E→F→G→E and E→F→H→E as shown in the *PV* diagram. The processes involved are purely isochoric, isobaric, isothermal or adiabatic.



Match the paths in List I with the magnitudes of the work done in List II and select the correct answer using the codes given below the lists.

List I	List II
(P) G→E	(1) $160P_0V_0\ln 2$
(Q) G→H	(2) $36P_0V_0$
(R) F→H	(3) $24P_0V_0$
(S) F→G	(4) $31P_0V_0$

Codes:

	(P)	(Q)	(R)	(S)
(A)	4	3	2	1
(B)	4	3	1	2
(C)	3	1	2	4
(D)	1	3	2	4

Solution

From the given figure, it can be concluded that process FG is isothermal and process FH is adiabatic.

$$\gamma_{\text{mono}} = 1 + \frac{2}{f} = \frac{5}{3}$$

$$P_0 V_G^{5/3} = 32 P_0 V_0^{5/3}$$

$$V_G = (32)^{3/5} V_0 = 8V_0$$

$$\Delta W_{GE} = P_0(V_0 - 32V_0) = -31P_0V_0$$

Thus, the correct mapping is (P)→(4).

$$\Delta W_{GH} = P_0(8V_0 - 32V_0) = -24P_0V_0$$

Thus the correct mapping is (Q)→(3).

$$\Delta W_{FH} = \frac{P_0(8V_0) - 32P_0V_0}{1-(5/3)} = \frac{-24P_0V_0}{-(2/3)} = 36P_0V_0$$

Thus the correct mapping is (R)→(2).

$$\Delta W_{FG} = 32RT_0 \ln 32 = 32RT_0 \ln 2^5 = 160RT_0 \ln 2 = 160P_0V_0 \ln 2$$

Thus the correct mapping is (S)→(1).

Hence, the correct option is (A).

20. Match List I of the nuclear processes with List II containing parent nucleus and one of the end products of each process and then select the correct answer using the codes given below the lists:

List I	**List II**
(P) Alpha decay	(1) ${}^{15}_{8}O \rightarrow {}^{15}_{7}N + \cdots$
(Q) β^{+} decay	(2) ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + \cdots$
(R) Fission	(3) ${}^{185}_{83}Bi \rightarrow {}^{184}_{82}Pb + \cdots$
(S) Proton emission	(4) ${}^{239}_{94}Pu \rightarrow {}^{140}_{57}La + \cdots$

Codes:

	P	Q	R	S
(A)	4	2	1	3
(B)	1	3	2	4
(C)	2	1	4	3
(D)	4	3	2	1

Solution

In alpha decay, charge number decreases by 2 and mass number decreases by 4. Therefore, the equation

$$ {}^{238}_{92}U \rightarrow {}^{234}_{90}Th + \cdots $$

represents an alpha decay.
Thus, correct mapping is (P)→(2).
In B^{+} decay, charge number decreases by 1 and mass number remains same. Thus, the equation

$$ {}^{15}_{8}O \rightarrow {}^{15}_{7}N + \cdots $$

represents beta decay.
Thus, the correct mapping is (Q)→(1).
The fission reaction is ${}^{239}_{94}Pu \rightarrow {}^{140}_{57}La + \cdots$
Thus, correct mapping is (R)→(4).
In proton emission, charge number decreases by 1 and mass number decreases by 1. Therefore, the equation

$$ {}^{185}_{83}Bi \rightarrow {}^{184}_{82}Pb + \cdots $$

represents proton emission.
Thus, the correct mapping is (S)→(3)
Hence, the correct option is (C).