

**NEET 2017  
PHYSICS**

1. Two astronauts are floating in gravitational free space after having lost contact with their spaceship. The two will
- (1) move towards each other.
  - (2) move away from each other.
  - (3) will become stationary.
  - (4) keeping floating at the same distance between them.

**Solution: (1)** The two astronauts move towards each other due to the gravitational force between them; however, it is a very slow process due to their lesser mass.

2. Young's double-slit experiment is first performed in air and then in a medium other than air. It is found that 8th bright fringe in the medium lies where 5th dark fringe lies in air. The refractive index of the medium is nearly
- (1) 1.59
  - (2) 1.69
  - (3) 1.78
  - (4) 1.25

**Solution: (3)** Let us consider the following two cases:

$$x_1 = x_{5^{\text{th dark}}} = (2 \times 5 - 1) \frac{\lambda D}{2d} \quad (1)$$

$$x_2 = x_{8^{\text{th dark}}} = \frac{8\lambda D}{\mu d} \quad (2)$$

Now,

$$x_1 = x_2$$

$$\frac{a}{2} \frac{\lambda D}{d} = \frac{8\lambda D}{\mu d}$$

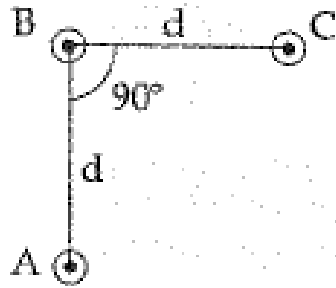
$$\Rightarrow \mu = \frac{16}{9} = 1.78$$

3. In a common-emitter transistor amplifier, the audio signal voltage across the collector is 3 V. The resistance of collector is 3 k $\Omega$ . If current gain is 100 and the base resistance is 2 k $\Omega$ , the voltage and power gain of the amplifier is
- (1) 15 and 200
  - (2) 150 and 15,000
  - (3) 20 and 2000
  - (4) 200 and 1000

**Solution: (2)** We have the following:

- Current gain is 100.
- **Voltage gain:**  $(A_v) = \beta \frac{R_c}{R_b} = 100 \left( \frac{3}{2} \right) = 150$
- **Power gain:**  $A_v \beta = 150 \times 100 = 15,000$

4. An arrangement of three parallel straight wires placed perpendicular to plane of paper carrying same current  $I$  along the same direction is shown in the figure. Magnitude of force per unit length on the middle wire  $B$  is given by:



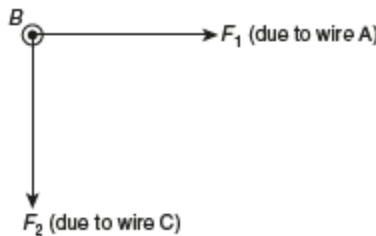
- (1)  $\frac{2\mu_0 I^2}{\pi d}$                       (2)  $\frac{\sqrt{2}\mu_0 I^2}{\pi d}$   
 (3)  $\frac{\mu_0 I^2}{\sqrt{2}\pi d}$                       (4)  $\frac{\mu_0 I^2}{2\pi d}$

**Solution: (3)** The force per unit length is

$$F = \frac{\mu_0 I_1 I_2}{2\pi d}$$

Now,

$$F_1 = \frac{(\mu_0 I) I}{2\pi d} = \frac{\mu_0 I^2}{2\pi d} = F_2$$



Therefore, at the middle wire  $B$ , the net force per unit length is

$$F_{\text{net}} = \sqrt{F_1^2 + F_2^2} = \frac{\mu_0 I^2}{\sqrt{2}\pi d}$$

5. The de Broglie wavelength of a neutron in thermal equilibrium with heavy water at a temperature  $T$  (Kelvin) and mass  $m$  is

- (1)  $\frac{h}{\sqrt{3mkT}}$                       (2)  $\frac{2h}{\sqrt{3mkT}}$   
 (3)  $\frac{2h}{\sqrt{mkT}}$                       (4)  $\frac{h}{\sqrt{mkT}}$

**Solution: (1)** From basic concepts, the kinetic energy of thermal neutron with equilibrium is  $\frac{3}{2}kT$ .

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mkE}} = \frac{h}{\sqrt{2m\left(\frac{3}{2}kT\right)}} = \frac{h}{\sqrt{3mkT}}$$

6. Radioactive material A has decay constant  $8\lambda$  and material B has decay constant  $\lambda$ . Initially, they have same number of nuclei. After what time, the ratio of number of nuclei of material B to that A will be  $1/e$ ?

- (1)  $\frac{1}{7\lambda}$  (2)  $\frac{1}{8\lambda}$   
 (3)  $\frac{1}{9\lambda}$  (4)  $\frac{1}{\lambda}$

**Solution: (1)** The decay constants of the two-given radioactive materials A and B are  $\lambda_A = 8\lambda$  and  $\lambda_B = \lambda$ , respectively.

Therefore, as initially, both radioactive materials have the same number of nuclei, we have the relation between the radiative decay between these two materials is

$$N_B = \frac{N_A}{e}$$

That is,  $N_0 e^{-\lambda t} = \frac{N_0 e^{-8\lambda t}}{e}$

$$-\lambda t = -8\lambda t - 1$$

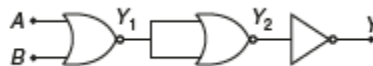
$$7\lambda t = -1 \Rightarrow t = \frac{-1}{7\lambda}$$

7. The given electrical network is equivalent to



- (1) OR gate (2) NOR gate  
 (3) NOT gate (4) AND gate

**Solution: (2)** The given electrical network is depicted in the following figure:



Therefore,

$$Y_1 = \overline{A + B}$$

$$Y_2 = \overline{Y_1} = \overline{\overline{A + B}} = A + B$$

Thus, the output of the given electrical network is

$$Y = \overline{Y_2} = \overline{A + B}$$

which satisfies a NOR gate.

8. The resistance of a wire is  $R$  ohm. If it is melted and stretched to  $n$  times its original length, its new resistance will be

- (1)  $\frac{R}{n}$  (2)  $n^2R$   
 (3)  $\frac{R}{n^2}$  (4)  $nr$

**Solution: (2)** Let the original resistance of the wire be  $R_1$  and that of the stretched wire be  $R_2$ .

Also, let the original length of the wire be  $l_1$  and that of the stretched wire be  $l_2$ .

Therefore, the relation between the ratio of the resistance and the length of the original and the stretched wire is given by

$$\frac{R_2}{R_1} = \frac{l_2^2}{l_1^2} = \frac{n^2 l_1^2}{l_1^2} \quad (1)$$

which is due to the given data that the stretched wire's length is  $n$  times of the original length.

Therefore, from Eq. (1), we get

$$\frac{R_2}{R_1} = n^2 \Rightarrow R_2 = n^2 R_1$$

9. Two cars moving in opposite directions approach each other with speed of 22 m/s and 16.5 m/s, respectively. The driver of the first car blows a horn having a frequency 400 Hz. The frequency heard by the driver of the second car is (velocity of sound: 340 m/s)

- (1) 361 Hz (2) 411 Hz  
 (3) 448 Hz (4) 350 Hz

**Solution: (3)** It is given that  $f_1 = 400$  Hz;  $v_s = 340$  m/s.



When both source and observer are moving toward each other, we get the frequency heard by the driver in Car 2 as follows:

$$\begin{aligned} f_2 &= \left( \frac{v_s + v_2}{v_s - v_1} \right) f_1 \\ &= \frac{340 + 16.5}{340 - 22} \times 400 = \frac{356.5}{31.8} \times 400 = 448 \text{ Hz} \end{aligned}$$

10. In an electromagnetic wave in free space, the root mean square value of the electric field is  $E_{\text{rms}} = 6$  V/m. The peak value of the magnetic field is

- (1)  $2.83 \times 10^{-8}$  T (2)  $0.70 \times 10^{-8}$  T

$$(3) 4.23 \times 10^{-8} \text{ T}$$

$$(4) 1.41 \times 10^{-8} \text{ T}$$

**Solution: (1)** For the given electromagnetic wave in free space, the ratio of the root mean square value of electric field to the root mean square value of magnetic field is expressed as

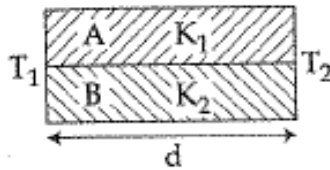
$$\frac{E_{\text{rms}}}{B_{\text{rms}}} = C$$

$$\Rightarrow B_{\text{rms}} = \frac{E_{\text{rms}}}{C} = \frac{6}{3 \times 10^6} = 2 \times 10^{-6} = \frac{B_0}{\sqrt{2}}$$

$$\Rightarrow B_0 = \sqrt{2} \times B_{\text{rms}} = \sqrt{2} \times 2 \times 10^{-6} = 2.83 \times 10^{-6} \text{ T}$$

which is the peak value of the magnetic field.

11. Two rods A and B of different materials are welded together as shown in the figure. Their thermal conductivities are  $K_1$  and  $K_2$ . The thermal conductivity of the composite rod will be



$$(1) \frac{3(K_1 + K_2)}{2}$$

$$(2) K_1 + K_2$$

$$(3) 2(K_1 + K_2)$$

$$(4) \frac{K_1 + K_2}{2}$$

**Solution: (4)** First, let us calculate the equivalent resistance of the composite welded unit as follows:

$$R_1 = \frac{d}{K_1 A}$$

$$R_2 = \frac{d}{K_2 A}$$

Therefore,

$$R_{\text{eq}} = \frac{R_1 R_2}{R_1 + R_2}$$

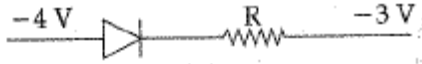
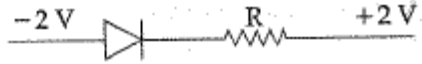
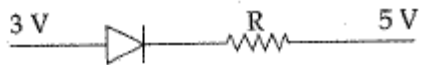

Thermal conductivity of the composite rod is obtained as follows:

$$\frac{d}{K_{\text{eq}} (2A)} = \frac{\left(\frac{d}{K_1 A}\right) \left(\frac{d}{K_2 A}\right)}{\frac{d}{A} \left(\frac{1}{K_1} + \frac{1}{K_2}\right)}$$

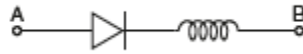
$$\frac{1}{2K_{eq}} = \frac{\left(\frac{1}{K_1 K_2}\right)}{\left(\frac{K_1 + K_2}{K_1 K_2}\right)} = \frac{1}{K_1 + K_2}$$

$$\Rightarrow K_{eq} = \frac{K_1 + K_2}{2}$$

12. Which one of the following represents forward bias diode?

- (1) 
- (2) 
- (3) 
- (4) 

**Solution: (4)** A diode is said to be forward biased when potential at point A is higher than that at point B (see the following figure). That is,  $V_A > V_B$ .



Hence, the diode circuit shown in option (4) is the one which satisfies the above-mentioned concept.

13. A 250-turn rectangular coil of length 2.1 cm and width 1.25 cm carries a current of 85  $\mu\text{A}$  and subjected to a magnetic field of strength 0.85 T. The work done for rotating the coil by  $180^\circ$  against the torque is

- (1) 4.55  $\mu\text{J}$  (2) 2.3  $\mu\text{J}$   
 (3) 1.15  $\mu\text{J}$  (4) 9.1  $\mu\text{J}$

**Solution: (1)** The torque of the coil is

$$\tau = BINAsin\theta$$

Therefore, the work done for rotating the coil by  $180^\circ$  against the torque  $\tau$  is

$$\int \tau d\theta = BIN A \int_q^x \sin\theta d\theta$$

$$= -BIN A(-1 - 1) = 2BIN A$$

$$= 2 \times 0.85 \times 85 \times 10^{-6} \times 250 \times (2.1 \times 1.25 \times 10^{-5})$$

$$= 94828.125 \times 10^{-10}$$

$$= 9.48 \times 10^{-6} \approx 9.48 \mu\text{J}$$

Which is close to option (1), which is the correct choice.

14. If  $\theta_1$  and  $\theta_2$  be the apparent angles of dip observed in two vertical planes at right angles to each other, then the true angle of dip  $\theta$  is given by

$$(1) \tan^2\theta = \tan^2\theta_1 + \tan^2\theta_2$$

$$(2) \cot^2\theta = \cot^2\theta_1 - \cot^2\theta_2$$

$$(3) \tan^2\theta = \tan^2\theta_1 - \tan^2\theta_2$$

$$(4) \cot^2\theta = \cot^2\theta_1 + \cot^2\theta_2$$

**Solution: (4)** We know that

$$\tan \theta = \frac{V}{H} \quad (1)$$

where  $\theta$  is true value of the angle of dip.

Now, let us assume that

$$\theta = \alpha$$

Now, the angles of dip  $\theta_1$  and  $\theta_2$  have different formula:

$$\tan \theta_1 = \frac{V}{H \times \cos \alpha} \quad (2)$$

$$\tan \theta_2 = \frac{V}{H \times \sin \alpha} \quad (3)$$

From Eqs. (1), (2) and (3), we get

$$\cot^2 \theta_1 + \cot^2 \theta_2 = \frac{H^2}{V^2} (\cos^2 \alpha + \sin^2 \alpha) = \cot^2 \theta$$

Therefore,

$$\cot^2 \theta = \cot^2 \theta_1 + \cot^2 \theta_2$$

15. A potentiometer is an accurate and versatile device to make electrical measurements of emf because the method involves

(1) potential gradients.

(2) a condition of no current flow through the galvanometer.

(3) a combination of cells, galvanometer and resistances.

(4) cells.

**Solution: (2)** Potentiometer an instrument, which works on the principle of Wheatstone bridge, that is, there is no current flows through the galvanometer. Hence, option (2) satisfies this condition.

16. The ratio of resolving powers of an optical microscope for two wavelengths  $\lambda_1 = 4000 \text{ \AA}$  and  $\lambda_2 = 6000 \text{ \AA}$  is

(1) 9 : 4

(2) 3 : 2

(3) 16 : 81

(4) 8 : 27

**Solution: (2)** The resolving power of a microscope is proportional to the wavelength  $\lambda$ .

Therefore, the ratio of the resolving power of the given microscope for the two wavelengths  $\lambda_1$  and  $\lambda_2$  is given by

$$\frac{\lambda_2}{\lambda_1} = \frac{6000}{4000} = \frac{3}{2}$$

That is, 3 : 2.

- 17.** A thin prism having refracting angle  $10^\circ$  is made of glass of refractive index 1.42. This prism is combined with another thin prism of glass of refractive index 1.7. This combination produces dispersion without deviation. The refracting angle of second prism should be

- (1)  $6^\circ$  (2)  $8^\circ$   
 (3)  $10^\circ$  (4)  $4^\circ$

**Solution: (1)** For dispersion without deviation, we have

$$\delta_1 = \delta_2$$

That is,

$$A_1(\mu_1 - 1) = A_2(\mu_2 - 1)$$

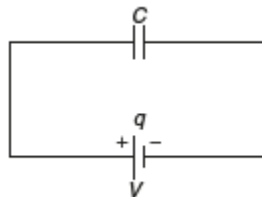
$$10(1.42 - 1) = A_2(1.7 - 1)$$

$$\Rightarrow A_2 = 6^\circ$$

- 18.** A capacitor is charged by a battery. The battery is removed and another identical uncharged capacitor is connected in parallel. The total electrostatic energy of resulting system:

- (1) decreases by a factor of 2.  
 (2) remains the same.  
 (3) increases by a factor of 2.  
 (4) increases by a factor of 4.

**Solution: (1)** The given situation is depicted in the following circuit diagram:

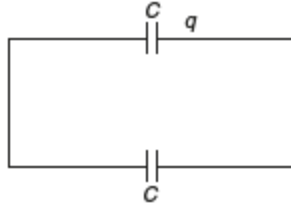


The charge on the capacitor is expressed as

$$q = CV$$

When it is connected with uncharged capacitor, we have





The voltage in the capacitor  $C$  is given by

$$V_C = \frac{q_1 + q_2}{C_1 + C_2} = \frac{q + 0}{C + C}$$

$$V_C = \frac{V}{2}$$

The initial energy is

$$U_i = \frac{1}{2} CV^2 \quad (1)$$

The final energy is

$$U_f = \frac{1}{2} C \left( \frac{V}{2} \right)^2 + \frac{1}{2} C \left( \frac{V}{2} \right)^2 = \frac{CV^2}{4}$$

The loss of energy is

$$U_i - U_f = \frac{CV^2}{4} \quad (2)$$

That is, from Eqs. (1) and (2), we see that the total electrostatic energy of the resulting system decreases by a factor of 2.

19. Preeti reached the metro station and found that the escalator was not working. She walked up the stationary escalator in time  $t_1$ . On other days, if she remains stationary on the moving escalator, then the escalator takes her up in time  $t_2$ . The time taken by her to walk up on the moving escalator will be

(1)  $\frac{t_1 t_2}{t_2 - t_1}$

(2)  $\frac{t_1 t_2}{t_2 + t_1}$

(3)  $t_1 - t_2$

(4)  $\frac{t_1 + t_2}{2}$

**Solution: (2)** The velocity of Preeti w.r.t. the elevator is

$$\frac{d}{t_1} = V_{\text{ground E}}$$

Velocity of the elevator w.r.t. the ground is

$$V_{\text{elev G}} = \frac{d}{t_2}$$

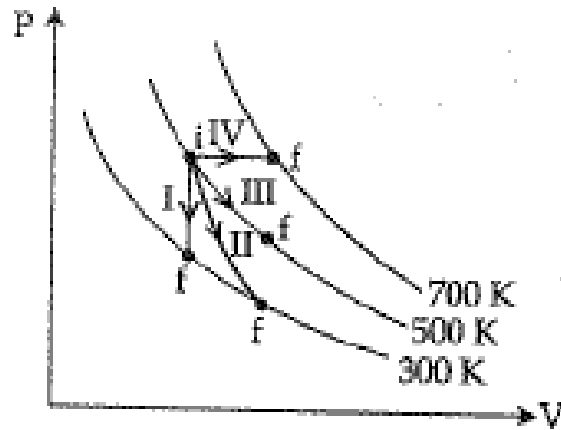
Therefore, the velocity of the girl w.r.t. the ground is

$$V_{\text{ground G}} = V_{\text{ground E}} + V_{\text{elev G}}$$

$$\frac{d}{t} = \frac{d}{t_1} + \frac{d}{t_2}$$

$$\frac{1}{t} = \frac{1}{t_1} + \frac{1}{t_2} \Rightarrow t = \frac{t_1 + t_2}{t_1 + t_2}$$

20. Thermodynamic processes are indicated in the following diagram:



Match the following:

**Column-I**

**P.** Process I

**Q.** process II

**R.** Process III

**S.** Process IV

**Column-2**

**a.** Adiabatic

**b.** Isobaric

**c.** Isochoric

**d.** Isothermal

(1) P → c, Q → a, R → d, S → d

(2) P → c, Q → d, R → b, S → a

(3) P → d, Q → b, R → a, S → c

(4) P → a, Q → c, R → d, S → b

**Solution: (1)** From the thermodynamic process depicted in the graph (provided in the question), we conclude the following:

- Process (I) → Constant volume → Isochoric
- Process (II) →  $PV^\gamma = k$  → Adiabatic
- Process (III) → Constant temperature → Isothermal
- Process (IV) → Constant pressure → Isobaric

21. One end of string of length  $l$  is connected to a particle of mass  $m$  and the other end is connected to a small peg on a smooth horizontal table. If the particle moves in circle with speed  $v$ , the net force on the particle (directed towards centre) will be ( $T$  represents the tension in the string)

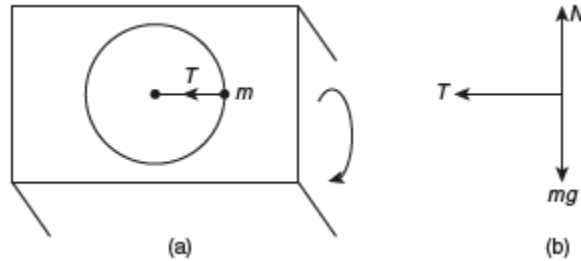
$$(1) T + \frac{mv^2}{l}$$

$$(2) T - \frac{mv^2}{l}$$

(3) Zero

(4)  $T$

**Solution: (4)** The given situation is depicted in Fig. (a) and its free-body diagram is depicted in Fig. (b).



The normal acting on the particle of mass  $m$  is

$$N = mg$$

The tension acting on the particle is

$$T = \frac{mv^2}{r}$$

Therefore, the resultant force acting on the particle is  $T$  (inwards).

**22.** The two nearest harmonics of a tube closed at one end and open at other end are 220 Hz and 260 Hz. What is the fundamental frequency of the system?

(1) 20 Hz

(2) 30 Hz

(3) 40 Hz

(4) 10 Hz

**Solution: (1)** The frequency of  $n$ th harmonic vibration in a closed pipe is

$$f_n = \left( \frac{2n-1}{42} \right) f = 220 \text{ Hz}$$

The frequency of  $(n+1)$ th harmonic vibration is

$$f_{n+1} = \frac{[2(n+1)-1]}{42} = \frac{(2n+1)f}{42} = 260 \text{ Hz}$$

However, we have

$$f_{(n+1)} - f_n = 260 \text{ Hz} - 220 \text{ Hz} = 40 \text{ Hz}$$

That is,

$$\frac{[2n+1]-[2n-1]f}{42} = 40$$

$$\frac{2f}{42} = 40$$

$$\Rightarrow \frac{f}{42} = 20 \text{ Hz}$$

which is the fundamental frequency of the system.

- 23.** The photoelectric threshold wavelength of silver is  $3250 \times 10^{-10} \text{ m}$ . The velocity of the electron ejected from a silver surface by ultraviolet light of wavelength  $2536 \times 10^{-10} \text{ m}$  is (Given  $h = 4.14 \times 10^{-15} \text{ eVs}$  and  $c = 3 \times 10^8 \text{ ms}^{-1}$ )

- (1)  $\approx 0.6 \times 10^6 \text{ ms}^{-1}$  (2)  $\approx 61 \times 10^3 \text{ ms}^{-1}$   
 (3)  $\approx 0.3 \times 10^6 \text{ ms}^{-1}$  (4)  $\approx 6 \times 10^5 \text{ ms}^{-1}$

**Solution:** \*(1), (4)

The photoelectric threshold wavelength of silver is given by

$$\lambda_0 = 3250 \text{ \AA}$$

and the velocity of the electron ejected from a silver surface by ultraviolet light of wavelength  $\lambda$  is given by

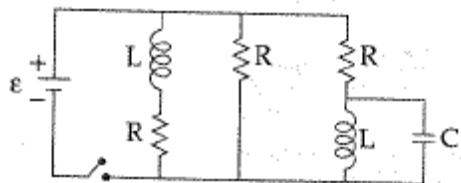
$$\lambda = 2536 \text{ \AA}$$

Now,

$$\begin{aligned} \frac{1}{2}mv^2 &= hc \left[ \frac{1}{\lambda} - \frac{1}{\lambda_0} \right] \\ \Rightarrow v &= \sqrt{\frac{2hc}{m} \left[ \frac{1}{\lambda} - \frac{1}{\lambda_0} \right]} \\ &= \sqrt{\frac{2 \times 12400 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}} \left[ \frac{714}{2536 \times 3250} \right]} \\ &= 0.6 \times 10^6 \text{ m/s} = 6 \times 10^5 \text{ m/s} \end{aligned}$$

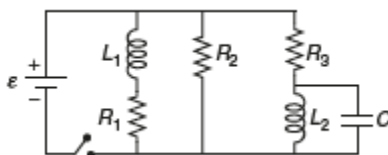
\*Conflict question because two options [both (1) and (4)] are correct for this question.

- 24.** Figure shows a circuit that contains three identical resistors with resistance  $R = 9.0 \Omega$  each, two identical inductors with inductance  $L = 2.0 \text{ mH}$  each, and an ideal battery with emf  $\varepsilon = 18 \text{ V}$ . The current  $I$  through the battery just after the switch closed is \_\_\_\_\_.

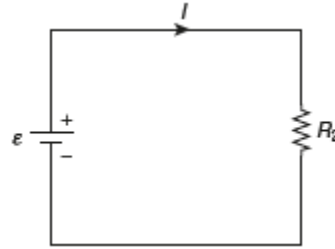


- (1) 0.2 A (2) 2 A  
 (3) 0 ampere (4) 2 mA

**Solution:** (2) Let us name the resistances and inductors as shown on the following circuit diagram:



At  $t = 0$ , no current flows through the resistances  $R_1$  and  $R_3$ . Therefore, the further simplified circuit is shown as follows:



Now, the current flow is given as

$$I = \frac{\varepsilon}{R_2} = \frac{18}{9} \Rightarrow I = 2 \text{ A}$$

- 25.** A spherical blackbody with a radius of 12 cm radiates 450 watt power at 500 K. If the radius were halved and the temperature is doubled, the power radiated (in watt) would be
- (1) 450    (2) 1000  
(3) 1800   (4) 225

**Solution:** (3) We have

$$\theta = \varepsilon \sigma A T^4$$

If the radius were halved, then we have

$$r_2 = r_{1/2}$$

Therefore,

$$A_2 = \frac{A_1}{4}$$

(since  $A \propto r^2$ )

Now,

$$T_2 = 2T$$

Therefore,

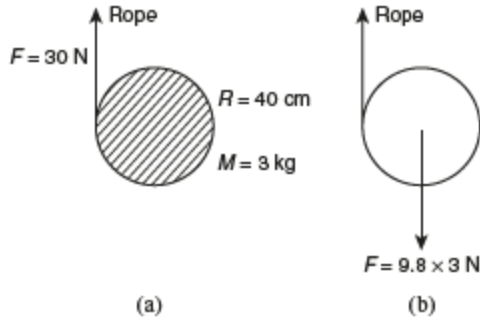
$$\frac{\theta_2}{\theta_1} = \frac{(A_1/4)(16T_1^4)}{A_1T_1^4} = 4$$

$$\Rightarrow \theta_2 = 4\theta_1 = 4 \times 450 = 1800$$

which is the power radiated by the given blackbody.

- 26.** A rope is wound around a hollow cylinder of mass 3 kg and radius 40 cm. What is the angular acceleration of the cylinder if the rope is pulled with a force of 30 N?
- (1)  $0.25 \text{ rad/s}^2$                       (2)  $25 \text{ rad/s}^2$   
(3)  $5 \text{ m/s}^2$                           (4)  $25 \text{ m/s}^2$

**Solution:** (2) We have the situation depicted as shown in Fig. (a). The free-body diagram of the situation is shown in the Fig. (b).



The torque about the central line of the cylinder is

$$\tau = F \times R = (30 \times 4) \text{ N m}$$

The angular acceleration is

$$\alpha = \frac{3 \times 4}{3 \times (0.4)^2} = \frac{10}{4} \text{ rad/s}^2 = 2.5 \text{ rad/s}^2$$

27. Two discs of same moment of inertia rotating about their regular axis passing through centre and perpendicular to the plane of disc with angular velocities  $\omega_1$  and  $\omega_2$ . They are brought into contact face to face coinciding the axis of rotation. The expression for loss of energy during this process is

(1)  $\frac{1}{4} I(\omega_1 - \omega_2)^2$

(2)  $I(\omega_1 - \omega_2)^2$

(3)  $\frac{1}{8} I(\omega_1 - \omega_2)^2$

(4)  $\frac{1}{2} I(\omega_1 + \omega_2)^2$

**Solution:** (1) Let angular velocity of combination be  $\omega$ .

From conservation of angular momentum, we have

$$I\omega_1 + I\omega_2 = (I + I)\omega$$

$$= \frac{1}{2}(\omega_1 + \omega_2)$$

The initial kinetic energy is given by

$$(\text{K.E.})_i = \frac{1}{2} I\omega_1^2 + \frac{1}{2} I\omega_2^2$$

The final kinetic energy is given by

$$(\text{K.E.})_f = \frac{1}{2} (2I)\omega^2 = \frac{1}{4} (\omega_1 + \omega_2)^2$$

The loss of energy due to the whole process is

$$\Delta(\text{K.E.}) = (\text{K.E.})_i - (\text{K.E.})_f$$

$$= \frac{1}{2} I(\omega_1^2 + \omega_2^2) + \frac{1}{4} (\omega_1^2 + \omega_2^2 + 2\omega_1\omega_2)$$

$$= \frac{I}{4} (\omega_1^2 + \omega_2^2 - 2\omega_1\omega_2)$$

$$= \frac{I}{4}(\omega_1 - \omega_2)^2$$

**28.** A gas mixture consists of 2 moles of O<sub>2</sub> and 4 moles of Ar at temperature  $T$ . Neglecting all vibrational modes, the total internal energy of the system is

- (1)  $15RT$  (2)  $9RT$   
 (3)  $11RT$  (4)  $4RT$

**Solution: (3)** The total internal energy of the given system (2 moles of O<sub>2</sub> and 4 moles of Ar) is obtained as follows:

$$U = \frac{f}{2}nRT$$

$$U_{\text{total}} = \frac{5}{2}(2)RT + \frac{3}{2}(4)RT = 11RT$$

**29.** The bulk modulus of a spherical object is  $B$ . If it is subjected to uniform pressure  $P$ , the fractional decrease in radius is

- (1)  $\frac{B}{3P}$  (2)  $\frac{3P}{B}$   
 (3)  $\frac{P}{3B}$  (4)  $\frac{P}{B}$

**Solution: (3)** the bulk modulus of an object is

$$B = \frac{P}{\left(\frac{\Delta V}{V}\right)}$$

$$\Rightarrow \frac{\Delta V}{V} = \frac{P}{B}$$

Therefore, after the decrease in radius of the spherical object, we get

$$3\frac{\Delta r}{r} = \frac{P}{B}$$

$$\Rightarrow \frac{\Delta r}{r} = \frac{P}{3B}$$

which is the fractional decrease of radius of the given spherical object.

**30.** Which of the following statements are correct?

- (a) Centre of mass of a body always coincides with the centre of gravity of the body.  
 (b) Centre of mass of a body is the point at which the total gravitational torque on the body is zero.  
 (c) A couple on a body produce both translational and rotational motion in a body.

(d) Mechanical advantage greater than one means that small effort can be used to lift a large load.

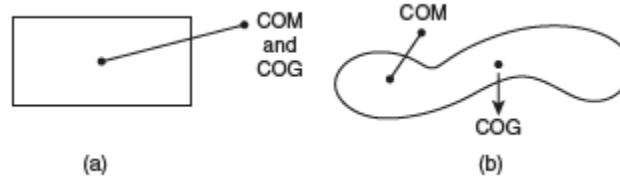
(1) (a) and (b)

(2) (b) and (c)

(3) (c) and (d)

(4) (b) and (d)

**Solution: (4)** It is not necessary that centre of mass (COM) and centre of gravity (COG) coincide in objects [see the figures: Fig. (a) depicts a square object where COM and COG coincide and Fig. (b) Depicts a shapeless object where COM and COG are at different locations on the object.]



### I. Centre of mass

- It is the point where the whole mass of body is concentrated.
- If an external force is applied on COM, its torque will be zero.

### II. Centre of gravity

- It is the point where the torque of gravitational force is zero.
- COM and COG may or may not coincide.

Now, we have

$$\text{Mechanical advantage} = \frac{\text{Output force}}{\text{Input force}}$$

If the mechanical advantage is greater than 1, then we have

$$\text{Output} > \text{Input}$$

Thus, less effort is required to lift a large load.

Hence, statements (b) and (d) are correct.

**31.** The acceleration due to gravity at a height 1 km above the Earth is the same as at a depth  $d$  below the surface of Earth. Then

(1)  $d = 1$  km

(2)  $d = \frac{3}{2}$  km

(3)  $d = 2$  km

(4)  $d = \frac{1}{2}$  km

**Solution: (2)** For the given situation, the acceleration due to gravity at height  $h$  is expressed as

$$g_n = g_0 \left( 1 - \frac{2h}{R} \right) \quad h = 1 \text{ km}$$

and the acceleration due to gravity at depth  $d$  is

$$g_d = g_0 \left( 1 - \frac{d}{R} \right)$$

$$g_n = g_d$$

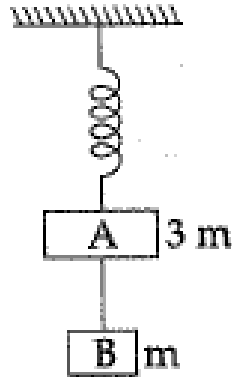


$$g_0 \left(1 - \frac{2h}{R}\right) = g_0 \left(1 - \frac{d}{R}\right)$$

Therefore,

$$d = 2h = 2 \times 1 \text{ km} = 2 \text{ km}$$

32. Two blocks A and B of masses  $3m$  and  $m$ , respectively, are connected by a massless and inextensible string. The whole system is suspended by a massless spring as shown in the figure. The magnitudes of acceleration of A and B immediately after the string is cut are, respectively,



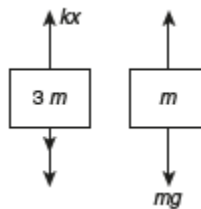
(1)  $\frac{g}{3}, g$

(2)  $g, g$

(3)  $\frac{g}{3}, \frac{g}{3}$

(4)  $g, \frac{g}{3}$

**Solution:** (1) The free-body diagram of the given situation (of masses  $3m$  and  $m$ ) is depicted in the following figures:



Before the string is cut, we have

$$kx = T + 3mg \quad (1)$$

$$T = mg \quad (2)$$

Therefore, from Eqs. (1) and (2), we get

$$kx = 4mg$$

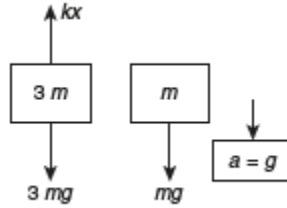
After the string is cut, we have

$$T = 0$$

$$a_A = \frac{kx - 3mg}{3m} = \frac{4mg - 3mg}{3m} = \frac{g}{3}$$

(upwards)

For, the mass  $m$ , the acceleration acts towards downwards as shown in the following figure:



That is  $a_B = g$ .

**33.** The ratio of wavelength of the last line of Balmer series and the last line of Lyman series is

- (1) 1 (2) 4  
 (3) 0.5 (4) 2

**Solution:** (2) For the last Balmer series:

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

$$\Rightarrow \lambda_B = \frac{4}{R}$$

For the last Lyman series:

$$\frac{1}{\lambda_L} = R \left( \frac{1}{1^2} - \frac{1}{\infty^2} \right)$$

$$\Rightarrow \lambda_L = \frac{1}{R}$$

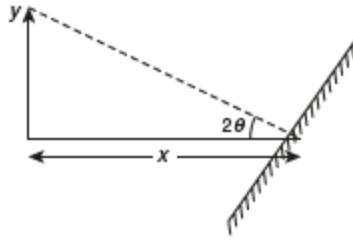
Therefore, the ratio of wavelengths between these two series is

$$\frac{\lambda_B}{\lambda_L} = \frac{4/R}{1/R} = 4$$

**34.** A beam of light from a source L is incident normally on a plane mirror fixed at a certain distance  $x$  from the source. The beam is reflected back as a spot on a scale placed just above the source L. When the mirror is rotated through a small angle  $\theta$ , the spot of the light is found to move through a distance  $y$  on the scale. The angle  $\theta$  is given by

- (1)  $\frac{y}{x}$  (2)  $\frac{x}{2y}$   
 (3)  $\frac{x}{y}$  (4)  $\frac{y}{2x}$

**Solution:** The given optical situation is depicted in the following figure:



When the mirror is rotated by a small angle  $\theta$ , the angle of reflection is  $2\theta$ .

$$\tan 2\theta = \frac{y}{x}$$

Since  $\theta$  is too small, we have the angle  $\theta$  obtained as follows:

$$2\theta = \frac{y}{x} \Rightarrow \theta = \frac{y}{2x}$$

- 35.** A spring of force constant  $k$  is cut into lengths of ratio 1 : 2 : 3. They are connected in series and the new force constant is  $k'$ . Then, they are connected in parallel and force constant is  $k''$ . Then  $k' : k''$  is

(1) 1 : 9

(2) 1 : 11

(3) 1 : 14

(4) 1 : 6

**Solution:** (2) The length of the spring segment is

$$\frac{l}{6}, \frac{l}{3}, \frac{l}{2}$$

As we know that the force constant  $k \propto \frac{1}{l}$ , the spring constant for spring segment is

$$k_1 = 6k; k_2 = 3k; k_3 = 2k$$

Thus, in parallel combination of the spring segments, we have

$$k'' = k_1 + k_2 + k_3 = 11k$$

Thus,

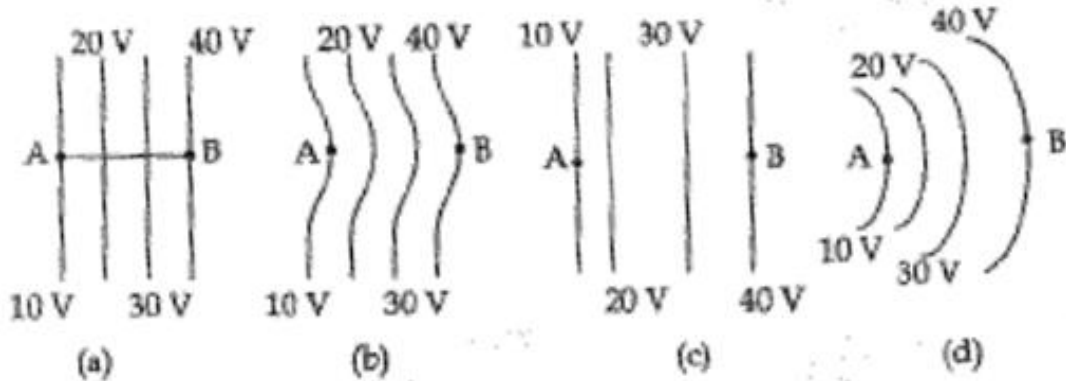
$$k_3 = 2k$$

Thus, in series combination of the spring segments, we have

$$k' = k \quad \text{(as it becomes original spring)}$$

Hence,  $k' : k'' = 1 : 11$ .

- 36.** The diagrams below show regions of equipotentials.



A positive charge is moved from A to B in each diagram.

- (1) In all the four cases, the work done is the same.
- (2) Minimum work is required to move  $q$  in figure (a).
- (3) Maximum work is required to move  $q$  in figure (b).
- (4) Maximum work is required to move  $q$  in figure (c).

**Solution: (1)** As we know that

$$W = q\Delta V = q(V_B - V_A) = q(40 - 10) = 30q$$

the work done is same in all four cases (i.e.  $\Delta V$  is same in all conditions).

**37.** Suppose the charge of a proton and an electron differ slightly. One of them is  $-e$ , the other is  $(e + \Delta e)$ . If the net of electrostatic force and gravitational force between two hydrogen atoms placed at a distance  $d$  (much greater than atomic size) apart is zero, then  $\Delta e$  is of the order of (Given: mass of hydrogen  $m_h = 1.67 \times 10^{-27}$  kg)

- (1)  $10^{-23}$  C
- (2)  $10^{-37}$  C
- (3)  $10^{-47}$  C
- (4)  $10^{-20}$  C

**Solution: (2)** Since the net electrostatics force and the gravitational force between the two hydrogen atoms placed at a distance apart is zero, we have

$$F_e = F_g$$

$$\frac{1}{4\pi\epsilon_0} \frac{\Delta e^2}{d^2} = \frac{Gm^2}{d^2}$$

$$9 \times 10^9 (\Delta e^2) = 6.67 \times 10^{-11} \times (1.67 \times 10^{-27}) \times (1.67 \times 10^{-27})$$

$$\Delta e^2 = \frac{6.67 \times 1.67 \times 1.67}{9} \times 10^{-74} \approx 10^{-37}$$

**38.** A physical quantity of the dimensions of length that can be formed out of  $c$ ,  $G$  and  $\frac{e^2}{4\pi\epsilon_0}$  is ( $c$  is the velocity of light,  $G$  is universal constant of gravitational and  $e$  is charge)

$$(1) c^2 \left[ G \frac{e^2}{4\pi\epsilon_0} \right]^{1/2}$$

$$(2) \frac{1}{c^2} \left[ \frac{e^2}{G4\pi\epsilon_0} \right]^{1/2}$$

$$(3) \frac{1}{c} G \frac{e^2}{4\pi\epsilon_0}$$

$$(4) \frac{1}{c^2} \left[ G \frac{e^2}{4\pi\epsilon_0} \right]^{1/2}$$

**Solution: (4)** Considering the dimensions, we have

$$[L] = [C]^a [G]^b \left[ \frac{e^2}{4\pi\epsilon_0} \right]^c$$

$$[L] = [LT^{-1}]^a [M^{-1}L^3T^{-2}]^b [ML^3T^{-2}]^c$$

$$[L] = L^{a+3b+3c} M^{-b+c} T^{-a-2b-2c}$$

$$a + 3b + 3c = 1$$

$$-b + c = 0$$

$$a + 2b + 2c = 0$$

On solving, we get  $a = -2$ ,  $b = 1/2$  and  $c = 1/2$ .

Therefore, the length is obtained as

$$\frac{1}{c^2} \left[ \frac{Ge^2}{4\pi\epsilon_0} \right]^{1/2}$$

- 39.** Two polaroids  $P_1$  and  $P_2$  are placed with their axis perpendicular to each other. Unpolarised light  $I_0$  is incident on  $P_1$ . A third polaroid  $P_3$  is kept in between  $P_1$  and  $P_2$  such that its axis makes an angle  $45^\circ$  with that  $P_1$ . The intensity of transmitted light through  $P_2$  is

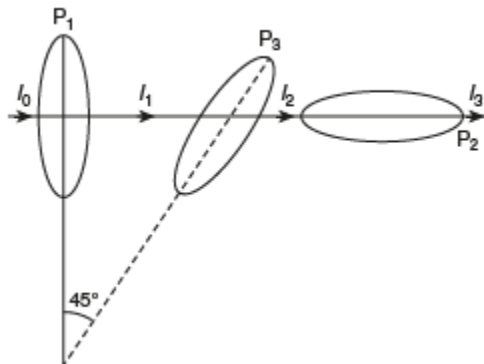
$$(1) \frac{I_0}{4}$$

$$(2) \frac{I_0}{8}$$

$$(3) \frac{I_0}{16}$$

$$(4) \frac{I_0}{2}$$

**Solution: (2)** The given optical situation of the polaroid's is depicted in the following figure:



Now,

$$I_2 = \frac{I_0}{2} \cos^2 45^\circ$$

$$= \frac{I_0}{2} \times \frac{1}{2} = \frac{I_0}{4}$$

$$I_2 = \frac{I_0}{4} \cos^2 45^\circ = \frac{I_0}{4} \times \frac{1}{2}$$

$$\Rightarrow I_2 = \frac{I_0}{8}$$

- 40.** A particle executes linear simple harmonic motion with an amplitude of 3 cm. When the particle is at 2 cm from the mean position, the magnitude of its velocity is equal to that of its acceleration. Then its time period in seconds is:

(1)  $\frac{\sqrt{5}}{2\pi}$  (2)  $\frac{4\pi}{\sqrt{5}}$

(3)  $\frac{2\pi}{\sqrt{3}}$  (4)  $\frac{\sqrt{5}}{\pi}$

**Solution: (2)** We have the velocity of the SHM as

$$v = \omega\sqrt{A^2 - x^2} \tag{1}$$

Also,

$$a = x\omega^2; v = a$$

Therefore, from Eq. (1), we get

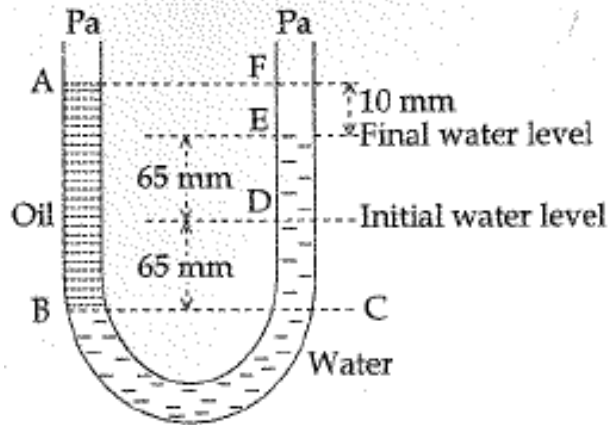
$$\omega\sqrt{A^2 - x^2} = x\omega^2$$

$$\sqrt{3^2 - 2^2} = 2\left(\frac{2\pi}{T}\right)$$

$$\sqrt{5} = \frac{4x}{T}$$

$$\Rightarrow T = \frac{4\pi}{\sqrt{5}}$$

- 41.** A U-tube, with both ends open to the atmosphere, is partially filled with water. Oil, which is immiscible with water, is poured into one side until it stands at a distance of 10 mm above the water level on the other side. Meanwhile, the water rises by 65 mm from its original level (see diagram). The density of the oil is



(1)  $425 \text{ kg/m}^3$

(2)  $800 \text{ kg/m}^3$

(3)  $928 \text{ kg/m}^3$

(4)  $650 \text{ kg/m}^3$

**Solution: (3)** For the water and oil in the U-tube, we have

$$h_{\text{oil}}\rho_{\text{oil}}g = h_{\text{water}}\rho_{\text{water}}g$$

$$140 \times \rho_{\text{oil}} = 130 \times \rho_{\text{water}}$$

$$\rho_{\text{oil}} = \frac{13}{14} \times 1000 \text{ kg/m}^3$$

$$\Rightarrow \rho_{\text{oil}} = 928 \text{ kg/m}^3$$

**42.** Consider a drop of rain water having mass 1 g falling from a height of 1 km. It hits the ground with a speed of 50 m/s, Take  $g$  constant with a value  $10 \text{ m/s}^2$ . The work done by the (i) gravitational force and the (ii) resistive force of air is

(1) (i) 1.25 J    (ii) -8.25 J

(2) (i) 100 J    (ii) 8.75 J

(3) (i) 10J    (ii) -8.75 J

(4) (i) -10 J    (ii) -8.25 J

**Solution: (3)** It is given that the mass of the rain water as

$$m = 1 \text{ g} = \left( \frac{1}{1000} \right) \text{ kg}$$

The height at which the rain drop is falling is

$$h = 1 \text{ km} = 1000 \text{ m}$$

The work done by the gravitational force is

$$W_g - mgh = 0$$

Therefore,

$$W_g = \frac{1}{1000} \times 10 \times 1000$$

Change in K.E. is

$$\frac{1}{2}mv^2 - 0 = \frac{1}{2} \times \frac{1}{1000} \times 50 \times 50 - 0$$

From work–energy theorem, we can write as

$$W_g + W_{\text{air resistance}} = \Delta(\text{K.E.})$$

$$10 \text{ J} + \text{Resistive force} = 1.25 - 10$$

where, 10 J is the work done by gravitational force on the rain drop and the resistive force of the air is  $-8.75 \text{ J}$ .

- 43.** The  $x$ - and  $y$ -coordinates of the particle at any time are  $x = 5t - 2t^2$  and  $y = 10t$ , respectively, where  $x$  and  $y$  are in meters and  $t$  in seconds. The acceleration of the particle at  $t = 2 \text{ s}$  is

- (1)  $5 \text{ m/s}^2$  (2)  $-4 \text{ m/s}^2$   
 (3)  $-8 \text{ m/s}^2$  (4)  $0$

**Solution: (2)** We have the  $x$ - and  $y$ -coordinates of the acceleration of the given particle obtained as follows:

$$x = 5t - 2t^2; \quad y = 10t$$

$$\frac{dx}{dt} = 5 - 4t; \quad \frac{dy}{dt} = 10$$

$$v_x = 10; \quad v_y = 10$$

$$\left(\frac{dv}{dt}\right)_x = -4; \quad \left(\frac{dv}{dt}\right)_y = 10$$

$$a_x = -4; \quad a_y = 0$$

- 44.** A long solenoid of diameter  $0.1 \text{ m}$  has  $2 \times 10^4$  turns per meter. At the centre of the solenoid, a coil of  $100$  turns and radius  $0.01 \text{ m}$  is placed with its axis coinciding with the solenoid axis. The current in the solenoid reduces at a constant rate to  $0 \text{ A}$  from  $4 \text{ A}$  in  $0.05 \text{ s}$ . If the resistance of the coil is  $10 \pi^2 \Omega$ , the total charge flowing through the coil during this time is

- (1)  $16 \mu\text{C}$  (2)  $32 \mu\text{C}$   
 (3)  $16\pi \mu\text{C}$  (4)  $32\pi \mu\text{C}$

**Solution: (2)** The required total charge flowing through the coil during the given time is obtained as follows:

$$q = \left[ \left( \frac{\Delta\phi}{\Delta t} \right) \cdot \frac{1}{R} \right] \Delta t$$

$$= \left[ \mu_0 n N \pi r^2 \frac{\Delta I}{\Delta t} \right] \frac{1}{R} \Delta t$$

$$= \left[ 4\pi \times 10^{-7} \times 2 \times 10^4 \times 100 \times \pi \times (10^{-2})^2 \times \left( \frac{4}{0.05} \right) \right] \frac{1}{10\pi^2} \times 0.05$$



$$= 32 \mu\text{C}$$

45. A Carnot engine, having an efficiency of  $\frac{1}{10}$  as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is

- (1) 90 J (2) 99 J  
(3) 100 J (4) 1 J

**Solution: (1)** Since we have

$$\beta = \frac{1-n}{n} = \frac{1-(1/10)}{(1/10)} = \frac{9/10}{1/10} = 9$$

and

$$\beta = \frac{\theta_2}{W}$$

we get the amount of energy absorbed from the reservoir as

$$\theta_2 = 9 \times 10 = 90 \text{ J}$$

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