DPP – 3 (Gravitation)

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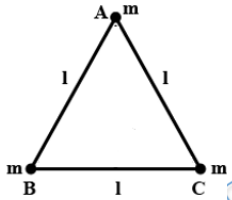
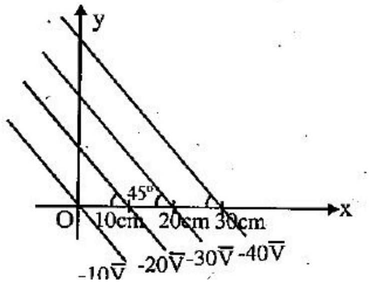
Q 1. Three mass points each of mass m are placed at the vertices of an equilateral triangle of side l. What is the gravitational potential at the centroid of the triangle.



(a) $\frac{3Gm}{l}$ (b) $-\frac{3Gm}{l}$

(c) $-\frac{3\sqrt{3}Gm}{l}$ (d) $-\frac{3\sqrt{2}Gm}{l}$

Q 2. The gravitational field strength $\vec{E}$ and gravitational potential V are related as $\vec{E} = -\left(\frac{\partial V}{\partial x}\hat{\imath} + \frac{\partial V}{\partial y}\hat{\jmath} + \frac{\partial V}{\partial z}\hat{k}\right)$. In the figure, transversal lines represent equipotential surfaces. A particle of mass m is released from rest at the origin. The gravitational unit of potential, 1 V = 1 cm^2/s^2. X-component of the velocity of the particle at the point (4cm,4cm) is



(a) 4 cm/s (b) 2 cm/s

(c) $2\sqrt{2}$ cm/s (d) 1 cm/s

Q 3. If gravitational field is given by $\vec{E} = -2x\hat{\imath} - 3y^2\hat{\jmath}$. If gravitational potential is zero at (0,0), find potential at (1,2)

(a) 9 J/kg (b) 3 J/kg

(c) -6 J/kg (d) -12 J/kg

Q 4. If gravitational potential is $V = x^2Y$, find gravitational field at (1,2).

(a) $\sqrt{13}$ N/kg (b) $\sqrt{17}$ N/kg

(c) 2 N/kg (d) 15 N/kg

Q 5. The potential inside a point in a solid sphere will be
(a) Same as that seen at the surface
(b) Will be less than what was seen at the surface
(c) Will be more than what was seen at the surface
(d) Will be equal to the potential at the surface

Q 6. The gravitational potential in a region is given by $V = 20(x + y)$ J/kg. Find the magnitude of the gravitational force on a particle of mass 0.5 kg placed at the origin.
(a) 10 N (b) $10\sqrt{2}$ N
(c) $2\sqrt{10}$ N (d) $\sqrt{2}$ N

Q 7. A particle of mass 5 kg is placed in a field of gravitational potential $v = (7x^2 - 21x)$ J/kg. Then its motion
(a) is SHM with angular frequency 1.67 rad/s
(b) is SHM with angular frequency 3.74 rad/s
(c) is oscillatory but no SHM
(d) is SHM with amplitude 5.5m

Q 8. Calculate the gravitational potential at the surface of the moon. The mass of the moon is 7.34×10^{22} kg and its radius is 1.74×10^6m. ($G = 6.67 \times 10^{-11}\ Nm^2/kg^2$)
(a) 1.74×10^6 J/kg (b) -1.74×10^6 J/kg
(c) 2.81×10^6 J/kg (d) -2.81×10^6 J/kg

Q 9. The distance between earth and moon is 3.8×10^8m. Determine the gravitational potential energy of earth-moon system. Given, mass of the earth = 6×10^{24}kg, mass of moon = 7.4×10^{22}kg and G = $6.67 \times 10^{-11}\ Nm^2/kg^2$
(a) 9.7×10^{28} J (b) -16.4×10^{28} J
(c) -7.8×10^{28} J (d) -2.6×10^{28} J

Q 10. In a gravitational field, at a point where the gravitational potential is zero
(a) The gravitational field is necessarily zero
(b) The gravitational field is not necessarily zero
(c) Nothing can be said definitely about the gravitational field
(d) None of these

Q 11. The gravitational field due to a mass distribution is $E = \frac{K}{x^3}$ in the x-direction. (K is a constant). Taking the gravitational potential to be zero at infinity, its value at a distance x is
(a) $\frac{K}{x}$ (b) $\frac{K}{2x}$
(c) $\frac{K}{x^2}$ (d) $\frac{K}{2x^2}$

Q 12. The change in potential energy, when a body of mass m is raised to a height nR from the earth's surface is (R = Radius of earth)
(a) $mgR\frac{n}{n-1}$ (b) nmgR
(c) $mgR\frac{n^2}{n^2+1}$ (d) $mgR\frac{n}{n+1}$

Q 13. A thin rod of length L is bent to form a semi circle. The mass of the rod is M. What will be the gravitational potential at the center of the circle?

(a) $-\frac{GM}{L}$ (b) $-\frac{GM}{2\pi L}$

(c) $-\frac{\pi GM}{2L}$ (d) $-\frac{\pi GM}{L}$

Q 14. Find the work done to take a particle of mass m from surface of the earth to a height equal to 2R.

(a) 2mgR (b) $\frac{mgR}{2}$

(c) 3mgR (d) $\frac{2mgR}{3}$

Q 15. The gravitational P.E. of a rocket of mass 100 kg at a distance of 10^7 m from the earths center is -4×10^9 J. The weight of the rocket at a distance of 10^9 m from the center of the earth is :

(a) 4×10^{-2} N (b) 4×10^{-9} N

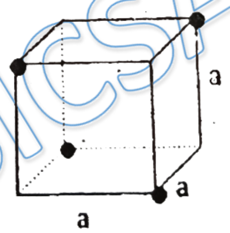
(c) 4×10^{-6} N (d) 4×10^{-3} N

Q 16. If a smooth tunnel is dug across a diameter of earth and a particle is released from the surface of earth, the particle oscillate simple harmonically along it. Time period of the particle is not equal to

(a) $2\pi\sqrt{\frac{R}{g}}$ (b) $\frac{2\pi}{\sqrt{GM}}R^{3/2}$

(c) 84.6 min (d) none of these

Q 17. Figure shows 4 identical masses of mass m, arranged on a cube as shown. The potential energy of the system is

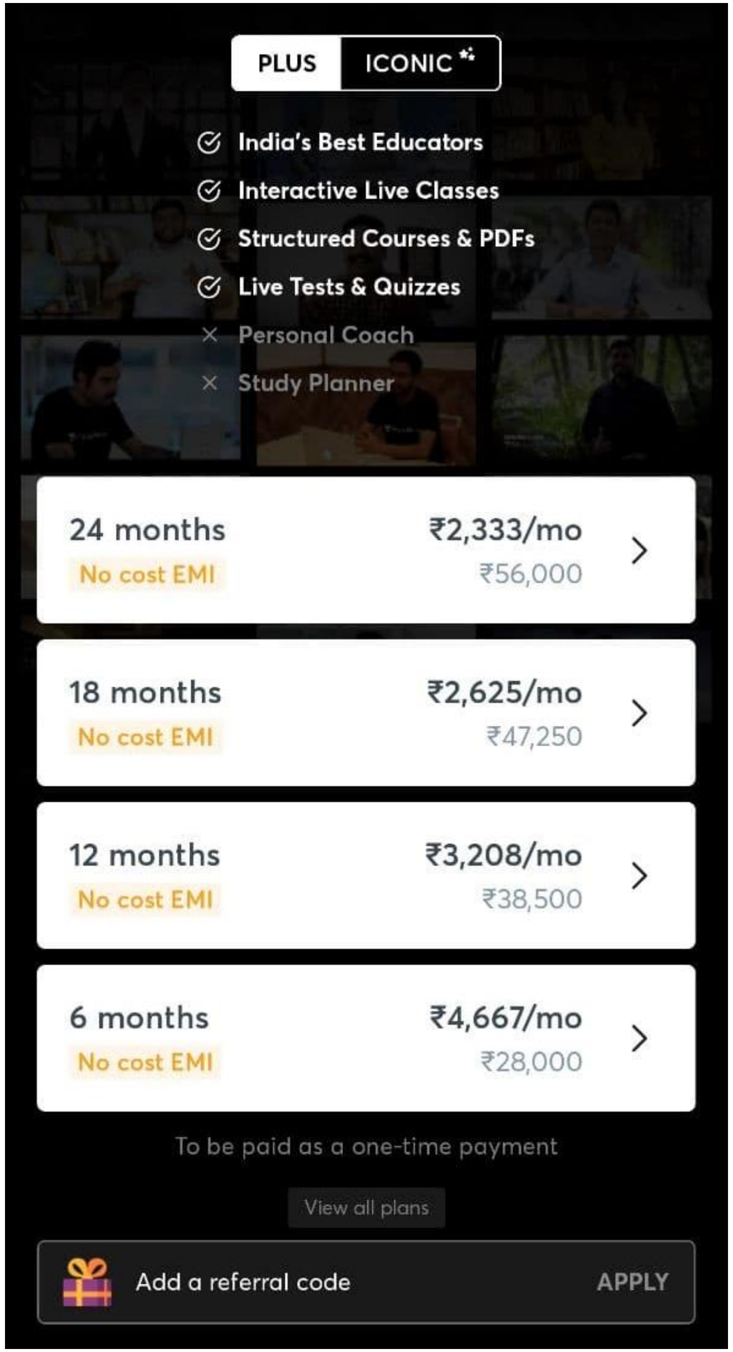


(a) $\frac{2\sqrt{2}Gm^2}{a}$ (b) $\frac{3\sqrt{2}Gm^2}{a}$

(c) $-\frac{2\sqrt{2}Gm^2}{a}$ (d) $-\frac{3\sqrt{2}Gm^2}{a}$

Answer Key

Q.1 c	Q.2 c	Q.3 a	Q.4 b	Q.5 b
Q.6 b	Q.7 b	Q.8 d	Q.9 c	Q.10 a
Q.11 d	Q.12 d	Q.13 d	Q.14 d	Q.15 a
Q.16 d	Q.17 d			



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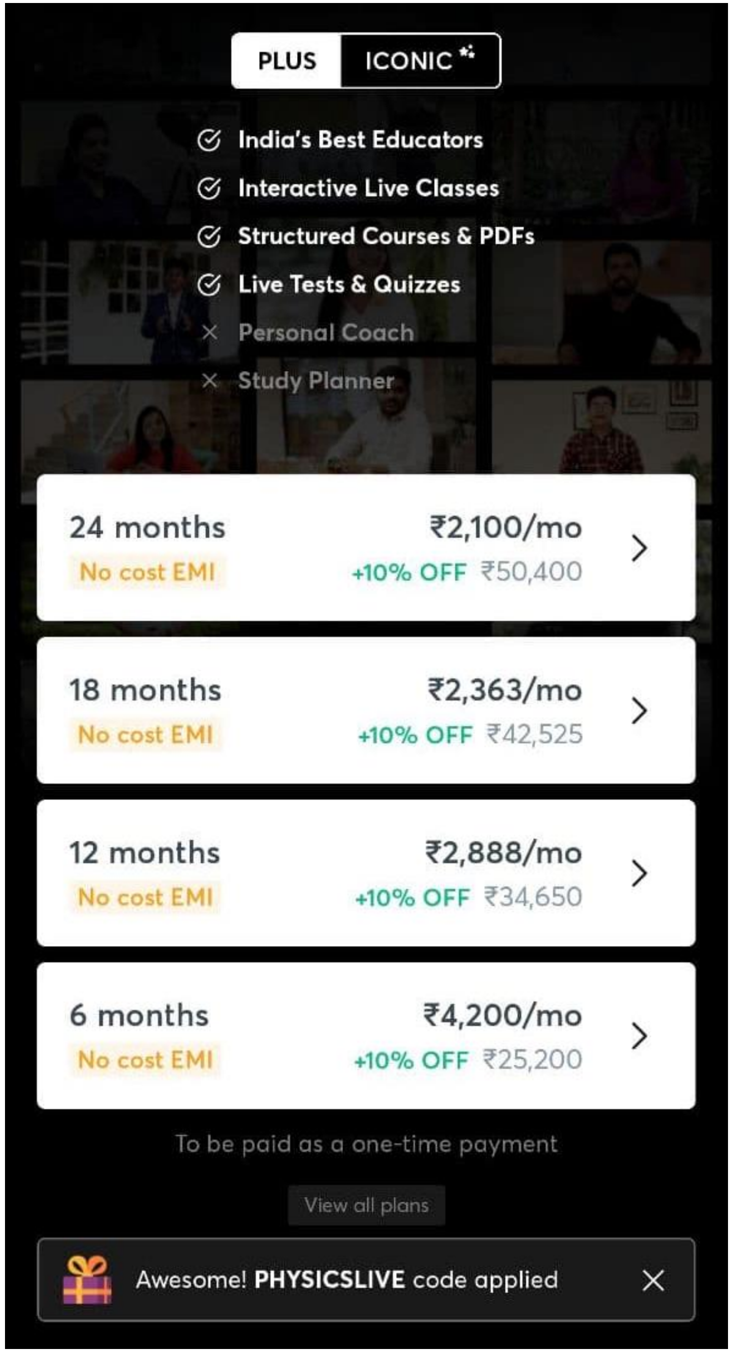


Written Solution

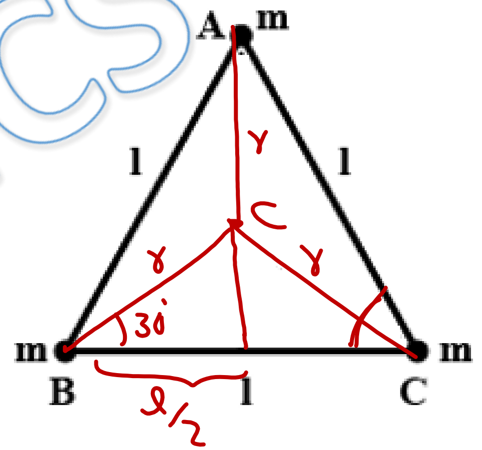
DPP-3 Gravitation: Gravitational Potential & Potential Energy

By Physicsaholics Team

Q.1) Three mass points each of mass m are placed at the vertices of an equilateral triangle of side l. What is the gravitational potential at the centroid of the triangle.

$\cos 30° = \frac{l}{2r} = \frac{\sqrt{3}}{2}$

$r = l/\sqrt{3}$



(a) $\frac{3Gm}{l}$

(b) $-\frac{3Gm}{l}$

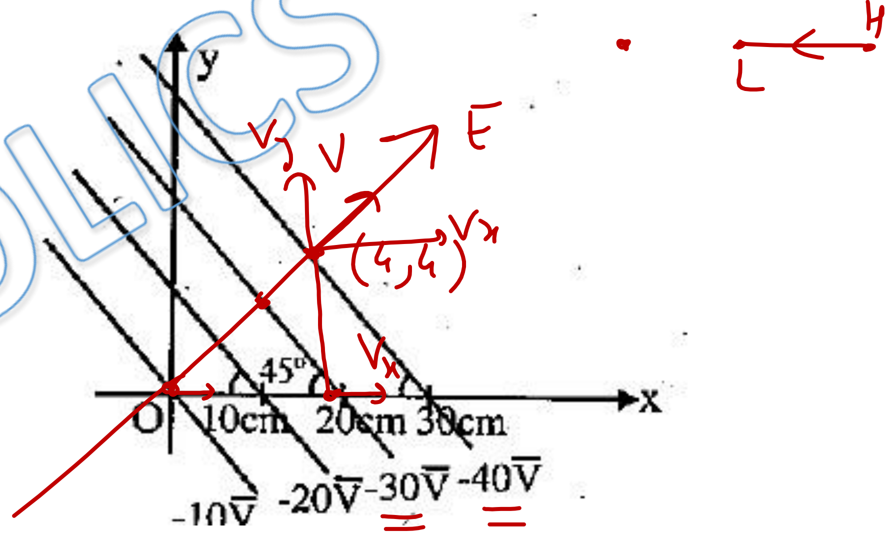
(c) $-\frac{3\sqrt{3}Gm}{l}$

(d) $-\frac{3\sqrt{2}Gm}{l}$

$V = -\frac{Gm}{r} \times 3$

$= -\frac{3Gm\sqrt{3}}{l}$

Q.2) The gravitational field strength $\vec{E}$ and gravitational potential V are related as $\vec{E} = -\left(\frac{\partial V}{\partial x}\hat{\imath} + \frac{\partial V}{\partial y}\hat{\jmath} + \frac{\partial V}{\partial z}\hat{k}\right)$. In the figure, transversal lines represent equipotential surfaces. A particle of mass m is released from rest at the origin. The gravitational unit of potential, 1 V = 1 cm^2/s^2. X-component of the velocity of the particle at the point (4cm,4cm) is



(a) 4 cm/s (b) 2 cm/s

(c) $2\sqrt{2}$ cm/s ✓ (d) 1 cm/s

$E_x = -\frac{\Delta V}{\Delta x} = \frac{10}{.1} = 100 N/kg$

$F_x = ma_x = 100m$

$a_x = 100 m/sec^2$

$V_x^2 = u_x^2 + 2a_x \times x$

$V_x^2 = 0 + 2 \times 100 \times \frac{4}{100}$

$V_x = 2\sqrt{2}$

Q.3) If gravitational field is given by $\vec{E} = -2x\hat{i} - 3y^2\hat{j}$. If gravitational potential is zero at (0,0), find potential at (1,2)

(a) 9 J/kg

(b) 3 J/kg

(c) -6 J/kg

(d) -12 J/kg

$$V = \int_{r}^{ref} \vec{E} \cdot \vec{dr}$$

$$= \int_{1,2}^{0,0} (-2x\hat{i} - 3y^2\hat{j}) \cdot (dx\hat{i} + dy\hat{j})$$

$$= \int_{1,2}^{0,0} -2x\,dx - 3y^2\,dy$$

$$= \left[-x^2 - y^3\right]_{1,2}^{0,0}$$

$$= \left[x^2 + y^3\right]_{0,0}^{1,2}$$

$$= 1 + 8 = 9$$

Q.4) If gravitational potential is $V = x^2Y$, find gravitational field at (1,2).

$E_x = -\frac{\partial V}{\partial x} = -(2xy) = -(2\times1\times2) = -4$

$E_y = -\frac{\partial V}{\partial y} = -(x^2) = -1$

(a) $\sqrt{13}$ N/kg

(b) $\sqrt{17}$ N/kg ✓

(c) 2 N/kg

(d) 15 N/kg

$\vec{E} = -4\hat{i} - \hat{j}$

$E = \sqrt{16+1}$

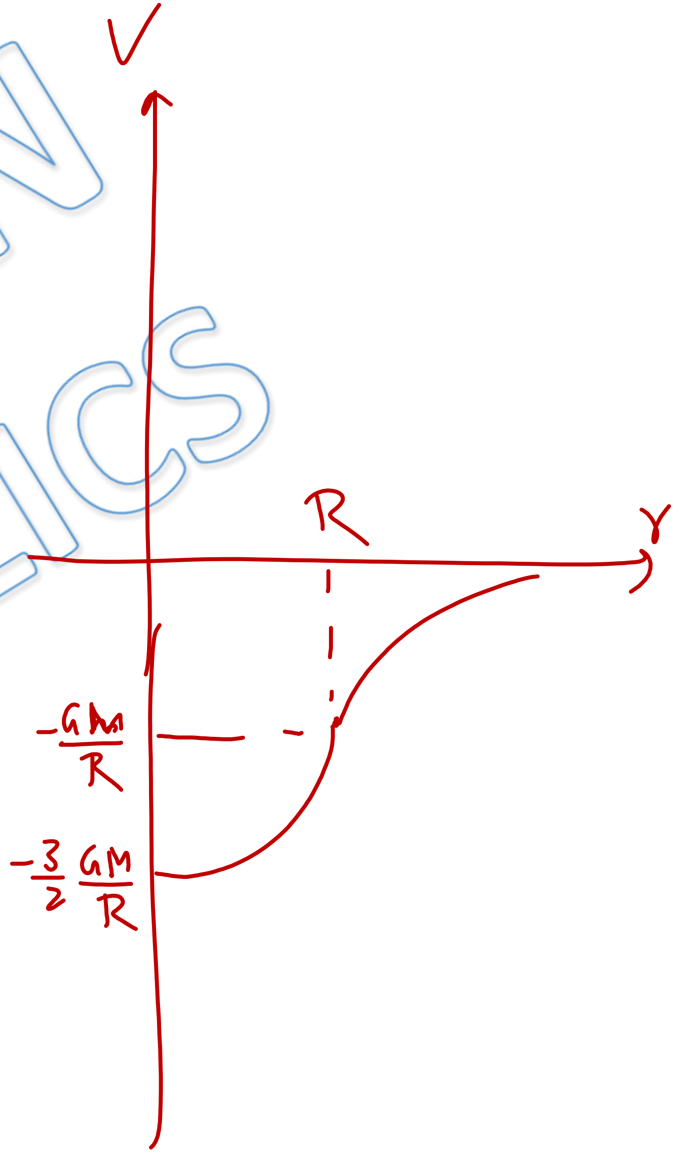
Q.5) The potential inside a point in a solid sphere will be

(a) Same as that seen at the surface

(b) Will be less than what was seen at the surface

(c) Will be more than what was seen at the surface

(d) Will be equal to the potential at the surface



Q.6) The gravitational potential in a region is given by $V = 20(x + y)$ J/kg. Find the magnitude of the gravitational force on a particle of mass 0.5 kg placed at the origin.

(a) 10 N

(b) $10\sqrt{2}$ N

(c) $2\sqrt{10}$ N

(d) $\sqrt{2}$ N

$E_x = -\frac{\partial V}{\partial x} = -20$

$E_y = -\frac{\partial V}{\partial y} = -20$

$E = 20\sqrt{2}$

$F = mE = 10\sqrt{2}$

Q.7) A particle of mass 5 kg is placed in a field of gravitational potential $v = (7x^2 - 21x)$ J/kg. Then its motion

(a) is SHM with angular frequency 1.67 rad/s

(b) is SHM with angular frequency 3.74 rad/s

(c) is oscillatory but no SHM

(d) is SHM with amplitude 5.5m

$E = E_x = -\frac{\partial v}{\partial x} = -(14x - 21)$

$E = -14(x - 3/2)$

$F = -70(x - 3/2)$

$a = -14(x - 3/2)$

$a = -14X$

$\omega^2 = 14$

$\omega = \sqrt{14}$

Q.8) Calculate the gravitational potential at the surface of the moon. The mass of the moon is 7.34×10^{22} kg and its radius is 1.74×10^{6}m. ($G = 6.67 \times 10^{-11}\ Nm^2/kg^2$)

(a) 1.74×10^{6} J/kg

(b) -1.74×10^{6} J/kg

(c) 2.81×10^{6} J/kg

(d) -2.81×10^{6} J/kg

$$V = -\frac{GM}{R} = -\frac{6.67 \times 10^{-11} \times 7.34 \times 10^{22}}{1.74 \times 10^{6}}$$

Q.9) The distance between earth and moon is 3.8×10^8m. Determine the gravitational potential energy of earth-moon system. Given, mass of the earth = 6×10^{24}kg, mass of moon = 7.4×10^{22}kg and G = $6.67 \times 10^{-11}\ Nm^2/kg^2$

(a) 9.7×10^{28} J
(b) -16.4×10^{28} J
(c) -7.8×10^{28} J
(d) -2.6×10^{28} J

$U = -\frac{Gm_1m_2}{r} = -\frac{6.67 \times 10^{-11} \times 7.4 \times 10^{22} \times 6 \times 10^{24}}{3.8 \times 10^8}$

$= -\frac{6.67 \times 7.4 \times 6}{3.8} \times 10^{27}$

$= -80.04 \times 10^{27}$

$= -8.004 \times 10^{28}$

Q.10) In a gravitational field, at a point where the gravitational potential is zero

(a) The gravitational field is necessarily zero
(b) The gravitational field is not necessarily zero
(c) Nothing can be said definitely about the gravitational field
(d) None of these

Q.11) The gravitational field due to a mass distribution is $E = \frac{K}{x^3}$ in the x-direction. (K is a constant). Taking the gravitational potential to be zero at infinity, its value at a distance x is

(a) $\frac{K}{x}$ (b) $\frac{K}{2x}$

(c) $\frac{K}{x^2}$ (d) $\frac{K}{2x^2}$

$$V = \int_{r}^{ref} \vec{E} \cdot \vec{dr} \qquad \int x^{-3}\, dr = \frac{x^{-2}}{-2}$$

$$= \int_{x}^{\infty} \frac{K}{x^3} dx$$

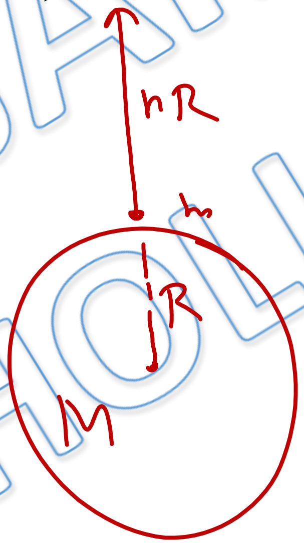
$$= \left[-\frac{K}{2x^2}\right]_x^{\infty}$$

$$= \frac{K}{2x^2}$$

Q.12) The change in potential energy, when a body of mass m is raised to a height nR from the earth's surface is (R = Radius of earth)

(a) $mgR\frac{n}{n-1}$ (b) $nmgR$

(c) $mgR\frac{n^2}{n^2+1}$ (d) $mgR\frac{n}{n+1}$



$$\Delta U = \left(-\frac{GMm}{R+nR}\right) - \left(-\frac{GMm}{R}\right)$$

$$= \frac{GMm}{R}\left[1 - \frac{1}{n+1}\right] = \frac{n}{n+1}\,\frac{GMm \times R}{R \times R}$$

$$= mgR\left(\frac{n}{n+1}\right)$$

Q.13) A thin rod of length L is bent to form a semi circle. The mass of the rod is M. What will be the gravitational potential at the center of the circle?

$l = \pi R$

$R = l/\pi$

(a) $-\frac{GM}{L}$ (b) $-\frac{GM}{2\pi L}$

(c) $-\frac{\pi GM}{2L}$ (d) $-\frac{\pi GM}{L}$

$V_c = -\frac{GM}{R}$

$= -\frac{\pi GM}{l}$

Q.14) Find the work done to take a particle of mass m from surface of the earth to a height equal to 2R.

Distance from centre of earth = 3R

(a) 2mgR

(b) $\frac{mgR}{2}$

(c) 3mgR

(d) $\frac{2mgR}{3}$ ✓

$W = \Delta U = \left(-\frac{GMm}{3R}\right) - \left(-\frac{GMm}{R}\right)$

$= \frac{2}{3}\frac{GMm}{R}$

but $\frac{GM}{R} = gR$

$= \frac{2}{3}mgR$

Q.15) The gravitational P.E. of a rocket of mass 100 kg at a distance of 10^7 m from the earths center is -4×10^9 J. The weight of the rocket at a distance of 10^9 m from the center of the earth is :

(a) 4×10^{-2} N
(b) 4×10^{-9} N
(c) 4×10^{-6} N
(d) 4×10^{-3} N

$$U = -\frac{GMm}{10^7} = -4 \times 10^9$$

$$GMm = 4 \times 10^{16}$$

$$F = \frac{GMm}{(10^9)^2} = \frac{4 \times 10^{16}}{10^{18}} = .04 \text{ N}$$

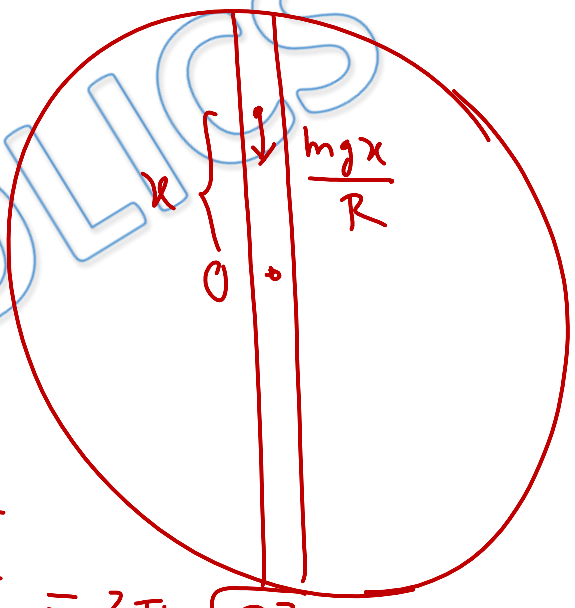
Q.16) If a smooth tunnel is dug across a diameter of earth and a particle is released from the surface of earth, the particle oscillate simple harmonically along it. Time period of the particle is not equal to

(a) $2\pi\sqrt{\frac{R}{g}}$

(b) $\frac{2\pi}{\sqrt{GM}}R^{3/2}$

(c) 84.6 min

(d) none of these



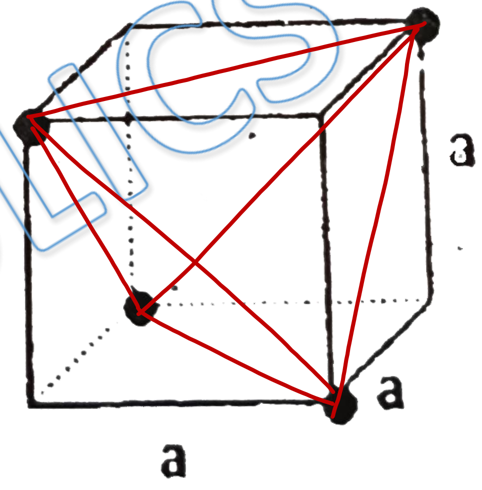
$F = \frac{mgx}{R}$

$a = \frac{gx}{R}$

$T = 2\pi\sqrt{\frac{R}{g}} = 2\pi\sqrt{\frac{R^3}{GM}}$

$T = 84.6$ min

Q.17) Figure shows 4 identical masses of mass m, arranged on a cube as shown. The potential energy of the system is



(a) $\frac{2\sqrt{2}Gm^2}{a}$ (b) $\frac{3\sqrt{2}Gm^2}{a}$

(c) $-\frac{2\sqrt{2}Gm^2}{a}$ (d) $-\frac{3\sqrt{2}Gm^2}{a}$

$U = 6\left(-\frac{Gm^2}{a\sqrt{2}}\right)$

$= -\frac{3\sqrt{2}Gm^2}{a}$

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