



PHYSICS

BOOKS - HC VERMA PHYSICS (HINGLISH)

GRAVITATION

Examples

1. Two particles of masses 1.0 kg and 2.0 kg are placed at a separation of 50 cm. Assuming

that the only forces acting on the particles are their mutual gravitation find the initial acceleration of the two particles.



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2. Find the work done in bringing three particles each having a mass of 100 g, from large distances to the vertices of an equilateral triangle of side 20 cm.



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3. A particle of mass M is placed at the centre of a uniform spherical shell of equal mass and radius a . Find the gravitational potential at a point P at a distance $\frac{a}{2}$ from the centre.



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4. A particle of mass 50 g experience a gravitastiona force of 2.0 N when placed at a particular point. Find the gravitational field at that point.



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



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6. The gravitational potential due to a mass distribution is $V = \frac{A}{\sqrt{x^2 + a^2}}$. Find the

gravitational field.



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7. Find the gravitational due to the moon at its surface. The mass of the moon is 7.36×10^{22} kg and the radius of the moon is 1.74×10^6 m. Assuming the moon be a spherically symmetric body



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8. Calculate the value of acceleration due to gravity at a point a. 5.0 km above the earth's surface and b. 5.0 km below the earth's surface. Radius of earth = 6400 km and the value of g at the surface of the earth is 9.80 ms^{-2}



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9. A satellite is revolving round the earth at a height of 600 km. find a. the speed of the

satellite and b. the time period of the satellite.

Radius of the earth = 6400 km and mass of the

earth = $6 \times 10^{24} \text{ kg}$.



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10. Calculate the escape velocity from the

moon. The mass of the moon = $7.4 \times 10^{22} \text{ kg}$

and radius of the moon = 1740 km



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Worked Out Examples

1. Three portion A , B and C each of mass m are placed in a line with $AB=BC=d$. Find the gravitational force on a fourth particle P of same mass placed at a distance d from the particle B on the perpendicular bisector of the line AC.



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2. Find the distance of a point from the earth's centre where the resultant gravitational field

due to the earth and the moon is zero. The mass of the earth is 6.0×10^{24} kg and that of the moon is 7.4×10^{22} kg. The distance between the earth and the moon is 4.0×10^5 km.



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3. Two particles of equal mass go round a circle of radius R under the action of their mutual gravitational attraction. Find the speed of each particle.



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4. Two particles A and B of masses 1 kg and 2 kg respectively are kept 1 m apart and are released to move under mutual attraction. Find The speed A when that of B is 3.6 cm/hr. What is the separation between the particles at this instant?



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5. The gravitational field in a region is given by

$$\vec{E} = (10Nkg^{-1}) \left(\vec{i} + \vec{j} \right). \text{ Find the work}$$

done by and external agent to slowly shift a particle of mass 2 kg from the point (0,0) to a point (5m,4m)



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6. A uniform solid sphere of mass M and radius a is surrounded symmetrically by a uniform thin spherical shell of equal mass and radius

2a. Find the gravitational field at a distance a , $\frac{3}{2}a$ from the centre, b. $\frac{5}{2}a$ as from the centre.



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7. The density inside a solid sphere of radius a is given by $\rho = \frac{\rho_0}{r}$, where ρ_0 is the density at the surface and r denotes the distance from the centre. Find the gravitational field due to this sphere at a distance $2a$ from its centre.



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8. A uniform ring of mass m and radius a is placed directly above a uniform sphere of mass M and of equal radius. The centre of the ring is at a distance $\sqrt{3}a$ from the centre of the sphere. Find the gravitational force exerted by the sphere on the ring.



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9. A particle is fired vertically upwards with a speed of 9.8 km s^{-1} . Find the maximum height

tattaine dby the prticle. Radius of earth =6400 k,m and g at the surface = $9.8ms^2$. Consider only earth's gravitastion.



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10. AS particle hagin form a spring stretches it by 1 cm at earth's surface. How much will hesame partile stretch the spring at a place 800 km above the earth's surface/ Radius of the earth=6400 km.



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11. A simple pendulum has a time period exactly 2 s when used in a laboratory at north pole.

What will be the time period if the same pendulum is used in a laboratory at equator?

Count for the earth's rotation only. Take

$$g = \frac{GM}{R^2} = 9.8 \text{ms}^{-2} \text{ and radius of earth}$$

=6400 km



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12. A satellite is to revolve round the earth in a circle of radius 8000 km. With what speed should this satellite be projected into orbit? What will be the time period?

Take g at the surface $= 9.8 \text{ m s}^{-2}$ and radius of the earth $= 6400 \text{ km}$.



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13. Two satellites S_1 and S_2 revolve round a planet in coplanar circular orbits in the same

sense. Their periods of revolutions are 1 h and 8 h respectively. The radius of the orbit of S_1 is 10^4 km . When S_2 is closest to S_1 , find a. The speed of S_2 relative to S_1 and b. the angular speed of S_2 as observed by an astronaut in S_1 .



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Short Answer

1. Can two particles be in equilibrium under the action of their mutual gravitational force?

Can three particles be? Can one of the three particles be?



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2. Is there any meaning of Weight of the earth?



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3. If heavier bodies are attracted more strongly by the earth why don't they fall faster

than the lighter bodies?



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4. Can you think of two particles which do not exert gravitational force on each other?



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5. The earth revolves round the sun because the sun attracts the earth. The sun also attracts the moon and this force is about twice as

large as the attraction of the earth on the moon. Why does the moon not revolve round the sun? Or does it?



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6. At noon, the sun and the earth pull the objects on the earth's surface in opposite directions. At midnight, the sun and the earth pull these objects in same direction. Is the weight of an object as measured by a spring

balance on the earth's surface , more at midnight as compared to its weight at noon?



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7. An apple falls from a tree. An insect in the apple finds that the earth is falling towards it with an acceleration. Who exerts the force needed to accelerate the earth with this acceleration?



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8. Suppose the gravitational potential due to a small system is $\frac{k}{r^2}$ at distance r from it. What will be the gravitational field? Can you think of any such system? What happens if there were negative masses?



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9. The gravitational potential energy of a two particle system is derived in this chapter as $U = -\frac{Gm_1m_2}{r}$. Does it follow from this equation that the potential energy for

$r = \infty$ must be zero? Can we choose the potential energy for $r = o$ to be 20 J and still use this formula? If no what formula should be used to calculate the gravitational potential energy at separation?



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10. The weight of an object is more at the poles than at the equator. Is it beneficial to purchase goods at equator and sell them at the pole? Does it matter whether a spring

balance is used or an equal beam balance is used?



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11. The weight of a body at the poles is greater than the weight at the equator. Is it the actual weight or the apparent weight we are talking about? Does your answer depend on whether only the earth's rotation is taken into account or the flattening of the earth at the poles is also taken into account?



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12. If the radius of the earth decreases by 1% without changing its mass, will the acceleration due to gravity at the surface of the earth increase or decrease? If so, by what per cent?



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13. A nut becomes loose and gets detached from a satellite revolving around the earth. Will

it land on the earth? If yes, where will it land? ?

If no how can an astonaut make it land on the earth?



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14. Is it necessary for the plane of the orbit of a satellite to pass through the centre of the earth?



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15. Consider earth satellites in circular orbits. A geostationalry satellite must be at a height of about 36000 km from the earth's surface. Will any satellite moving at this height be a geostationary satellite? Will any satelite moving at this eight have a time period of 24 hours?



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16. No part of India is situated on the equator.

Is it possible to have a geostationary satellite which always remains over New Delhi?



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17. As the earth rotates about its axis, a person living in his house at the equator goes in a circular orbit of radius equal to the radius of the earth. Why does he/she not feel weightless as a satellite passenger does?





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18. Two satellites going in equatorial plane have almost same radii. As seen from the earth one moves from east to west and the other from west to east. Will they have the same time period as seen from the earth? If not which one will have less time period?



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19. A spacecraft consumes more fuel in going the earth the moon than it takes for a return trip. Comment on this statement.



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Objective 1

1. A acceleration of moon with respect to earth is 0.0027 m s^{-2} and the acceleration of anpple falling on earth's surface is about 10 m s^{-2} .

Assume that the radius of the moon is one fourth of the earth's radius. If the moon is stopped for an instant and then released, it will fall towards the earth. The initial acceleration of the moon toward the will be

A. $10ms^{-2}$

B. $0.0027ms^{-2}$

C. $6.4ms^{-2}$

D. $5.0ms^{-2}$

Answer: B



2. The acceleration of the moon just before it strikes the earth in the previous question is

A. $10ms^{-2}$

B. $0.00227ms^{-2}$

C. $6.4ms^{-2}$

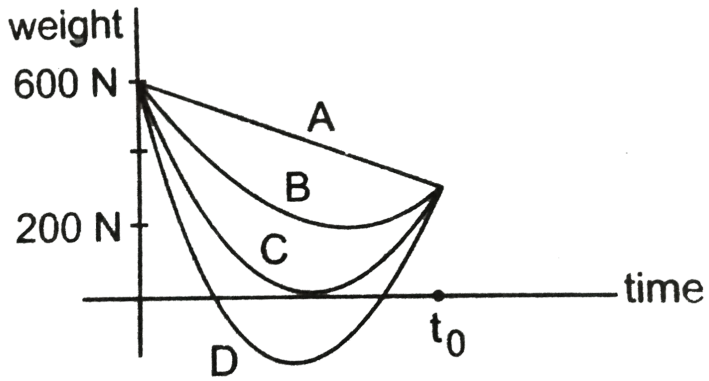
D. $5.0ms^{-2}$

Answer: C



3. Suppose the acceleration due to gravity at Earth's surface is 10m s^{-2} and at the surface of Mars it is 4.0m s^{-2} . A passenger goes from Earth to Mars in a spaceship with a constant velocity. Neglect all other objects in sky. Which part of figure best represents the weight (net gravitational force) of the passenger as a

function of time?



A. A

B. B

C. C

D. D

Answer: C



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4. Consider a planet in some solar system which has a mass double the mass of the earth and density equal to the average density of the earth. An object weighing W on the earth will weigh

A. W

B. $2W$

C. $\frac{W}{2}$

D. $2^{1/3}W$ at the planet

Answer: D



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5. If the acceleration due to gravity at the surface of the earth is g , the work done in slowly lifting a body of mass m from the earth's surface to a height R equal to the radius of the earth is

A. $\frac{1}{2}mgR$

B. $2mgR$

C. mgR

D. $\frac{1}{4}mgR$

Answer: A



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6. A person brings a mass of 1 kg from infinity to a point . Initially the mass was at rest but it moves at a speed of 2 m s^{-1} as it reaches A. The work done by the person on the mass is -3J. The potential at A is

A. $-3Jkg^{-1}$

B. $-2Jkg^{-1}$

C. $-5Jkg^{-1}$

D. none of these

Answer: C



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7. Let V and E represent the gravitational potential and field at a distance r from the centre of a uniform solid sphere. Consider the

two statements.

A. the plot of V against r is discontinuous

B. The plot of E against r is discontinuous.

A. -3J/Kg

B. -2J/Kg

C. -5J/Kg

D. none

Answer: C



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8. Let V and E represent the gravitational potential and field at a distance r from the centre of a uniform solid sphere. Consider the two statements.

A. the plot of V against r is discontinuous

B. The plot of E against r is discontinuous.

A. both A and B are true

B. A is true but B is false

C. B is true but A is false

D. both A and B are false

Answer: D



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9. Take the effect of bulging of earth and its rotation in account. Consider the following statements:

A. There are points outside the earth where the value of g is equal to its value at the equator.

B. There are points outside the earth where the value of g is equal to its value at the poles.

A. both A and B are true

B. A is true but B is false

C. B is true but A is false

D. both and B are false

Answer: B



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10. The time period of an earth satellite in circular orbit is independent of

A. the mass of the satellite

B. radius of the orbit

C. none of them

D. both of them

Answer: A



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11. The magnitude of gravitational potential energy of the moon earth system is U with zero potential energy at infinite separation.

The kinetic energy of the moon with respect to the earth is K .

A. $U < K$

B. $U > K$

C. $U=K$

D.

Answer: B



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12. Figure shows the elliptical path of a planet about the sun. The two shaded parts have equal area. If t_1 and t_2 be the time taken by the planet to go from a to b and from c to d respectively

A. $t_1 < t_2$

B. $t_1 = t_2$

C. $t_1 > t_2$

D. insufficient information to deduce the relation between t_1 and t_2



Answer: B



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13. A person sitting in a chair in a satellite feels weightless because

A. the earth does not attract the objects in
a satellite

B. the normal force by the chair on the person balances the earth's attraction

C. the normal force is zero

D. the person in satellite is not accelerated

Answer: C



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14. A body is suspended from a spring balance kept in a satellite. The reading of the balance is W_1 when the satellite goes in an orbit of

radius R and is W_2 when it goes in an orbit of radius $2R$.

A. $W_1 = W_2$

B. $\frac{1}{2}mgR$

C. mgR

D. $W_1 \neq W_2$

Answer: A



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15. The kinetic energy needed to project a body of mass m from the earth's surface to infinity is

A. $\frac{1}{4}mgR$

B. $\frac{1}{2}mgR$

C. mgR

D. $2mgR$

Answer: C



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16. A particle is kept at rest at a distance R (earth's radius) above the earth's surface. The minimum speed with which it should be projected so that it does not return is

A. $\sqrt{\frac{GM}{4R}}$

B. $\sqrt{\frac{GM}{2R}}$

C. $\sqrt{\frac{GM}{R}}$

D. $\sqrt{\frac{2GM}{R}}$

Answer: D



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17. A satellite is orbiting the earth close to its surface. A particle is to be projected from the satellite to just escape from the earth. The escape speed from the earth is v_c . Its speed with respect to the satellite

A. will be less than v_e

B. will be more than v_e

C. will be equal to v_e

D. will depend on direction of projection

Answer: D



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Objective 2

1. Let V and E denote the gravitational potential and gravitational field at a point. It is possible to have

A. $V = 0$ and $E = 0$

B. $V = 0$ and $E \neq 0$

C. $V = 0$ and $E = 0$

D. $V \neq 0$ and $E \neq 0$

Answer: A::C::D



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2. Inside a uniform spherical shell

A. the gravitational potential is zero

B. the gravitational field is zero

C. the gravitational potential is same everywhere

D. the gravitational field is same everywhere

Answer: B::C::D



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3. A uniform spherical shell gradually shrinks maintainig its shape. The gravitational potential at the centre

A. increases

B. decreases

C. remains constant

D. oscillates

Answer: B



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4. Consider a planet moving in an elliptical orbit around the Sun. The work done on the planet by the gravitational force of the Sun

A. is zero in any small part of the orbit

B. is zero in some parts of the orbit

C. is zero in one complete revolution

D. is zero in no part of the motion

Answer: B::C



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5. Two satellites A and B move round the earth in the same orbit. The mass of B is twice the mass of A.

A. Speeds of A and B are equal

B. The potential energy of earth +A is same
is that of earth +B

C. The kinetic energy of A and B are equal

D. The total energy of earth +A is same as
that of earth +B

Answer: A



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6. Which of the following quantities remain constant in a planetary motion (consider elliptical orbits) as seen from the sun?

A. speed

B. Angular speed

C. kinetic energy

D. Angular momentum

Answer: D



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Exercises

1. Two spherical balls of mass 10 kg each are placed 10 cm apart. Find the gravitational force of attraction between them.



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2. Four particles having masses, m , wm , $3m$, and $4m$ are placed at the four corners of a square of edge a . Find the gravitational force

acting on a particle of mass m placed at the centre.



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3. Three equal masses m are placed at the three corners of an equilateral triangle of side a .
a. find the force exerted by this system on another particle of mass m placed at a. the mid point of a side b. at the centre of the triangle.



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4. Three uniform spheres each having a mass M and radius a are kept in such a way that each touches the other two. Find the magnitude of the gravitational force on any of the spheres due to the other two.



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5. For particles of equal masses M move along a circle of radius R under the action of

their mutual gravitational attraction. Find the speed of each particle.



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6. Find the acceleration due to gravity of the moon at a point 1000 km above the moon's surface. The mass of the moon is 7.4×10^{22} kg and its radius is 1740 km.



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7. Two small bodies of masses 10 kg and 20 kg are kept a distance 1.0 m apart and released. Assuming that only mutual gravitational force are acting, find the speeds of the particles when the separation decreases to 0.5 m.



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8. A semicircular wire has a length L and mass M . A particle of mass m is placed at the centre

of the circle. Find the gravitational attraction on the particle due to the wire.



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9. Derive an expression for the gravitational field due to a uniform rod of length L and mass M at a point on its perpendicular bisector at a distance d from the centre.



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10. Two concentric spherical shells have masses M_1, M_2 and radii $R_1, R_2 (R_1 + R_2)$.

What is the force exerted by this system on a particle of mass m_1 if it is placed at a distance

$\frac{R_1 + R_2}{2}$ from the centre?



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11. A tunnel is dug along a diameter of the earth. Find the force on a particle of mass m

placed in the tunnel at a distance x from the centre.



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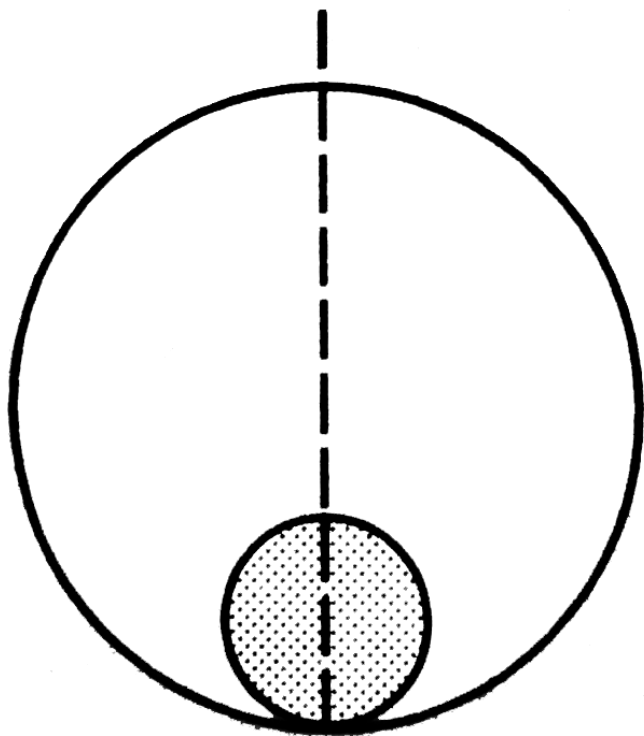
12. A tunnel is dug along a chord of the earth a perpendicular distance $\frac{R}{2}$ from the earth's centre. The wall of the tunnel may be assumed to be frictionless. Find the force exerted by the wall on a particle of mass m when it is at a distance x from the centre of the tunnel.



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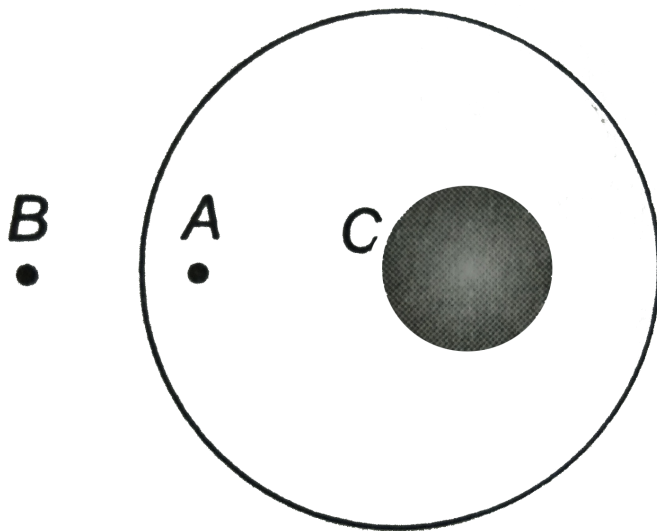
13. a solid sphere of mass m and radius r is placed inside a hollow thin spherical shell of mass M and radius R as shown in figure. A particle of mass m is placed on the line joining the two centres at a distance x from the point of contact of the sphere and the shell. Find the magnitude of the resultant gravitational force on this particle due to the sphere and the shell if a.

r < *x* < 2*r*, *b.* 2*r* < *x* < 2*R* and *c.* *x* > 2*R*.



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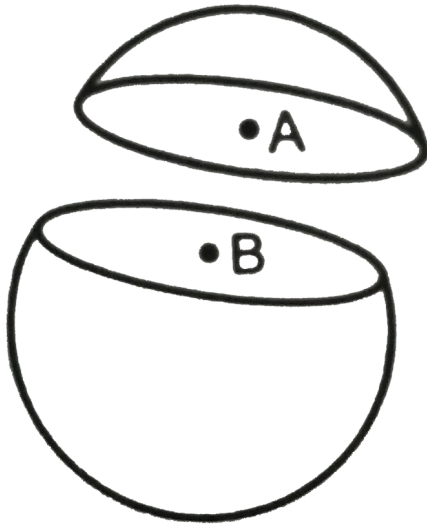
14. A uniform metal sphere of radius R and mass m is surrounded by a thin uniform spherical shell of same mass and radius $4R$. The centre of the shell C falls on the surface of the inner sphere. Find the gravitational fields at points A and B .



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15. A thin spherical shell having uniform density is cut in two parts by a plane and kept separated as shown in figure. The point A is the centre of the plane section of the first part and B is the centre of the plane section of the second part. Show that the gravitational field at A due to the first part is equal in magnitude to the gravitational field at B due

to the second part.



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16. Two small bodies of masses 2.00 kg and 4.00 kg are kept at rest at a separation of 2.0 m . Where should a particle of mass 0.10 kg be

placed to experience no net gravitational force from these bodies? The particle is placed at this point. What is the gravitational potential energy of the system of three particles with usual reference level?



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17. Three particles of mass m each are placed at the three corners of an equilateral triangle of side a . Find the work which should be done on

this system to increase the sides of the triangle to $2a$.



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18. A particle of mass 100 g is kept on the surface of a uniform sphere of mass 10 kg and radius 10 cm . Find the work to be done against the gravitational force between them to take the particle away from the sphere.



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19. The gravitational field in a region is given by $\vec{E} = (5Nkg^{-1})\vec{i} + (12nk^{-1})\vec{j}$.. a.find the magnitude of the gravitational force acting on a particle of mass 2 kg th gravittional fore actiing on a particle of mass 2 kg placed at the origin. B. Find the potential at teh points (12m,0) and (o,5m) if the potential at teh origin is taken to be zero. C. Find the change in gravitationa potential energyif a particle of mass 2 kg is taken from the origin to teh point (12m,5m). d. Find the change in

potential energy if the particle is taken from $(12\text{m}, 0)$ to $(0, 5, \text{m})$.



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20. The gravitational potential in a region is given by $V = 20\text{Nkg}^{-1}(x+y)$. A. Show that the equation is dimensionally correct b. Find the gravitational field at the point (x, y) Leave your answer in terms of the unit vector \vec{i} , \vec{j} , \vec{k} . C. Calculate the magnitude of the

gravitational force on a particle of mass 500 g placed at the origin.



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21. The gravitational field in a region is given by

$$E = \left(2\vec{i} + \vec{j} \right) Nkg^{-1}$$

show that no work is done by the gravitational field when particle

is moved on the line $3y + 2x = 5$.



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22. Find the height over the earth's surface at which the weight of a body becomes half of its value at the surface.



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23. What is the acceleration due to gravity on the top of Mount Everest? Mount Everest is the highest mountain peak on the world at the height of 8848 m. The value at sea level is 9.80ms^{-2} .





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24. find the acceleration due to gravity in a mine of depth 640 m if the value at the surface is 9.800 ms^{-2} . The radius of the earth is 6400 km.



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25. A body is weighted by a spring balance to be 1.000 kg at the north pole. How much will it

weight at the equator. Account for the earth's rotation only.



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26. A body stretches a spring by a particular length at the earth's surface at equator. At what height above the south pole will it stretch the same spring by the same length? Assume the earth to be spherical.



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27. At what rate should the earth rotate so that the apparent g at the equator becomes zero? What will be the length of the day in this situation?



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28. A pendulum having a bob of mass m is hanging in a ship sailing along the equator from east to west. When the ship is stationary with respect to water the tension in the string is T_0 . a. Find the speed of the ship due to

rotation of the earth about its axis. b. find the difference between T_0 and the earth's attraction on the bob. c. If the ship sails at speed v . what is the tension in the string ?
Angular speed of earth's rotation is ω and radius of the earth is R .



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29. The time taken Mars to revolve round the sun is 1.88 years. Find the ratio of average

distance between mars and the sun to that between the earth and the sun.



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30. The moon takes about 27.3 days to revolve round the earth in a nearly circular orbit of radius 3.84×10^5 k. Calculate the mass of the earth from these datas.



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31. A mars satellite moving in an orbit of radius 9.4×10^3 km take 27540 s to complete one revolution. Calculate the mass of mars.



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32. A satellite of mass 1000 kg is supposed to orbit the earth at a height of 2000 km above the earth's surface. Find a. its speed in the orbit b. its kinetic energy. c. The potential

energy of the earth satellite system and d. its time period. Mass of the earth $= 6 \times 10^{24} \text{ kg}$.



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33. a. Find the radius of the circular orbit of a satellite moving with an angular speed equal to the angular speed of earth's rotation. b. If the satellite is directly above the north pole at some instant find the time it takes to come over the equatorial plane. Mass of the earth $= 6 \times 10^{24} \text{ kg}$



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34. What is the true weight of an object in a geostationary satellite that weighed exactly 1.0 N at the north pole?



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35. The radius of a planet is R_1 and a satellite revolves round it in a circle of radius R_2 . The time period of revolution is T . Find the

acceleration due to the gravitational of the plane at its surface.



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36. find the minimum colatitude which can directly receive a signal from a geostationary satellite.



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37. A particle is fired vertically upward from earth's surface and it goes up to a maximum height of 6400 km. find the initial speed of particle.



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38. A particle is fired vertically upward with a speed of 15 km s^{-1} . With what speed will it move in interstellar space. Assume only earth's gravitational field.





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39. A mass of 6×10^{24} kg (equal to the mass of the earth) is to be compressed in a sphere in such a way that the escape velocity from its surface is $3 \times 10^8 \text{ms}^{-2}$. What should be the radius of the sphere?



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