PHYSICS

BOOKS - HC VERMA PHYSICS (ENGLISH)

GRAVITATION

Example

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 brigning three particles each having a mass of 100 g, from large distances to the vertices of an equilateal 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 gravitational 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 7.36×10^2 klg and the radius of the moon is 1.74×10^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 $= 6 \times 10^{24} kg.$

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10. Calculate the escape velocity from the moon. The mass of the moon $= 7.4 \times 10^{22} kg$ and radius of the moon `=1740km

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Worked Out Examples

1. Three points A , B and C each of mass m is placed in a line with AB=BC=d. Find the gravitational force on a fourth particle P of the

same mass placed at a distance d from 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 $7.4x10^{22}$ kg. The distance between the earth and the moon is $4.0 \times 10^{5} km$.

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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 $\vec{E} = (10Nkg^{-1})\left(\vec{i} + \vec{j}\right)$. Find the work done by an 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 center , b. $\frac{5}{2}a$ from the center.

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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 ast the surface and r denotes the distance from

the centre. Find the graittional field due to this sphere at a distance 2a from its centre.

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

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9. A particle is fired vertically upward with a speed of $9.8kms^{-1}$. Find the maximum height attained by the particle. Radius of earth =6400 km and g at the surface $= 9.8ms^{-2}$. Consider only earth's gravitation.

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10. A particle hanging form a spring stretches it by 1 cm at earth's surface. How much will the same particle 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 pendu,um has a time eriod exactly 2 s when used i a laboratory at north pole. What wil be the time period if the same pendulum is used in a labroator at equator? Ccount for the earth's rotation only. Take $g = \frac{GM}{R^2} = 9.8ms^{-2}$ and radius of earth =6400 km

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12. A satellite is to revolve round the earth in as 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 $= 9.8ms^{-2}$ and radius of the earth =6400 km.

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13. Two satellite S_1 and S_2 revolve round a planet in coplanar circular orbits in the same sense. Their periods of revolutions are 1 h nd 8 h respectively. The radius of the orbit of S_1 is $10^4 km$. When S_2 is closet 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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Objective 1

1. An acceleration of moon with respect to earth is 0.0027 ms^{-2} and the acceleration of an apple falling on earth's surface is about $10ms^{-2}$. 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

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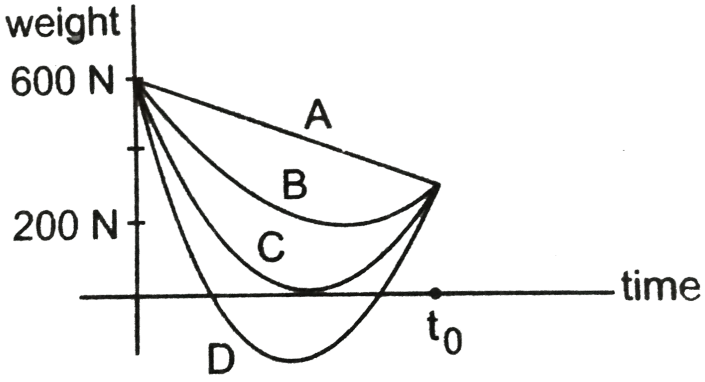
2. Suppose the acceleration due to gravity at earth's surface is $10ms^{-2}$ and at the surface of Mars it is $4.0ms^{-2}$. A passenger goes from the earth to the mars in a spaceship with a constant velocity. Neglect all other object in sky. Which part of figure best represent the weight (net gravitational force) of the

passenger as a function of time?



A. A

B. B

C. C

D. D

Answer: C

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3. 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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4. If the acceleration due to gravity at the surface of the earth is g, the work done in slowly lifting a body ofmass 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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5. A person brings a mass of 1 kg infinity to a point A. Initially the mass was at rest but it moves at a speed of $2ms^{-1}$ as it reached 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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6. 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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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 agasinst r is discotinuous

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

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

B.There are points outside the earth where the earth where the value of g is equla 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

9. The time period of an earth satelite 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

10. 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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11. Figure shows the elipticla path of a planet about the sun. The two shaded parts have equal area. If t_1 and t_2 be the tim 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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12. A person sitting on a chair in a satellite feels weightless because

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

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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13. 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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14. 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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15. 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 is 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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16. 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_e. Its speed with respect to the satellite

A. wil be less than v_e

B. will be more thant 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 possile 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 si 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

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

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

A. is zero is 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

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 quantites related to planets remains same during their motion in 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, 2m, 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 center.

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3. Three equal masses m are placed at the three corners of an equilateral triangle of side 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 center 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. Four 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 x10^22 ' 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 center 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 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 if it is placed at a distance $\frac{R_1 + R_2}{2}$ from the center?

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11. A tunnel is dug along a diameter of the earth. Find the force in on a particle of mass m placed in the tunnel at a distance x from the centre.

A. $\frac{GMm}{R^3}x$

B. $\frac{GMm}{R^2}x$

C. $\frac{GMm}{R^3}x^2$

D. zero

Answer: A

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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 centers as 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

$a). r < x < 2r, b). 2r < x < 2R$ and $c). x > 2R$

.

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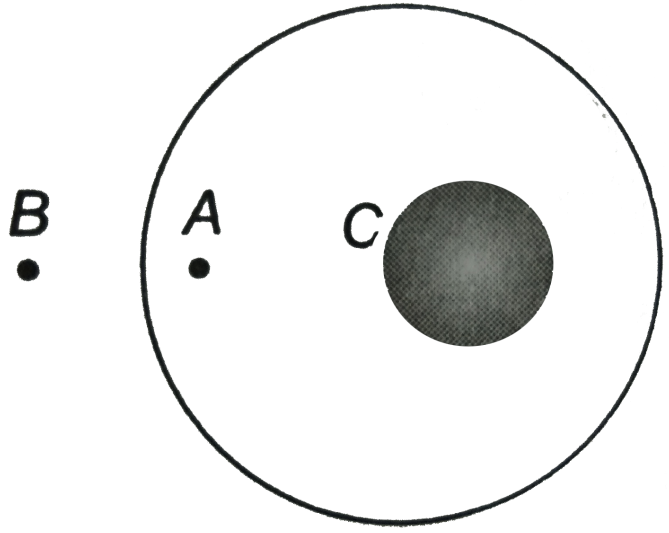
14. A uniform metal sphere of radius R and mass m is surrounded by a thin uniform spherical shell of same mass and radius $4R$. The centre of the shell C falls on the surface of the inner sphere. Find the gravitational fields at points A and B.



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15. A thin sphereical shell having uniform density is cut in two parts by as plane and kept separated as shown in figure. The point A is the center of the plane section of the first part and B is the center 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 particle with usual reference level?

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17. Three particle of mas m each are placed at the three corners of an equlateral 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 $\vec{E} = \left(5Nkg^{-1}\right)\vec{i} + \left(12Nkg^{-1}\right)\vec{j}$.. a. find the magnitude of the gravitational force acting on a particle of mass 2 kg placed at the origin b. Find the potential at the points (12m,0) and (0,5m) if the potential at the origin is taken to be zero. c. Find the change in gravitational

potential energy if a particle of mass 2 kg is taken from the origin to the point (12m,5m). d. Find the change in potential energy if the particle is taken from (12m,0) to (0,5m)`.

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20. The gravitational potential in a region is given by $V = 20Nkg^{-1}(x + y)$. 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 fore 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 move on the line $3y + 2x = 5$.

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22. Find the height over the eart's surface at which the weight of a body becomes half of its alue t 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 of the world at the height of 8848 m. The value at see 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 surfaceis 9.800 ms^-2`. The rdius of the earth is 6400 km.

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25. A body is weighed by a spring balance to be $1000n$ 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 mas 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 by 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 around the earth in a nearly circular orbit of radius $3.84 \times 10^5 km$. Calculate the mass of the earth from these data.

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

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32. A satellite of mass $1000kg$ is supposed to orbit the earth at a height of $2000km$ 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 $= 6 \times 10^{24} kg$.

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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 $= 6 \times 10^{24} kg$

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34. What is the true weight of an object in a geostationary satellite that weighed exactly 10.0 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 gravitation 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 fom 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 $15kms^{-1}$. 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 $3 \times 10^{8} ms^{-1}$. What should be the radius of the sphere?

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Question For Short Answers

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

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2. If heavier bodies are attracted more strongly by the earth why don't they fal faster than the lighter bodies?

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

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4. The earth revolves round the sun because the sun attracts the erth. The sun also attracts the moon and this force is about twice as large as the attraction of the earth on the mon. Why does the moon not revolve round the sun? Or does it?

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5. At noon, the sun and the earth pull theobjects on the earth's surface in opposite directions. At midnight, the sun and the earth pul these objects in same direction. Is the weight of an object as mearured by a spring baslance on the earth's surface , more at midnight as compared to its weight as noon?

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6. An apple fals from a tree. An insect in the apple filnds that the earth is falling towards it with an acelerartiong. Who exerts the force needed to accelerate the earth with this acceleration?

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7. Suppose the gravitational portential due to a small system is $\frac{k}{r^2}$ at distance r from it. What will be the gravitational fied? Can you think of

any such system? What happens if there were negative masses?

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8. 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 shoud be used to

calculalte the gravitational potential energy at separation?

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9. 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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10. 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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11. If the radius of the earth decreases by 1% without changing its mass, will the acceleration

dure to gravity at the surface of the earth increase or decrease? If so, by what per cent?

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12. A nut becomes lose 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 astronaut make it land on the earth?

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

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14. Consider earth satellites in circular orbits. A geostationary 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 satellite

moving at this height have a time period of 24 hours?

15. No part of India is situated on the equator. Is it possible to have a geostationary satellilte which always remains over New Delhi?

16. 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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17. Two satellites going in equatoral 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 on will have less time period?

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

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