PHYSICS

BOOKS - S CHAND PHYSICS (ENGLISH)

GRAVITATION

Solved Examples

1. Two bodies of masses 1 kg and 6×10^{24} kg are placed with their centres $6.38 \times 10^{6} m$ apart. Calculate the force of attraction

between the two masses. Also find the initial acceleration of the two masses. [Assume that no other forces act on them]

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2. Find the value of G from the following data. Mass of the earth $= 6 \times 10^{24} kg$, radius of the earth = 6371km and $g = 9.8 m / s$

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3. Assuming the earth b to be a homogeneous sphere determine the density of the earth from the following data. $g = 9.8m/s^2, G = 6.67 \times 10^{-11} Nm^2 kg^2,$ radius of the earth = 6372km.

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4. The mass of a body on the surface of the earth is 70kg. What will be its (i) mass and (ii)

weight at an altitude of 100km? Radius of the earth is 6371km.

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5. How much a body of mass 60 kg weight at (i) the pole, (ii) the equator and (iii) a latitude of 30° ? Radius of earth is 6371km.

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6. What is the decrease in weight of a body of mass 800 kg when it is taken into a mine of depth 1500m? Radius of the earth is 6371km.

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7. Calculate the gravitational intensity on the surface of Mars assuming it to be a uniform sphere. Given mass of Mars is $6.420 \times 10^{23} kg$, its radius is $3.375 \times 10^{6} m$.

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8. Find the gravitational potential due to a body o fmass 10kg at a distance (i) 10m and (ii) 20 m from the body. Gravitational constant $G = 6.67 \times 10^{-11} Nm^2 kg^{-1}$.

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9. Find the escape velocity of a body from the surface of Mars. Assume it as a uniform sphere of mass $6.42 \times 10^{23} kg$ and radius $3.375 \times 10^6 m$.

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10. Suppose there is an artificial satellite revolving round the planet mars at a height of 125 km. What is the orbital velocity of the artificial satellite. Radius of Mars is $3.375 \times 10^6 m$ and the mass of the Mars is $6.420 \times 10^{23} kg$.

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11. Find the escape speed from the earth for a 6000kg spacecraft and find the kinetic energy it must have at the surface of the earth in order to escape the Earth's gravitational field? Mass of the earth is $5.98 \times 10^{24} kg$ and its radius is $6.37 \times 10^{6} m$

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12. Find the workdone to move an earth satellite of mass m from a circular orbit of

radius 2R to one of radius 3R.

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Additional Solved Problems

1. The acceleration due to gravity at the moon's srface is $1.67ms^{-2}$. If the radius of the moon is $1.74 \times 10^6 m$, calculate the mass of the moon. Use the known value of G.

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2. On the surface of earth a body weighs 99N. What is the gravitational force on it at a height equal to half the radius of the earth?

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3. Find the escape velocity of a body from the surface of the earth. Given radius of earth $= 6.38 \times 10^6 m.$

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4. Determine the escape velocity of a body from the moon. Take the moon to be a uniform sphere of radius $1.74 \times 10^6 m$, and the mass $7.36 \times 10^{22} kg$? $\left(G = 6.67 \times 10^{-11} Nm^2 kg^{-2}\right)$

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5. What is the orbital velocity of an artifical satellite revolving round the earth at a height 100 km?

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6. Calculate the height above the earth at which the geostationary satellite is orbiting the earth. Radius of earth = 6400km. Mass of earth

$= 6 \times 10^{24} kg.\ G = 6.67 \times 10^{-11} Nm^2 kg^{-2}.$

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7. Find the mass of the earth from the following data. The period of lunar orbit

around the earth is 27.3 days and radius of the orbit

$3.9 \times 10^5 km$. $G = 6.67 \times 10^{-11} Nm^{-2} kg^{-2}$.

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8. In an imaginary planetary system, the central star has the same mass as our sun, but is much brighter so that only a planet twice the distance between the earth and the sun can support life. Assuming biological evolution (including aging process etc.) on that is

similar to ours, what would be the average life span of a 'human' on that planet in terms of its natural year? The average life span of a human on the earth may be taken to be 70 years.

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9. Three mass points each of mass m are placed at the vertices of an equilateral triangle of side 1. What is the gravitational field and

potential due to the three masses at the centroid of the triangle ?

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10. If a spaceship orbits the earth at a height of 500 km from its surface, then determine its (i) kinetic energy, (ii) potential energy, and (iii) total energy (iv) binding energy. Mass of the satellite = 300 kg, Mass of the earth $= 6 \times 10^{24} kg$, radius of the earth $= 6.4 \times 10^{6} m, G = 6.67 \times 10^{-11} \text{N-m}^2 kg^{-2}$

. Will your answer alter if the earth were to shrink suddenly to half its size ?

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11. A rocket is fired from the earth towards the sun. At what point on its path is the gravitational force on the rocket zero? Mass of the sun is $2 \times 10^{30} kg$, mass of the earth is $6 \times 10^{24} kg$. Neglect the effect of other planets etc. (orbital radius $= 1.5 \times 10^{11} m$).

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12. A spaceship is satationed on Mars. How much energy must be expended on the space ship to rocket it out of the solar system ? Mass of the space ship = 1000 kg. Mass of the sun $= 2 \times 10^{30} kg$, Mass of Mars $= 6.4 \times 10^{23} kg$, radius of Mars = 3395 km, radius of the orbit of Mars $= 2.28 \times 10^{8} km$, $G = 6.67 \times 10^{-11} Nm^2 kg^{-2}$

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13. 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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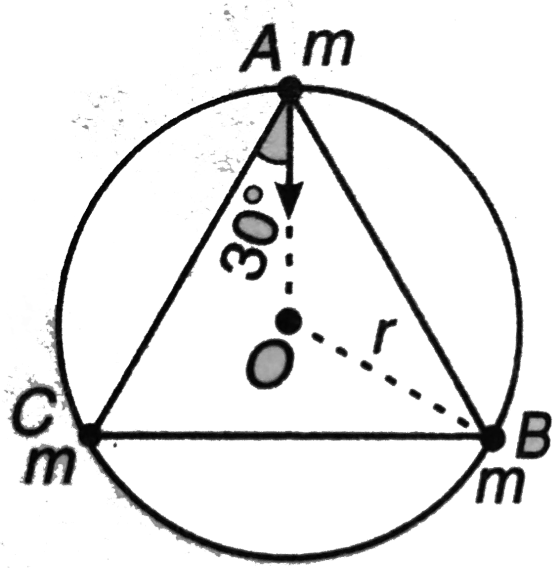
14. Three particles each of mass m, are located at the vertices of an equilateral triangle of side a. At what speed must they move if they all revolve under the influence of their gravitational force of attraction in a circular orbit circumscribing the triangle while still

preserving the equilateral triangle ?



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15. An artificial satellite is moving in a circular orbit around the earth with a speed equal to

half the magnitude of escape velocity from the surface of earth. (Radius of earth $= 6400km$)

(a) Dentermine the height of the satellite above the earth's surface.

(b) If the satellite is stopped suddenly in its orbit and allowed to fall freely on the earth, find the speed with which it hits the surface of earth.

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Conceptual Short Answer Questions With Answers

1. Define gravitational constant G.

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2. Two objectes of mass m and 4m are at rest at and infinite seperation. They move towards each other under mutual gravitational attraction. If G is the universal gravitational constant. Then at seperation r

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3. A body is taken from equator to pole. What happens to (1) its mass (2) its weight.

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4. What will happen to the weight of a body at the equator if earth stops rotating?

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5. The mass of a body is less in a mine. Is it true?

6. What is the height of a synchronous satellite?

7. Define gravitational potential and gravitational potential energy.

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8. A satellite needs no fuel to move round a planet in a stable orbit. Why?

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9. What is the maximum value of gravitational potential? Where ?

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10. Why earth does not fall towards sun due to its attrraction?

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11. A body is taken to a height equal to radius of earth and then to a depth equal to radius of earth. What will be its weight in each case ?

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12. The space rockets are launched from west to east. Why?

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13. Explain the reason of weightlessness inside a satellite.

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14. Explain why

(a) there is no atmosphere on moon

(b) there is fall in temperature with altitude

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15. Gravitational force is weak force but still it is considered the most important force. Why?

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16. Do the forces of friction and other contact forces arises due to gravitational attraction? If not, what is the origin of these forces?

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17. We can shield a charge from electric fields by putting it inside a hollow conductor. Can we shield a body from the gravitational influence of nearby matter by putting it inside a hollw sphere or by some other means ?

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18. An astronaut inside a small spaceship orbitting around the earth cannot detect gravity. If the space station orbtitting around

the earth has a large size, can he hope to detect gravity ?

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19. If you compare the gravitational force on the earth due to the sun to that due to the moon, you would find that the sun's pull is greater than moon's pull. However , the tidal effect of the moon's pull is greater than the tidal effect of the sun. Why?

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20. A comet orbits the sun in a highly elliptical orbit. Which of the following quntities remains constant throughout its orbit ?

(i) Linear Spped (ii) Angular speed

(iii) Angular momentum (iv) Kinetic energy

(v) Potential energy (vi) Total energy

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21. The escape velocity of a body from the earth depends on

(i) the mass of the body

(ii) the location from where it is projected.

(iii) the direction of projection.

(iv) the height of the location from where the body is launched.

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22. What are the conditions required for a boyd to become earth's satellite when fired by a rocket?

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Long Answer Questions

1. A satellite of mass m is moving in a circular or orbit of radius R around the earth. The radius of the earth is r and the acceleration due to gravity at the surface of the earth is g. Obtain expressions for the following :

(a) The acceleration due to gravity at a distance R from the centre of the earth

(b) The linear speed of the satellite

(c) The time period of the satellite

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2. Deduce an expression for the minimum velocity with which a rocket must be fired to escape earth's gravitational field.

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3. Explain why hydrogen is found in abundance around the sun while it is absent from the

earth's atmosphere? Why there is no atmosphere on the moon?

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4. Assertion : Astronauts in a satellite moving around the earth are in a weightless condition.

Reason : The satellite and its contents are falling freely at the same rate.

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5. Derive an expression to explain the decrease in acceleration due to gravity inside the earth as one approaches the centre.

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6. Define gravitational potential and its unit.

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7. What are the conditions for a satellite to be stationary?

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8. State Newton's law of gravitational.

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9. Write down the relation between the universal gravitational constant G and the

acceleration due to gravity at the earth's surface.

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10. What do you understand by the term velocity of escape?

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11. Explain why

(a) there is no atmosphere on moon

(b) there is fall in temperature with altitude

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12. Derive and explain Kepler's laws of planetary motion.

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13. State Newton's law of gravitational.

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Short Answer Questions

1. Dependence of intensity of gravitational field (E) of earth with distance (r) from centre of earth is correctly represented by

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2. Define gravitational potential and gravitational potential energy.

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3. Derive an expression for the gravitational potential energy of a body lying at a height above the surface of the earth.

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4. Obtain the dimensional formula of G and gravitational potential.

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5. Distinguish between inertial and gravitational mass.

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6. What is a satellite? What is the difference between natural satellite and artificial satellite.

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7. Give the full form of (i) Inteslat and (ii) Insat.

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8. Write a note on synchronous satellite.

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9. Derive an expression for the period of a geostationary satellite.

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10. Write a note on apiculture.

Watch Video Solution

11. Derive an expression for the escape velocity of a body from any planet.

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12. Can you find the mass of sun without weighing?

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13. Explain why some planets do not have atmosphere.

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14. What are the conditions for a satellite to be stationary?

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15. (a) Explain Stokes Law

(b) Define terminal velocity

(c) Describe an experiment to determine the terminal velocity

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16. What is the energy of a satellite revolving in a stable orbit.

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17. Suppose a body is carried from earth to moon. What happens to its weight?

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18. If the diameter of the earth becomes two times its present value and its mass remains unchanged then how would the weight of an object on the surface of the earth be affected ?

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19. "No fuel is required for satellite to revolve round earth. But fuel required for aeroplane". Why?

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20. A satellite is launched into a circular orbit of radius R around earth while a second satellite is launched into an orbit of radius 1.02R. The percentage difference in the time period is

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21. What is a parking orbit ? Why is it called so ?

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22. A ball is released from height h and another from 2h. The ratio of time taken the two balls to reach the ground is

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23. The time period of a simple pendulum of length 9.8 m is

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24. Assertion : The principle of superposition is not valid for gravitational force

Reason : Gravitational forces are non-conservative.

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25. What is the frequency of oscillation of a simple pendulum mounted in a cabin that is freely falling under gravity ?

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26. To an astronaut in a space-ship, the earth appears :

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27. Which of the following reactions isnot correct according to the law of conservation of mass?

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Very Short Answer Questions

1. According to Newton's law of gravitation each particle attracts every other particle. But we do not see bodies on the surface of the earth moving towards each other. Why?

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2. The force of gravity is proportional to the masses of the bodies. Then why doesn't a heavy body fall faster than a light body?

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3. Is it possible to shield a body from the gravitational attraction of other bodies?

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4. Suppose the earth stops rotating about its axis what will be its effect on the weight of a body.

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5. Is it possible to put an artificial satellite in an orbit in such a way that it always remain visible directly over New Delhi ?

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6. What is the weight of a body in geostationary satellite?

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7. A person in an artificial satellite of earth feels weightlessness. But a person on the moon has weight eventhough moon is also a satellite . Why ?

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8. Can we find the mass of a satellite by finding its Time period?

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9. There is no atmosphere on the moon because

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10. What is the energy required by a satellite to keep it orbiting?

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11. The space rockets are launched from west to east. Why?

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12. What is the frequency of osciallation of a simple pendulum mounted in a cabin that is freely falling under gravity?

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Selected Problems From Newton S Law Of Gravitation

1. Two spheres of masses 38 kg and 15 kg each are placed with their centres 20 cm apart. The force of attraction between them is equal to 0.1 milligram wt. Calculate the constant of gravitation.

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2. Calculate the gravitational force of attraction between a proton of mass $1.67 \times 10^{-27} kg$ and an electron of mass 9.1×10^{-31} kg separated by distance of 1 Fermi ? $G = 6.67 \times 10^{-11} Nm^2 kg^{-2}$.

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3. A 50kg boy is standing near a 60 kg girl. If the distance between them is 1m, calculate the

gravitational force of attraction between them?

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4. The force of attraction between two particles of masses 12 kg ans 25kg is $1.4 \times 10^{-8} N$ .Calculate the separation between the particles.

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Selected Problems From Mass Density Of Earth Planets

1. Calculate the mass of the earth from the following data. Radius of the earth, 6371km, $g = 9.8ms^{-2}$

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2. Density of earth is $5.488 \times 10^3 kgm^{-3}$. Assume earth to be a hemogeneous sphere,

find the value of g on the surface of the earth.

Use the known values of R and G.

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3. The radius of the moon is $1/4$ th the radius of the earth and its mass is $1/80$ th the mass of the earth. Calculate the value of g on the surface of the moon.

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4. Mass of moon is $7.349 \times 10^{22} kg$ and its radius is $1.738 \times 10^{6} m$. Calculate its mean density and acceleration due to gravity on its surface. Given $G = 6668 \times 10^{-11} Nm^{2} kg^{-2}$.

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5. If the mass of Mars is 0.107 M_E and its radius is 0.53 R_E, estimate the gravitational field g at the surface of Mars.

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6. If the radius of the earth shrinks by 3.5% (mass remains constant) then how would the value of acceleration due to gravity change?

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7. A star 2.5 times the mass of the sun and collapsed to size of 12 km rotates with a speed of 1.5 rev per second (extremely compact stars of this kind are known as neutron stars. Certain observed stellar objects called pulsars

are believed to belong to this category). Will an object placed on its equator remain stuck to its surface due to gravity? (Mass of the sun $= 2 \times 10^{30} kg$)

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8. The acceleration due to gravity at the surface of the earth is g. Calculate its value at the surface of the sum. Given that the radius of sun is 110 times that of the earth and its mass is 33×10^4 times that of the earth.

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9. The mass of Mars is $(1/9)$times that of the earth and its radius is $(1/2)$ that of the earth. What is the weight of a body having a mass of 100kg on the surface of the earth?

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Selected Problems From Variation Of G With Altitude Latitude Depth

1. What is the value of g at a height 8848 m above sea level. Given g on the surface of the earth is $9.8ms^{-2}$. Mean radius of the earth $= 6.37 \times 10^{6}m$.

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2. A body weights 63N on the surface of the earth. What is the gravitational force on it due to the erath at a height equal to half the radius of the earth?

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3. Assuming earth to be a sphere of radius 6400km, calculate the height above the earth's surface at which the value of acceleration due to gravity reduces to half its value on the erath's surface.

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4. Calculate the height at which a man's weight becomes $(4/9)$ of his weight on the

surface of the earth, if the radius of the earth is 6400km.

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5. A what height above the earth's surface the value of g becomes 25% of its value on the earth if radius of the earth is 6400km.

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6. What is the ratio of the weights of a body when it is kept at a height 500m above the surface of the earth and 500m below the surface of the earth, if the radius of the earth is 6400km.

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7. If the earth were a perfect sphere of radius $6.37 \times 10^6 m$, rotating about its axis with a period of 1 day $\left(= 8.64 \times 10^6 s \right)$, how much

would the acceleration due to gravity differ from the poles to the equator.

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8. How mcuh faster than its present rate should the earth rotate about its axis so that the weight of a body at the equator becomes zero? Also calculate the new length of the day.

(c) What would happen if rotation becomes faster ?

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9. With what speed should the earth rotate in order that the weight of a man on the equator is reduced to half his present weight , if the radius of the earth is 6400km.

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10. Assuming the earth tobe a sphere of uniform mass density, how much would a body weigh half way down to the centre of the earth if it weighed 250N on the surface?

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11. Find the acceleration due to gravity at a point 64km below the surface of the earth. R = 6400 k, g on the surface of the earth $= 9.8ms^{-2}$.

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12. Determine the decrease in the weight of a body when it is taken 32 km below the earth

surface. Take radius of the earth as 6400 km.

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13. Compare the weigths of a body when it is kept (i) 400m above the surface of the earth and (ii) 800 m below the surface of the earth.

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14. What is the ratio of the weights of a body when it is kept at a height 500m above the

surface of the earth and 500m below the surface of the earth, if the radius of the earth is 6400km.

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Selected Problems From Intensity Of Gravitational Field And Gravitational Potential

1. Calcualte the intensily of gravitational field due to a body of mass 20kg at a distance of 50cm from the body ?

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2. A geostationary satellite orbits the earth at a height of nearly 36,000 km from the surface of earth. What is the potential due to earth's gravity at the site of this satellite? (Take the potential energy at infinity to be zero). Mass of the earth $6.0 \times 10^{24} kg$, radius = 6400km.

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3. Two heavy spheres each of mass 100kg and radius 0.10m are placed 1.0m apart on a horizontal table. What is the gravitational field and potential at the mid-point of the line joining the centres of the spheres? Is an object placed at the point in equilibrium ? If so, is the equilibrium stable or unstable?

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4. Calculate the surface potentail of the earth. Gravitational constant G, mass of the earth and the radius of the earth are given ?

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5. Two bodies of masses m_1 and m_2 are placed distant d apart. Show that the position where the gravitational field due to them is zero, the potential is given by,

$$V = -\frac{G}{d}\left(m_1 + m_2 + 2\sqrt{m_1 m_2}\right)$$

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6. Calculate the distance from the earth to the point where the gravitational field due to the earth and the moon cancel out. Given that the earth-moon distance is $3.8 \times 10^8 m$ and the mass of earth is 81 times that of moon.

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7. Two masses 800 kg and 600kg are at a distance 0.25 m apart. Calculate the

magnitude of the gravitational intensity at a point distant 0.20 m from the 800 kg and 0.15 m from the 600 kg mass. $G = 6.66 \times 10^{-11} Nm^2 kg^{-2}$.

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Selected Problems From Gravitational Potential Energy

1. What is the change in potential energy of a body of mass 10kg when it is taken to a height

of 2R from the earth's surface ? G given

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2. Calculate the gravitational potential energy of a body of mass 100 kg at a distance of 6 km from the centre of the earth.

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3. A rocket is fired vertically with a speed of $5kms^{-1}$ from the earth's surface. How far

from the earth does the rocket go before returning to the erath? Mass of the earth $= 6.0 \times 10^{24} kg$, mean radius of the earth $= 6.4 \times 10^{6} m$. $G = 6.67 \times 10^{-11} Nm^{2} kg^{-2}$.

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4. Two stars each of 1 solar mass $\left(= 2 \times 10^{30} kg \right)$ are approaching each other for a head-on collision. When they are at a distance $10^{9} km$ apart their speeds are negligible . What is the speed with which they

collide? The radius of each star is 10^4km. Assume the starts to remain undistorted untile they collide, $G = 6.67 \times 10^{-11} Nm^2 kg^{-2}$.

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Selected Problems From Escape Velocity

1. The escape speed of a body on the earth's surface is 11.2 km s^{-1}. A body is projected with thrice of this speed. The speed of the body

when it escapes the gravitational pull of earth is

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2. What is the escape velocity of a body from the solar system? Calculate using the following data. Mass of the sun $= 2 \times 10^{30} kg$. The distance between earth and the sun $= 1.5 \times 10^{11} m$.

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3. If the earth has mass 9 times and radius twice that of the planet Mars, calculate the minimum velocity required by a rocket to pull out of the gravitational force of Mars. Escape velocity on the surface of the earth in $11.2 km / s$

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4. The escape velocity of a particle on earth (radius R and mass M) is 11.2 kms^{-1} . What is

the escape velocity on another planet with radius $R/2$ and mass $M/4$?

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5. Jupiter has a mass 318 times that of earth, and its radius is 11.2 times the earth's radius Estimate the escape velocity of a body from Jupiter's surface, given that the escape velocity from the earth's surface $11.2 kms^{-1}$.

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6. Calculate the escape velocity of an atmospheric particle 1000 km above the surface of the earth. Given $R = 6.4 \times 10^6 m$ and $g = 9.8 ms^{-2}$.

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7. A stone has a mass of 500g. How much energy must be imparted to the stone in order that it escapes form the earth?

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8. The radius of a planet is double that of earth but their average are the same. If the escape velocities at the planet and the earth are v_p and v_e respectively , then prove that $v_p = 2v_e$.

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9. What is the ratio of the escape velcoities from two planets of equal densities but different masses M_1 and M_2 ?

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10. With what velocity a body of mass m be projected vertically upwards so that it may be able to reach a height nR above earth's surface

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11. The escape velocity of a projectile on the earth's surface is $11.2 kms^{-1}$. A body is

projected out with 4 times this speed. What is the speed of the body far way from the earth?

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12. Find the orbital velocity of an artifical satellite of the earth in an orbital close to the earth?

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13. An artifical satellite cicles round the earth at a distance of 3400 km. Calculate the orbital velocity. Given the radius of the earth is 6400km. G $= 9.8ms^{-2}$.

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14. What should be the percentage increase in the orbital velcoity to escape velocity ?

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15. A spaceship is launched into a circular orbit close to the earth's surface . What additional velocity has now to be imparted to the spaceship in the orbit to overcome the gravitational pull. Radius of earth $= 6400km$, $g = 9.8m/s^2$.

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16. What should be the percentage increase in the kinetic energy of a satellite to enable it to escape?

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17. An earth satellite makes a complete revolution around the earth in 120 minutes. If the orbit is circular calculate the height of satellite above the earth. Radius of the earth = 6400 km g = $9.8ms^{-2}$.

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18. Find the period of revolution of a satellite revolving the earth at a height of 200km above earth's surface ? Radius of earth = 6400 km

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19. A satellite revolve round a planet in an orbit just above the surface of a planet. Taking $G = 6.67 \times 10^{-11} Nm^2 kg^2$ and mean density

of the planet $5.51 \times 10^3 kg/m^3$ find the period of the planet.

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20. A satellite is in a circular orbit about a planet of radius R. If the altitude of the satellite is h and its period is T, show that the density of the planet is $\rho = \frac{3\pi}{GT^2}\left[1 + \frac{h}{R}\right]^3$

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From Kepler S Laws And Energy Of A Satellite

1. A saturn year is 29.5 times the earth year. How far is the saturn from the sun if the earth is 1.50×10^8km away from the sum?

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2. The distance of two planets from the sun are 10^{13} and 10^{12} m respectively. The ratio of the periods of the planet is

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3. If earth is $1/4$ of its present distance formt he sun, then what is the duration of the year?

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4. Find the mass of the sun from the following data. The mean orbital radius of earth around the sun is 1.5×10^8km.

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5. A satellite of mass 50kg orbits the earth at a height of 100km. Calcualte (i) K.E. (ii) P.E. and (iii) total energy . Given $G = 6.67 \times 10^{-11} Nm^2 kg^{-2}$. Radius of the arth is 6400 and mass of the earth is 6×10^{24} kg.

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From The Hubble Telescop

1. The mass of the Hubble space telescope is 11600 kg. What is its weight when it is in its orbit 598 km above the earth's surface ? Take R = 6400km.

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2. Calculate the orbital speed of the Hubble space telescope orbiting at a height of 598 km above the earth's surface. Take R = 6400km. Mass of earth -5.98×10^{24}kg

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