PHYSICS

BOOKS - NAVNEET SCIENCE (HINGLISH)

GRAVITATION

Numerical Problems For Practice

1. A satellite of mass 1000 kg revolves around the earth in a circular path. If the distance between the satellite and the centre of the earth is 4000 km, find the gravitational force exerted on the satellite by the earth.

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2. The masses of two spheres are 10 kg and 20 kg respectively. If the distance between their centres is 100m, find the magnitude of the

gravitational force between them.

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3. A satellite revolves around the earth along a circular path. If the mass of the satellite is 1000 kg and its distance from the centre of the earth is 20000 km, find the magnitude of the earth's gravitational force acting on the satellite.

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4. Find the acceleration due to gravity at a distance of 20000 km from the centre of the earth.

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5. What is the weight of a body of mass 100 kg at the south pole ?

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6. What is the weight of a body of mass 20 kg at the equator ?

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7. A body is released from the top of a tower of height 50 m. Find the velocity with which the body hits the ground. $\left(g = 9.8m/s^2\right)$

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8. A body is thrown vertically upward with a velocity of 9.8 m/s. Calculate the maximum height attained by the body. $\left(g = 9.8m/s^2\right)$

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9. A particle of mass $10^{-6}kg$ performs uniform circular motion. Its period is 10 s and the radius of the circle is 2 m. Find (i) the speed of the particle

(ii) the centripetal acceleration of the particle (iii) the centripetal force on the particle.

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10. Find the gravitational potential energy of a body of mass 200 kg on the earth's surface.

$\left[\mathrm{M(earth)} = 6 \times 10^{24}\mathrm{kg}, \mathrm{R\ (earth)} = 6400km\right]$

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11. Find the gravitational potential energy of a body of mass 10 kg when it is at a height of 6400 km from the earth's surface.

[Given : mass of the earth and radius of the earth.]

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12. Find the escape velocity of a body from the moon.

$[\mathrm{M(moon)} = 7.36 \times 10^{22} kg \mathrm{R(moon)} = 1.74 \times 10^{6} m]$

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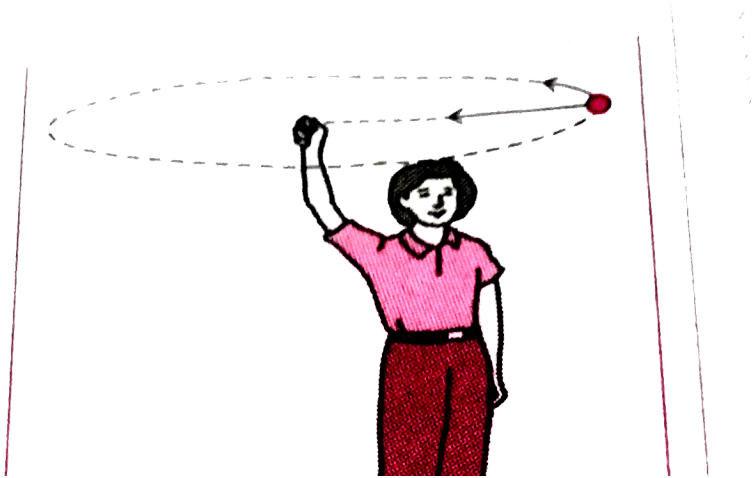
Try This

1. Tia a stone to one end of a string. Take the other end in your hand and rotate the string so that the stone moves along a circle as shown in figure 1.1 (a). Are you applying any force on the stone? In which direction is this force acting ? How will you stop this force from acting ? What will be the effect on the stone ?



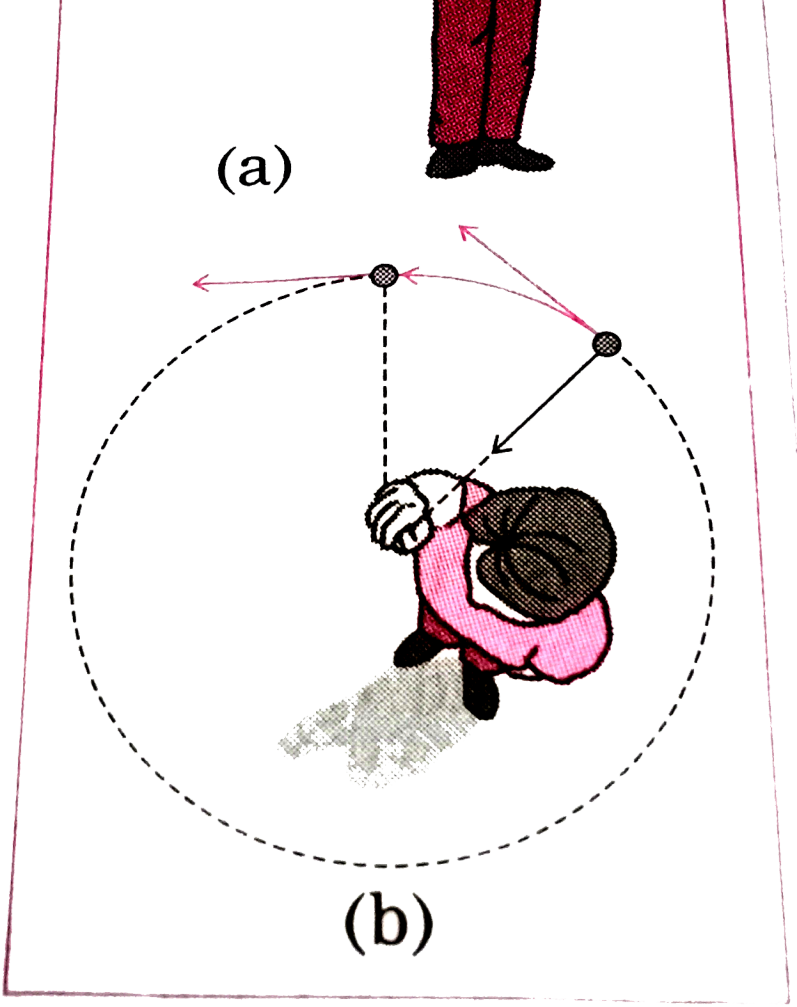


Fig. 1.1 : A stone tied to a string, moving along a circular path and its velocity in tangential direction

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2. Take a small stone. Hold it in your hand. What are the forces acting on the stone ? Now release the stone. What do you observe ? What are the forces acting on the stone after you release it ?

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Use Your Brain Power

1. Is there a gravitational force between two objects kept on a table or between you and your friend sitting next to you ? If yes, why don't the two move towards each other ?

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2. If area ESF in figure 1.5 is equal to area ASB,, what will you infer about EF?

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3. Show that in SI units, the units, the unit of G is the newton. m^2kg^{-2}

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4. According to Newton's law of gravitation, every object attracts every other object.

Thus, if the earth attract an apple towards itself, the apple also attracts the earth towards itself with the same force. Why then does the apple fall toward the earth, but the earth does not move towards the apple ?

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5. The gravitational force due to the earth also acts on the moon because of which it revolves around the earth. Similar situation exists for the artificial satellites orbiting the earth. The moon and the artificial satellites orbit the earth. The earth attracts them towards itself but unlike the falling apple,they do not fall on the earth, why?

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6. Will your weight remain constant as you go above the surface of the earth?

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7. Suppose you are standing on a tall ladder. If your distance from the centre of the earth is 2 R, what will be your weight ?

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8. According to Newton's law of gravitation, the earth's gravitational force is higher on an object of larger mass. Why doesn't that object fall down with higher velocity as compared to an object with lower mass ?

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9. Assuming the acceleration in Example 2 above remains constant, how long will Mahendra take to move 1 cm towards Virat ?

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Think About It

1. What would happen if there were no gravity ?

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2. What would happen if the value of G was twice as large?

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3. Will the direction of the gravitational force change as we go inside the earth ?

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4. What will be the value of g at the centre of the earth ?

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Can You Tell

1. What would be the value of g on the surface of the earth if its mass was twice and its radius half of what it is now ?

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Questions Answers

1. The ratio $g_{(\text{earth})} / g_{(\text{moon})}$ is equal to .....

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2. The value of the acceleration due to gravity ..... As we move from the equator to a pole.

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3. If the earth shrinks to half of its radius, its mass remaining the same, the weight of an object on the earth will become ..... Times.

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4. SI unit of weight is Newton.

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5. The CGS unit of weight is the .....

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6. The weight of a body is ..... at the poles.

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7. Outside the earth, the weight of a body veries as .....

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8. Dut to the ..... Force, the earth attracts all objects towards it.

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9. The acceleration due to gravity does dose not depend on the..... Of the body.

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10. According to Kepler's first law, the orbit of a planet is ..... with the sun at one of the .....

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11. According to Kelper's second law, the line joining the planet and the Sun ..... In equal intervals of time.

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12. According to Kepler's third law $T^2 \propto r^n$, where n = ...

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13. For a freely falling object we can write Newton's second equation of motion as .....

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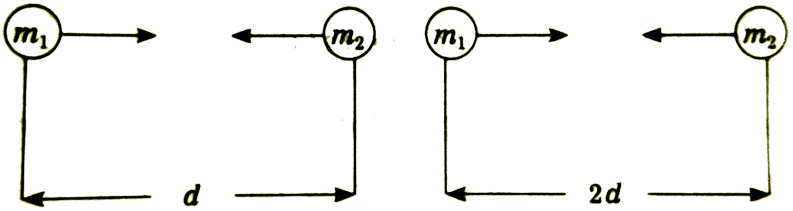
14. Write the proper answer in the square.



If this $F = x$ Then $F =$ _____

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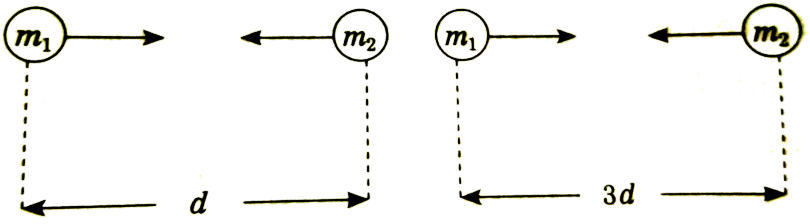
15. Write the proper answer in the square.



If $F = \frac{Gm_1m_2}{d^2}$ then F = _____

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16. The gravitational force between two particles separated by a distance r varies as .....

A. $\frac{1}{r}$

B. r

C. r^2

D. $\frac{1}{r^2}$

Answer: d

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17. In the usual notation, the acceleration due to gravity at a height h from the surface of the earth is .....

A. $\frac{g(GM)}{(R+h)}$

B. $g = \frac{GM}{\sqrt{R+h}}.$

C. $g = \frac{GM}{(R+h)^2}$

D. $g = GM(R+h)^2$

Answer: c

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18. The SI unit of the universal constant of gravitation is ..... .

A. $N.\, m^2 / kg^2$

B. $N.\, kg^2 / m^2$

C. m / s^2

D. $kg.\, m / s^2$

Answer: a

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19. The escape velocity of a body from the earth's surface, $v_{esc} =$ ..... .

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

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

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

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

Answer: c

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20. How much will a person with 72 N weight on the earth, weigh on the moon?

A. 12 N

B. 36 N

C. 21 N

D. 63 N

Answer: a

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21. What will be the weight of a person on the earth, who weights 9 N on the moon ?

A. 3 N

B. 15 N

C. 45 N

D. 54 N

Answer: d

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22. If the separation between two particles is doubled, the gravitational force between the particles becomes half the initial force.

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23. The CGS unit of the universal constant of gravitation is the dyne $cm^2 / gram^2$.

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24. At the centre of the earth , the value of the acceleration due to gravity becomes zero.

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25. The weight of a body is minimum at the poles.

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26. Mass is a vector quantity.

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27. Weight is a vector at the equator.

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28. g has maximum value at the equator.

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29. Outside the earth, g varies as $1/(R+h)^2$.

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30. The value of G changes from place to place.

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31. The value of g increases with altitude.

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32. The escape velocity of a body does not depend on the mass of the body.

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33. The mass of a body is the amount of matter present in it.

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34. Study the entries in the following table the rewrite then putting the connected items in a single row :

I	II	III
Mass	m/s^2	Zero at the centre of the earth
Weight	kg	Measure of inertia
Acceleration due to gravity	$N \cdot m^2/kg^2$	Same in the entire universe
Gravitational constant	N	Depends on height

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35. Study the entries in the following table the rewrite then putting the connected items in a single row :

Column A	Column B
(1) Escape velocity	(a) $\frac{-GMm}{R+h}$
(2) Gravitational acceleration	(b) $\sqrt{\frac{2GM}{R}}$
(3) Gravitational potential energy	(c) $\frac{Gm_1m_2}{r^2}$
(4) Gravitational force	(d) $\frac{GM}{r^2}\ (r \geqslant R)$
	(e) $\frac{-GMm}{2(R+h)}$

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36. State the SI and CGS units of G.

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37. State any one characteristic of gravitational force.

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38. Name the force that keeps a satellite in the orbit around the earth.

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39. Name the force due to which the earth revolves around the Sun.

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40. What is the acceleration due to gravity at a height h (= radius of the earth) from the surface of the earth ? ltbgt $\left(g = 9.8m/s^2\right)$

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41. What is the relation between the SI unit of weight and CGS unit of weight?

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42. Write the formula for the centripetal force acting on a body performing circular motion.

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43. Write the formula for the escape velocity of a body from the earth's surface.

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44. What is the value of the acceleration due to gravity at the centre of the earth?

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45. What are the factors on which the maximum height attained by a body thrown upwards depends?

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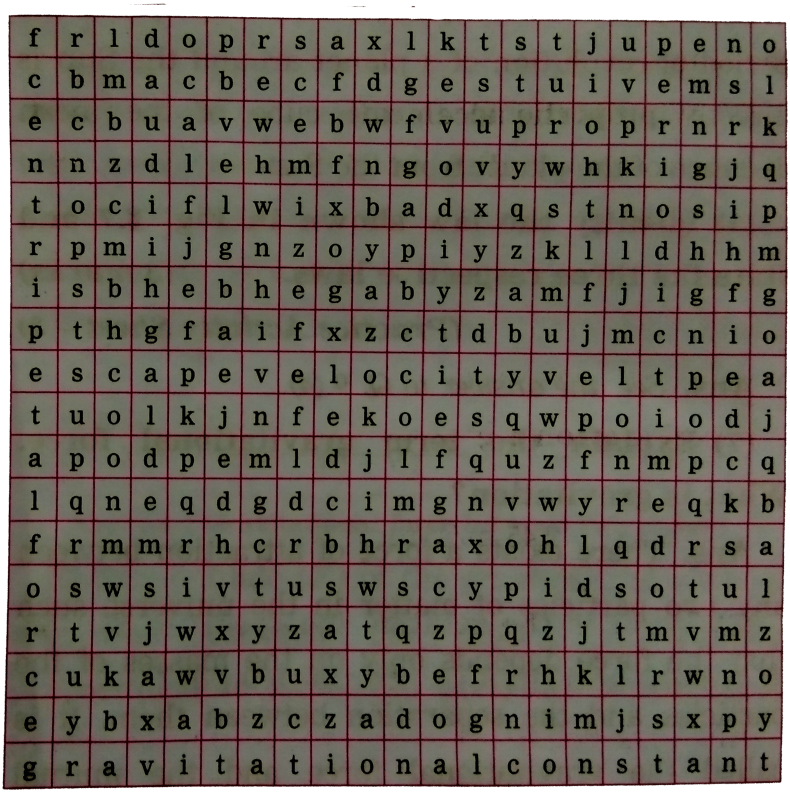
Answer The Following Questions

1. Some of the important terms in the chapter Gravitation are given in the following box. Find them:



f	r	l	d	o	p	r	s	a	x	l	k	t	s	t	j	u	p	e	n	o
c	b	m	a	c	b	e	c	f	d	g	e	s	t	u	i	v	e	m	s	l
e	c	b	u	a	v	w	e	b	w	f	v	u	p	r	o	p	r	n	r	k
n	n	z	d	l	e	h	m	f	n	g	o	v	y	w	h	k	i	g	j	q
t	o	c	i	f	l	w	i	x	b	a	d	x	q	s	t	n	o	s	i	p
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i	s	b	h	e	b	h	e	g	a	b	y	z	a	m	f	j	i	g	f	g
p	t	h	g	f	a	i	f	x	z	c	t	d	b	u	j	m	c	n	i	o
e	s	c	a	p	e	v	e	l	o	c	i	t	y	v	e	l	t	p	e	a
t	u	o	l	k	j	n	f	e	k	o	e	s	q	w	p	o	i	o	d	j
a	p	o	d	p	e	m	l	d	j	l	f	q	u	z	f	n	m	p	c	q
l	q	n	e	q	d	g	d	c	i	m	g	n	v	w	y	r	e	q	k	b
f	r	m	m	r	h	c	r	b	h	r	a	x	o	h	l	q	d	r	s	a
o	s	w	s	i	v	t	u	s	w	s	c	y	p	i	d	s	o	t	u	l
r	t	v	j	w	x	y	z	a	t	q	z	p	q	z	j	t	m	v	m	z
c	u	k	a	w	v	b	u	x	y	b	e	f	r	h	k	l	r	w	n	o
e	y	b	x	a	b	z	c	z	a	d	o	g	n	i	m	j	s	x	p	y
g	r	a	v	i	t	a	t	i	o	n	a	l	c	o	n	s	t	a	n	t

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2. What is centripetal force ?

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3. Define centripetal force?

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4. Give one example of centripetal force.

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5. Name the force responsible for the motion of a planet around the Sun.

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6. Write the three laws given by Kepler. How did they help Newton to arrive at the inverse square law of gravity?

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7. Explain with a diagram : Kepler's three laws. Hence show that gravitational force, $F \propto \frac{1}{r^2}$ (in the usual notation).

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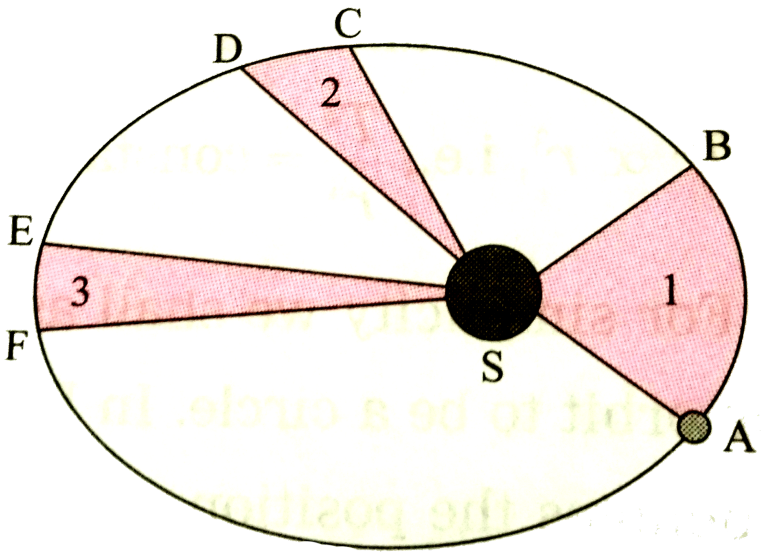
8. In the following figure, an orbit of a planet around the Sun (S) has been shown. AB and CD are the distance convered by the planet in equal time. Lines AS and CS sweep equal areas in equal intervals of time. Hence, areas ASB and CSD are equal.

(a) Which laws do we understand from the above description?



(Schematic diagram)

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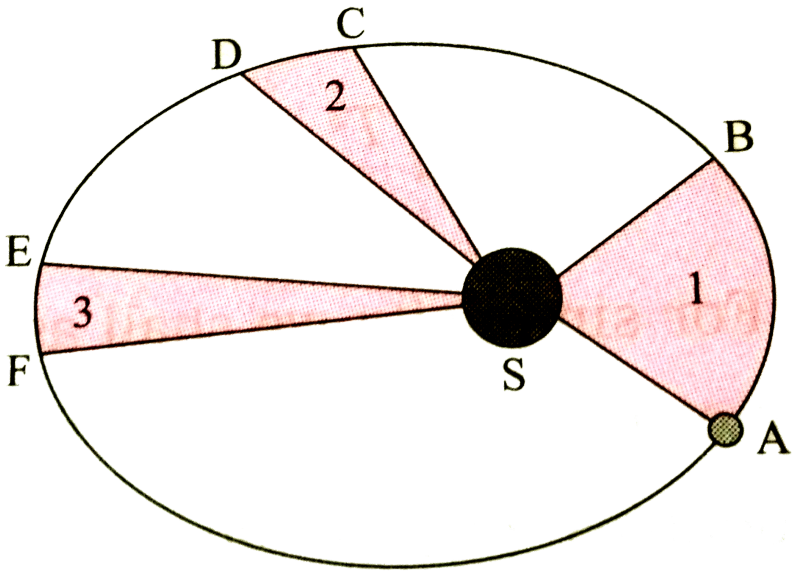
9. In the following figure, an orbit of a planet around the Sun (S) has been shown. AB and CD are the distance convered by the planet in equal time. Lines AS ad CS sweep equal areas in equal intervals of time. Hence, areas ASB and CSD are equal.

(b) Write the law regarding area swept.



(Schematic diagram)

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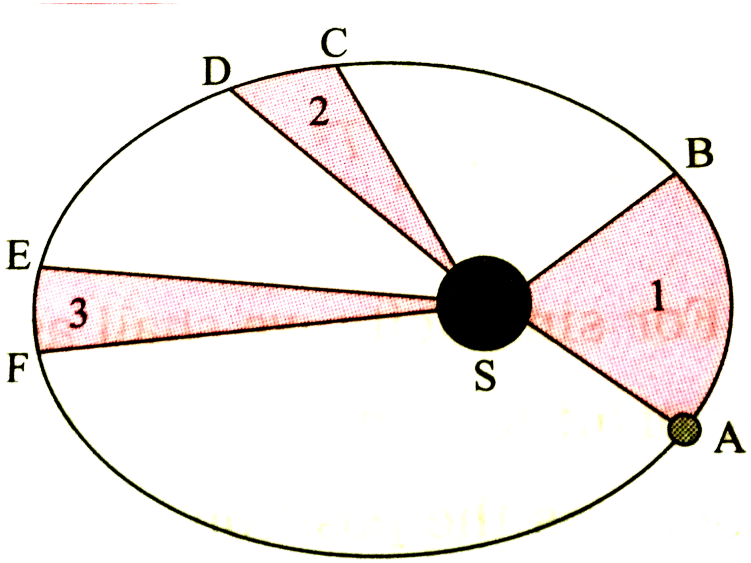
10. In the following figure, an orbit of a planet around the Sun (S) has been shown. AB and CD are the distance convered by the planet in equal time. Lines AS ad CS sweep equal areas in equal intervals of time. Hence, areas ASB and CSD are equal.

Write the law $T^2 \propto r^3$ in your words.



(Schematic diagram)

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11. Explain the term gravitational force. What is gravitation?

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12. Let the period of revolution of a planet at a distance R from a star be T. Prove that if it was at a distance of 2R from the star, its period of revolation will be $\sqrt{8}T$.

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13. State Newton's universal law of gravitation. Express it in mathematical form.

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14. Why is the constant of gravitation called a universal constant ?

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15. Newton's law of gravitation is called the universal for of gravitation. Why ?

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16. If the distance between two bodies is increased by a factor of 5, (i) by what factor will the gravitational force change if the masses are kept consant ? (ii) by what factor will the mass of one of them have to be altered, keeping the other mass the same, to maintain the same gravitational force between the two bodies.?

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17. Determine the SI unit of the universal constant of gravitation from the formula for the gravitational force between two particles. Hence, state the CGS unit of the constant of gravitation.

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18. Define G (universal gravitational constant).

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19. State the importance of Newton's universal law of gravitation .

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20. Compare the gravitational force on a body of mass 1 kg due to the earth with the force on the same body due to another body of mass 1 kg at a distance of 1 m from the first body. (Mass of the earth $= 6 \times 10^{23} kg$, radius of the earth = 6400 km)

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21. Explain the term the earth's gravitational force. What is the value of g?

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22. Write a short note on the earth's gravitational force.

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23. Take two balls of different masses, go to the top of a building, drop them simultaneously and observe what happens to the balls.

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24. Take two similar pages from your notebook. Crumple one paper and allow this and the other paper to fall on the ground simultaneously. What do you observe?

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25. Take a feather and a paper. Allow them to fall to the ground simultaneously. Which will reach the ground earlier? Why?

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26. What is the acceleration Due to Gravity?

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27. What is meant by 'free fall' hence define acceleration due to gravity.

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28. From to newton's law of gravitation, derive the formula for the acceleration due to gravity.

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29. Explain the factors affecting the value of g .

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30. If $g = GM/r^2$, then where will the value of g be high, at Goa Beach or on the top of the Mount Everest ?

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31. Explain why the value of g is zero at the centre of the earth .

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32. Does the value of g change while going deep inside the earth ? Why ?

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33. Why does an object released from the hand , fall on the earth ?

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34. Does the value of g depend on the mass of the falling body ? Why ?

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35. Define mass . State its SI and CGS units.

Watch Video Solution

36. Define weight . State its SI and CGs units .

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37. As per the request of one of his friends from the equator , Rahul buys 100 grams of silver at the north pole . He hands it over to his friend at the equator . Will the friend agree with the weight of the silver bought ? If not , why ?

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38. If the value of g suddenly becomes twice its value , it will become two times more difficult to pull a heavy object along the floor . Why ?

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39. What is the difference between mass and weight of an object ? Will the mass and weight of an object on the earth be the same as their values on Mars ? Why ?

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40. What is free fall ?

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41. Define free fall .

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42. Explain the term free fall and state the corresponding kinematical equations of motion in the usual notation .

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43. During a free fall , will a heavier object accelerate more than a lighter one ?

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44. If you had to calculate the mass of the earth , how would you do it ?

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45. What is gravitational potential energy?

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46. Define gravitational potential energy. Write the formula for it.

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47. What is escape velocity? Obtain an expression for it.

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48. Define escape velocity.

Watch Video Solution

49. Explain the term escape velocity.

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50. Write a short note on escape velocity.

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51. Using the law of conservation of energy, obtain the expression for the escape velocity.

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52. Express escape velocity in terms of g and R.

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53. Express escape velocity in terms of g, R and ρ (the earth's density).

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Give Scientific Reasons

1. If a feather and a stone are released from the top of a building simultaneously, the stone reaches the ground earlier than the feather.

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2. The weight of a body is different on different planets.

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3. With a specific initial velocity, we can jump higher on the moon than on the earth.

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Distinguish Between

1. Write the differences between mass and weight of an object.

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2. universal gravitational constant and gravitational acceleration of the earth.

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Solve The Following Examples Numerical Problems

1. The time taken by the earth to complete one revolution around the sun is $3.156 \times 10^7 s$. The distance between the earth and the sun is 1.5×10^{11} m. Find the speed of revolution of the earth.

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2. Assuming that the earth performs unifrom circular motion around the Sun, find the centripetal acceleration of the earth. [Speed of the earth

$= 3 \times 10^4$ m/s. distance between the earth and the Sun $= 1.5 \times 10^{11}$ m

]

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3. What will be the gravitational force on 60 kg man on the Moon, Mars and Jupiter? Are they the same? Why ?

$\mathrm{M\ (Moon)} = 7.36 \times 10^{22}, \mathrm{kg\ R(Moon)} = 1.74 \times 10^6 m,$

$\mathrm{M\ (Mars)} = 6.4 \times 10^{23} \mathrm{kg}, \mathrm{R\ (Mars)} = 3.395 \times 10^6 m,$

$\mathrm{J\ (Jupiter)} = 1.9 \times 10^{27} \mathrm{kg}. \mathrm{R\ (Jupiter)} = 7.15 \times 10^7 m,$

$G = 6.67 \times 10^{-11} N.\ m^2\ /\ kg^2$

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4. The masses of the earth and moon are $6 \times 10^{24} kg$ and 7.4×10^{22} kg , respectively , The distance between them is 3.84×10^5 km. Calculate the gravitational force of attraction between the two. Use $G = 6.7 \times 10^{-11} N.\ m^2 kg^{-2}$

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5. Mahendra nad Virat are sitting at a distance of 1 metre from each other. Their masses are 75 kg and 80 kg respectively. What is the gravitational force between them ?

$G = 6.67 \times 10^{-11} N.m^2/kg^2.$

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6. Spheres A and B of uniform density have masses 1 kg and 100 kg respectively. Their centres are separated by 100m. (i) Find the gravitational force betweeen them.

$\left[M_{(\text{earth})} = 6 \times 10^{24} kg, R_{(\text{earth})} = 6400 km\right]$

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7. Spheres A and B of uniform density have masses 1 kg and 100 kg respectively. Their centres are separated by 100m. (ii) Find the

gravitational force on An due to the earth.

$\left[M_{(\text{earth})} = 6 \times 10^{24} kg, R_{(\text{earth})} = 6400 km\right]$

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8. Spheres A and B of uniform density have masses 1 kg and 100 kg respectively. Their centres are separated by 100m. (ii) Find the gravitational force on An due to the earth.

$\left[M_{(\text{earth})} = 6 \times 10^{24} kg, R_{(\text{earth})} = 6400 km\right]$

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9. Spheres A and B of uniform density have masses 1 kg and 100 kg respectively. Their centers are separated by 100m. (iv.) If A begins to fall, starting from rest, due to the earth's downward pull, what will be its velocity after one second ? How much time will it take to fall through 1 cm ?

$\left[M_{(\text{earth})} = 6 \times 10^{24} kg, R_{(\text{earth})} = 6400 km\right]$

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10. Two spheres of uniform density have masses 10 kg and 40 kg. The distance between the centres of the spheres is 200 m. Find the gravitatioanl force between them.

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11. Find the gravitational force between a man of mass 50 kg and a car of mass 1500 kg separated by 10 m.

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12. Find the magnitude of the gravitational force between the Sun and the earth. (Mass of the Sun $= 2 \times 10^{30}$kg, mass of the earth $= 6 \times 10^{24} kg$ and the distance between the centres of the Sun and the earth $= 1.5 \times 10^{11} m$,

$\left(G = 6.67 \times 10^{-11} N.m^2/kg^2\right)$

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13. The mass of the earth is $6 \times 10^{24} kg$. The distance between the earth and the sun is 1.5×10^{11} m. If the gravitational force between the two is 3.5×10^{22} N, what is the mass of the Sun ? Use $G = 6.7 \times 10^{-11} N.m^2 kg^{-2}$ gt

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14. Find the magnitude of the acceleration due to gravity at the surface of the earth. (M $= 6 \times 10^{24}$ Kg, R = 6400 Km)

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15. The radius of plant A is half the radius of planet B . If the mass of A is M_A, what must be the mass of B so that the value of g on B is half of its value on A ?

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16. An object takes 5 s to reach the ground from a height of 5 m on a plant. What is the value of g on the plant ?

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17. The mass of an imaginary planet is 3 times the mass of the earth. Its diameter 25600 km and the earth's diameter is 12800 km. Find the acceleration due to gravity at the surface of the planet. [g (earth) $= 9.8m/s^2$]

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18. If the acceleration due to gravity on the surface of the earth is $9.8m/s^2$, what will be the acceleration due to gravity on the surface of a planet whose mass and radius both are two times the corresponding quantities for the earth ?

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19. A stone thrown vertically upwards with initial velocity u reaches a height h before coming down. Show that the time taken by it to go up is the same as the time taken to come down.

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20. An object thrown vertically upwards reaches a height of 500 m. What was its initial velocity ?

How long will the object take to come back to the earth ? Assume $g = 10m/s^2$

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21. A ball falls off a table and reaches the ground in 1 s. Assuming g = $10m/s^2$, calculate its speed on reaching the ground (2 marks) and the height of the table.

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22. A body is relased from the top of a building of height 19.6 m. Find the velocity with which the body hits the ground .

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23. A stone on a bridge on a river falls into the river. If it takes 3 seconds to reach the surface of water, find (i) velocity of the stone at the instant it touches the surface of water (ii) the height of the bridge from the surface of water.

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24. A stone is dropped from rest the top of a building 44.1 m high. It takes 3 s to reach the ground. Use this information to calcualte g.

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25. A metal ball of mass 5 kg falls from a height of 490 m. How much time will it take to reach the ground ?

$(g = 9.8m/s^2)$

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26. If the weight of a body on the surface of the moon is 100 N, what is its mass ? $(g = 1.63m/s^2)$

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27. A 100 kg bag of wheat is placed on a plank of wood. What is the weight of the beg and what is the reaction force exerted by the plank?

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28. The mass and weight of an object on the earth are 5 kg nad 49 N respectively. What will be their values on the moon ? Assume that the acceleration due to gravity on the moon is 1/6th of that on the earth.

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29. Find the gravitational potential energy of a body of mass 10 kg when it is on the earth's surface. [M(earth) $= 6 \times 10^{24} kg, \mathrm{R}\,(\mathrm{earth}) = 6.4 \times 10^{6} m, G = 6.67 \times 10^{-11} N.\, m^2 / kg^2$]

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30. If the body in Ex. (26) performs uniform circular motion around the earth at a hight of 3600 km from the earh's surface, what will be its gravitational potential energy?

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31. A body of mass of 20 kg is at rest on the earth's surface. (i) Find its gravitational potential energy. (ii) Find the kinetic energy to be provided to the body to make it free from the gravitational influenece of the earth.

$(g = 9.8m/s^2, R = 6400km)$

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32. If the body in Ex. (28) is moving at 100 m/s on the earth's surfarce, what will be its (i) kinetic energy (ii) total energy ?

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33. A satellite of mass 100 kg performs uniform circular motion around the earth at a height of 6400 km from the earth's surface. Find the gravitational potential energy.

$[g = 9.8m/s^2, R = 6400km]$

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34. Find the escape velocity of a body from the earth.

[M (earth) = 6×10^{24} kg, R (earth) = 6.4×10^{6} m.

G = $6.67 \times 10^{-11} N.\, m^2 / kg^2$]

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35. Find the escape velocity of a body from the earth. [R(earth) $= 6.4 \times 10^{6} m$, ρ (earth) $= 5.52 \times 10^{3} kg/m^3$, $G = 6.67 \times 10^{-11} N.\, m^2 /$

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36. Calculate the escape velocity of a body from the moon. [g(moon) $= 1.67 m/s^2$, R(moon) $= 1.74 \times 10^{6} m$]

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37. The mass of (an imaginary) planet is four times that of the earth and its radius is double the radius of the earth. The escape velocity of a body from the earth is $11.2 \times 10^3 m / s$. Find the escape velocity of a body from the planet.

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