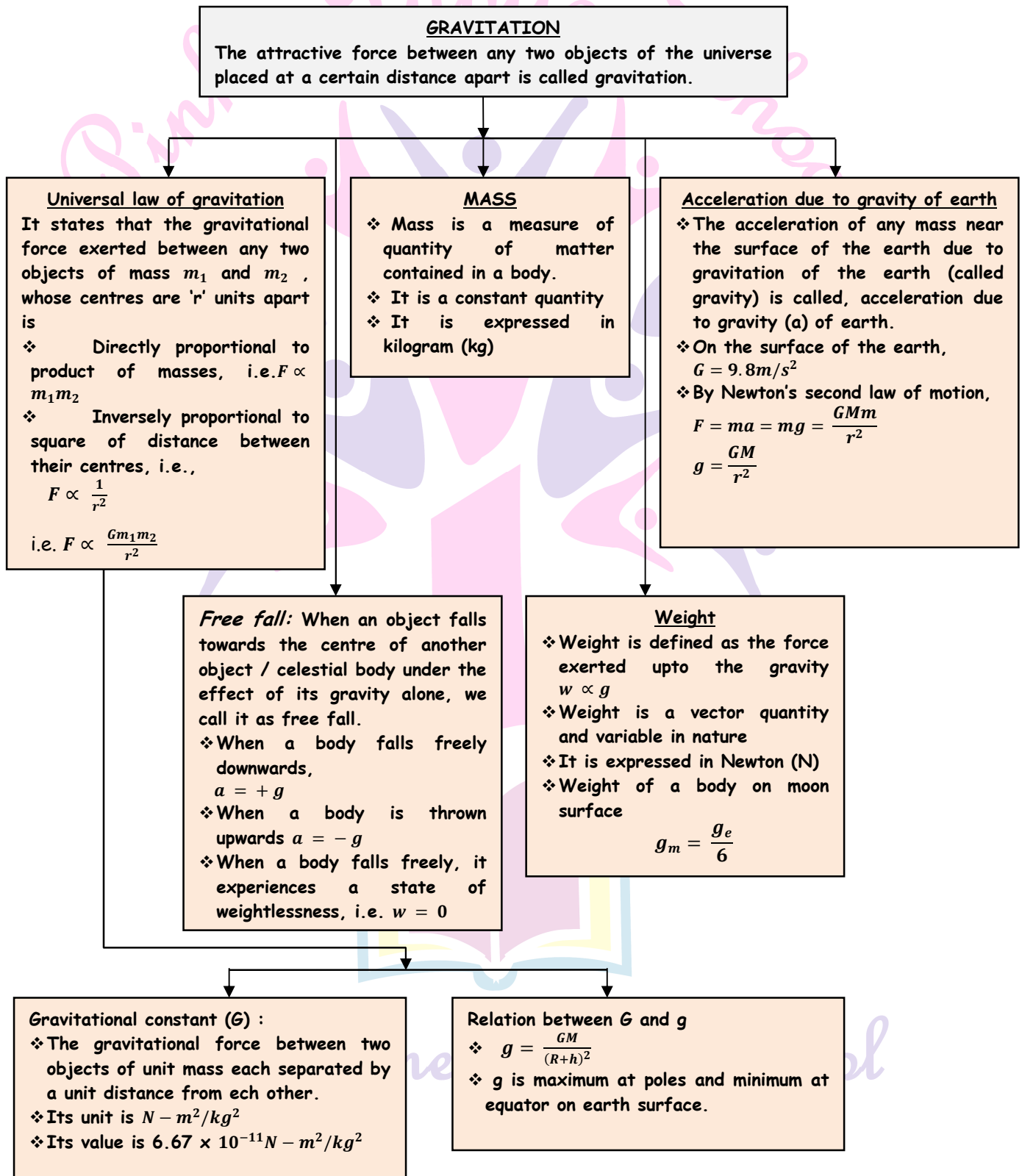


Grade : IX

Lesson 10A. GRAVITATION

CHAPTER AT A GLANCE



Know the terms

Objective : To compare the effect of air resistance on different bodies

Materials Required : A feather, a coin and a stopwatch

Method :

1. One student reaches the terrace of building with feather and coin, while the other stand down with the stopwatch
[Caution: Remember not to lean against the railing or boundary wall of the terrace]
2. The student from the terrace drop down the feather and coin simultaneously the stop watch is started by the other student
3. Time taken by the feather to reach the ground is noted
4. Similarly time taken by coin to reach the ground is found out
5. Do they take equal time to reach down?

Conclusion : The coin and feather taken different times to reach the earth. Feather falls much slowly as compared to coin because it experiences greater air resistance during its course of fall. However, both of them experience the same value of acceleration due to gravity. If they were made to fall in vacuum, they would reach the ground in same time.



Next Generation School

Objective Type Questions

Multiple choice questions

1. Variation of g with distance r from the centre of earth with ($r > R$), is best given as
 - a) $g \propto \frac{1}{r}$
 - b) $g \propto \frac{1}{r^2}$
 - c) $g \propto r$
 - d) $g \propto r^2$
2. There is no atmosphere on moon as
 - a) it is closer to the earth
 - b) it revolves round the earth
 - c) it gets light from the SUN
 - d) the gases have less requirement of velocity or energy to escape from its surface.
3. Four planets A, B, C and D made up of same material have radius of $\frac{r}{2}$, r , $2r$ and $4r$ respectively. The order of the planets in increasing order of the acceleration due to gravity (on their surface) is
 - a) A, B, C, D
 - b) B, C, D, A
 - c) A, C, B, D
 - d) D, C, B, A
4. Acceleration due to gravity is
 - a) dependent on mass of the planet for points outside the planet.
 - b) dependent directly on the radius of the planets under comparison are made of same material.
 - c) inversely proportional to square of radius for all points on the surface of the planet.
 - d) All of these.
5. The wrong option among the following is
 - a) gravitational force acts on the line joining the masses.
 - b) independent of the other masses.
 - c) always attractive by nature.
 - d) does not form action - reaction pair

6. An apple and a stone dropped from certain height accelerates
- a) equally
 - b) differently
 - c) depending on density
 - d) depends on the position of the SUN
7. A 60 kg man weighs W kg on the moon. W is
- a) 60 kg
 - b) 10 kg
 - c) 5 kg
 - d) 70 kg
8. Weight of 1 kg is
- a) 9.8 newton
 - b) 1 kg - wt
 - c) both a and b
 - d) either a or b
9. Acceleration due to gravity on the surface of the moon is $\frac{1}{6}$ th of its value on the surface of the earth as they have different
- a) mass
 - b) density
 - c) radius
 - d) All of these
10. A body at rest having uniform acceleration is
- a) non -existing
 - b) can be realised only on the moon
 - c) any body thrown vertically up against gravity
 - d) possible only near the SUN
11. Acceleration due to gravity on the surface of the earth is the greatest
- a) at poles
 - b) at equator
 - c) at 23.6° latitude
 - d) uniform at all places
12. Acceleration due to gravity varies with
- a) height
 - b) depth
 - c) shape of the planet
 - d) All of these
13. The value of quantity G in the law of gravitation (NCERT Exemplar problem)
- a) depends on mass of the earth only
 - b) depends on radius of the earth only
 - c) depends on both mass and radius of the earth
 - d) is independent of mass and radius of the earth.

14. Two particles are placed at some distance. If the mass of each of the two particles is doubled, keeping the distance between them unchanged, the value of gravitational force between them will be. (NCERT Exemplar problem)
- a) $\frac{1}{4}$ times b) 4 times c) $\frac{1}{2}$ times d) unchanged
15. The atmosphere is held to the earth by. (NCERT Exemplar problem)
- a) gravity b) wind c) clouds d) earth's magnetic field
16. The force of attraction between two unit point masses separated by a unit distance is called (NCERT Exemplar problem)
- a) gravitational potential b) acceleration due to gravity
c) gravitational field d) universal gravitational constant
17. The weight of an object at the centre of the earth of radius R is
- a) zero
b) infinite
c) R times the weight at the surface of the earth
d) $1/R^2$ times the weight at surface of the earth.
18. An apple falls from a tree because of gravitational attraction between the earth and apple. If F_1 is the magnitude of force exerted by the earth on the apple and F_2 is the magnitude of force exerted by apple on earth, then
- a) F_1 is very much greater than F_2 b) F_2 is very much greater than F_1
c) F_1 is only a little greater than F_2 d) F_1 and F_2 are equal

1. b	2. d	3. d	4. a	5. d	6. a	7. a	8. a	9. d	10. c
11. a	12. d	13. d	14. b	15. d	16. d	17. a	18. d		

Match the following

19.

Column I	Column II
1. Weight of 1 kg	A) $6.6 \times 10^{-11} \text{ Nm}^2 / \text{kg}^2$
2. Wobbling	B) 9.8 Newton
3. Value of G	C) 9.8 m/s^2
4. Value of 'g' on earth	D) Tides in ocean
5. Law of Gravitation	E) Pressure of numerous invisible celestial objects

1. B	2. E	3. A	4. C	5. D
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Fill in the blanks

20. Freely falling objects weight _____.
21. The ration of weight to mass of body on earth is _____.
22. Centripetal force due to earth on moon is _____ to square of distance between them.

20. zero	21. 9.8 m/s^2	22. inversely proportional
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True or False

23. Gravitational force can be attractive or repulsive
24. When both masses and separation between them is tripled the force of attraction remains the same.
25. Two equal masses separated by a distance experience a force F . On placing equal mass at the midpoint, the force becomes half.
26. Weight of a falling body of mass m is mg .

23. False	24. True	25. False	26. False
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Direction (Q -27 and Q-28) : In the following questions, the Assertion and Reason have been put forward. Read the statements carefully and choose the correct alternative from the following:

- a) Both the Assertion and the Reason are correct and the Reason is the correct explanation of the Assertion
- b) The Assertion and the Reason are correct but the Reason is not correct explanation of the Assertion
- c) Assertion is true but the Reason is false
- d) The statement of the Assertion is false but the Reason is true

27. Assertion : A feather and stone dropped from a height reach the ground at different times.

Reason : Acceleration due to gravity acting on a body is directly proportional to its mass

- c) Assertion is true but the Reason is false

28. Assertion : The earth and an object attract each other with equal force but earth does not move towards the object

Reason : Acceleration produced in earth due to the object is very less because its mass is much more than the object.

- a) Both the Assertion and the Reason are correct and the Reason is the correct explanation of the Assertion

29. Briefly explain why Newton pondered over the existence of gravitation?

It is said an apple fell on Newton's head when he was sitting under a tree. He thought if earth attracts an apple, can it also attract the moon? Is the force same in both cases? This led to the study on gravitation.

30. What is the difference between gravity and gravitation?

Gravitational pull of the earth is called gravity.

Gravitation is the attractive force between any two objects in the universe

31. State the significance of universal law of gravitation

Planetary motion around the sun, occurrence of tides etc, are phenomena which are possible due to law of gravitation.

32. If gravitational force acts between all objects, why don't they move towards each other?

The gravitational force is very weak, hence objects kept on a surface don't move towards each other.

33. Give reasons for the following observations : an object dropped from a height falls towards the earth ; all planets go round the sun .

When dropped from height, object falls towards the earth acting on object, while all planets go round the sun due to gravitational force of sun acting on them

34. Write the direction of acceleration due to gravity.

Acceleration due to gravity is always directed towards the centre of the planet or celestial body on which it is measured.

35. Define the universal gravitational constant (G).

The gravitational force between two objects of unit mass each, separated by a unit distance is equal to universal gravitational constant, i.e. when $m_1 = m_2 = 1 \text{ kg}$ and $r = 1 \text{ m}$ then $F = G$.

36. State Newton's law of gravitation

It states that the gravitational force exerted between any two objects of mass m_1 and m_2 whose centres are 'r' units apart, is

Directly proportional to product of masses i.e. $F \propto m_1 m_2$

inversely proportional to square of distance between their centres i.e. $F \propto \frac{1}{r^2}$

$$\text{i.e. } F = \frac{Gm_1m_2}{r^2}$$

37. What is the force of gravity between the earth and mass of 1 kg placed on its surface?

$$\text{Gravitational force, } F = \frac{Gm_1m_2}{r^2}$$

$$\text{Mass of earth } m_1 = 6 \times 10^{24} \text{ kg.}$$

$$\text{Mass of object } m_2 = 1 \text{ kg.}$$

$$\text{Distance between them, } r = 6 \times 10^6 \text{ m}$$

$$G = 6.67 \times 10^{-11} \times 10^{-11} \text{ Nm}^2 / \text{Kg}^2$$

$$F = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 1}{(6 \times 10^6)^2} = 9.8 \text{ N}$$

38. The value of gravitational constant G on earth is $6.67 \times 10^{-11} \text{ Nm}^2/\text{Kg}^2$. What is its value on the surface of moon?

' G ' on moon = $6.67 \times 10^{-11} \text{ Nm}^2/\text{Kg}^2$ as it is a constant

39. Which force is responsible for motion of moon around the earth? What would happen if there was no such force?

Motion of moon around the earth is due to centripetal force of earth. If there was no such force, the moon would pursue a uniform straight line motion.

40. State the name and type of force which is responsible for the formation of tides in the sea.

Tides in the sea are caused due to gravitational pull of moon.

41. Why is law of gravitation called a universal law?

It is called a universal law as it is applicable to all bodies, whether big or small, whether celestial or terrestrial.

42. If gravitational force exists between every two objects in the universe, why don't you and your friend sitting together experience it?

Gravitational force is a weak force. It exists between all objects, but it is too weak to be experienced by small masses such as human beings.

43. Why does moon exert lesser force of attraction on objects than earth?

Weight of an object on moon is the force with which moon attracts it. Mass of moon is less than that of earth. Thus, it exerts lesser force of attraction on object than earth.

44. How will the gravitational force of attraction between two objects change if their masses are doubled?

If masses are doubled, force becomes four times as $F \propto m_1 m_2$

45. Distance between two objects is halved. How does the gravitational force between them change?

When distance is halved, F becomes four times as $F \propto \frac{1}{r^2}$

46. What do you mean by free fall?

When a body falls towards the centre of a celestial body under the influence of its gravity alone, then it is said to be in free fall.

47. What is acceleration due to gravity?

The acceleration experienced by an object during the course of its free fall is called acceleration due to gravity.

48. Two objects of masses m_1 and m_2 are dropped in vacuum from a height above the surface of earth (m_1 is greater than m_2). Which one will reach the ground first and why?

Both objects will reach the ground simultaneously because acceleration due to gravity is independent of mass of falling object.

49. What does it mean to state that an object experience equal acceleration due free fall?

It means that acceleration experienced by an object during free fall is independent of its mass. It does not depend on size or mass of object.

50. How does the value of 'g' vary with mass of the object?

The value of g is independent of mass of the object instead it depends on the mass of earth / celestial body.

51. How is Newton's second law of motion related to universal law of gravitation?

By Newton's second law of motion,

$$F = mg \therefore (a = g)$$

By law of gravitation, $F = \frac{GMm}{R^2}$

Or $mg = \frac{GMm}{R^2}$ or $g = \frac{Gm}{R^2}$

52. Does velocity of a body during free fall remain constant? Why / why not?

The velocity of a body increases at every point of its motion during free fall as acceleration due to gravity acts on it.

53. Write the equation of free fall

$$V = u + gt$$

$$H = ut + \frac{1}{2}gt^2$$

$$v^2 = u^2 + 2gh$$

Where symbols have usual meanings

54. The value of g on the surface of the earth is 9.8 m/s^2 . What will be its value on the surface of the moon?

It will be $\frac{1}{6}$ th of $9.8 \text{ m/s}^2 = \frac{1}{6} \times 9.8 = 1.63 \text{ m/s}^2$

55. The ball is dropped from a tower of height 5 m. With what velocity does it strike the ground? Find it strike the ground?

$$[g = 10 \text{ m/s}^2]$$

$$h = 5 \text{ m}, u = 0, g = 10 \text{ m/s}^2$$

$$v^2 = u^2 + 2gh = 0 + 2 \times 10 \times 5$$

$$\Rightarrow v = 10 \text{ m/s.}$$

56. A stone dropped from a tree takes 2s to reach the ground. Find its velocity on striking the ground

$$T = 2 \text{ s}, u = 0, g = 9.8 \text{ m/s}^2$$

$$V = u + gt = 0 + 9.8 \times 2 = 19.6 \text{ m/s.}$$

57. Identify vector and scalar quantities: Weight, acceleration due to gravity, mass, gravitational constant.

Vector : weight and acceleration due to gravity

Scalar : mass

Gravitational constant is neither a vector nor a scalar quantity. It is a constant

58. Mass of a book is 500 g on surface of the earth. What will be its mass at a height equal to radius of earth?

$$M = 0.5 \text{ kg}$$

At any height equal to radius of earth, it remains the same, i.e. 500 g as mass is constant everywhere.

59. What is the relation between mass and weight of a body?

Weight = Mass \times acceleration due to gravity

60. Define weight

The force of gravitation exerted upon an object by earth or any other celestial body called its weight.

61. What is the weight of an object at centre of earth?

Zero because at centre of earth $g = 0$

62. Define 1 kg weight. Express it in newton

The force exerted by earth upon an object of mass 1 kg on its surface is called 1 kg weight.

In Newton, $1 \text{ kg wt} = 1 \text{ kg} \times 9.8 \text{ m/s}^2 = 9.8 \text{ N}$

63. State the SI unit of (a) mass (b) weight

a) kilogram

b) newton

64. Why does the weight of a body vary from poles to equator.

Weight of the body decreases from poles to equator.

65. What will be the weight of an object on the earth whose mass is 10 kg, $g = 10 \text{ m/s}^2$

$M = 10 \text{ kg}, g = 10 \text{ m/s}^2$

$W = mg = 10 \times 10 = 100 \text{ N}$

66. How does weight vary with the value of g ?

$W = mg$. Thus weight varies in direct proportion with g .

67. A spring balance reading 15 g - wt for a mass suspended at it, is dropped. What will it read during the course of its fall?

It will read zero, as it experiences weightlessness during free fall.

68. Convert a force of 5 kg - wt into SI unit of force.

$1 \text{ kg} = 9.8 \text{ N}$

$5 \text{ kg wt} = 5 \times 9.8 = 49.0 \text{ N}$

69. "Several phenomena of celestial bodies were believed to be unconnected but universal law of gravitation was successful to explain them". Mention any two phenomena.

Two phenomena explained by universal law of gravitation are:

a) motion of planets around the sun in their orbits.

b) Presence of atmosphere around the earth.

70. Derive the expression of the universal law of gravitation [CBSE 2012]

Ans. For objects of masses m_1 and m_2 separated by a distance r .

$$F \propto m_1 m_2$$

$$F \propto \frac{1}{r^2}$$

$$\text{Or } F \propto \frac{m_1 m_2}{r^2}$$

$$\text{Or } F \propto \frac{Gm_1 m_2}{r^2}$$

Where $G = 6.67 \times 10^{-11} \text{ Nm}^2 = \text{gravitational constant}$.

71. Moon does not have atmosphere, why? [CBSE 2014]

Ans. Moon does not have strong gravity to hold atmospheric gases.

72. If you jump on the moon you will rise much higher than if you jump on the earth. Why?

Acceleration due to gravity (g) is much less on the moon surface, Hence $h = \frac{v^2 - u^2}{2g}$ is larger.

73. As object is dropped from a certain point to fall freely under gravity. Write its equation of motion in connections of:

a) distance travelled, time taken and its acceleration.

b) final velocity, acceleration and the distance moved

when an object is dropped, initial velocity $u=0$: acceleration, $a = g$

$$\text{a) } s = \frac{1}{2}gt^2 \quad \text{b) } v^2 = 2gh$$

74. Find the weight of a 80kg man on the surface of the moon. What should be his mass on the earth and on the moon? ($g_e = 9.8\text{m/s}^2$; $g_m = 1.63\text{m/s}^2$) [CBSE 2012]

Mass on the earth = Mass on the moon

$$= 80\text{kg}$$

$$\text{Weight on moon, } W_m = 1.63\text{m/s}^2 \times 80 = 130.4$$

75. What is the distance covered by a freely falling body during the first three seconds of its motion? ($g = 10\text{m/s}^{-2}$)

$$u = 0, t = 3\text{s}, g = 10\text{m/s}^{-2}$$

$$s = ut + \frac{1}{2}gt^2$$

$$= 0 + \frac{1}{2} \times 10 \times (3)^2 = 45\text{m}$$

76. A toy car falls to the ground in 0.4s. Calculate its speed just before striking the ground. (Assume $g = 10\text{m/s}^{-2}$)

$$t = 0.4\text{s}, u = 0, g = 10\text{m/s}^{-2}$$

$$v = u + gt = 0 + 10 \times 0.4 = 4 \text{ m/s}$$

Short answer type questions

1. The weight of a body on the surface of the earth is 392N. What will be the weight of this body on a planet whose mass is double that of the earth and radius is four times that of the earth?

$$g_e = 'g' \text{ on earth} = \frac{GM_e}{(R_e)^2} = 9.8\text{m/s}^{-2}$$

Where M_e = Mass of earth,

R_e = Radius of earth,-

Mass of planet = $2M_e$; Radius of planet = $4R_e$

$$\begin{aligned} \therefore g_{\text{planet}} = 'g' &= \frac{GM_p}{R_p^2} = \frac{G(2M_e)}{(4R_e)^2} \\ &= \left(\frac{1}{8}\right) g_e = \left(\frac{1}{8} \times 9.8\right) \end{aligned}$$

$$\begin{aligned} \text{Weight on planet} &= \frac{\text{Weight on earth}}{8} \\ &= \frac{392 \text{ N}}{8} = 49\text{N} \end{aligned}$$

2. The gravitational force between two objects is 100N. How should the distance between these objects be changed so that the force between them becomes 50 N?

[CBSE 2016]

$F = 100 \text{ N}$. when distance between objects is R

$F \propto \frac{1}{R^2}$ [inverse square law]

If F becomes $\left(\frac{F}{2}\right)$, then let distance becomes R' .

$$\text{Ratio } \frac{F}{(F/2)} = \frac{(R')^2}{R^2}$$

$$\Rightarrow 2 = \frac{R'^2}{R^2} \Rightarrow \frac{R'}{R} = \sqrt{2}$$

$$\Rightarrow R' = \sqrt{2} R$$

i.e. distance is increased $\sqrt{2}$ times.

3. Two bodies 'P' and 'Q' having masses m_1 and m_2 , when separated by a distance d_1 extra a force 'F' on each other: what happens when

(a) masses of both the objects are doubled.

(b) distance between the two bodies is reduced to half.

(c) the space between the two objects has no air and it is complete vacuum

[CBSE 2012]

(a) When masses of both objects are doubled, F becomes 4 times, as $F \propto m_1 m_2$,

(b) when distance is reduced to half, F becomes 4 times, as $F \propto \frac{1}{r^2}$

(c) The gravitational force will remain the same, however there will be no air resistance between them

$$u = 0, h = 10\text{m}, g = 20\text{m/s}$$

$$\text{As } v = u + gt$$

$$\Rightarrow t = \frac{v}{g} = \frac{20}{20} = 1\text{s}$$

4. A stone is thrown vertically upwards with a velocity of 40m/s and is caught back.

Taking $g = 10\text{m/s}^2$, calculate the maximum height reached by the stone. What is the net displacement and total distance covered by the stone? [CBSE 2012]

$$u = 40\text{m/s}, g = -10\text{m/s}^2, v = 0$$

$$h = \frac{v^2 - u^2}{2g} = \frac{0 - (40)^2}{-2 \times 10} = 80\text{m}$$

Net displacement = 0 [as the stone returns back to its initial position]

$$\text{Distance} = 2 \times 80 = 160\text{m}$$

5. (i) Seema buys few grains of gold at the poles as per the instructions of one of her friends. She hands over the same when she meets her at the equator. Will the friend agree with the weight of gold bought? If not, why?

(ii) If the moon attracts the earth. Why does the earth not move towards the moon?

[CBSE 2012]

(i) No, as 'g' at poles is greater than 'g' at equator, weight at poles is greater than weight at equator. Thus, Seema's friend will not agree with weight of gold she bought.

(ii) Acceleration due to gravity of the earth towards the moon is very less, since its mass is much greater than that of the moon.

6. What happens to the magnitude of the force of gravitation between two objects if

(i) distance between the objects is tripled?

(ii) mass of both object is doubled?

(iii) mass of both objects as well as distance

(i) If distance is tripled, i.e. $R \rightarrow 3R$

By Newtons law, $F \propto \frac{1}{R^1}$

Thus F becomes $\left(\frac{1}{3}\right)^2$ = one ninth of its original value

(ii) Masses are doubled i.e. $M'_1 \rightarrow 2M_1$

$$M'_2 \rightarrow 2M_2$$

By Newton's law, $F \propto M_1M_2$

Thus F becomes $(2) \times (2) = 4$ times its original value

(iii) Masses $M_1 \rightarrow 2M_1, M_2 \rightarrow 2M_2$

Distance $R \rightarrow 2R$

By Newton's law $F \propto \frac{M_1M_2}{R^2}$

$$\text{Or } F = \frac{GM_1M_2}{R^2}$$

On changing masses and distance

$$F^1 = \frac{G(2M_1)(2M_2)}{(2R)^2} = \frac{GM_1M_2}{R^2} = F$$

Thus force remains unchanged

7. When is an object said to be in free fall? What is meant by acceleration due to gravity? Derive an expression for acceleration for an object falling freely.

An object falling towards another due to gravitational force is said to be in free fall.

Such an object falls with an acceleration is called acceleration due to gravity.

By Newton's II Law of motion $a = g$

$F = mg$ (for an object of mass m)

By Law of Gravitation, $F = \frac{GMm}{R^2}$

(where M is mass of the planet and R is distance between centres of object and planet.

$$\Rightarrow mg = \frac{GMm}{R^2} \text{ or } g = \frac{GM}{R^2}$$

8. (a) What is meant by free fall?

(b) Two objects of masses M_1 and M_2 are dropped in vacuum from a height above the surface of earth ($M_1 > M_2$), will there be any difference in the time in which the two respectively reach the ground? Give [CBSE 2012]

(a) Refer to Q.46 [Solved Question Bank]

(b) The two objects will reach the ground simultaneously as acceleration due to gravity is independent of mass of falling body and there is no air resistance,

9. State universal law of gravitation, The gravitational force between two objects is 100 N. How should the distance between the objects be changed so that the force between them becomes 50 N? [CBSE 2012]

Universal law of gravitation states that force of gravitation between any two objects is directly proportional to product of their masses and inversely proportional to square of distance between their centres.

$$F = 100 \text{ N}$$

If F is halved, i.e. 50N, the distance between objects should be increased by $\sqrt{2}$ times as

$$F = \frac{1}{r^2}$$

10. (a) Centripetal force is required for a body to move on a circular path. What provides this force to the moon to move around the earth? Write an expression for it.

(b) A stone is released from the top of tower 19.6m high. Calculate the final velocity just before touching the ground. [CBSE 2012]

(a) The gravitational pull of the earth provides the centripetal force to the moon to move around it.

$$F = \frac{GM_{\text{earth}} M_{\text{moon}}}{R^2}$$

Where M_{earth} = Mass of earth

M_{moon} = Mass of moon

R = Distance between their centres

b) $u = 0$, $h = 19.6 \text{ m}$, $g = 9.8 \text{ m/s}^2$

$$v = \sqrt{u^2 + 2gh}$$

$$v = \sqrt{0 + 2 \times 9.8 \times 19.6}$$

$$= 19.6 \text{ m/s.}$$

11. i) Give reason for the following

a) A sheet of paper falls slower than when it is crumpled into a ball

b) A body weighs more at the poles than at equator

ii) What is meant by the statement that acceleration due to gravity is 9.8 ms^{-2} ?

i) a) The sheet of paper has larger surface area and experiences greater air resistance during free fall. So it falls slowly

b) Value of 'g' is greater at poles as compared to equator because $r_p < r_{eq}$ and $g \propto \frac{1}{r^2}$

ii) It means that a freely falling body accelerate at 9.8 m/s^2 towards the centre of earth, during the course of its fall towards the earth.

12. If the distance between two masses be increased by a factor would the mass of one of them hence to be altered to maintain the same gravitational force?

By law of gravitation, of $F \propto \text{mass}$

$$F \propto \frac{1}{(\text{distance})^2}$$

If distance is increased by a factor of 6, F decreases by $\frac{1}{36}$ times

Thus, mass should be increased by $(6)^2$ times i.e. 36 times

Thus, mass also has to be increased

13. a) How does the gravitational force between two objects depend on the distance between them?

b) Explain your answer with reason :

In which case the force of attraction will be larger?

i) Force of attraction of the earth on a body of mass 1 kg.

ii) Force of attraction of a body of mass 1 kg on the earth.

a) F varies inversely as square of distance between the bodies.

b) The force will be equal and opposite, according to the universal law of gravitation

14. a) Which is greater, the attraction of the earth for 1 kg of iron or the attraction of 1 kg iron for the earth? Why?

b) A boy throws a ball vertically upwards and catches it back in 10s. Calculate

i) the velocity with which it was thrown up and

ii) maximum height attained by the ball.

(Take $g = 10 \text{ ms}^{-2}$)

a) The force is equal and opposite, however, acceleration produced in iron is much higher since its mass is very less as compared to the earth.

b) Time to rise up = $t = \frac{10s}{2} = 5s$

$$g = -10 \text{ m/s}^2, v = 0$$

$$\text{i) } u = v - gt = 0 - (-10) \times 5 = 50 \text{ m/s}$$

$$\begin{aligned} \text{ii) } h &= ut + \frac{1}{2}gt^2 \\ &= (50 \times 5) + \left(\frac{1}{2}\right) \times (-10) \times 25 \\ &= 125 \text{ m} \end{aligned}$$

15. A stone is dropped from the edge of a roof.

a) How long does it take to fall 4.9m ?

b) How fast does it move at the end of that fall?

c) What will be its acceleration after 2 seconds?

$$\text{Given : } u = 0, g = 9.8 \text{ m/s}^2$$

$$\text{a) } 4.9 \text{ m} = \frac{1}{2}gt^2; t = \sqrt{\frac{2 \times 4.9}{9.8}} = 1 \text{ s}$$

$$\text{b) } v = u + gt = 0 + 9.8 \times 1 = 9.8 \text{ m/s}$$

c) Acceleration = 9.8 m/s^2 and remains constant.

16. Mona weighs 750 N on Earth

i) On the planet Mars, the force of gravity is 38% of that of Earth. How will Mona weigh on Mars?

ii) What will be Mona's mass on Earth

$$(g = 10 \text{ m/s}^2)^2$$

$$\text{Value of } g \text{ on Mars, } g_m = 0.38 \text{ times value of } g \text{ on Earth} = 0.38 \times 9.8$$

$$\therefore \text{Weight on Mars} = 0.38 \times \text{weight on earth}$$

$$= 0.38 \times 750 = 285 \text{ N}$$

$$\text{Mass of Earth} = \frac{750 \text{ N}}{g \text{ on Earth}} = \frac{750 \text{ N}}{10} = 75 \text{ kg}$$

17. A stone is dropped from the top of a building.

a) How long does it take to fall 19.6 m?

b) How fast does it move at the end of this fall?

c) What is its acceleration after (i) 1s and ii) 2s? ($g = 10 \text{ m/s}^2$)

$$u = 0, g = 9.8 \text{ m/s}^2$$

$$a) h = ut + \frac{1}{2}gt^2$$

$$\text{or } t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 19.6}{9.8}} = 2s$$

$$b) v = u + gt = 0 + 9.8 \times 2 = 19.6 \text{ m/s.}$$

$$c) a = 9.8 \text{ m/s}^2 \text{ and is constant}$$

18. Find the gravitational force of attraction between earth ($M = 6 \times 10^{24} \text{ kg}$) and a body of mass 10 kg kept on its surface. Given ($R = 6400 \text{ km}$)

$$F = \frac{GM_1M_2}{R^2} = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 10}{(6.4 \times 10^6)^2} = 98N$$

19. A fire cracker is fired and it rises to a height of 1000m. Find the

(i) velocity by which it was released

(ii) time taken by it to reach the highest point (take $g = 9.8 \text{ m/s}^2$) [CBSE 2014]

Height, $h = 1000\text{m}$, $g = -9.8 \text{ m/s}^2$

Final velocity $v = 0$

(i) initial velocity, $u = \sqrt{v^2 - 2gh}$ [Third equation]

$$= \sqrt{0 - 2(-9.8)(1000)}$$

$$= \sqrt{19600} = 140 \text{ m/s}$$

$$(ii) \text{ time, } t = \frac{v-u}{g} = \frac{0-140}{-9.8} = \frac{100}{7} \text{ s}$$

$$= 14.3\text{s}$$

20. State the difference between gravitation and gravity, what would happen if gravitational force of the earth vanished away?

Gravitational pull of earth exerted on an object is called gravity while gravitation is a universal phenomenon of attraction between two bodies present anywhere. If gravitation of the earth is vanished away, all objects would float freely in the state of weightlessness. There would be no atmosphere and pull of other celestial bodies would significantly act.

21. State Kepler's laws of planetary motion.

Kepler derived three laws governing the planetary motion.

(a) The orbit of a planet is an ellipse with the sun at one of the foci.

(b) The line joining the planet and the sun sweeps equal areas in equal intervals of time,

(c) The cube of mean distance of a planet from the sun is directly proportional to square of

orbital period, i.e., $\frac{r^3}{T^2} = \text{constant}$.

22. Obtain a relation between the weight of an object on the surface of earth and that on moon.

Value of g on earth $g_e = 6 \times 'g'$ on moon (g_m)

Weight = mg (m = mass)

Weight on earth = $W_e = mg_e$

Weight on moon = $W_m = mg_m$

i.e. $mg_e = m(6g_m) = 6mg_m$

Weight on earth = 6 times weight on moon.

23. How did Newton arrive at the inverse square rule?

According to Kepler's third law, the gravitational force acting on planet provide it the centripetal force which is related to orbital velocity v and orbital radius, r

$$F = \frac{mv^2}{r} \quad (\because m - \text{mass of planet})$$

$$\therefore v = \frac{2\pi r}{T} \Rightarrow F = \frac{4\pi^2 mr^2}{rT^2}$$

From Kepler's third law of planetary motion

$$T^2 \propto r^3$$

$$\Rightarrow F = \frac{4\pi^2 m}{r^2} \quad F \propto \frac{1}{r^2}$$

24. Derive the formula for the gravitational force using the factors on which it depends

Gravitational force (F) between two objects of masses m_1 and m_2 whose centres are separated by distance r is

a) directly proportional to product of masses : $F \propto m_1 m_2$

b) inversely proportional to square of distance :

$$F \propto \frac{1}{r^2}$$

$$\Rightarrow F \propto \frac{m_1 m_2}{r^2}$$

$$\Rightarrow F = G \frac{m_1 m_2}{r^2}$$

Where G = Gravitational constant

25. a) Name the balances used to measure mass and weight

b) Weight of an object will be lessor or more at Antarctica as compared to the weight of object at Delhi. Give reason for your answer.

a) Mass is measured by beam balance

Weight is measured by spring balance

b) Earth is flattened at poles. So distance of the body from its centre is less. As $g \propto \frac{1}{r^2}$ hence value of 'g' in Antarctica will be more as compared to that in Delhi. Consequently its weight will be more in Antarctica than in Delhi.

26. A body weighs 30 kg on surface of earth. Find its weight on a planet whose mass is $\left(\frac{1}{9}\right)^{\text{th}}$ the mass of earth and radius is half of earth.

'g' on planet = g_p ; 'g' on earth = g_e

If M_e = mass of earth ; R_e = radius of earth

M_p mass of planet ; R_p = radius of planet

Given : $M_p = \frac{1}{9} M_e$; $R_p = \frac{1}{2} R_e$

Then $g_e = \frac{GM_e}{R_e^2} = 9.8 \text{ ms}^{-2}$

$$g_p = \frac{GM_p}{R_p^2} = \frac{G\left(\frac{1}{9}M_e\right)}{\left(\frac{1}{2}R_e\right)^2}$$

$$= \left(\frac{4}{9} \times 9.8\right) \text{ms}^{-2}$$

Weight on planet = mg_p

$$= 30 \times \text{kg} \times \left(\frac{4}{9} \times 9.8\right) \text{ms}^{-2}$$

$$= 130.6 \text{ N or } 13.3 \text{ kgwt.}$$



Next Generation School

Long answer type questions

1. a) Earth revolves around sun due to the gravity of sun. Why does the earth not move towards sun ?

b) State and derive the formula for gravitational force of attraction between sun and earth.

a) The earth bound to sun by gravitational force which provide it centripetal force to revolve in circular / elliptical path (orbit) around the sun.

b) If M_e = Mass of the earth, M_s = Mass of the sun

R = Distance between their centres.

then by Newton's law of gravitation,

$$F \propto M_e M_s$$

$$F \propto \frac{1}{R^2}$$

$$F \propto \frac{M_e M_s}{R^2}$$

Or
$$F = \frac{G M_e M_s}{R^2}$$

Where G = universal gravitational constant.

2. On what factors does acceleration due to gravity depend? An object weighs 600 N on the earth. Find its weight on the surface of moon, given mass of the moon = 7.4×10^{22} kg, radius of the moon = 1.74×10^6 m

It depends on mass of the celestial body and distance between its centre and the centre of the object.

$$\text{Mass of object} = \frac{600 \text{ N}}{9.8 \text{ m/s}^2} = 60 \text{ kg}$$

$$g_{\text{moon}} = \frac{GM_M}{R^2} = \frac{6.67 \times 10^{-11} \times 7.4 \times 10^{22}}{(1.74 \times 10^6)^2}$$

$$= 1.63 \text{ m/s}^2$$

Weight on the surface of the moon

$$= mg_{\text{moon}} = 60 \times 1.63 = 97.80 \text{ N}$$

3. (i) A person weight 110.84 N on moon surface, whose acceleration due to gravity is 1/6 of that earth. If the value of g on earth is 9.8 ms^{-2} . Calculate the (a) g on the moon (b) mass of person on the moon (c) weight of person on the earth.

(ii) How does the value of g on the earth is related to the mass of the earth and its radius? Derive it.

(i) (a) Let g' be the g on moon

$$g' = \frac{g}{6} = \frac{9.8}{6} = 1.63$$

(b) mass of the person on the moon

$$= \frac{110.84}{1.63} = 68 \text{ kg}$$

(c) Weight of the person on the earth

$$= mg = 68 \times 9.8 = 666.4 \text{ N}$$

ii) Let mass of the earth be M and an object falling freely towards it be m . The distance between centres of earth and the object is R .

From Newton's law of gravitation,

$$F = \frac{GMm}{R^2} \quad \text{-----(i)}$$

Also from second law of motion, force exerted on object

$$F = ma$$

Since $a = g$ (i.e. acceleration due to gravity)

$$F = mg \quad \text{---(ii)}$$

Equating both eqn. (i) and (ii)

$$\text{We get} \quad mg = F = \frac{GMm}{R^2} \quad \text{or} \quad g = F = \frac{GM}{R^2}$$

Next Generation School

4. State universal law of gravitation. Explain its significance . Mass of an object is 20 kg. Find its weight on earth and on moon.

Universal law of gravitation states that the gravitational force (F) between two bodies of masses m_1 and m_2 whose centres are separated by distance 'r' is

a) Directly Proportional to the product of masses ; $F \propto m_1 m_2$

b) inversely proportional to the square of distance between their centre;

$$F \propto \frac{1}{r^2}$$

$$\text{i.e., } F \propto \frac{m_1 m_2}{r^2} \quad \text{or} \quad F = \frac{G m_1 m_2}{r^2}$$

where, G = gravitational constant

Universal law of gravitation has successfully explained different phenomenons which were earlier considered to be separate:

(a) It explains the about the force which holds us on earth

(b) It explain the cause of motion of the moon around the earth

(c) it explains the cause of motion of the moon around the earth

(d) it explains about occurrence of tides in the ocean.

'g' on earth, $g_e = 9.8 \text{ m/s}^{-2}$

'g' on moon, $g_m = 1.6 \text{ m/s}^{-2}$

Weight = mg , $m=20\text{kg}$

Weight on earth, $W_e = mg_e$

$$= 20 \times 9.8 = 196\text{N}$$

Weight on moon, $W_m = mg_m$

$$= 20 \times 1.6 = 32 \text{ N}$$

Next Generation School

5. (a) A metallic bar has a mass 200g at poles. Does it change when taken to equator?

b) Does its weight change when brought to equator? If yes, how?

c) What would happen if there was no acceleration due to gravity?

d) Differentiate between acceleration due to gravity and universal gravitational constant . Derive a relation between 'g' and 'G'

a) No, mass remains constant everywhere

b) Yes weight of bar decreases at equator because value of 'g' is less at equator than at poles.

c) If there was no acceleration due to gravity, all objects would keep on moving in a straight line path with uniform velocity.

d)

'G'	'g'
a) It is the universal gravitation constant	a) It is acceleration produced due to gravity
b) Value of $G = 6.678 \times 10^{-11} \text{ Nm}^2 / \text{Kg}^2$ remain constant at every point	b) Its value changes from point to point
c) It is equal to force between two unit masses separated by unit distance	c) It is equal to acceleration experienced by a body of any mass
d) It has an extremely small value	d) It has relatively large magnitude.

Acceleration due to gravity :

i) The gravitational force exerted by earth upon an object is called its gravity.

ii) The acceleration of a body near the surface of earth due to its gravity is called acceleration due to gravity (g) .

By Newton's law of gravitation

$$F = \frac{GMm}{r^2} \quad \text{----(i)}$$

If M = mass of earth

m = mass of object

r = distance between centres of earth and object

Also, by Newton' second law ,

$$F = ma$$

(a = acceleration due to gravity = g)

i.e. $F = mg$ ---(ii)

Equating R.H.S. of (i) and (ii),

$$Mg = \frac{GMm}{r^2} \text{ or } g = F = \frac{GM}{r^2}$$

(On surface of earth, $g = 9.8 \text{ ms}^{-2}$)

Ncert Based activities

Short answer type questions

1. What is the source of centripetal force that a planet requires to revolve around the Sun? On what factors does that force depend?

The gravitational force of attraction of the Sun provides centripetal acceleration to the planet to revolve around the sun.

$$F \propto \text{Mass of the Sun}$$

$$F \propto \text{Mass of the planet}$$

$$F \propto \frac{1}{(\text{distance between Sun and Planet})^2}$$

2. On the earth a stone is thrown from a height in a direction parallel to the earth's surface while another stone is simultaneously dropped from the same height. Which stone would reach the ground first and why?

Both reach the ground together because time to reach the ground depends only on vertical height.

Initial velocity in downward direction is zero and the value of ' g ' is same in both cases.

3. Suppose gravity of the earth suddenly becomes zero, then in which direction will the moon begin to move if no other celestial body affects it?

Moon will move along a straight line in tangential direction at the point where gravitational force ceases to exist.

4. Identical packets are dropped from two aeroplanes, one above the equator and the other above the north pole, both at height h . Assuming all conditions are identical, will those packets take same time to reach the surface of the earth? Justify your answer.

$$t = \sqrt{\frac{2h}{g} \left(\text{since } h = ut + \frac{1}{2} gr^2 \text{ and } u = 0 \right)}$$

$$g_{\text{poles}} > g_{\text{equator}}$$

$$\text{Thus, } t_{\text{poles}} < t_{\text{equator}}$$

5. The weight of any person on the moon is about $1/6$ times that on the earth. He can lift a mass of 15kg on the earth. What will be the maximum mass, which can be lifted by the same force applied by the person on the moon?

The person can lift a mass of $15 \times 6 = 90$ kg on the moon by applying the same force.

6. Calculate the average density of the earth in terms of g , G and R .

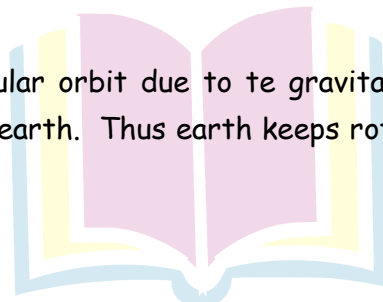
$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{M}{\frac{4}{3}\pi R^3}$$

$$\text{As } g = \frac{GM}{R^2}, M = \frac{gR^2}{G}$$

$$\therefore \rho = \frac{gR^2}{G \frac{4}{3}\pi R^3} = \frac{3g}{4G\pi R}$$

7. The earth is acted upon by gravitation of the Sun, even though it does not fall into the Sun. Why?

The earth remains in its circular orbit due to the gravitational force acting on it. Which provides centripetal force to the earth. Thus earth keeps rotating around Sun and does not fall into the Sun.



Next Generation School

Long answer type questions

8. How does the weight of an object vary with respect to mass and radius of the earth?

In a hypothetical case, if the diameter of the earth becomes half of its present value and its mass becomes four times of its present value, then how would the weight of any object on the surface of the earth be affected?

$$W = mg \text{ and } g = \frac{GM}{R^2}$$

Hence $W \propto \text{Mass of the earth (M)}$

$$W \propto \frac{1}{(\text{radius of the earth})^2}$$

As M becomes 4 times and R is halved W becomes

$$W' = \frac{4GMm}{(\frac{R}{2})^2} = \frac{4GMm}{\frac{R^2}{4}} \text{ or 16 times}$$

Thus the weight becomes 16 times of earlier weight.

9. How does the force of attraction between the two bodies depend upon their masses and distance between them? A student thought that two bricks tied together would fall faster than a single one under the action of gravity. Do you agree with this hypothesis or not? Comment.

According to Newton's law of gravitation

$$F \propto m_1 m_2 \text{ (i.e. product of masses)}$$

$$F \propto \frac{1}{r^2} \text{ (i.e. square of distance between them)}$$

$$\text{Time taken during free fall, } t = \sqrt{\frac{2h}{g}}$$

Thus the hypothesis of student is incorrect as t is independent of mass of bricks.

10. Two objects of masses m_1 and m_2 having the same size are dropped simultaneously from height h_1 and h_2 respectively, find out the ratio of time they would take in reaching the ground. Will this ratio remain the same if (i) one of the objects is hollow and the other one is solid and (ii) both of them are hollow, size remaining the same in each case, Give reason.

$$t = \sqrt{\frac{2h}{g}} \text{ or } t \propto \sqrt{h}$$

$$\text{Thus, } \frac{t_1}{t_2} = \sqrt{\frac{h_1}{h_2}}$$

(i) If one object is hollow and the other is solid, the ratio of time to reach the ground remains the same, as t is independent of masses.

(ii) The result is still unchanged as t depends only on height of fall.