FOCUS ACADEMY

Kg to 12
English&Gujarati Medium

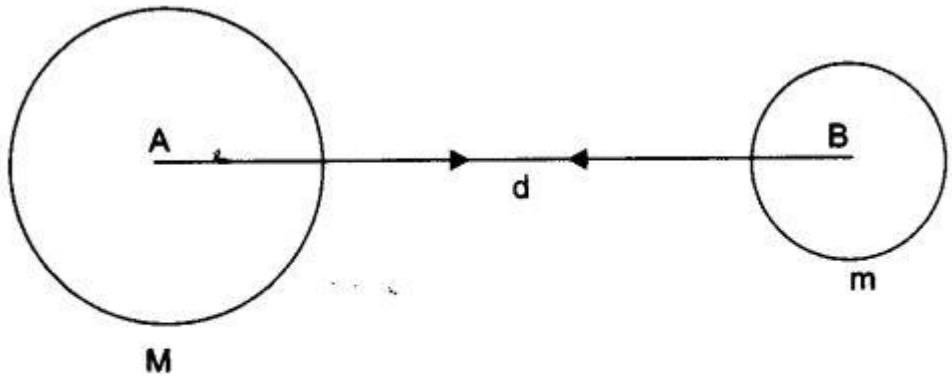
BRANCH 1- 19-B MUSLIM SOC, B/H FIRDOS MASJID DANILIMDA AHMEDABAD	BRANCH2-2ND 3RD AND 4TH FLOOR,UNIQUE APT. JUHAPURA CROSS ROAD, AHMEDABAD

Class 9 **Revision Notes** **Science**

CHAPTER-10 GRAVITATION

Facts that Matter

The universal law of gravitation: Every object in the universe attracts every other object with a force which is proportional to the product of their masses and inversely proportional to the square of the distance between them.
The force is along the line joining the centres of two objects.



Gravitational force between two uniform objects is directed along the line joining their centres.

Let two objects A and B of masses M and m lie at a distance of d from each other as shown in the figure.
Let F be the force of attraction between the law of gravitation

$$F \propto \frac{Mm}{d^2}$$

$$F = G\frac{Mm}{d^2} \qquad \because \quad G = \text{universal gravitational constant}$$

$$G = \frac{Fd^2}{Mm}$$

G is called a universal constant because its value does not depend on the nature of intervening medium or temperature or any other physical variable.
S.I. unit of G = Nm^2/kg^2
Value of G = 6.673 x 10-11 Nm^2/kg^2 (Found by Henry Cavendish)

Importance of universal law of gravitation
Universal law of gravitation successfully explained several phenomena like :

- **the force that binds us to the earth.**
- **the motion of moon around the earth.**
- **the motion of planets around the sun.**
- **the tides due to the moon and the sun.**

Freefall
When an object falls down towards the earth under the gravitational force alone, we say the object is in free fall.
The velocity of a freely falling body changes and is said to be accelerated. This acceleration is called acceleration due to gravity, denoted by 'g'. Unit is m/s^2.

As $F = ma$ ($\because a = g$)

$F = mg$

and $F = G\frac{Mm}{d^2}$ ($\therefore$ Universal law of gravitation)

From (*ii*) and (*iii*)

$\therefore \quad mg = G\frac{Mm}{d^2}$

$\therefore \quad g = \frac{GM}{d^2}$

M = Mass of the earth

d = Distance between the object and the earth

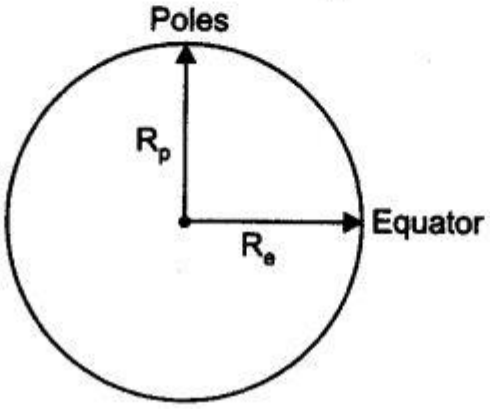
G = Gravitational constant

If the object is placed on the earth then $d = R$

(R = radius of the earth)

$\therefore \quad g = \frac{GM}{R^2}$

Earth is not a sphere it is flattened at poles.



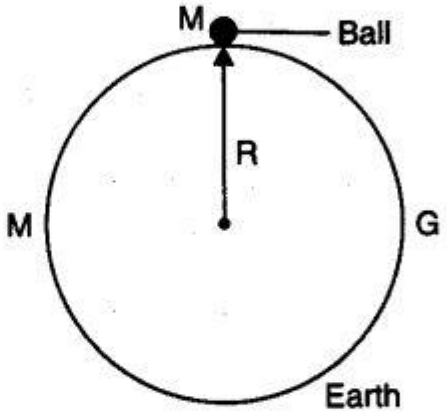
Hence R_p – Radius at pole and R_e – Radius at equator

$$R_e > R_p$$

$$g \propto \frac{1}{R}$$

∴ The value of 'g' is more at poles = (9.9 m/s^2)
and less at equator = (9.8 m/s^2)

Calculation of value of *g*



$$g = G \frac{M}{R^2}$$

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

$M = 6 \times 10^{24}$ kg (Mass of the earth)

$R = 6.4 \times 10^6$ m

On substituting the given values

$$g = \frac{6.7 \times 10^{-11} Nm^2\ kg^{-2} \times 6 \times 10^{24} kg}{(6.4 \times 10^6 m)^2}$$

$g = 9.8\ m/s^2$.

The motion of objects under the influence of gravity 'g' does not depend on the mass of the body. All objects small, big, heavy, light, hollow or solid fall at the same rate.

The three equation of motion viz.

(i) $v = u + at$ (ii) $s = ut + \frac{1}{2}at^2$ (iii) $v^2 - u^2 = 2as$ are true for motion of objects under gravity. For free fall, value of acceleration $a = g = 9.8\ ms^{-2}$.

If an object is just let fall from a height then in that as u = 0 and a = g = 9.8 m/s^2.

If an object is projected vertically upward with an initial velocity u, then a = – g = – 9.8 ms^{-2} and the object will go to a maximum height h where its final velocity becomes zero (i.e., v = 0).

Mass: Mass of an object is the measure of its inertia. It is the matter present in it. It remains the same everywhere in the universe.
Weight: The force of attraction of the earth on the object is known as the weight of the object. It's S.I. unit is Newton.
W = m x g

$$W_m = \frac{GM_m \times m}{R_m^2}$$

W_m = weight of an object on moon
M_m = mass of the moon = 7.36×10^{22}
R_m = radius of the moon = 1.74×10^6
$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$

$$\therefore \quad W_m = G\,\frac{7.36 \times 10^{22} kg \times m}{(1.74 \times 10^6 m)^2}$$

$$W_m = 2.431 \times 10^{10}\ G \times m$$

and $$W_e = 1.474 \times 10^{11}\ G \times m$$

$$\therefore \quad \frac{W_m}{W_e} = \frac{\text{Weight of object on moon}}{\text{Weight of object on earth}} = \frac{2.431 \times 10^{10} Gm}{1.474 \times 10^{11} Gm} = \frac{1}{6}.$$

$\therefore$ Weight of an object on moon = $\frac{1}{6}$th the weight of an object on the earth.

Question 1:

What do you mean by free fall?

ANSWER:

Gravity of the Earth attracts every object towards its centre. When an object is released from a height, it falls towards the surface of the Earth under the influence of gravitational force. The motion of the object is said to have free fall.

Question 2:

What do you mean by acceleration due to gravity?

ANSWER:

When an object falls towards the ground from a height, then its velocity changes during the fall. This changing velocity produces acceleration in the object. This acceleration is known as acceleration due to gravity (*g*). Its value is given by 9.8 m/s^2.

Page No 138:

Question 1:

What are the differences between the mass of an object and its weight?

ANSWER:

S. No.	Mass	Weight
I.	Mass is the quantity of matter contained in the body.	Weight is the force of gravity acting on the body.
II.	It is the measure of inertia of the body.	It is the measure of gravity.
III.	Mass is a constant quantity.	Weight is not a constant quantity. It is different at different places.
IV.	It only has magnitude.	It has magnitude as well as direction.
V.	Its SI unit is kilogram (kg).	Its SI unit is the same as the SI unit of force, i.e., Newton (N).

Question 2:

Why is the weight of an object on the moon $\frac{1}{6}^{th}$ its weight on the earth?

ANSWER:

Let M_E be the mass of the Earth and m be an object on the surface of the Earth. Let R_E be the radius of the Earth. According to the universal law of gravitation, weight W_E of the object on the surface of the Earth is given by,

Question 1:

Why is it difficult to hold a school bag having a strap made of a thin and strong string?

ANSWER:

It is difficult to hold a school bag having a thin strap because the pressure on the shoulders is quite large. This is because the pressure is inversely proportional to the surface area on which the force acts. The smaller is the surface area; the larger will be the pressure on the surface. In the case of a thin strap, the contact surface area is very small. Hence, the pressure exerted on the shoulder is very large.

Question 2:

What do you mean by buoyancy?

ANSWER:

The upward force exerted by a liquid on an object immersed in it is known as buoyancy. When you try to immerse an object in water, then you can feel an upward force exerted on the object, which increases as you push the object deeper into water.

Question 3:

Why does an object float or sink when placed on the surface of water?

ANSWER:

If the density of an object is more than the density of the liquid, then it sinks in the liquid. This is because the buoyant force acting on the object is less than the force of gravity. On the other hand, if the density of the object is less than the density of the liquid, then it floats on the surface of the liquid. This is because the buoyant force acting on the object is greater than the force of gravity.

Question 1:

You find your mass to be 42 kg on a weighing machine. Is your mass more or less than 42 kg?

ANSWER:

When you weigh your body, an upward force acts on it. This upward force is the buoyant force. As a result, the body gets pushed slightly upwards, causing the weighing machine to show a reading less than the actual value.

Question 2:

You have a bag of cotton and an iron bar, each indicating a mass of 100 kg when measured on a weighing machine. In reality, one is heavier than other. Can you say which one is heavier and why?

ANSWER:

The bag of cotton is heavier than the iron bar. This is because the surface area of the cotton bag is larger than the iron bar. Hence, more buoyant force acts on the bag than that on an iron bar. This makes the cotton bag heavier than its actual value. For this reason, the iron bar and the bag of cotton show the same mass on the weighing machine, but actually the mass of cotton bag is more that that of the iron bar.

Actual weight = Measured Weight + Buoyant Force

Question 1:

How does the force of gravitation between two objects change when the distance between them is reduced to half?

ANSWER:

According to the universal law of gravitation, gravitational force (*F*) acting between two objects is inversely proportional to the square of the distance (*r*) between them, i.e.,

If distance *r* becomes *r*/2, then the gravitational force will be proportional

to

Hence, if the distance is reduced to half, then the gravitational force becomes four times larger than the previous value.

Question 2:

Gravitational force acts on all objects in proportion to their masses. Why then, a heavy object does not fall faster than a light object?

ANSWER:

All objects fall on ground with constant acceleration, called acceleration due to gravity (in the absence of air resistances). It is constant and does not depend upon the mass of an object. Hence, heavy objects do not fall faster than light objects.

Question 3:

What is the magnitude of the gravitational force between the earth and a 1 kg object on its surface? (Mass of the earth is 6×10^{24} kg and radius of the earth is 6.4×10^{6} m).

ANSWER:

According to the universal law of gravitation, gravitational force exerted on an object of mass *m* is given by:

Where,

Mass of Earth, $M = 6 \times 10^{24}$ kg

Mass of object, m = 1 kg

Universal gravitational constant, G = 6.7×10^{-11} Nm^2 kg^{-2}

Since the object is on the surface of the Earth, r = radius of the Earth (R)

$r = R = 6.4 \times 10^6$ m

Gravitational force,

Question 4:

The earth and the moon are attracted to each other by gravitational force. Does the earth attract the moon with a force that is greater or smaller or the same as the force with which the moon attracts the earth? Why?

ANSWER:

According to the universal law of gravitation, two objects attract each other with equal force, but in opposite directions. The Earth attracts the moon with an equal force with which the moon attracts the earth.

Question 5:

If the moon attracts the earth, why does the earth not move towards the moon?

ANSWER:

The Earth and the moon experience equal gravitational forces from each other. However, the mass of the Earth is much larger than the mass of the moon. Hence, it accelerates at a rate lesser than the acceleration rate of the moon towards the Earth. For this reason, the Earth does not move towards the moon.

Question 6:

What happens to the force between two objects, if

(i) the mass of one object is doubled?

(ii) the distance between the objects is doubled and tripled?

(iii) the masses of both objects are doubled?

ANSWER:

(i) Doubled (ii) One-fourth and one-ninth (iii) four times

According to the universal law of gravitation, the force of gravitation between two objects is given by:

(i) *F* is directly proportional to the masses of the objects. If the mass of one object is doubled, then the gravitational force will also get doubled.

(ii) *F* is inversely proportional to the square of the distances between the objects. If the distance is doubled, then the gravitational force becomes one-fourth of its original value.

Similarly, if the distance is tripled, then the gravitational force becomes one-ninth of its original value.

(iii) *F* is directly proportional to the product of masses of the objects. If the masses of both the objects are doubled, then the gravitational force becomes four times the original value.

Question 7:

What is the importance of universal law of gravitation?

ANSWER:

The universal law of gravitation proves that every object in the universe attracts every other object.

Question 8:

What is the acceleration of free fall?

ANSWER:

When objects fall towards the Earth under the effect of gravitational force alone, then they are said to be in free fall. Acceleration of free fall is 9.8 m s^{-2},

which is constant for all objects (irrespective of their masses).

Question 9:

What do we call the gravitational force between the Earth and an object?

ANSWER:

Gravitational force between the earth and an object is known as the weight of the object.

Question 10:

Amit buys few grams of gold at the poles as per the instruction of one of his friends. He hands over the same when he meets him at the equator. Will the friend agree with the weight of gold bought? If not, why? [*Hint*: The value of *g* is greater at the poles than at the equator].

ANSWER:

Weight of a body on the Earth is given by:

$W = mg$

Where,

m **= Mass of the body**

g **= Acceleration due to gravity**

The value of *g* is greater at poles than at the equator. Therefore, gold at the equator weighs less than at the poles. Hence, Amit's friend will not agree with the weight of the gold bought.

Question 11:

Why will a sheet of paper fall slower than one that is crumpled into a ball?

ANSWER:

When a sheet of paper is crumbled into a ball, then its density increases. Hence, resistance to its motion through the air decreases and it falls faster than the sheet of paper.

Question 12: Gravitational force on the surface of the moon is only as strong as gravitational force on the Earth. What is the weight in newtons of a 10 kg object on the moon and on the Earth?

ANSWER:

Weight of an object on the moon Weight of an object on the Earth

Also,

Weight = Mass × Acceleration

Acceleration due to gravity, g = 9.8 m/s^2

Therefore, weight of a 10 kg object on the Earth = 10 × 9.8 = 98 N

And, weight of the same object on the moon

Question 13:

A ball is thrown vertically upwards with a velocity of 49 m/s. Calculate

(i) the maximum height to which it rises.

(ii)the total time it takes to return to the surface of the earth.

ANSWER:

(i) 122.5 m (ii) 10 s

According to the equation of motion under gravity:

$v^2 - u^2 = 2gs$

Where,

u = Initial velocity of the ball

v = Final velocity of the ball

s = Height achieved by the ball

g = Acceleration due to gravity

At maximum height, final velocity of the ball is zero, i.e., $v = 0$

$u = 49$ m/s

During upward motion, g = − 9.8 m s^{-2}

Let *h* be the maximum height attained by the ball.

Hence,

Let *t* be the time taken by the ball to reach the height 122.5 m, then according to the equation of motion:

$$v = u + gt$$

We get,

But,

Time of ascent = Time of descent

Therefore, total time taken by the ball to return = 5 + 5 = 10 s

Question 14:

A stone is released from the top of a tower of height 19.6 m. Calculate its final velocity just before touching the ground.

ANSWER:

According to the equation of motion under gravity:

$$v^2 - u^2 = 2gs$$

Where,

u = Initial velocity of the stone = 0

v = Final velocity of the stone

s = Height of the stone = 19.6 m

g = Acceleration due to gravity = 9.8 m s^{-2}

$\therefore v^2 - 0^2 = 2 \times 9.8 \times 19.6$

$v^2 = 2 \times 9.8 \times 19.6 = (19.6)^2$

$v = 19.6$ m s^{-1}

Hence, the velocity of the stone just before touching the ground is 19.6 m s^{-1}.

Question 15:

A stone is thrown vertically upward with an initial velocity of 40 m/s. Taking g = 10 m/s^2, find the maximum height reached by the stone. What is the net displacement and the total distance covered by the stone?

ANSWER:

According to the equation of motion under gravity:

$v^2 - u^2 = 2gs$

Where,

u = Initial velocity of the stone = 40 m/s

v = Final velocity of the stone = 0

s = Height of the stone

g = Acceleration due to gravity = −10 m s^{-2}

Let h be the maximum height attained by the stone.

Therefore,

Therefore, total distance covered by the stone during its upward and downward journey = 80 + 80 = 160 m

Net displacement of the stone during its upward and downward journey

= 80 + (−80) = 0

Question 16:

Calculate the force of gravitation between the earth and the Sun, given that the mass of the earth = 6×10^{24} kg and of the Sun = 2×10^{30} kg. The average distance between the two is 1.5×10^{11} m.

ANSWER:

According to the universal law of gravitation, the force of attraction between the Earth and the Sun is given by:

Where,

M_{Sun} = Mass of the Sun = 2×10^{30} kg

M_{Earth} = Mass of the Earth = 6×10^{24} kg

R **= Average distance between the Earth and the Sun = 1.5×10^{11} m**

G = Universal gravitational constant = 6.7×10^{-11} Nm^2 kg^{-2}

Question 17:

A stone is allowed to fall from the top of a tower 100 m high and at the same time another stone is projected vertically upwards from the ground with a velocity of 25 m/s. Calculate when and where the two stones will meet.

ANSWER:

Let the two stones meet after a time *t*.

(i) <u>For the stone dropped from the tower:</u>

Initial velocity, $u = 0$

Let the displacement of the stone in time t from the top of the tower be s.

Acceleration due to gravity, g = 9.8 m s^{-2}

From the equation of motion,

(ii) <u>For the stone thrown upwards:</u>

Initial velocity, $u = 25$ m s^{-1}

Let the displacement of the stone from the ground in time t be s'.

Acceleration due to gravity, g = −9.8 m s^{-2}

Equation of motion,

The combined displacement of both the stones at the meeting point is equal to the height of the tower 100 m.

In 4 s, the falling stone has covered a distance given by equation (1) asTherefore, the stones will meet after 4 s at a height (100 − 80) = 20 m from the ground

Question 18:

A ball thrown up vertically returns to the thrower after 6 s. Find

(a) the velocity with which it was thrown up,

(b) the maximum height it reaches, and

(c) its position after 4 s.

ANSWER:

(a) 29.4 m/s (b) 44.1 m (c) 39.2 m above the ground

(a) Time of ascent is equal to the time of descent. The ball takes a total of 6 s for its upward and downward journey.

Hence, it has taken 3 s to attain the maximum height.

Final velocity of the ball at the maximum height, $v = 0$

Acceleration due to gravity, $g = -9.8\ m\ s^{-2}$

Equation of motion, $v = u + gt$ will give,

$0 = u + (-9.8 \times 3)$

$u = 9.8 \times 3 = 29.4\ ms^{-1}$

Hence, the ball was thrown upwards with a velocity of $29.4\ m\ s^{-1}$.

(b) Let the maximum height attained by the ball be h.

Initial velocity during the upward journey, $u = 29.4\ m\ s^{-1}$

Final velocity, $v = 0$

Acceleration due to gravity, $g = -9.8\ m\ s^{-2}$

From the equation of motion,

(c) Ball attains the maximum height after 3 s. After attaining this height, it will start falling downwards.

In this case,

Initial velocity, $u = 0$

Position of the ball after 4 s of the throw is given by the distance travelled by it during its downward journey in 4 s − 3 s = 1 s.

Equation of motion, will give,

Total height = 44.1 m

This means that the ball is 39.2 m (44.1 m − 4.9 m) above the ground after 4 seconds.

Question 19:

In what direction does the buoyant force on an object immersed in a liquid act?

ANSWER:

An object immersed in a liquid experiences buoyant force in the upward direction.

Question 20:

Why does a block of plastic released under water come up to the surface of water?

ANSWER:

Two forces act on an object immersed in water. One is the gravitational force, which pulls the object downwards, and the other is the buoyant force, which pushes the object upwards. If the upward buoyant force is greater than the downward gravitational force, then the object comes up to the surface of the water as soon as it is released within water. Due to this reason, a block of plastic released under water comes up to the surface of the water.

Question 21:

The volume of 50 g of a substance is 20 cm^3. If the density of water is 1 g cm^{-3}, will the substance float or sink?

ANSWER:

If the density of an object is more than the density of a liquid, then it sinks in the liquid. On the other hand, if the density of an object is less than the density of a liquid, then it floats on the surface of the liquid.

Here, density of the substance =

The density of the substance is more than the density of water (1 g cm^{-3}). Hence, the substance will sink in water.

Question 22:The volume of a 500 g sealed packet is 350 cm^3. Will the packet float or sink in water if the density of water is 1 g cm^{-3}? What will be the mass of the water displaced by this packet?

ANSWER:Density of the 500 g sealed

packet

The density of the substance is more than the density of water Hence, it will sink in water.

The mass of water displaced by the packet is equal to the volume of the packet, i.e., 350 g.