4. GRAVITATION

Universal law of Gravitation.

All bodies in the universe attract each other. The force of mutual attraction between two bodies is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

That is, Gravitational force, $F = Gm_1xm_2/d^2$

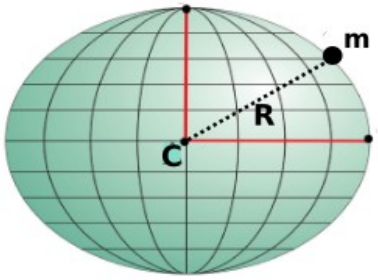
G is a constant and is called gravitational constant. Its value is $6.67x10^{-11}Nm^2/kg^2$

This value was determined by Henry Cavendish.

Force of Gravity.

The earth attracts all the objects towards its centre. This attractive force is called force of gravity.

Force of gravity on an object on the surface of earth can be calculated using universal law of gravitation.



Let m be the mass of the object, M be the mass of Earth and R be the radius of Earth,

Force of gravity, $F = GMm/R^2$

Since the earth is not perfectly spherical, its radius is not same everywhere. Radius is maximum at the equator and minimum at the poles. Since gravity is inversely proportional to distance (here radius), gravity is maximum at the poles where R is minimum and gravity is minimum at the equator where R is maximum.

Similarly when an object is raised from the surface of the earth or it is moved from surface towards the centre, gravity decreases.

Acceleration due to gravity.

Acceleration produced on a body due to force of gravity is called acceleration due to gravity.

Acceleration due to gravity, $g = GM/R^2$

As the value of R is different at different places, acceleration due to gravity is also different. On the the surface, the value of g is maximum at poles and minimum at the equator. The average value of g on the surface is 9.8 m/s^2.The value of g at the centre of the earth is zero.

From the equation $g = GM/R^2$, it is seen that acceleration due to gravity mass of the object is independent of mass of the objects, acceleration due to gravity (g) is same for all objects irrespective of difference in their masses.

Value of Acceleration due to gravity on the moon.

Size and mass of the moon is less than that that of earth. Hence the value of g on the moon is 1.62 m/s^2 . It is only about 1/6th of the value of g on the earth.

Mass and Weight.

Mass of a body is the amount of matter contained in it. Its unit is kilogram. Weight of a body is the force with which the earth attracts it towards the centre. kgwt and newton are the units of weight.

1kgwt is equal to the force of attraction exerted by the earth on an object of mass 1 kg.

1kgwt = 9.8 N.

Common balance is used to measure mass of an object. But spring balance is used to measure weight. The mass of an object is constant. But the wight of an object will be different at different places. On the surface of the earth, weight will be maximum at the poles and minimum at the equator. Similarly the weight of an object decreases when it is raised from the surface and moving towards the centre of the earth. Weight of an object at the centre of the earth is be zero.

Free fall.

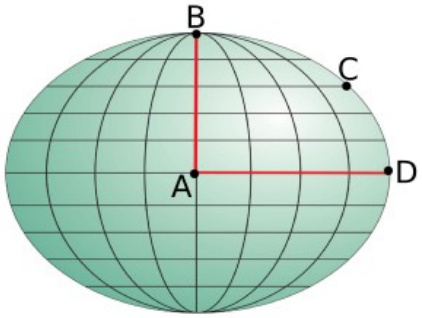
It is the fall of a body only under the influence of gravity is called free fall. When a body is allowed fall down, it is considered as a free fall as the friction of air and buoyancy are negligible.

The weight of a freely falling body will be zero while it is falling.

PRACTICE QUESTIONS AND ANSWERS

1. The mathematical expression for Universal Law of Gravitation is given. $F = G.m_1m_2/d^2$
a. Name the scientist who formulated this law?
b. What does 'G' stand in the equation? What is its value?
c. Name the scientist who determined the value of 'G' for the first time.
d. Two objects are kept at certain distance. What will be the change in the gravitational force between them if mass of both objects are doubled?
e. What will be the force if the distance between them is doubled?
Ans.a.Sir Isac Newton.
b. Gravitational constant. $G = 6.67x10^{-11}\ Nm^2/kg^2$.
c. Henry Cavendish.
d. Gravitational force will become four times greater.
e. Then gravitational force becomes 1/4th.
2. Two objects having masses 1 kg each are kept at 1 m apart. Calculate the gravitational force between them.
Ans. $F = G.m_1m_2/d^2 = 6.67x10^{-11} \times 1x1/1^2 = 6.67x10^{-11}$ N
3.Two bodies having masses 1 kg& 5 kg each are placed 1 m apart. Which is the body that experiences more gravitational force?
Ans. Both bodies will be experienced the same gravitational force.
4. An aircraft fell down while it was flying.
a. Name the force responsible for falling down the aircraft?
b. Why doesn't the earth move towards the aircraft due to this force?
Ans.a. Force of gravity.
b. As mass of earth is much greater than that of aircraft, acceleration produced on the earth by the aircraft is too small.
5. What is the difference between force of gravity and gravitation?
Ans. The force of attraction between earth and a body is known as force of gravity whereas the force of attraction between any two bodies is force of gravitation.
6. The acceleration produced in a body due to the gravitational pull of earth is called acceleration due to gravity(g)
a. Write down expression for calculating acceleration due to gravity. What does each variables in the expression indicate?
b. What is the average value of acceleration due to gravity on the surface of earth?
c. On the surface of earth where the acceleration due to gravity is maximum?
d. What is the value of 'g' at the centre of the earth?
e. Two balls of same size and different masses are dropped from certain height. Which of them will reach the ground first? Justify your answer.
Ans. a. $g = GM/R^2$ G – Gravitational constant, M – Mass of the earth, R – Radius of the earth.
b. $g = 9.8\ m/s^2$
c. At the poles.
d. Zero.
e. Both will reach the ground simultaneously. Because acceleration of freely falling body (acceleration due to gravity) is independent of mass of the object.
7. Mass and weight are two different physical quantities.
a. What is the relation between them?
b. Name an instrument used for measuring weight.
c. What will be the weight of a body of mass 10 kg on the surface of earth?
d. What will be the mass of this body at the moon?
e. "If the body is brought to the centre of the earth, its mass will be zero" Comment to this statement.

Ans.a. Weight is the product of mass (m) and acceleration due to gravity(g). That is, weight = mg.
b. Spring balance.
c. Weight of a body of 10 kg mass = mg = 10x9.8 = 98 N.
d. Mass at the moon is 10 kg (because mass of an object is same everywhere.)
e. This statement is wrong. The mass of a body will be same everywhere and hence the mass of the body at the centre of the earth will be 10 kg itself. But weight of this body at the centre will be zero.
8. It is marked as A,B,C & D in the picture of globe.



a. If mass of a body at B is 2 kg, what will be its mass at A,C&D?
b. What feature of earth is responsible for a body possessing different weight at different places on the surface?
c. The weight of the body at A,B,C&D are different. Write them in ascending order.
Ans.a. Mass will be 2 kg itself at all places.
b. Due to the difference in radius.
c. A,D,C,B
9. A stone falls from height is considered to be 'free fall'.
a. What is 'free fall'?
b. A body of mass 10 kg is in free fall. What will be the mass of the body while it is in free fall? What will be its weight then?
Ans.a. When a body is falling towards earth only under the influence of gravity is called free fall.
b. As the mass of an object is constant, its mass will 10 kg itself while it is in free fall. But weight will be zero then.
10. When a stone is projected vertically upwards with certain velocity from equator, it reaches up to 50m height. If the stone is projected with the same velocity from the pole of the earth, is there any possibility for change in the attainable height? Justify.
Ans.As gravitational force at the pole is comparatively greater than that at the equator, retardation produced on the stone is also greater. So attainable height from the pole will be less than 50 m.
11. A stone falling freely from certain height at the north pole takes 10 s to reach the ground. If the same stone is dropped from the same height at the equator , will there any change in time?
Ans. As acceleration due to gravity at the equator is comparatively small, it will take more than 10 s to reach the ground at the equator.
12. Two objects having certain masses are kept at 2 m apart. What happens to the gravitational force if masses of the objects and separation between them are doubled?
Ans. There will not be any change in gravitational force.
13. Check whether the following statements are true or false. Correct the false statements.
a. Weight is a vector quantity.
b. The value of gravitational constant 'G' is 9.8 SI unit.
c. When a body is brought from north pole to equator, its mass will decrease.
d. If an object is brought from north pole to equator, its weight will increase.
e. Weight of a body at the centre of the earth will be zero.
f. When an object is moved from surface of the earth towards its centre, its weight will be decreased.
g. Weight of a body decreases when the body is being raised from the surface of the earth.
Ans.a. True. b. False. The value of gravitational constant 'G' is 6.67×10^{-11} SI unit.
c. False. The mass of an object will be same everywhere.
d.False.If an object is brought from north pole to equator, its weight will decrease.
e. True. f. True. g. True.

14. Complete the following statements.
a. It is at ..... where an objects experiences maximum weight. (poles/equator)
b. Acceleration due to gravity on the surface of moon is .....
b. ..... is the scientist who formulated the law of universal gravitation. (Isac Newton/Galileo)
c. ..... is the scientist who determined the value gravitational constant G (Cavendish/Galileo)
d. The average value of 'g' on the surface of earth is .....
Ans.a. At pole b. 1.62 m/s^2 c. Isaac Newton d. Cavendish e. 9.8 m/s^2.
15. What will be the approximate weight of a body on the moon which has 60 kgwt on the earth?
Ans. The acceleration due to gravity on the moon is only 1/6th of that on the earth. Hence weight also will be 1/6th. There fore weight on the moon = 60x1/6 = 10 kgwt
16. The gravitational force on a freely falling body by the earth is equal to the force acts on the earth by the falling body. Then why the earth doesn't move towards the falling body?
Ans. According to Newton's second law of motion, acceleration produced on a body is inversely proportional to its mass. Since the mass of earth is very large, acceleration produced on the earth is negligible. That is why it doesn't move or accelerate towards the falling object.
17. kilogram weight (kgwt)and newton (N) are the units of weight. What is the relation between the two?
Ans. 1 kgwt = 9.8 N
18. What is the weight of an object whose mass is 30 kg?
Ans. Weight = mg = 30x9.8 = 294 N