ATOMIC ENERGY CENTRAL SCHOOL-KAKRAPAR

CLASS- IX

SUBJECT- PHYSICS

NAME OF THE CHAPTER- GRAVITATION

MODULE-3

Subtopics-

How does the value of g changes form pole to equator?

Weight of an object on the moon.

Motion of objects under the influence of Gravitational force of the Earth

How does the value of g changes form pole to equator?

We know that,

$$g = \frac{GM_e}{R_e^2}$$

i.e g α 1/square of radius of Earth

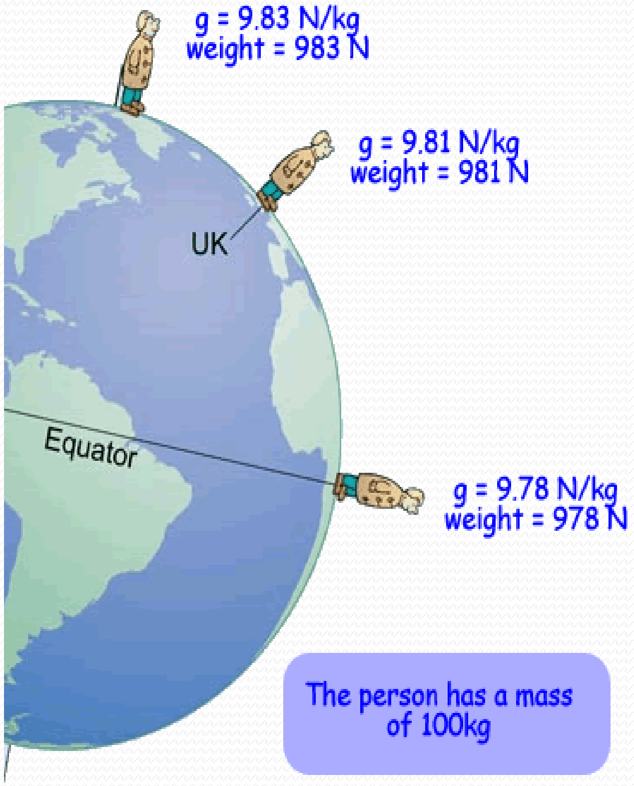
As the earth is an **oval shape**, its radius near the **equator is more** than its radius near poles. Since for a source mass, the **acceleration due to gravity** is inversely proportional to the square of the radius of the earth, it varies with latitude due to the shape of the earth.

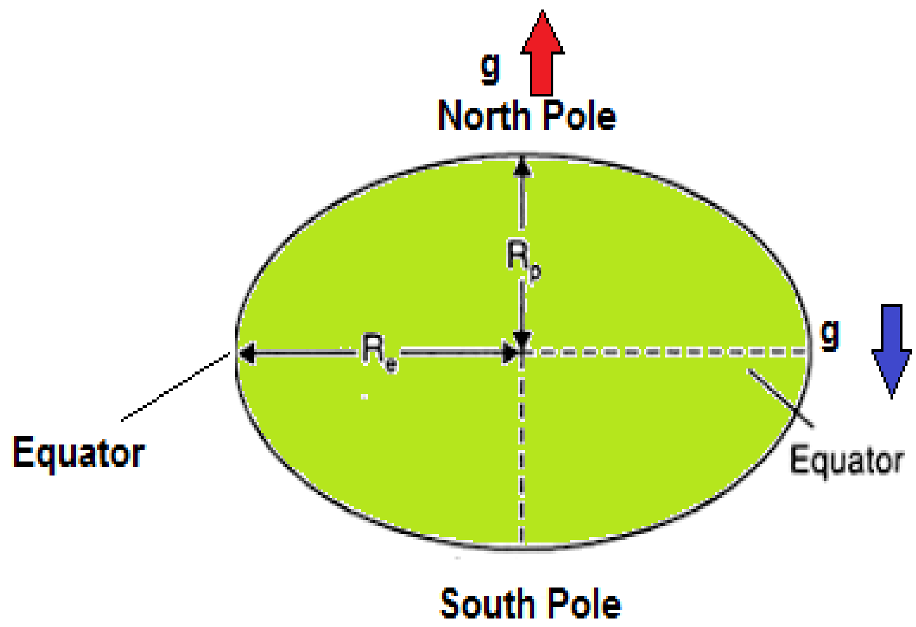
$g_p/g_e = R^2_e/R^2_p$

Where g_e and g_p are the accelerations due to gravity at equator and poles, R_e and R_p are the radii of earth near equator and poles respectively.

From the above equation, it is clear that acceleration due to gravity is more at poles and less at equator. So if a person moves from the poles to equator his weight decreases as the value of g decreases.

How does the value of g changes form Pole to Equator?





As we know that g is inversely proportional to Radius of Earth

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?

Let *m* be the mass of the gold bought.

suppose the acceleration due to gravity at poles and at equator be g and g' respectively. Acceleration due to gravity at poles is slightly greater than that at equator.

$$g = \frac{GM_e}{R_e^2}$$

i.e $g \propto 1/$square of radius of Earth

$\therefore$ Weight of gold at poles $W_p = mg$

Weight of gold at equator $W_e = mg'$

But as $g > g'$ $\Rightarrow W_p > W_e$

Hence the weight of gold is slightly less at equator.

So the friend will not agree with Amit about the weight of gold bought.

Weight of an object on the moon:

Suppose the mass of the moon is M_m and its radius is R_m. If a body of mass m is placed on the surface of moon, then weight of the body on the moon is

$$W_m = \frac{GM_m m}{R_m^2} \quad ...(1)$$

Weight of the same body on the earth's surface will be

$$W_e = \frac{GM_e m}{R_e^2} \quad ...(2)$$

where M_e = mass of earth and R_e = radius of earth.

Dividing equation (1) by (2), we get

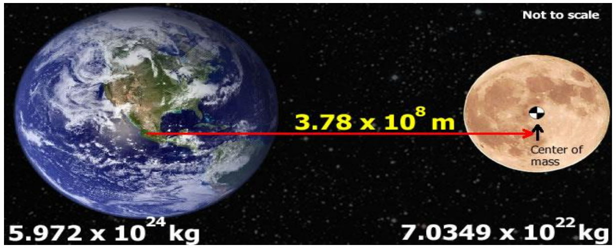
$$\therefore \frac{W_m}{W_e} = \frac{M_m}{M_e} \times \frac{R_e^2}{R_m^2} \quad ...(3)$$

Now, mass of the earth, $M_e = 6 \times 10^{24}$ kg

mass of the moon, $M_m = 7.4 \times 10^{22}$ kg

radius of the earth, R_e = 6400 km

and radius of the moon, R_m = 1740 km



Thus, equation (3) becomes,

$$\frac{W_m}{W_e} = \frac{7.4 \times 10^{22}\text{ kg}}{6 \times 10^{24}\text{ kg}} \times \left(\frac{6400\text{ km}}{1740\text{ km}}\right)^2$$

or $$\frac{W_m}{W_e} \approx \frac{1}{6} \quad \text{or} \quad W_m \approx \frac{W_e}{6}$$

The weight of the body on the moon is about one-sixth of its weight on the earth.

Example-1

A car falls off a ledge and drops to the ground in 0.5 s. Let $g = 10\ m\ s^{-2}$ (*for simplifying the* calculations).

(i) What is its speed on striking the ground?

(ii) What is its average speed during the 0.5 s?

(iii) How high is the ledge from the ground?

Solution:

Solution:

Time, $t = ½$ *second*

Initial velocity, $u = 0\ m\ s^{-1}$

Acceleration due to gravity, $g = 10\ m\ s^{-2}$

Acceleration of the car, $a = + 10\ m\ s^{-2}$ (downward)

(i) speed $v = u + a\,t$

$v = 0 + a\,t$

$v = 10 \times 0.5\ s$

$= 5\ \text{m s}^{-1}$

Continue from page-5

(ii) average speed $= \frac{u+v}{2}$

$= (0 \text{ m s}^{-1} + 5 \text{ m s}^{-1})/2$

$= 2.5 \text{ m s}^{-1}$

(iii) distance travelled, $s = ½\, a\, t^2$

$= ½ \times 10 \text{ m s}^{-2} \times (0.5 \text{ s})^2$

$= ½ \times 10 \text{ m s}^{-2} \times 0.25 \text{ s}^2$

$= 1.25 \text{ m}$

Thus,

(i) its speed on striking the ground $= 5 \text{ m s}^{-1}$

(ii) its average speed during the 0.5 s $= 2.5 \text{ m s}^{-1}$

(iii) height of the ledge from the ground $= 1.25$ m.

Example-2

An object weighs 10 N when measured on the surface of the earth. What would be its weight when measured on the surface of the moon?

Solution:

We know,

Weight of object on the moon

= (1/6) × its weight on the earth.

That is,

$$W_m = \frac{W_e}{6} = \frac{10}{6} \text{ N.}$$

$$= 1.67 \text{ N.}$$

Thus, the weight of object on the surface of the moon would be 1.67 N.

Example-3 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.

Let the two stones meet after a time t.

When the stone dropped from the tower

Initial velocity, u = 0 m/s

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

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

From the equation of motion,

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

$$s = 0 \times t + \frac{1}{2} \times 9.8 \times t^2$$

$$\Rightarrow s = 4.9t^2 \quad \dots\dots\dots\dots\dots\dots\dots\dots (1)$$

When the stone thrown upwards

Initial velocity, $u = 25\ ms^{-1}$

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

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

Equation of motion,

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

$$s' = 25 \times t - \frac{1}{2} \times 9.8 \times t^2$$

$$\Rightarrow s' = 25t - 4.9t^2 \quad \dots\dots\dots\dots\dots\dots\dots\dots (2)$$

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

$$s' + s = 100$$

$$\Rightarrow 25t - 4.9t^2 + 4.9t^2 = 100$$

$$\Rightarrow t = \frac{100}{25} s = 4s$$

In 4 s,
The falling stone has covered a distance given by (1) as $s = 4.9 \times 4^2 = 78.4\ m$
Therefore, the stones will meet after 4 s at a height (100 – 78.4) = 20.6 m from the ground.

Motion of objects under the influence of Gravitational force of the Earth

Activity __________________ 10.3

- Take a sheet of paper and a stone. Drop them simultaneously from the first floor of a building. Observe whether both of them reach the ground simultaneously.
- We see that paper reaches the ground little later than the stone. This happens because of air resistance. The air offers resistance due to friction to the motion of the falling objects. The resistance offered by air to the paper is more than the resistance offered to the stone. If we do the experiment in a glass jar from which air has been sucked out, the paper and the stone would fall at the same rate.

WORKSHEE BASED ON MODULE-3

- Mass of an object is 10 kg. What is its weight on the earth? An object weighs 10 N when measured on the surface of the earth. What would be its weight when measured on the surface of the moon?
- *Why is the weight of an object on the moon* 1/6 *th its weight on the earth?*
- How does the value of g changes form pole to equator?
- What is SI unit of Gravitation force?
- Give the standard value of acceleration due to gravity(g)on earth surface.
- 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?

THANK YOU