Gravitation - Lesson 15
Weight on other planets

Like us, different planets have different masses, and therefore different 'g'. 'g' on earth is higher than that of the moon, why? Because the moon weighs way less than the earth (about 81.25 times less), and also it's much smaller that the earth (about 3.6 times smaller). This results in a samller gravitational pull which is about six times less than that of the earth. This also means that if you measure weight on the moon, you would weigh six times less, i.e., a person weighing 60 N on Earth will weigh only 10 N. Another consequence of this is that you can jump way higher than you can on the earth. But this is not the case on all planets. If you happen to visit Jupiter, a massive planet, the same person will weigh about 150 N, which is much more than your body might be used to carry, about 2.5 times that of the earth. Even crazier would be visiting the Sun (Good luck coming without burning to ashes), and you will weigh 1680 N, 28 times your weight (assuming you weigh 60 N), this will surely crush your bones if you manage, somehow, to evade the scorching heat on the surface of the Sun. To find out the acceleration due to gravity on a planet, we just need to know the mass of the planet and its radius, as g is given by,

$$g_{planet} = G\frac{M}{r^2}$$

To compare it to the earth's gravitational acceleration, just divide it by 9.8.

$$g_{relative} = \frac{g_{planet}}{g_{earth}}$$

As mass remains the same, we can use the relative acceleration to find the weight of an object on other planets. First let us calculate the acceleration due to gravity on moon.
Mass of the moon, $M_m = 7.36 \times 10^{22}\ kg$
Radius of the moon, $R_m = 1.74 \times 10^{6}\ m$
Universal gravitational contant, $G = 6.67 \times 10^{-11} N\ m^2\ kg^{-2}$

Acceleration due to gravity is given by,

$$g_{moon} = G\frac{M_m}{R_m}$$
$$g_{moon} = (6.67 \times 10^{-11} N\ m^2\ kg^{-2}) \times \frac{7.36 \times 10^{22}\ kg}{(1.74 \times 10^{6}\ m)^2}$$
$$g_{moon} = 1.621\ m\ s^{-2}$$

Comparing Moon's acceleration due to gravity to earth's,

$$g_{relative} = \frac{g_{moon}}{g_{earth}}$$
$$g_{relative} = \frac{1.621}{9.8}$$
$$g_{relative} = \frac{1}{6}$$

This means that the an object will weigh 6 times as less as it weighs on earth. For example, if an object weighs 600 N on earth, it will weigh just 100 N on moon.

Let us look at a few examples:

1. **Example 1:** How far will you jump on the moon, if you can jump 1 m on earth, given that you are jumping with the same initial vertical velocity?

   Answer
   We know that acceleration due to gravity on moon (a_m) is about $\frac{1}{6}$ times that of the earth (g). It is intuitive to conclude that you would jump 6 m on the moon, which is correct. Let's prove it below:

   The ratio of accelration due to gravity on earth and on moon,

$$\frac{a}{a_m} = \frac{6}{1}$$

Final velocity will be 0 $m\ s^{-1}$ on earth as well as on moon, because when you jump, at the highest point, you will stop momentarily.

Using the equation, $v^2 = u^2 + 2as$
Final velocity on earth,

$$v_e^2 = u_e^2 + 2gs_e = 0$$
$$\implies u_e^2 = -2gs_e$$

Final velocity on moon,

$$v_m^2 = u_m^2 + 2a_m s_m = 0$$
$$\implies u_m^2 = -2a_m s_m$$

As initial velocities is same, we can write,

$$-2a_m s_m = -2gs_e$$
$$\implies s_m = \frac{g}{a_m} s_m$$
$$\implies s_m = \frac{6}{1} \times 1$$
$$\implies s_m = 6\ m$$

2. **Example 2:** Mass of an object is 50 kg50 kg. What is its weight on the moon?

   Answer
   Mass, m = 50 kg,
   Acceleration due to gravity, g = 1.621 $m\ s^{-2}$.

   We know that,

$$W = m \times a_m$$
$$= 50 \times 1.621$$
$$= 81.05\ N$$

   Thus, the weight of the object is 81.05 N.

3. **NCERT Example:** 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?

   Answer

We know, Weight of object on the moon = (1/6) × its weight on the earth. That is,

$$W_m = \frac{W_e}{6} = \frac{10}{6}\ N$$
$$= 1.67\ N$$

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

You should, now, be able to answer the following questions:

1. The mass of an object on earth is 20 *kg*. What will be its mass on the moon?
2. Calculate your weight. Now calculate your weight if you were on the moon?
3. How far will you jump on the Jupiter, if you can jump 1 *m* on earth? The acceleration due to gravity on jupiter is about 2.36 times that of the earth.
4. If a stone of mass 10 *kg* is dropped from a distance of 10 *m* on the moon, what is its speed when it hits the ground? What will be the answer if the stone has a mass of 100 *kg* or a 1000 *kg*?

Conclusion

Different planets have different acceleration due to gravity which depends on the planet's mass and radius.

Note to Teacher

The lesson aims to exemplify the different weight on different planets. The goal is to understand that weight is present due to gravity and that the acceleration due to gravity is different on different planets. As a result, weight along with other parameters related to motion changes.

Student Worksheet

1. How far will you jump on the moon, if you can jump 2 *m* on earth?
2. How much will a 100 *kg* object weigh on the sun ($g_s = 28.02 \times g_e$)?
3. If an object weigh 98 *N* on earth and 6.958 *N* on Pluto. Find the ratio of the ratio of the gravitational acceleration of pluto with respect to earth?

Answers

1. The will be 20 *kg* as the mass of an object is constant everywhere.

2. Weight of an object on earth can be calculated as follows,

$$\begin{aligned}\text{Weight on earth} &= \text{Mass} \times \text{Acceleration on earth}\\ &= 10 \times 9.8\\ &= 98\ N\end{aligned}$$

   As the gravitational force on the surface of the moon is only $\frac{1}{6}^{th}$ as strong as gravitational force on the earth, it implies that the acceleration due to gravity on moon will also be $\frac{1}{6}^{th}$ times the acceleration due to gravity on earth. Hence, the object's weight on moon can be calculated as,

$$\begin{aligned}\text{Weight on moon} &= \text{Mass} \times \text{Acceleration on moon}\\ &= \text{Mass} \times \frac{\text{Acceleration on earth}}{6}\\ &= 10 \times \frac{9.8}{6}\\ &= 16.3\ N\end{aligned}$$

3. ________________ *kg*. As the acceleration due to gravity is 2.36 times more than that of the earth, the height jumped will be 2.36 times as less as on earth.

$$\text{Height jumped, } h = \frac{1}{2.36} = 0.423\ m$$

4. As the mass of object has no effect on an object under freefall, the final velocity can be calculated as follows:
   Initial velocity, $u = 0\ m\ s^{-2}$
   Distance, $s = 10\ m$
   acceleration, $g = \frac{9.8}{6} = 1.625\ m\ s^{-2}$

$$\begin{aligned}\text{Final velocity, } v^2 &= u^2 + 2as\\ &= 0^2 + 2 \times 1.625 \times 10\\ \implies v &= \sqrt{32.5}\ m\ s^{-1}\\ v &= 5.7\ m\ s^{-1}\end{aligned}$$

   The answer will be the same for a 100 *kg* or, a 1000 *kg* stone
   .

Student Worksheet Answers

1. As the acceleration due to gravity is 6 times less than that of the earth, the height jumped will be 6 times as more as on earth.

$$\text{Height jumped, } h = 6 \times 2 = 12\ m$$

2. As acceleration due to gravity is 28.02 times more that that on the earth, the acceleration due to gravity on sun is given by,
   $g_s = 28.02 \times 9.8 = 274.6\ m\ s^{-2}$

$$\begin{aligned} Weight &= m \times g_s \\ &= 100\ kg \times 274.6\ m\ s^{-2} \\ &= 27460\ N \end{aligned}$$

3.

$$Ratio = \frac{6.958}{9.8} = 0.071$$