Mass and Weight

Mass

Mass is a measure of the amount of matter present in an object. It is a scalar quantity, and it does not change from location to location. In other words, your mass is the same no matter where you go.

The unit of mass is the kilogram (kg).

Weight

The terms mass and weight are often confused with one another, but it is important to distinguish between them. Mass is a property of an object itself. Weight, on the other hand, is a force – the pull of gravity acting on an object. Since it is a force, weight is a vector quantity. Its direction is simply "down."

Unlike mass, the weight of an object is not constant — an object's weight depends on the strength of the gravitational field at its current location. For example, your weight will be different on the Moon $(g = 1.6\ N/kg)$ than it is on Earth $(g = 9.8\ N/kg)$.

The unit of weight is the same as that for all other forces, Newtons (N).

The weight of an object can be calculated by determining the gravitational force acting on it. This is done using the formula:

$$\vec{F_g} = m \cdot \vec{g}$$

The direction of this force is down, or toward the center of the Earth.

Example 1

What is the weight of a $15\ kg$ crate on Earth? How much would the same crate weigh on the Moon?

Example 2
Calculate the mass of a car whose weight is 14700 N .

Apparent Weight

Consider a person standing in a moving elevator. If the elevator is traveling at a constant velocity, then the acceleration is zero. thus, we have the following situation:

If the elevator is accelerating upward, then the magnitude of the normal force must be greater than the gravitational force.

If the elevator is accelerating downward, then the opposite is true.

Example 3
A $65\ kg$ woman descends in an elevator that briefly accelerates at $0.20g$ downward when leaving a floor. She stands on a scale that reads in *kg*. (a) During this acceleration, what is her weight and what does the scale read? (b) What does the scale read when the elevator descends at a constant speed of $2.0\ m/s$?

Note: The scale in (a) gives a reading that is less than the woman's actual weight of $65\ kg$. This phenomenon, in which an object seems to weigh less (or more) than it actually does is known as **apparent weight**.

In general:

- an object that is accelerating upwards will seem heavier than normal
- an object that is accelerating downward will seem lighter than normal

True Weightlessness
An object is truly weightless only if the gravitational force acting on it is zero. This will only occur in the compete absence of a gravitational field.

Mass and Weight Worksheet

1. What is the force of gravity at the Earth's surface on
   a. a 50 kg girl? (490 N)
   b. a 100 g bullet? (0.98 N)

2. If the gravitational field constant on the surface of the moon is 1.6 N/kg, what is the force of gravity on the two masses in the previous question, if they are on the surface of the moon? (80 N, 0.16 N)

3. What would be the force of gravity on a 60.0 kg astronaut if she could stand on the surface of
   a. Mars? (223 N)
   b. Uranus? (629 N)
   c. Pluto? (18.6 N)

4. A passenger in an elevator has a mass of 100 kg. Calculate the force, in Newtons, exerted on the passenger by the elevator, if the elevator is
   a. at rest. (980 N [up])
   b. moving with an upward acceleration of $30\ \text{cm/s}^2$. (1010 N [up])
   c. moving with a downward acceleration of $15\ \text{cm/s}^2$. (965 N [up])
   d. moving upward with a uniform velocity of 14 cm/s. (980 N [up])
   e. falling freely (the cable breaks). (0)

5. An elevator, complete with contents, has a mass of 2000 kg. By drawing free-body diagrams and by performing the necessary calculations, determine the value of F_T (the tension in the elevator cable) when
   a. the elevator is at rest. (19 600 N)
   b. the elevator is moving upward at a constant velocity of 2.0 m/s. (19 600 N)
   c. the elevator is moving downward at a constant velocity of 2.0 m/s. (19 600 N)
   d. the elevator is accelerating upward at $1.0\ \text{m/s}^2$. (21 600 N)
   e. the elevator is accelerating downward at $1.0\ \text{m/s}^2$. (17 600 N)

6. A man measures the acceleration of an elevator by using a spring scale. He fastens the scale to the roof, and suspends a mass from it. If the scale reads 98 N when the elevator is at rest, and 93 N when the elevator is moving,
   a. what is the acceleration of the elevator? ($0.50\ \text{m/s}^2$)
   b. in which direction is the elevator accelerating?

7. In a disaster film, an elevator full of people falls freely when the cable snaps. In the film, the people are shown pressed upward against the ceiling. Is this good physics? Explain.

8. A 0.10 g spider is descending on a strand that supports it with a force of 0.00056 N. What is the acceleration of the spider? Ignore any air resistance. ($4.2\ \text{m/s}^2$ [down])

9. A fish hangs from a spring scale supported from the roof of an elevator.

   a. If the elevator has an upward acceleration of 1.2 m/s^2 and the scale reads 200 N, what is the true force of gravity on the fish? (178 N)
   b. Under what circumstances will the scale read 150 N? ($\vec{a} = 1.55$ m/s^2 [down])
   c. What will the scale read if the elevator cable breaks? (0)