SPH3U UNIVERSITY PHYSICS

FORCES

☞ Mass & Weight (P.165-167)

The Difference Between Mass & Weight

The terms "mass" and "weight" are used interchangeably in everyday language, but these two words have different meanings. ***Mass*** *is the quantity of matter in an object. The only way to change the mass of an object is to either add or remove matter. The mass of an object does not change due to location or changes in gravitational field strength. The units of mass are kilograms (kg) and is measured using a balance.*

MASS (m)

- quantity of matter in an object (kg)
- constant – only changes if the quantity of matter changes
- measured using a balance

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The Difference Between Mass & Weight

Weight *is a measure of the force of gravity, F_g, acting on an object. Since weight and the force of gravity are the same quantity, the weight of an object depends on location and the magnitude of Earth's gravitational field strength at that location. Weight is a vector, and its magnitude is measured in newtons with a spring scale or a force sensor.*

WEIGHT (F_g)

- measure of the force of gravity acting on object (N)
- varies – depends on the magnitude of **g** at that location
- measured using a spring scale or force sensor

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Mass & Weight

PRACTICE

1. Suppose you wanted to make some money by purchasing precious materials such as gold at one altitude and selling them for the same price in dollars per newton at another altitude. Describe the conditions that would favour your "buy high and sell low" strategy.

   buy at high altitude (lower g so less $) and sell at lower altitude (higher g so more $).

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Mass & Weight

PRACTICE

2. An astronaut on the surface of Mars finds that a rock accelerates at a magnitude of 3.6 m/s^2 when it is dropped. The astronaut also finds that a force scale reads 180 N when the astronaut steps on it.
   (a) What is the astronauts mass as determined on the surface of Mars?

   (a) m = 50 kg

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Mass & Weight

PRACTICE

2. An astronaut on the surface of Mars finds that a rock accelerates at a magnitude of 3.6 m/s^2 when it is dropped. The astronaut also finds that a force scale reads 180 N when the astronaut steps on it.
   (b) What should the force scale read if the astronaut stepped on it on Earth?

   (b) F = 490 N

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Mass & Weight

PRACTICE

3. A 500 g mass is hung on a force scale at a location where the magnitude of the gravitational field strength is 9.8 N/kg, but the scale reads 4.7 N.
   (a) What should the scale reading be?

   (a) F = 4.9 N

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Mass & Weight

PRACTICE

3. A 500 g mass is hung on a force scale at a location where the magnitude of the gravitational field strength is 9.8 N/kg, but the scale reads 4.7 N.
   (b) What could have accounted for the error in the measurement?

   (b) the scale was not properly calibrated

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Free Fall, Weightlessness, & Microgravity

*Astronauts aboard the International Space Station experience a sensation often referred to as **weightlessness** or **microgravity** while on the station orbiting Earth. However, the terms weightless and microgravity are misleading because they do not explain what is really happening.*

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Free Fall, Weightlessness, & Microgravity

At the altitude where the space station orbits Earth, the force of gravity acting on the astronauts and the station is about 90% of what it is on Earth's surface. With such a large force, microgravity or weightlessness are not good descriptions.

NOTE!
Without this large force of gravity, the space station would not have stayed in its orbit around Earth.

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Free Fall, Weightlessness, & Microgravity

It was Newton who first saw the connection between falling objects, projectiles, and satellites in orbit. Imagine a large cannon on the top of a high mountain firing cannon balls horizontally at greater and greater speeds. At first the cannon balls fall quickly to the ground. As their initial speeds increase, the cannon balls travel farther and farther. At very high speeds, a new factor affects the distance. Since Earth is round, the surface of landing curves downwards.

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Free Fall, Weightlessness, & Microgravity

The cannonball must travel down and around before landing. When a certain critical speed is reached, the cannon ball's path curves downward at the same rate as Earth's curvature. The cannon ball is then said to be in orbit – a constant free fall, always falling toward Earth, but never landing. The space station and everything inside also undergo the same type of accelerated motion as the imaginary cannon ball does.

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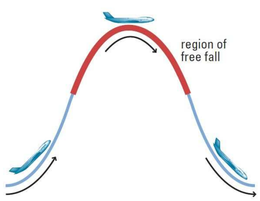
Free Fall, Weightlessness, & Microgravity

When you jump from a height to the ground, you momentarily experience free fall. Virtually no force is acting upward on you as the force of gravity pulls you down toward Earth. However, the time interval is so short that the sensation does not really have time to take effect. The interval of free fall or "weightlessness" is extended for astronauts during training.

Free Fall, Weightlessness, & Microgravity

The astronauts are placed in the cargo hold of a large military transport plane. First, the plane climbs to a high altitude. Then, it dives to gain speed. Next, it pulls into a large parabolic path and into a dive. It is during the upper part of the parabolic path that the plane is in free fall for about 30 s, and the astronauts can "float" around inside the cargo hold, experiencing the sensation of "weightlessness".



Free Fall, Weightlessness, & Microgravity

WEIGHTLESSNESS or MICRO GRAVITY

- terms often used to describe falling objects (and the sensation)
- are misleading because gravity is still in effect (needed by objects to keep them in orbit around Earth)
- a better explanation is "the object is experiencing a constant free-fall effect" (i.e. the object is falling towards the Earth's surface but never reaches it)

NOTE!

The space station and the astronauts inside are experiencing a constant "free-fall" effect which gives us/them the illusion of weightlessness or microgravity.

Mass & Weight

PRACTICE

4. A 74 kg astronaut goes up to the ISS on a mission. During his stay, the gravitational field strength on the station is 8.6 N/kg.
   (a) What is the mass of the astronaut on the station?

   (a) m = 74 kg

Mass & Weight

PRACTICE

4. A 74 kg astronaut goes up to the ISS on a mission. During his stay, the gravitational field strength on the station is 8.6 N/kg.
   (b) What is the difference between the astronaut's weight on Earth's surface and his weight on the station?

   (b) F_{diff} = 89 N

Mass & Weight

PRACTICE

4. A 74 kg astronaut goes up to the ISS on a mission. During his stay, the gravitational field strength on the station is 8.6 N/kg.
   (c) Why does the weight of the astronaut change but not his mass when moving from the surface of Earth to the station?

   (c) weight depends on g whereas mass depends on the quantity of matter

Mass & Weight

PRACTICE

4. A 74 kg astronaut goes up to the ISS on a mission. During his stay, the gravitational field strength on the station is 8.6 N/kg.
   (d) Why does the astronaut appear weightless on the station?

   (d) the astronaut is experiencing a constant free-fall effect

Mass & Weight

PRACTICE

5. A 24 kg object sits on top of a scale calibrated in newtons. Determine the reading on the scale (to 3 significant digits) if:
   (a) the object is at rest and no one is pushing on it.

   (a) F = 235 N

Mass & Weight

PRACTICE

5. A 24 kg object sits on top of a scale calibrated in newtons. Determine the reading on the scale (to 3 significant digits) if:
   (b) the object is at rest and someone is pushing down on it with a force of 52 N.

   (b) F = 287 N

Mass & Weight

PRACTICE

5. A 24 kg object sits on top of a scale calibrated in newtons. Determine the reading on the scale (to 3 significant digits) if:
   (c) the object is at rest and someone is pulling up on it with a force of 74 N.

   (c) F = 161 N

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✔ Check Your Learning

TEXTBOOK

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