

Show equations, substitutions, units, and vector directions. Explain your reasoning. Use sensible rounding.

Answers appear below each question beside a vertical bar. Equivalent correct reasoning is acceptable.

Constants	$g_{\text{Earth}} = 9.8 \text{ m/s}^2$ $g_{\text{Moon}} = 1.6 \text{ m/s}^2$
Equations	$\Sigma F = F_{\text{net}} = ma$ $F_g = mg$ $1 \text{ N} = 1 \text{ kg}\cdot\text{m/s}^2$

Draw only forces acting ON the chosen object. State a positive direction.

2.1 Newton's First Law

1. A bus brakes suddenly. Explain why an unbelted passenger continues moving forward and how a seat belt changes the passenger's motion. Is inertia a force?

The passenger initially shares the bus's forward velocity. Inertia is resistance to changing velocity, not a force. The belt exerts a backward force that slows the passenger with the bus.

2. A crate slides east at constant velocity while a person pushes it east with 48 N. Find the friction force and net force. Explain why equilibrium does not require rest.

Friction = 48 N west. Net force = $48 - 48 = 0 \text{ N}$. Equilibrium means zero acceleration, so an object can remain at rest or continue at constant velocity.

2.2 Types of Forces

3. For each interaction, name the force and classify it as contact or long-range: a cable supports a sign, water supports a boat, a floor supports a box, Earth pulls on a ball, air slows a falling leaf.

Cable: tension, contact. Water: buoyant force, contact. Floor: normal force, contact. Earth: gravity, long-range. Air: air resistance, contact.

4. A sled slides east while a horizontal rope pulls it east. Name all four forces on the sled, their sources, and their directions. Ignore air resistance.

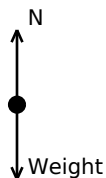
Earth exerts gravity down. Snow exerts normal force up and friction west. The rope exerts tension east. Friction opposes the sliding relative to the snow.

ANSWER KEY

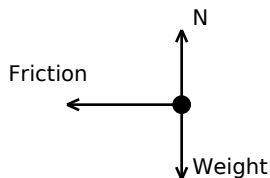
2.3 Free-Body Diagrams

5. Draw separate free-body diagrams for (a) a book at rest on a desk, (b) a puck sliding right and slowing down, and (c) an elevator speeding up while rising. Label forces and use relative arrow lengths.

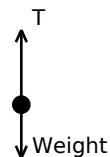
(a) Book



(b) Puck

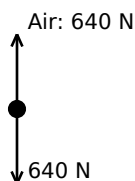


(c) Elevator



(a) Equal upward normal and downward weight. (b) Equal upward normal and downward weight, plus friction left. (c) Upward tension is larger than downward weight. No velocity arrows belong in a free-body diagram.

6. A 640 N skydiver falls straight down at constant speed. Draw and label the free-body diagram. Find the air-resistance force and acceleration.



Weight = 640 N down and air resistance = 640 N up, with equal arrow lengths. Net force is zero, so $a = 0 \text{ m/s}^2$. Constant downward motion does not require a downward net force.

2.4 Net Force

7. Two students push a cart east with 85 N and 65 N. Friction acts west with 110 N. Find the net force. If the cart is moving west, does it initially speed up or slow down?

Take east as positive. $F_{\text{net}} = 85 + 65 - 110 = +40 \text{ N}$, or 40 N east. A cart moving west initially slows because net force and acceleration point opposite its velocity.

8. A cable pulls upward on a 980 N load with 1176 N. Find the net force and predict the acceleration direction. Does this information alone tell you the velocity direction?

$F_{\text{net}} = 1176 - 980 = 196 \text{ N}$ upward. Acceleration is upward. Velocity could be up, down, or momentarily zero. Force determines acceleration, not the current velocity.

ANSWER KEY**2.5 Newton's Second Law**

9. A 12.0 kg box experiences a 72 N horizontal push right and 24 N friction left. Find its acceleration. What push would produce 5.0 m/s² right if friction stays 24 N?

| $F_{\text{net}} = 72 - 24 = 48 \text{ N right. } a = 48/12.0 = 4.0 \text{ m/s}^2 \text{ right. Required push} - 24 = (12.0)(5.0), \text{ so push} = 84 \text{ N right.}$

10. A 6.0 kg cart accelerates at 3.0 m/s². Find the net force. Predict acceleration if (a) this force doubles or (b) the mass doubles while the original force stays constant.

| $F_{\text{net}} = ma = (6.0)(3.0) = 18 \text{ N. (a) } a = 36/6.0 = 6.0 \text{ m/s}^2. \text{ (b) } a = 18/12 = 1.5 \text{ m/s}^2.$

2.6 Mass and Weight

11. An astronaut has a mass of 65 kg. Find her weight on Earth and on the Moon. State her mass on the Moon and explain the difference between mass and weight.

| Earth: $F_g = (65)(9.8) = 637 \text{ N, about } 640 \text{ N. Moon: } (65)(1.6) = 104 \text{ N, about } 100 \text{ N. Mass remains } 65 \text{ kg. Mass measures inertia, while weight is a gravitational force that depends on local } g.$

12. An object weighs 294 N on Earth. Find its mass. On another planet it weighs 111 N. Find the gravitational field strength there.

| $m = F_g/g = 294/9.8 = 30 \text{ kg. Other planet: } g = F_g/m = 111/30 = 3.7 \text{ N/kg} = 3.7 \text{ m/s}^2.$

ANSWER KEY**2.7 Newton's Third Law**

13. A swimmer pushes water backward with 120 N. Identify the reaction force. Explain why the two forces do not cancel on the swimmer.

The water pushes the swimmer forward with 120 N. One force acts on the water and the other on the swimmer. They do not cancel in the net force on either individual object.

14. Two skaters of masses 40 kg and 60 kg push apart. Each experiences a 180 N force. Calculate each acceleration and compare the directions. Are the weight and normal force on one skater a third-law pair?

$a_{40} = 180/40 = 4.5 \text{ m/s}^2$. $a_{60} = 180/60 = 3.0 \text{ m/s}^2$. The accelerations point in opposite directions. Weight and normal force are not a third-law pair because both act on the same skater.

Unit 2 Review

15. A 20 kg crate starts from rest on a level floor. A horizontal 70 N pull acts right while 30 N friction acts left for 3.0 s. Find net force, acceleration, final velocity, and displacement.

$F_{\text{net}} = 70 - 30 = 40 \text{ N right}$. $a = 40/20 = 2.0 \text{ m/s}^2$. $v_f = 0 + (2.0)(3.0) = 6.0 \text{ m/s right}$. $\Delta x = \frac{1}{2}(2.0)(3.0)^2 = 9.0 \text{ m right}$.

16. Correct each claim: (a) Motion requires a net force. (b) A heavier stationary object has no inertia. (c) A scientific theory eventually becomes a law.

(a) A change in velocity requires net force. Constant velocity does not. (b) Any object with mass has inertia, whether moving or at rest. (c) Theories explain phenomena and laws describe patterns. A theory does not become a law.