Chapter 3 – Laws of Motion

Section Review 3.1

1. State Newton's first law in your own words.

An object at rest will stay at rest until an outside force acts on it to move. An object in motion will stay in motion at the same velocity until an outside force acts on it to change its speed or direction.

2. How is mass related to inertia?

There is a direct proportional relationship between an object's mass and its inertia. Inertia can be thought of as resistance to motion; as an object has more mass it also has more inertia and thus, it is more resistant to changes in its motion.

3. What do pounds and newtons measure? Why do scientists use newtons instead of pounds?

Pounds and newtons both measure force, which is really the pull of the acceleration due to gravity on an object. Newtons are a standardized unit, and the SI unit for force is defined by Newton's laws.

4. What is net force and how is it determined?

The net force on a body (or object) describes the total sum of all forces acting on that body (or object). It is determined by adding all the forces (taking into account their direction, not just magnitude) acting on the object.

5. Why are vehicle seat belts and air bags designed with Newton's first law of motion in mind?

When a moving vehicle comes to a sudden stop due to a collision or slamming on the breaks, all bodies and objects in the car are still in motion at whatever velocity the car was traveling in prior to the sudden stop. Air bags are designed to cushion the impact of those moving human bodies.

Section Review 3.2

1. List three units in which acceleration can be measured.

a. feet/s/s

b. mi/hr/s

c. m/s/s

2. According to Newton's second law, what causes acceleration? What resists acceleration?

An object undergoes an acceleration when a *force* is applied to it. By looking at the equation $a = F/m$, it is apparent that the greater the force applied, the greater the acceleration. The equation also suggests that an increase in mass will resist the tendency of an object to accelerate.

3. An 8,000-kg helicopter's velocity increases from 0 m/s to 25 m/s in 5 s. Calculate its acceleration and the net force acting on it.

Use the equation: $a = \frac{v_f - v_i}{t}$ to calculate the value for acceleration first: $a = \frac{25\frac{m}{s} - 0\frac{m}{s}}{5\,s} = 5\,\frac{m}{s^2}$

Then use $F = ma; F = (8000kg)\left(5\,\frac{m}{s^2}\right); F = 40{,}000\ N$

4. Define the term *net force*.

If two forces on an object are acting in the same exact direction (i.e., both acting "east"), then the net force is the sum of those two forces. If two forces act in opposite directions (east and west), then the net force is the difference between those two forces.

5. Describe the conceptual relationship between energy and force.

Forces are created any time there is a difference in energy. As an example, a car at the top of a hill has more energy than when it sits at the bottom; from this example we would expect a downhill force (gravity) to exist.

Section Review 3.3

1. Describe the motion of a freely-falling object. Use the words *velocity, acceleration,* and *distance* in your answer.

An object in free fall is subject to the acceleration due to gravity, and starts accelerating at a rate of 9.8 m/s^2 (if there's no air resistance); this means that the downward velocity of the object increases by 9.8 m/s every second it is in free fall.

2. What is the difference between mass and weight?

Mass defines the amount of matter any body or object has, whereas weight encompasses both the mass and the force due to gravity on an object. A bowling ball has exactly the same mass whether Earth or Jupiter, but on Jupiter it weighs so much more, due to the increased gravitational pull.

3. If you drop a feather and a baseball in a place where there is no air resistance, how will their motions compare? Explain.

In free fall, if there is no air resistance (such as in a vacuum), then the baseball and the feather will have the exact same motion, and will hit the ground at the same time. If there is air resistance, however, the feather would be much more impacted by that, and would hit the ground much later than the baseball.

Chapter 3 Review

Understanding Vocabulary

Select the correct term in the Word Bank on page 72, to complete the sentences.

1. "Objects continue moving in the same way," is a way of stating __*Newton's First Law*___.

2. An object with more mass has more ___*matter*____.

3. The total of all forces acting on an object is called the __*net force*___.

4. __*Newton's Second Law*___ relates force, mass, and acceleration in the equation $F=ma$.

5. The force of gravity on an object is its __*weight*____.

6. When the force due to gravity equals the force due to air resistance, the speed of a falling object is called its _*terminal velocity*__.

Reviewing Concepts

Section 3.1

1. Define the term force and give three examples of forces.

A force is a push or pull, or any action that has the ability to change the motion of an object.

a. There is a force due to gravity that pulls all bodies towards earth.

b. Tension is a force that pulls on an object to move it.

c. There are electrostatic forces that can either be repulsive (same charges), or attractive (opposite charges).

2. Give an example of Newton's first law in everyday life.

When a vehicle comes to a sudden stop or turns a sharp corner, all objects within the vehicle continue their motion, which is why items fall off the dashboard, or off the seats.

Objects rolling on a table come to a stop due to the force of friction between the object and table surface.

3. Explain why Newton's first law is also known as the law of inertia.

Since an objects motion is very tied in to its inertia (the amount of matter it contains), Newton's first law is also known as the law of inertia.

4. List two units for measuring mass and two units for measuring force.

a. gram b. kilogram

a. pounds b. ounces

5. One newton is the ___*amount of force*_ it takes to change the ___*motion*___ of a __*1 kg*_ mass by __*1 meter/ second*___ in 1 s.

Section 3.2

6. What is the net force of an object with zero acceleration?

Since F = ma, it is mathematically acceptable to state if the acceleration factor ("a") of the product ("F") is zero, than the net force is zero. Simply stated, if there is no acceleration, then there is no force on the object.

7. Which of the following have zero acceleration?

a. a car moving forward at a constant velocity

b. a kicked ball

c. a skater turning left

d. a parked car

8. Write the equation for Newton's second law that you would use in each of the following scenarios. Let F = force, m = mass, and a = acceleration.

a. You know mass and acceleration and want to find the force. $F = ma$

b. You know mass and force and want to find the acceleration. $a = F/m$

c. You know force and acceleration and want to find the mass. $m = F/a$

9. Provide an example of Newton's second law in everyday life.

Since F = m/a, then we can assume a heavier baseball bat (increased mass) will exert a greater force on a ball, than a lighter one (smaller mass).
We can also assume that we would need to exert a greater amount of force to move (accelerate) a shopping cart loaded with bricks than one loaded with Styrofoam peanuts.

Section 3.3

10. By how much does the speed of an object in free fall change each second?

Since the object is subject to the acceleration due to gravity, it is increasing in speed or velocity by 9.8 m/s, every second it falls.

11. A ball is thrown straight up into the air. As it moves upward, its speed _*decreases*_ by _*9.8 m/s*_ each second. As it falls back down its speed _*increases*_ by _*9.8 m/s*_ each second.

12. An astronaut carries a rock from the Moon to Earth. Is the rock's mass the same on earth as it is on the Moon? Is its weight the same? Explain.

The mass of the rock remains the same because the amount of matter does not change, but the force due to gravity which impacts the force "felt" by the rock does change, so the weight of the rock will be much greater on Earth than on the moon.

13. What is the direction of air resistance on a falling object?

Air resistance acts against the force of gravity on an object in free fall. This is obvious when you watch a piece of paper fall to the floor - air resistance seems to push up against the paper.

14. Which two forces are equal when an object is at its terminal speed?

When an object reaches terminal speed, the forces of both air resistance and gravity are equal. .

Solving Problems

Section 3.1

1. Order the following mass measurements from smallest to largest: 0.5 kg, 1,000 g, 5 kg, 50 g.

First step, change all the masses to equal units, either kg or g, then place in order.

50 g (0.050 kg) 0.5 kg 1000 g (1 kg) 5 kg

2. Dani and Gina are pushing on a box. Dani pushes with 250 N of force and Gina pushes with 100 N of force.

a. What is the net force if they both push in the same direction?

Since the forces exerted by both Dani and Gina are in the same direction, add the 250 N and 100 N; 250 N + 100 N = 350 N in the direction both are pushing.

b. What is the net force if they push in opposite directions?

Since the forces exerted by both Dani and Gina are in opposite directions, find the difference between the two forces: 250 N – 100 N = 150 N in the direction Dani is pushing.

Section 3.2

3. Use your knowledge of Newton's second law to answer the following:

a. What is the net force required to accelerate a 1,000-kg car at 3 m/s^2?

Use $F = ma; F = (1{,}000\ kg)\left(3\frac{m}{s^2}\right) = 3{,}000\frac{kg \cdot m}{s^2}\ or\ 3{,}000\ N$; recollect that 1 N = 1 kg·m/s^2

b. You pull your little cousin in a wagon. You must pull with a net force of 50 N to accelerate her at 2 m/s^2. What is her mass?

Rearrange $F = ma; m = \frac{F}{a}; m = \frac{50N}{2\frac{m}{s^2}} = 25\ \frac{kg \cdot \frac{m}{s^2}}{\frac{m}{s^2}}\ or\ 25\ kg$, because the units for acceleration cancel.

c. A 1,500-N force is applied to a 1,000-kg car. What is the car's acceleration?

Rearrange $F = ma; a = \frac{F}{m}; a = \frac{1{,}500 kg \cdot m/s^2}{1000\ kg} = 1.5\ \frac{m}{s^2}$, because units for mass cancel out.

Section 3.3

4. You drop a ball from the edge of a cliff. It lands 4 s later.

a. Make a table showing the ball's speed each second for 4 s.

Speed (m/s)	9.8	19.6	29.4	39.2
Time (s)	1	2	3	4

b. What is the ball's average speed during the first second it is in free fall?

9.8 m/s

c. What is the ball's average speed for the whole 4 s?

Use $v_{avg} = \frac{v_f + v_i}{2}; v_{avg} = \frac{39.2\frac{m}{s} + 0\frac{m}{s}}{2};\ v_{avg} = 19.6\frac{m}{s}$

d. What distance does the ball fall during the 4 s?

Use $d = v_{avg} \cdot t; d = \left(19.6\frac{m}{s}\right)(4\ s) = 78.4\ m$

5. During a science experiment, your teacher drops a tennis ball out of a window. The ball hits the ground 3 s later.

a. What was the ball's speed when it hit the ground? Ignore air resistance.

Use $v = gt; v = \left(9.8\frac{m}{s^2}\right)(3\ s) = 29.4\frac{m}{s}$

b. What was the ball's average speed during the 3 s?

Use $v_{avg} = \frac{v_f+v_i}{2}; v_{avg} = \frac{29.4\frac{m}{s}+0\frac{m}{s}}{2};\ v_{avg} = 14.7\frac{m}{s}$

c. How high is the window?

Use $d = v_{avg} \cdot t; d = \left(14.7\frac{m}{s}\right)(3\ s) = 44.1\ m$

6. Answer the following questions about mass and weight:

a. How many newtons does a 5-kg backpack weigh on Earth?

Use $F_w = mg;\ F_w = (5\ kg)\left(9.8\frac{m}{s^2}\right) = 49\ N$

b. How many newtons does a 5-kg backpack weigh on the Moon?

Use $F_w = mg;\ F_w = (5\ kg)\left(1.6\frac{m}{s^2}\right) = 8\ N$

c. Aya's mass is 45 kg. What is her weight in newtons on Earth?

Use $F_w = mg;\ F_w = (45\ kg)\left(9.8\frac{m}{s^2}\right) = 441\ N$

d. What is Aya's mass on the moon?

45 kg, her mass will not change wherever she goes.

e. What is Aya's weight in newtons on the Moon?

Use $F_w = mg;\ F_w = (45\ kg)\left(1.6\frac{m}{s^2}\right) = 72\ N$

Test Practice

Section 3.1

1. According to Newton's first law, only ________ has the ability to change motion

a. inertia b. mass c. force d. gravity

2. A force of 1-N is applied to a 1-kg mass. What acceleration does the force produce?

a. 4.454 m/s^2 b. 4.448 m/s^2 c. 9.8 m/s^2 d. 1 m/s^2

3. Look at the figure on page 73. The net force on the block is 200 N. How large is force A?

a. 100 N b. 200 N c. 300 N d. 400 N

4. Because of their ________, a pair of sunglasses on the dashboard will continue moving forward when the car turns sharply.

a. acceleration b. inertia c. velocity d. weight

Section 3.2

5. Which of the following does not represent Newton's second law?

a. $a = F/m$ b. $F = ma$ c. $m = F/a$ d. $F = m/a$

6. A 3,000-N force is applied to a car which causes an acceleration of 3 m/s^2. What is the mass of the car?

a. 1,000 kg b. 3,000 kg c. 6,000 kg d. 9,000 kg

7. A skater is coasting at a constant velocity. A net force is necessary for all of the following *except*

a. the skater accelerates.
b. the skater continues in the same direction at the same speed.
c. the skater stops.
d. the skater turns to the right.

8. Note the figure on page 74. A 20-N force is applied to each block. How much greater is the acceleration of block A than the acceleration of block B?

a. two times greater b. four times greater
c. five times greater d. They have the same acceleration.

Section 3.3

9. Anjali throws a soccer ball straight up in the air with an initial velocity of 19.5 m/s. What will the velocity of the ball be after 3 s?

a. -9.8 m/s b. 0 m/s c. 9.8 m/s d. 48.8 m/s

10. A coconut falls from a tree. What is the average velocity after 2 s?

a. 0 m/s b. 4.9 m/s c. 9.8 m/s d. 19.6 m/s

11. A 50-kg space explorer pilots a rocket to a newly discovered planet. The explorer's weight on the new planet is 250 N. What is the strength of gravity (g) on this planet?

a. 0.2 N/kg b. 5 N/kg c. 9.8 N/kg d. 25 N/kg

12. The _________ velocity of an object in free fall is reached when the forces of gravity and air resistance are equal.

a. average b. initial c. final d. terminal