Chapter 4 – Conservation Laws

Section Review 4.1
1. List three action and reaction pairs in the picture at right, on page 82 in text.

a. Force of paddle on water, and force of water on paddle.
b. Force of man's hand on paddle, and force of paddle on man's hand.
c. Force of boat on water and force of water on boat.

2. Why don't action and reaction forces cancel?
Multiple forces applied to the ***same*** *object combine to create a net force on that object (taking into account direction), Action and reaction forces refer to forces on different objects – operating on each other. So, these forces do not cancel. An action force from one object impacts a second object which "returns" a reaction force to the first object.*

3. Use impulse to explain how force is related to changes in momentum.
The net force applied to an object multiplied by the time the force acts on the object is equal to the change in momentum, or impulse. That is, a force applied to an object will cause a change in momentum (either change in mass and/or change in velocity). Thus force causes impulse.

4. Explain the law of conservation of momentum and how it relates to Newton's third law.
The law of momentum conservation states that the total amount of momentum in a system of interacting objects remains constant (is conserved) as long as all forces act only on the objects in the system. The law of conservation of momentum is derived from Newton's 3rd law, which states that forces come in action-reaction pairs that are equal and opposite. Since the forces are equal, the changes in momentum are also equal.

Section Review 4.2
1. What are the units of energy and what do they mean?
Energy is measured in joules (J) which is the energy needed to push with the force of 1 Newton over a distance of 1 meter.

2. What is *work* in physics and what is the relationship between work and energy?
In physics, work is the transfer of energy that results from applying a force over a distance. Work is a form of energy.

3. How can you increase an object's potential or kinetic energy?
Potential energy is energy dur to position – it increases the higher an object is from a starting point (such as the ground). Kinetic energy is an energy of motion, and increases with velocity.

4. What happens to the kinetic and potential energy of a ball as it falls toward the ground?
The potential energy decreases, as the kinetic energy increases.

5. Explain what it means to say that energy is "conserved."
By saying energy of conserved, t energy can never be created or destroyed. Rather, it changes from one form to another. So, total energy (potential + kinetic) remains unchanged.

Section Review 4.3

1. List three examples of elastic collisions and three examples of inelastic collisions not already mentioned in this chapter.

   a. *Elastic: Collision of hockey puck and stick*
   b. *Elastic: Collision of glass marbles*
   c. *Elastic: A bouncing superball*

   a. *Inelastic: two cars colliding (bumpers absorb some energy by collapsing)*
   b. *Inelastic: An asteroid falling to earth*
   c. *Inelastic: A ball of clay dropped on a table*

2. Are momentum and kinetic energy conserved in all collisions? Explain.
Momentum is conserved in both elastic and inelastic collisions (as long as there are no outside forces, such as friction). Kinetic energy of a system decreases after an inelastic collision, but stays the same before and after an elastic collision.

3. What is the definition of *impulse*?
Impulse, also called change in momentum, is equal to force multiplied by the time the force acts:

*Impulse = F*t*

4. Why will an egg break if it is dropped on the ground but not if it is dropped on a pillow?
Both dropped eggs would have the same momentum (equals mass times velocity). The impulse when they land (or change in momentum) is also the same, and can be expressed as force times time. Since an egg dropped on a pillow has a longer (larger) stopping time, it will have a smaller force acted on it.

Chapter 4 Review

Understanding Vocabulary

Refer to the Word Bank on page 98, and select the correct term to complete the below sentences.

1. ___*Impulse*_____ is calculated by multiplying a force and the time needed for the force to act.

2. According to __*Newton's third law*___ for every action force, there is a reaction force equal in strength and opposite in direction.

3. The mass of an object multiplied by its velocity equals its ____*momentum*___.

4. The _*law of conservation of energy*_ states that energy can never be created or destroyed, just changed from one form to another.

5. Energy due to position is known as ___*potential energy*___.

6. When two objects collide and stick together or change shape, it is called a(n) __*inelastic collision*__.

Reviewing Concepts

Section 4.1

1. State Newton's third law in your own words.
For every action force, there is an equal and opposite reaction force.

2. Action and reaction forces always have the _*same*_ strength and act in _*opposite*_directions.

3. You and a friend are sitting across from each other on chairs with wheels. You push off each other and move in opposite direction. Explain the following:

a. How does the force you feel compare to the force your friend feels?
Same force, but opposite direction

b. If your mass is greater than your friend's mass, how do your accelerations compare?
If my mass is greater, then my friend's acceleration is faster.

4. A book rests on a table. The force of gravity pulls down on the book. What prevents the book from accelerating downward?
The normal force, or force from table, pushes up on the book with an equal and opposite force.

5. Provide three examples of Newton's third law in everyday life. List the action and reaction forces in each example.

a. *I am on roller blades, and push on wall. The wall pushed back on me, and I start rolling away from the wall.*

b. *I am walking my dog who pulls away from me; the dog feels me pull on the leash.*

c. *When you walk, your foot pushes down on the ground, and ground pushes back on you with equal, but opposite force, thus propelling you forward.*

6. What two things does an object require to have momentum?
a. mass
b. velocity

7. Consider an airplane at rest and a person walking through the airport.
a. Which has greater mass? *airplane*
b. Which has greater velocity? *Person; airplane has zero velocity as it is at rest.*
c. Which has greater momentum? Explain. *Person walking has greater momentum. Plane's momentum is zero since it has no velocity.*

8. Explain the two different ways to calculate *impulse*.
Since impulse is the change in momentum, created by a force exerted over time, impulse can be calculated as either
*a. Force * time*
b. change in momentum $= mv_2 - mv_1$

9. Is the unit used to represent impulse the same as the unit for momentum? Explain.
Since impulse is change in momentum it has the same units as momentum. It can be shown as kg m/s or N x s, which is equivalent.

10. State the law of conservation of momentum in your own words.
Total momentum within a system stays the same unless there's an outside force. If I apply a force, creating momentum, there is an offsetting momentum (opposite direction) – like a seesaw.

11. You and your little cousin are standing on in-line skates. You push on each other and both move backwards.

a. Which of you moves back at a greater speed? Use the law of conservation of momentum to explain your answer.
Smaller person moves backwards at faster speed as mass times velocity for each person must be same (offsetting, so nets to zero). That is, $m_1v_1 = m_2v_2$

b. How does your impulse compare to your cousin's impulse?
Impulse for each of us is the same in magnitude opposite in direction

12. When you jump, you move upward with a certain amount of momentum. Earth moves downward with an equal amount of momentum. Why don't you notice the Earth's motion?
The mass of earth is so large compared to person jumping.

Section 4.2

13. What is anything with energy able to do?
Anything with energy is able to change or cause a change.

14. The *joule* is an abbreviation for what combination of units?
N-m (Newton x meter)

15. When work is done, __*energy*___ is transferred.

16. How can you increase the gravitational potential energy of an object?
Raise its height

17. Explain why a bicycle at rest at the top of a hill has energy.
It has potential energy = mass x gravity x height, and so is capable of becoming active due to the fore of gravity and its position at the top of the hill.

18. Which two quantities are needed to determine an object's kinetic energy?

a. *mass*
b. *velocity or speed*

19. What happens to a car's kinetic energy if its speed doubles? What if the speed triples?
Kinetic energy is proportional to the square of the velocity, If the speed doubles, kinetic energy quadruples. If the speed triples, kinetic energy is nine times as great ($3^2 = 9$).

20. A ball is thrown up into the air. Explain what happens to its potential and kinetic energies as it moves up and then back down.
As ball moves up, its kinetic energy decreases (as it slows down) and its potential energy increases as its height increases.
As ball comes back down, kinetic energy increases (with velocity) and potential energy decreases.

21. Explain what it means to say energy is conserved as a ball falls toward the ground.
The total energy of the ball is conserved as it falls to the ground. As the ball falls, its velocity increases and its height decreases. This causes an increase in kinetic energy, with offsetting decrease in potential energy. That is, its potential energy is transferred into kinetic energy as it approaches the ground. Its total energy stays constant.

22. Will we ever run out of energy on Earth? Might we run out of certain forms of energy? Explain.
The total amount of energy on earth stays constant, and it will not run out. Certain forms of energy, such as oil and gas, may run out, as they have been transformed into a different type of energy.

Section 4.3

23. Distinguish between *elastic* and *inelastic* collisions.
In an elastic collision, objects bounce off of each other with no loss of kinetic energy in the system. The kinetic energy before the collision and the kinetic energy after the collision are the same. In an inelastic collision, objects collide and stick together or change shape. In an inelastic collision, some of the kinetic energy of the system is transformed into other energy forms.

24. Classify each collision as elastic or inelastic.

a. A dog catches a tennis ball in his mouth.
inelastic
b. A ping-pong ball bounces off a table.
elastic
c. You jump on a trampoline.
elastic
d. A light bulb is knocked onto the floor and breaks.
inelastic

25. Is momentum conserved during elastic collisions? Is it conserved during inelastic collisions? Explain.
Momentum is conserved during both elastic and inelastic collisions.

26. Why does bouncing nearly always cause a greater force than simply stopping during a collision?
Bouncing almost always causes greater force that stopping during a collision because the change in momentum is greater. If the object stops, its velocity goes to zero in the collision. If the object bounces, its velocity changes direction, resulting in a larger total change in velocity, and a larger momentum change. The force of the collision depends on the momentum change.

27. Cars that crumple in a collision are safer than cars that bounce when they collide. Explain why this is so.
The car body is designed to absorb the momentum of a crash by crumpling as slowly as possible to reduce the force of the impact. This is done by spreading out the change in momentum over a longer period of time. Recall that Force x time = change in momentum. So, Force = change in momentum divided by time.

28. What is the secret to catching a water balloon without breaking it? Explain using what you know of physics.
To reduce the force on the balloon, move your hands along with the motion of the balloon to spread out the momentum change over a longer period of time.

Solving Problems

Section 4.1

1. You throw a basketball by exerting a force of 20 N. According to Newton's third law, there is another 20-N force created in the opposite direction. If there are two equal forces in opposite directions, how does the ball accelerate?
The two equal forces are acting on different objects. The action force of 20N is applied to the basketball, which accelerates away from you. The reaction force from the basketball causes you to accelerate in opposite direction.

2. What is the momentum of a 2-kg ball traveling at 4 m/s?
P = mv = 2 kg x 4 m/s = 8 kg · m/s

3. How fast does a 1,000-kg car have to move to have a momentum of 50,000 kg·m/s?
v = p ÷ m = (50,000 kg · m/s) ÷(1,000 kg) = 50 m/s

4. Idil's momentum is 110 kg·m/s when she walks at 2 m/s. What's her mass?
m = p ÷ v = (110 kg · m/s) ÷ (2 m/s) = 55 kg

5. Which has more momentum: a 5,000-kg truck moving at 10 m/s or a sports car with a mass of only 1,200 kg moving at 50 m/s?
Truck: p = mv = 5,000 kg x 10 m/s = 50,000 kg · m/s
Car: p = mv = 1,200 kg x 50 m/s = 60,000 kg · m/s, so the sports car has more momentum.

6. Two hockey players on ice skates push off each other. One has a mass of 60 kg. the other has a mass of 80 kg.

a. If the 80-kg player moves back with a velocity 3 m/s, what is his momentum?
P = mv = -80 kg x 3 m/s = - 240 kg · m/s

b. What is the 60-kg player's momentum?
Smaller player would have same momentum due to conservation of momentum: 240 kg · m/s

c. What is the 60-kg player's velocity?
v = p ÷ m = (240 kg · m/s) ÷(60 kg) = 4 m/s

7. A 75-kg astronaut floating in space throws a 5-kg rock at 5 m/s. How fast does the astronaut move backwards?
By conservation of momentum, astronaut's momentum = rock's momentum.
p of rock = mv = 5 kg x 5 m/s = 25 kg · m/s, so p of astronaut = 25 kg · m/s;
v = p ÷ m = (25 kg · m/s) ÷(75 kg) = 0.33 m/s

8. A 2-kg ball is accelerated from rest to a speed of 8 m/s.

a. What is the ball's change in momentum?

Change in momentum $= mv_2 - mv_1$ *or* $m(v_2 - v_1) = 2$ *kg (8 m/s – 0 m/s) = 2 kg (8 m/s)*

= 16 kg · m/s

b. What is the impulse?

Impulse = change in momentum; so, 16 kg · m/s

c. A constant force of 32 N is used to change the momentum. For how much time does the force act

F x t = impulse, so, 32N x t = 16 kg · m/s

T = (16 kg · m/s) ÷ 32 N = 0.5 sec

9. A 1,000-kg car uses a braking force of 10,000 N to stop in 2 s.

a. What impulse acts on the car?

Impulse = Force x time = (10,000 N) x (2 s) = 20,000 N·s or 20,000 kg · m/s

b. What is the change in momentum of the car?

Change in momentum = impulse, so 20,000 N·s or 20,000 kg · m/s

c. What was the initial speed of the car?

Change in momentum $= m(v_2 - v_1)$, *where m = 1,000 kg and* $v_2 = 0$ *(comes to stop).*

20,000 kg · m/s = 1,000 kg $(v_2 - 0$ *m/s).*

v_2 *= 20,000 kg · m/s ÷ 1,000 kg = 20 m/s*

Section 4.2

10. A 5-kg can of paint is sitting on top of a 2-m-high step ladder. How much work did you do to move the can of paint to the top of the ladder? What is the potential energy of the can of paint?

Since Work = Force times Distance, we must first find the force of the can. Recall,

F (weight) = mass x gravity = (5 kg) x 9.8 m/s^2 *= 49 N*

So, W = F x d = 49N x 2 m = 98 N·m, or 98 joules

E(potential) = Ep = m x g x h = (5 kg) x (9.8 m/s^2 *) x (2m) = 98 N·m or 98 joules*

11. How much work is done to move a 10,000-N car 20 m?

Since Work = Force times Distance,

use, W = F x d = 10,000N x 20 m = 200,000 N·m, or 200,000 joules

12. Which has more potential energy, a 5-kg rock lifted 2 m off the ground on Earth, or the same rock lifted 2 m on the Moon? Why?

E(potential) = Ep = m x g x h. Since gravity is greater on Earth compared to the Moon, the rock has more potential energy on the Earth.

13. At the end of a bike ride up a mountain, Chris was at an elevation of 500 m above where he started. If Chris's mass is 60 kg, by how much did his potential energy increase?

Ep = mgh = (60kg) x (9.8 m/s^2 *) x (500m) = 294,000 joules*

14. Alexis is riding her skateboard. If Alexis has a mass of 50 kg:

a. What is her kinetic energy if she travels at 5 m/s?

$E_k = ½ m v^2 = ½ (50 kg) (5m/s)^2 = 625$ joules

b. What is her kinetic energy if she travels at 10 m/s?

$E_k = ½ m v^2 = ½ (50 kg) (10m/s)^2 = 2,500$ joules

c. Alexis's 50-kg dog Bruno gets on the skateboard with her. What is their total kinetic energy if they move at 5 m/s?

$E_k = ½ m v^2 = ½ (50 kg+50 kg) (5m/s)^2 = 1,250$ joules

d. Based on your calculations, does doubling the mass or doubling the speed have more of an effect on kinetic energy?

Doubling the speed has more of an effect on kinetic energy. Doubling the speed increases the kinetic energy by 4 times, while doubling the mass only increases the kinetic energy by 2 times.

15. A 1-kg coconut falls out of a tree from a height of 12 m. Determine the coconut's potential and kinetic energy at each point shown in the figure on page 100. At point A, its speed is zero.

Position	*Potential Energy (joules)*	*Kinetic Energy (joules)*
A	*117.6*	*0*
B	*88.2*	*29.4*
C	*58.8*	*58.8*
D	*29.4*	*88.2*
E	*0*	*117.6*

Section 4.3

16. A demolition derby is a car-crashing contest. Suppose an 800-kg car moving at 20 m/s crashes into the back of and sticks to a 1,200-kg car moving at 10 m/s in the same direction. Refer to the figure on page 100, and answer the below:

a. Is this collision elastic or inelastic? Why?

The collision is inelastic since the cars stick to each other.

b. Calculate the momentum of each car before the collision.

Momentum of 800 kg car: p = mv = (800kg) x (20m/s) = 16,000 kg · m/s

Momentum of 1,200 kg car: p = mv = (1,200kg) x (10m/s) = 12,000 kg · m/s

c. What is the total momentum of the stuck-together cars after the collision? Why?

The momentum of the stuck together cars equals the sum of the momentums of the two cars just prior to the collision because the momentum of the system is conserved. The total momentum before the collision is the total momentum after the collisions:

16,000 kg · m/s + 12,000 kg · m/s = 28,000 kg · m/s

d. What is the speed of the stuck-together cars after the collision?

Restating p = mv, we derive v = p ÷ m = 28,000 kg · m/s ÷ (800 kg + 1,200 kg) =

28,000 kg · m/s ÷(2,000 kg) = 14 m/s

17. A 5-kg ball moving at 6 m/s collides with a 1-kg ball at rest. The balls bounce off each other and the second ball moves in the same direction as the first ball at 10 m/s. What is the velocity of the first ball after the collision? Refer to the figure on page 100.

Using net momentum before collision = net momentum after collision:

$$m_1v_1 + m_2v_2 = m_3v_3 + m_4v_4$$

Before collision, $(5\ kg)(6\ m/s) + (1\ kg)(0\ m/s) = (5\ kg)\ v + (1\ kg)(10\ m/s)$

$$30\ kg \cdot m/s = 5\ kg \times v + 10\ kg \cdot m/s$$

$$20\ kg \cdot m/s = 5\ kg \times v$$

$$v = 4\ m/s$$

18. Yanick and Nancy drive two identical 1,500-kg cars at 20 m/s. Yanick slams on the brakes and his car comes to a stop in 1 s. Nancy lightly applies the brakes and stops her car in 5 s.

a. How does the momentum change of Yanick's car compare to the momentum change of Nancy's car?

The change in momentum is exactly the same for both cars: same mass and same speed.

b. How does the impulse on Yanick's car compare to the impulse on Nancy's car?

The impulse of both cars is the same, since they start with same momentum and cars both come to stop (zero momentum).

c. How does the force of Yanick's brakes compare to the force of Nancy's brakes?

The force of Yanick's brakes is 5 times larger than the force of Nancy's brakes because Yanick stops 5 times faster: F = Impulse divided by time.

d. Calculate the stopping force for each car.

F·t = Change in momentum = (1,500 kg) x 20 m/s = 30,000 N·s for both cars.
Force for Yanick's car when t = 1sec: (F) (1s) = 30,000 N·s, so F = 30,000 N
Force for Nancy's car when t = 5 sec: (F) (5s) = 30,000 N·s, so F = 6,000 N

19. Your neighbor's car breaks down. You and a friend agree to push it two blocks to a repair shop while your neighbor steers. The two of you apply a net force of 800 N to the 1,000-kg car for 10 s.

a. What impulse is applied to the car?

Impulse = F·t = (800N)(10 s) = 8,000 N·s

b. At what speed is the car moving after 10 s? The car starts from rest.

Impulse = Change in momentum
$F \cdot t = 8{,}000\ N \cdot s = mv_2 - mv_1 = 1{,}000\ kg\ (v_2 - 0\ m/s)$. *So, velocity = 8 m/s*

Test Practice

Section 4.1

1. Newton's third law describes action and reactions forces which

a. are equal in strength. b. are acting in the same direction.

c. are always applied to the same object. d. always cancel each other out.

2. A person with a mass of 50 kg is in a canoe with a mass of 30 kg. The canoe is moving at 5 m/s. What is the momentum of the person and canoe?

a. 16 kg·m/s b. 150 kg·m/s c. 250 kg·m/s d. 400 kg·m/s

3. Impulse is the product of

a. force and mass. b. force and time.
c. mass and acceleration. d. mass and velocity.

4. How much time should a 50-N force take to increase the speed of a 5-kg car from 10 m/s to 30 m/s?

a. 0.5 s b. 1 s c. 2 s d. 3 s

Section 4.2

5. Joules are a unit of measurement for all of the following except

a. kinetic energy. b. potential energy. c. momentum. d. work.

6. A 60-kg woman is on a ladder 2 m above the ground. What is her potential energy?

a. 60 J b. 120 J c. 588 J d. 1,176 J

7. A 1-kg cat is perched in a tree 4 m off the ground. It jumps out of the tree. The cat's velocity halfway down is 10 m/s. What is the cat's kinetic energy halfway down?

a. 5 J b. 8 J c. 50 J d. 100 J

8. Take a look at the figure on page 102. At which point does the car on the ramp have the greatest potential energy?

a. A b. B c. C d. D

Section 4.3

9. In a collision between objects, kinetic energy is not lost when

a. the objects change shape. b. the objects stick together.

c. the collision is inelastic. d. the collision is elastic.

10. Refer to the figure on page 102. A 6,000-kg train car moving at 10 m/s strikes a second 4,000-kg parked train car. The cars stick together and move along the track. What is their velocity after the collision?

a. 4 m/s b. 6 m/s c. 10 m/s d. 15 m/s

11. Which of the following is an example of a nearly-elastic collision?

a. marbles collide and bounce off each other.
b. ice skaters collide and hold on to each other.
c. trucks crash and stick together.
d. a ceramic mug fall to the floor and breaks.

12. A 15-kg child ice skating at 1 meter per second collides with a skater at rest. The skaters grab onto each other and continue moving at 0.5 m/s. What is the mass of the second skater?

a. 7.5 kg b. 15 kg c. 30 kg d. 45 kg