SOLUTIONS TO THE MODULE #10 STUDY GUIDE

1. a. Inertia – The tendency of an object to resist changes in its velocity

b. Friction – A force that opposes motion, resulting from the contact of two surfaces

c. Kinetic friction – Friction that opposes motion once the motion has already started

d. Static friction – Friction that opposes the initiation of motion

2. Newton's First Law – An object in motion (or at rest) will tend to stay in motion (or at rest) until it is acted upon by an outside force.

Newton's Second Law – When an object is acted on by one or more outside forces, the total force is equal to the mass of the object times the resulting acceleration

Newton's Third Law – For every action, there is an equal and opposite reaction.

3. Newton's First Law of Motion tells us that an object will not change velocity until acted on by an outside force. Often, this force is friction. In this problem, once the ball is thrown, no forces (not even friction) are operating on the ball. Thus, even in a year, its velocity will still be 3.0 meters per second to the west.

4. The beanbag will not fall next to the tree. Instead, it will fall north of the tree. This is once again an application of Newton's First Law. While it is in the boy's hand, the beanbag has a velocity going north. When the boy drops the beanbag, it will still have a velocity going north. Thus, as it falls, it will travel north. When it lands, then, it will be north of the tree. In fact, ignoring air resistance, when it hits the ground, it will be right next to wherever the boy is at that instant, because it will be traveling north with the boy's velocity.

5. The beanbag will land next to the tree. In this case, the beanbag has no initial velocity. It is at rest with the boy standing next to the tree. When the running boy taps the beanbag lightly, it simply falls to the ground.

6. The boxes will slam into the front seat. The boxes have the same velocity as the car. When the car stops, they continue to move with the same velocity. This makes them move forward relative to the car, slamming them into the front seat.

7. Remember, friction is caused by molecules on each surface attracting one another, and the strength of the attraction depends on how close they can get to each other. When the road gets wet, the grooves in the road get filled with water. This makes it harder for the bumps on the tires to fit into them, which makes it hard for the molecules to get close to one another. Thus, the water fills in the grooves in the road, reducing how close the tire molecules can get to the road molecules. This can become an even bigger problem when a film of water gets trapped under the tires, causing the tires to lose contact with the road. Essentially, they are traveling on the water, not the road. This situation is called "hydroplaning," and it causes the tire molecules to be so far from the road molecules that very little friction exists.

8. The static frictional force is greater than the kinetic frictional force. When the refrigerator is not moving, the man must overcome static friction to get it moving. Once it is moving, the man only needs to overcome the kinetic frictional force.

9. Since the object is moving with a constant velocity, we know its acceleration is *zero.* Since the total force exerted on an object is equal to the object's mass times its acceleration (Newton's Second Law), then the total force on the object is zero as well. This means that the child exerts enough force to counteract kinetic friction, but no more. We must be talking about kinetic friction, because the toy is already moving. Thus, the child exerts a force of 10 Newtons to the east.

10. Since we know the child's mass and acceleration, we can calculate the total force acting on the child.

$$\text{total force} = (\text{mass}) \cdot (\text{acceleration})$$

$$\text{total force} = (20\ \text{kg}) \cdot \left(2.0 \frac{\text{m}}{\text{sec}^2}\right) = 40\ \text{Newtons}$$

Since we are ignoring friction, the only force involved is the force that the father exerts. Thus, the total force is equal to the father's force. Since the child is accelerating north, the father must be pushing with a force of 40 Newtons north.

11. Since it takes more than 25 Newtons to get the object moving, the static frictional force is 25 Newtons east. Once it is moving, however, it accelerates at 0.1 meters per second^2. This means the total force on the object is:

$$\text{total force} = (\text{mass}) \cdot (\text{acceleration})$$

$$\text{total force} = (15\ \text{kg}) \cdot \left(0.10 \frac{\text{m}}{\text{sec}^2}\right) = 1.5\ \text{Newtons}$$

This force is the combination of the applied force (20 Newtons) and the kinetic frictional force (we know to use the kinetic frictional force because it is moving). Since the kinetic frictional force opposes motion, it is opposite of the applied force. Thus, the total force is the applied force minus the frictional force.

$$20\ \text{Newtons} - \text{kinetic frictional force} = 1.5\ \text{Newtons}$$

Thus, in order for the total force to be 1.5 Newtons, the kinetic frictional force must be 18.5 Newtons east.

12. The first part is easy. If the static frictional force is 700 Newtons, the worker must apply more than 700 Newtons of force to get the box moving. To accelerate the box once it is moving, the total force must be:

$$\text{total force} = (\text{mass}) \cdot (\text{acceleration})$$

$$\text{total force} = (500 \text{ kg}) \cdot \left(0.10 \frac{\text{m}}{\text{sec}^2}\right) = 50 \text{ Newtons}$$

This total force is made up of the worker's force minus the kinetic frictional force. We were told the kinetic frictional force is 220 Newtons, so we can say:

$$\text{worker's force} - 220 \text{ Newtons} = 50 \text{ Newtons}$$

The worker's force, then, must be <u>270 Newtons south</u>.

13. Static friction keeps objects from moving. If the gardener had to exert slightly more than 100 Newtons of force to get the rock moving, <u>the static frictional force is 100 Newtons</u>. Once it got moving, the gardener keeps it moving at a constant velocity eastward. This tells us that the acceleration is zero, which means the total force on the rock is zero. Thus, the gardener applies enough force to overcome the kinetic frictional force, but no more. <u>The kinetic frictional force, then, must be 45 Newtons to the west</u>.

14. The total force on the rock can be calculated from the mass and acceleration:

$$\text{total force} = (\text{mass}) \cdot (\text{acceleration})$$

$$\text{total force} = (710 \text{ kg}) \cdot \left(0.20 \frac{\text{m}}{\text{sec}^2}\right) = 142 \text{ Newtons}$$

Now what is this force made of? Well, one man is pushing east with 156 Newtons, and the other is pushing east at 220 Newtons. Since those forces are in the same direction, they add. Friction is there as well, however, and it opposes the motion. Thus, it subtracts.

$$156 \text{ Newtons} + 220 \text{ Newtons} - \text{kinetic frictional force} = 142 \text{ Newtons}$$

When we add 156 and 220, we get 376.

$$376 \text{ Newtons} - \text{kinetic frictional force} = 142 \text{ Newtons}$$

So, the kinetic frictional force is equal to whatever number leaves 142 when subtracted from 376. That's 234. Thus, the kinetic frictional force must be <u>234 Newtons west</u>.

15. <u>The equal and opposite force is exerted by the doghouse on the child</u>.

16. <u>The player exerts a force on the ball because the ball's velocity changed. This means there was an acceleration, which means a force was exerted on the ball. The equal and opposite force is exerted by the ball on the player and is evidenced by the pain that the player feels when he catches the ball</u>.

17. The wall exerts a force of <u>20 Newtons west</u>, because it is equal and opposite of the man's force.