Study Questions/Problems Week 3

I have selected these as worthy problems. Read them all and do those that seem interesting. Good practice for exam on Thursday.

Chapter 5:

- Conceptual Questions 5, 7, 9, 17, 19
- Conceptual Exercises 2, 3, 7, 11
- Problems 1, 9, 13, 18, 21, 27, 29, 30, 35, 38, 43

Answers/solutions for even numbered CQs and CEs, and all problems are on following pages—don't peek until you have done your best to solve a problem.

Chapter 5: Newton's Laws of Motion

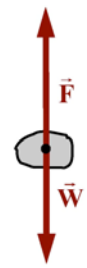
Answers to Even-Numbered Conceptual Exercises

2. **(a)** This is sometimes true. For example, if the skateboarder is moving down the ramp, the motion is in the same direction as the net force. On the other hand, if the skateboarder moves up the ramp, the direction of motion is opposite to the direction of the net force. In general, there is no reason for the direction of motion to be in the same direction as the net force. **(b)** This is never true. The acceleration of an object is *always* in the direction of the net force. **(c)** This is always true, as mentioned in part (b). **(d)** This is sometimes true. Again, the fact that an object accelerates in a certain direction tells you nothing about its direction of motion, or whether it is instantaneously at rest. An example would be a skateboarder coasting upward on a ramp. At the skateboarder's highest point, he or she is instantaneously at rest, though still accelerating in a direction pointing down the ramp.

See following pages for Problem solutions

Solutions to Ch. 5 Problems

1. **Picture the Problem**: The free body diagram for this problem is shown at right.



Strategy: Use the free body diagram to determine the net force on the rock, then apply Newton's Second Law to find the acceleration of the rock. Let upward be the positive direction.

Solution: 1. Find the net force:

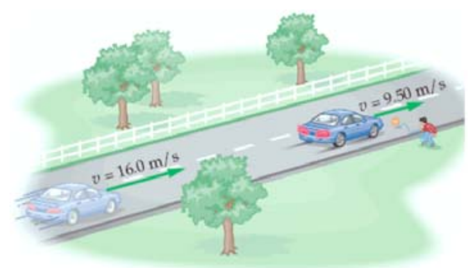
$$\sum \vec{\mathbf{F}} = (-40.0 \text{ N})\hat{\mathbf{y}} + (46.2 \text{ N})\hat{\mathbf{y}} = (6.2 \text{ N})\hat{\mathbf{y}}$$

2. Now apply Newton's second law (equation 5-1) to find $\vec{\mathbf{a}}$:

$$\vec{\mathbf{a}} = \frac{\sum \vec{\mathbf{F}}}{m} = \frac{(6.2 \text{ N})\hat{\mathbf{y}}}{5.00 \text{ kg}} = \boxed{(1.2 \text{ m/s}^2)\hat{\mathbf{y}}}$$

Insight: If the astronaut were to exert less than 40.0 N of upward force on the rock, it would accelerate downward.

$\boxed{9.}$ **Picture the Problem**: The car is accelerated horizontally in the direction opposite its motion in order to slow it down from 16.0 m/s to 9.50 m/s.



Strategy: Use equation 5-1 and the definition of acceleration to determine the net force on the car as it slows down. Then use equation 2-10 to find the distance traveled by the car as it slows down.

Solution: 1. (a) Use equation 5-1 and the definition of acceleration to find the net force on the car:

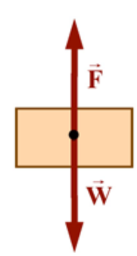
$$\vec{\mathbf{F}} = m\vec{\mathbf{a}} = m\frac{\Delta \vec{\mathbf{v}}}{\Delta t} = (950 \text{ kg})\frac{(9.50 - 16.0 \text{ m/s})}{(1.20 \text{ s})}\hat{\mathbf{x}} = (-5100 \text{ N})\hat{\mathbf{x}}$$
$$= \boxed{5.1 \text{ kN opposite to the direction of motion}}$$

2. (b) Use equation 2-10 to find the distance traveled by the car as it slows down:

$$\Delta x = \tfrac{1}{2}(v_0 + v)\Delta t = \tfrac{1}{2}(16.0 + 9.50 \text{ m/s})(1.20 \text{ s}) = \boxed{15.3 \text{ m}}$$

Insight: We must consider "950 kg" as having only two significant figures because the zero is ambiguous. That limits the net force to two significant figures, even though the acceleration $(-5.42 \text{ m/s}^2)\hat{\mathbf{x}}$ has three significant figures.

13. **Picture the Problem**: The free body diagram of the brick is shown at right.



Strategy: Use the vectors depicted in the free body diagram to answer the questions.

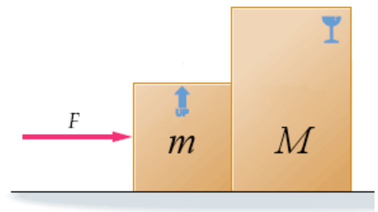
Solution: 1. (a) There are $\boxed{\text{two forces}}$ acting on the brick.

2. (b) The forces acting on the brick are due to $\boxed{\text{gravity and your hand}}$.

3. (c) $\boxed{\text{No}}$, these forces are not equal and opposite, because acceleration of the brick is nonzero: $\sum \vec{\mathbf{F}} = \vec{\mathbf{F}} + \vec{\mathbf{W}} = m\vec{\mathbf{a}}$ so that $\vec{\mathbf{F}} = m\vec{\mathbf{a}} - \vec{\mathbf{W}}$

4. (d) $\boxed{\text{No}}$, these forces are not an action-reaction pair, because they are acting on the same object.

Insight: Action–reaction pairs always act on different objects. The magnitude of $\vec{\mathbf{F}}$ is greater than the magnitude of $\vec{\mathbf{W}}$ (although it looks like they subtract in step 3, remember $\vec{\mathbf{W}}$ points in the negative direction) by the amount $m\,a$.



Picture the Problem: The light box of mass *m* sits adjacent to the heavy box of mass *M* as depicted in the figure at right.

Strategy: The boxes must each have the same acceleration, but because they have different masses the net force on each must be different. These observations allow you to use Newton's Second Law for each individual box to determine the magnitudes of the contact forces. First find the acceleration of both boxes and then apply equation 5-1 to find the contact forces.

Solution: 1. (a) The 7.50 N force accelerates all the boxes together:

$$F = (m+M)a \quad \Rightarrow \quad a = \frac{F}{m+M} = \frac{5.0\text{ N}}{5.2+7.4\text{ kg}} = \underline{\underline{0.40\text{ m/s}^2}}$$

2. Find the contact force by writing Newton's Second Law for the heavy box only:

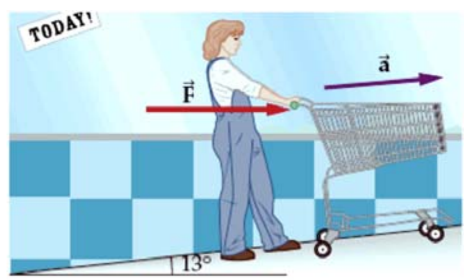
$$\sum \vec{\mathbf{F}} = F_{\text{c12}} = M\,a = (7.4\text{ kg})(0.40\text{ m/s}^2) = \boxed{3.0\text{ N}}$$

3. (b) When the force is applied to the heavier box the contact force between them will be $\boxed{\text{less than}}$ it was before , because the lighter box requires less force for the same acceleration, and the contact force is the only force on the lighter box.

4. (c) Find the contact force by writing Newton's Second Law for the lighter box only:

$$\sum \vec{\mathbf{F}} = F_{\text{c12}} = m\,a = (5.2\text{ kg})(0.40\text{ m/s}^2) = \boxed{2.1\text{ N}}$$

Insight: Another way to view the answer to (b) is to say the inertia of the heavier box shields the lighter box from experiencing some of the pushing force. In case (a) the lighter box provides less shielding and the contact force is greater.



21. **Picture the Problem**: The cart is pushed partly into the incline and partly up the incline by the pushing force $\vec{\mathbf{F}}$, as shown in the figure at right.

Strategy: Write Newton's Second Law for the *x* direction, where $\hat{\mathbf{x}}$ points up the incline and parallel to it. Solve the resulting equation for the magnitude of $\vec{\mathbf{F}}$.

Solution: The component of the force pushing up the incline is $F\cos\theta$ and the component of the weight pushing down the incline is $mg\sin\theta$:

$$\sum F_x = F\cos\theta - mg\sin\theta = ma$$

$$F = \frac{ma + mg\sin\theta}{\cos\theta} = \frac{(7.5\text{ kg})\left[1.41 + (9.81\text{ m/s}^2)\sin 13^\circ\right]}{\cos 13^\circ}$$

$$F = \boxed{28\text{ N}}$$

Insight: They'd better offer double coupons at this store, because a 13° incline is a 23% grade; danger territory for over-the-road truckers and a lot of extra work for the average grocery shopper!

27. **Picture the Problem**: The uncoupled train car coasts up the incline, slowing down under the influence of gravity, and briefly comes to rest before accelerating backwards down the incline.

Strategy: After the last car breaks free, it will continue coasting up the incline until the force of gravity brings it momentarily to rest. Let the $\hat{\mathbf{x}}$ direction point uphill and parallel to the incline. The only force acting on the train car is the parallel component of its weight, $W_x = mg\sin\theta$. Use the known acceleration $a_x = -g\sin\theta$ to find the time required to bring the train car to a stop, and then use equation 2-10 to determine the distance it travels along the incline while slowing down.

Solution: 1. (a) Find the time required to stop the train car:

$$t = \frac{v - v_0}{a_x} = \frac{0 - v_0}{-g\sin\theta} = \frac{3.15\text{ m/s}}{\left(9.81\text{ m/s}^2\right)\sin 3.9°} = \boxed{4.7\text{ s}}$$

2. (b) Use Eq. 2-10 to find the distance traveled while stopping:

$$x = \tfrac{1}{2}\left(v_0 + v\right)t = \tfrac{1}{2}\left(3.15 + 0\text{ m/s}\right)\left(4.7\text{ s}\right) = \boxed{7.4\text{ m}}$$

Insight: In most cases when motion occurs along an inclined surface it is much simpler to tilt the coordinate axes until they are parallel and perpendicular to the incline, as it was in this case.

29. **Picture the Problem**: The suitcase is accelerated straight upward by the applied force.

Strategy: There are two forces acting on the suitcase, the applied force $\vec{\mathbf{F}}$ acting upward and the force of gravity $\vec{\mathbf{W}}$ acting downward. Use Newton's Second Law together with the known acceleration to determine the mass and weight of the suitcase. Let upward be the positive direction.

Solution: 1. (a) Write out Newton's Second Law:

$$\sum F_y = F - mg = ma$$

$$m = \frac{F}{a + g} = \frac{115\text{ N}}{0.725 + 9.81\text{ m/s}^2} = \boxed{10.9\text{ kg}}$$

2. (b) Now use equation 5-5 to find the weight:

$$W = mg = (10.9\text{ kg})\left(9.81\text{ m/s}^2\right) = \boxed{107\text{ N}}$$

Insight: Note that mass and weight have different units. A 107-N suitcase weighs about 24 pounds.

30. **Picture the Problem**: The baby's brain gains a little bit of mass (and therefore weight) each day.

Strategy: Multiply the mass gain by the acceleration of gravity in order to find the weight gain. Then use the given rate of gain to find the time elapsed for the brain to gain 0.15 N in weight.

Solution: 1. (a) Multiply the mass gain by g to find the weight gain:

$$\Delta m = R\,\Delta t = \left(\frac{1.6\text{ mg}}{\text{min}}\right)\left(\frac{1\times10^{-6}\text{ kg}}{\text{mg}}\right)\times\left(1\text{ day}\right)\left(\frac{1440\text{ min}}{\text{day}}\right) = 2.3\times10^{-3}\text{ kg}$$

$$\Delta W = \Delta m\, g = \left(2.3\times10^{-3}\text{ kg}\right)\left(9.81\text{ m/s}^2\right) = \boxed{0.023\text{ N}}$$

2. (b) Use the given rate to find the time elapsed, converting W to m using equation 5-5:

$$\Delta t = \frac{\Delta m}{R} = \frac{\Delta W}{g\,R} = \frac{\left(0.15\text{ N}\right)}{\left(9.81\text{ m/s}^2\right)\left(1.6\text{ mg/min}\right)}\times\left(\frac{1\text{ mg}}{1\times10^{-6}\text{ kg}}\right)\left(\frac{1\text{ day}}{1440\text{ min}}\right)$$

$$\Delta t = \boxed{6.6\text{ days}}$$

Insight: The weight of the brain of the newborn is approximately 300 grams (10% of body weight) in contrast to the adult brain, which weighs approximately 1400 grams (2% of body weight). If the newborn brain kept gaining weight at the rate of 1.6 mg/min it would reach adult size in 480 days or about 16 months. In actuality it reaches the adult brain weight between six and fourteen years of life.

35. **Picture the Problem**: The seeds fall from the tree at constant speed.

Strategy: Because the fruit is falling with constant speed, we conclude that the net force on it is zero. Use Newton's Second Law to determine the force the air exerts on the seeds.

Solution: 1. (a) Use Newton's Second Law to find the force of air resistance:

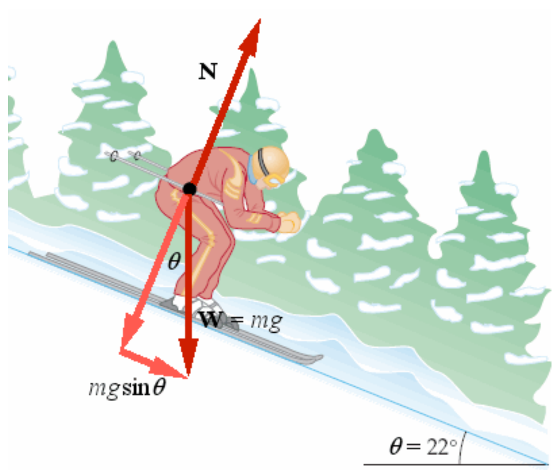
$$\sum \vec{\mathbf{F}} = \vec{\mathbf{F}}_{\text{air}} + \vec{\mathbf{W}} = 0$$

$$\vec{\mathbf{F}}_{\text{air}} = -\vec{\mathbf{W}} = -\left(-mg\right) = \left(0.00121\text{ kg}\right)\left(9.81\text{ m/s}^2\right) = \boxed{0.0119\text{ N}}$$

2. (b) If the constant speed of descent is greater than 1.1 m/s, the acceleration still remains zero, so that the force of air friction remains the $\boxed{\text{same}}$ as in part (a).

Insight: The force of air friction depends upon speed and the shape of the object that is passing through the air. A seed with a more streamlined shape will fall at a greater and greater speed until $\vec{\mathbf{F}}_{\text{air}}$ increases to 0.0119 N and the net force becomes zero once again. At that point the seed is said to have achieved its *terminal velocity*.

38. **Picture the Problem**: The skier glides down a 22° incline.



Strategy: In the free body diagram the normal force is perpendicular to the slope but the weight vector points straight downward. Write Newton's Second Law along the y direction to find N.

Solution: 1. (a) The free body diagram is drawn at right.

2. (b) Set $\sum F_y = 0$ and solve for N:

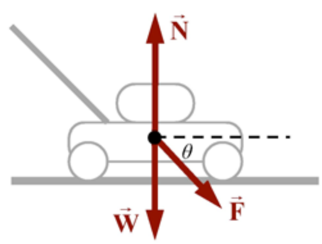
$$\sum F_y = N - mg\cos\theta = ma_y = 0$$

$$N = mg\cos\theta = \left(65\text{ kg}\right)\left(9.81\text{ m/s}^2\right)\cos 22°$$

$$N = 590\text{ N} = \boxed{0.59\text{ kN}}$$

Insight: If θ were to increase to 90° the skier would be falling straight downward and the normal force on him would be zero. If θ were to decrease to 0° the normal force would equal the weight.

43. Picture the Problem: The free body diagram of the lawn mower is shown at right.



Strategy: Write Newton's Second Law in the vertical direction to determine the normal force.

Solution: 1. (a) Use Newton's Second Law to find N:

$$\sum F_y = N - F\sin\theta - mg = ma_y = 0$$

$$N = F\sin\theta + mg$$

$$= \left(209\text{ N}\right)\sin 32° + \left(18\text{ kg}\right)\left(9.81\text{ m/s}^2\right)$$

$$N = 290\text{ N} = \boxed{0.29\text{ kN}}$$

2. (b) If the angle between the handle and the horizontal is increased, the normal force exerted by the lawn will increase because it must still balance the weight plus a larger downward force than before.

Insight: The vertical acceleration of the lawn mower will always remain zero because the ground prevents any vertical motion.