Physics 100: Homework Assignment #1
SOLUTIONS

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Problem 1:
Copernicus postulated that the Earth moves around the Sun (rather than the other way around), but he was troubled about the idea. What concepts of mechanics was he missing (concepts later introduced by Galileo and Newton) that would have eased his doubts?
Exercise #2, Chapter 2 of Conceptual Physics, 10th ed., *by Paul Hewitt.*

> **Answer:** *One of the things he was bothered by was the long-held belief of Aristotle that objects, including the Earth, naturally come to rest unless they are forced to move by an external force(the motion of the other planets was considered special– they had the property of* quintessence *so that their natural state was to move in circles). One thing that bothered Copernicus is that nobody could imagine a force large enough to keep the Earth moving around the Sun. Galileo and Newton understood that objects had inertia– that they tended to keep moving in a straight line at constant speed (or sit still) unless acted on by an external force– in the cases of objects 'naturally' coming to rest, friction was identified as the responsible force. So for the Earth, there doesn't need to be an external force to keep it moving, just so long as it isn't being affected by friction. As we will learn in subsequent chapters, gravity is what keeps the Earth moving in an ellipse around the Sun rather than just moving through space in a straight line.*
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> *There was another prevailing argument against the moving Earth. It went something like this: if the Earth were to move around the Sun, it would have to be traveling at speeds of around 30 km/s to make it all the way around in one year (that bit's pretty much right). People argued that if a bird were to drop from a tree to snatch up a worm, and it took one second for it land, the Earth would have therefore moved some 30 km out from under the bird, leaving it mighty confused in a neighboring county just before it met with a presumably unpleasant and messy landing. Since birds had been observed to drop from trees to eat worms, with confusion and harm coming only to the worm, people argued that there was no way the Earth could be moving around the Sun. What these people did not understand is the concept of relative motion: the bird and the air were moving around the Sun, with the Earth at 30 km/s, so the velocity of both the bird and air,* relative to the Earth, *were basically zero (not counting a gentle breeze or the bird's downward velocity as it fell).*

Problem 2:
In tearing a paper towel or plastic bag from a roll, why is a sharp jerk more effective than a slow pull?
Exercise #12, Chapter 2 of Conceptual Physics, 10th ed., *by Paul Hewitt.*

Answer: *The roll of paper towels has inertia, like all things with mass, and tends to resist changes in its motion. If you pull on the paper towel slowly, the roll can 'keep up with the force' and change its motion. The end result is that you'll unwind all of the towels from the roll (cat's love this trick...). If you jerk on the towel quickly, the main roll can't 'keep up with the force' and it's resistance to move, combined with the force you're exerting, puts enough stress on the perforated line of the paper towel that you're pulling on that it will break free from the main roll.*

Problem 3:
What does it meant to say that something is in mechanical equilibrium?
Review Question #14, Chapter 2 of Conceptual Physics, 10^{th} ed., *by Paul Hewitt.*

Answer: *An object is in mechanical equilibrium if the sum of all forces acting on it (a.k.a.* F_{net}*) is zero. Equivalently, this means that the object's motion doesn't change– it's speed AND direction remain constant. Something with constant speed, but moving in a circle, like a car around a race track, is* ***not*** *in mechanical equilibrium as its direction is changing. Something that is moving in a straight line but changing speeds, like a car along a straight-away in rush hour traffic, is also* ***not*** *in mechanical equilibrium as its speed is changing. Only things that move in straight lines at constant speeds or are sitting still (a special case where the constant speed is zero) are in mechanical equilibrium.*

Problem 4:
If you push on a crate with a force of 100 N and it slides at constant velocity, how much is the friction acting on the crate? (i.e. how much of a force is friction providing)
Review Question #21, Chapter 2 of Conceptual Physics, 10^{th} ed., *by Paul Hewitt.*

Answer: *Since the crate is sliding at constant velocity, it's in mechanical equilibrium (as we will learn in Ch. 3,* ***velocity*** *is a measurement of both speed and direction, so having a constant velocity implies both constant speed and direction, hence equilibrium. Since we haven't covered this, yet, you had to assume a constant speed and direction...). As it is in mechanical equilibrium, the sum of all forces acting on it must be zero. Presumably, the vertical force of gravity is canceled by the support force (it isn't falling through the ground), so we must only balance the horizontal forces. As 100 N is being applied in one direction, friction must provide 100 N in the opposite direction to cancel it out.*

Problem 5:
If you're in a car at rest that gets hit from behind, you can suffer a serious neck injury called whiplash. What does whiplash have to do with Newton's first law?
Exercise #13, Chapter 2 of Conceptual Physics, 10^{th} ed., *by Paul Hewitt.*

Answer: *Your body is pushed forward by the seat of the car. If you don't have a headrest on your seat, then your head is not directly pushed by the car along with your body. As your head has inertia, it tends to resist changes in its motion, so that it will try to remain still while your body is pushed forward– causing a lot of strain on your neck (whiplash). Note that your body has inertia, as well, but that the force of the car seat acting on your body is more than enough to overcome it.*

Problem 6:
Consider a pair of forces, one having a magnitude of 20 N and the other a magnitude of 12 N. What maximum net force is possible for these two forces? What is the minimum net force possible?
Exercise #13, Chapter 2 of Conceptual Physics, 10^{th} ed., *by Paul Hewitt.*

> **Answer:** *The maximum net force results when the two forces are pointing in the same direction– when they are acting together. In this case, they add to make a net force with a magnitude of 32 N. The minimum net force occurs when the two forces oppose each other– when they are acting against each other. In this case, one is subtracted from the other to make a net force with a magnitude of 8 N. Note that the minus sign in an answer of -8 N only refers to the direction– when we talk about the size of a force, we're talking about its magnitude so that a force of 8 N is as large as a force of -8 N. Of course, including the minus sign in your answer does not make it incorrect!*

Problem 7:
When a ball is tossed straight up, it momentarily comes to a stop at the top of its path. Is it in equilibrium during this brief moment? Why or why not?
Exercise #24, Chapter 2 of Conceptual Physics, 10^{th} ed., *by Paul Hewitt.*

> **Answer:** *The ball is not in equilibrium during the brief moment it is not moving. This can be argued in two different (eqquivalent) ways. (1) For something to be in equilibrium, the net force on the ball has to be zero. The net force on the ball is not zero, as it there is gravity acting on it (even when it's not moving) and there is no support force to cancel gravity out while the ball is in the air (it's not in contact with any surface, and the viscosity of the air is simply not enough to matter). (2) To be in equilibrium, the motion of the ball must be constant: both its speed AND direction must not be changing. This applies to an object at rest: its speed (zero) must remain constant. The ball's motion is not constant, even while it is instantaneously at rest, as during the entire toss of the ball, it's motion is changing. At the top of the arc, its direction of motion in the process of being reversed from 'up' to 'down' and its speed is changing from being zero to being non-zero (an instant later, it will be falling with non-zero speed).*

Problem 8:
Can you say that no force acts on a body at rest? Or is it correct to say that no *net* force acts on it? Defend your answer.
Exercise #30, Chapter 2 of Conceptual Physics, 10^{th} ed., *by Paul Hewitt.*

> **Answer:** *I is correct to say that no* **net** *force acts on the body at rest. Consider a coffee cup sitting at rest and not moving, on top of a table. The force of gravity is surely acting on it. To keep it from falling down, the table provides an upward force, the 'support' (or 'normal') force which cancels out gravity. This is one simple example where there are multiple forces acting on an object at rest that cancel each other out ($F_{net}=0$).*

Problem 9: Two people stand on a painter's staging, which weighs 300 N and is supported by two cables. One person weighs 250 N and the other weighs 300 N. The tension in the left cable is 400 N. What is the tension in the right cable?
Adapted from Exercise #27, Chapter 2 of Conceptual Physics, 10^{th} ed., *by Paul Hewitt.*

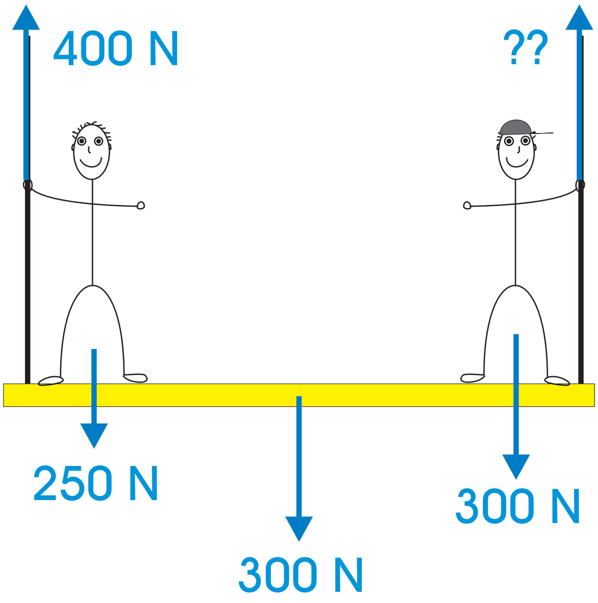

Figure 1: Diagram for Problem 9.

Answer: *The tension in the right cable is 450 N. Because the scaffolding and people on it are in mechanical equilibrium (they're not falling to the ground, presumably), the total net force acting on the scaffolding must be zero. In other words, the upward forces (the tensions in the cables) must cancel the downward forces (the weights of the scaffolding and people). As the forces are acting in opposite directions, this is the same thing as saying that the total up forces are equal (in magnitude) to the total downward forces. If we call* T *the unknown tension (labeled* ?? *in Figure 1), this translates to the following equation:*

$$total\ upward\ forces = \ total\ downward\ forces$$

$$400\ N + T = 250\ N + 300\ N + 300\ N$$

$$T = 250\ N + 300\ N + 300\ N - 400\ N$$

$$T = 450\ N$$

Problem 10:

If you toss a coin straight upward while riding in a train, where does the coin land when (A) the motion of the train is uniform along a straight-line track? (B) When the train slows while the coin is in the air? (C) When the train is turning?

Exercise #48, Chapter 2 of Conceptual Physics, 10^{th} ed., *by Paul Hewitt.*

Answer: *Refer to Figure 2. The key to this problem is recognizing that the horizontal*[1] *speed and direction of motion of the coin is the same as the train's at the instant it is dropped* and *that neither the coin's horizontal speed or direction of motion change during free-fall,* regardless of what the train is doing at that time. *Recall the demonstration with the cart on the track. (A) If the train's motion is uniform (i.e. not changing speed*

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[1] Of course, the coin's *vertical* speed is changing as it starts from rest and falls due to gravity.

or direction) the coin will land exactly below where it was tossed (relative to the train) because the coin's horizontal speed and direction match that of the train. This is shown in Figure 2A. (B) If the train is slowing down, the coin will land ahead of where it was dropped, relative to the train, because the coin's forward speed is greater than the train's during free-fall (the train is slowing down). This is illustrated in Figure 2B. The dashed outline shows the position the car would have been when the coin landed if it had continued moving straight ahead without changing its speed. (C) When the train is turning, the coin will appear to land toward the side of the train which is on the outside the track, as shown in Figure 2C. This is because the train's horizontal direction changed, but the coin's did not. Again, the dashed outline shows where the train car would have been at that time if it had continued straight without changing speed.

Problem 11:

Consider an airplane that flies due east on a trip, then returns flying due west. Flying in one direction, the plane flies with the rotation of the Earth, and in the opposite direction, against the Earth's rotation. But, in the absence of winds, the times of flight are equal either way. Why is this so?

Exercise #50, Chapter 2 of Conceptual Physics, 10^{th} ed., *by Paul Hewitt.*

Answer: *This is because the plane's maximum speed is measured relative to the air, regardless of the direction it flys through the air. If the air is moving with the surface of the Earth (there is no wind– the air's speed relative to the Earth is zero) then the plane's maximum speed relative to the Earth doesn't change in either a westward or eastward flight path. So the amount of time for both legs of the flight is the same.*

A toy boat traveling in water describes a similar situation. The boat's maximum speed is determined by how fast it can move relative to the water it's in, just as the plane's maximum speed is determined by how fast it can move relative to the surrounding air. In other words, a toy boat with a maximum speed of 10 mph moves 10 mph relative to the water it's in not *the land surrounding the water. To see this, consider a boat moving at it's maximum speed in a large tub of water welded to the trailer of a semi– all of which is moving down the freeway at 55 mph. If the boat travels from the rear axle (the back) of the semi to the cab (the front) the speed of the toy boat* relative to the road *would be 65 mph. If the boat were moving from the cab toward the rear axle, its speed* relative to the road *would be 45 mph. If the semi were stopped at a stop sign, the boat's speed would be 10 mph* relative to the road, *regardless of which direction the boat were traveling in the tub of water. In all cases, the boat's speed* relative to the water *was 10 mph.*

The same reasoning applies to the boat if it moves in a river with a rushing current of 15 mph, relative to the land: if it moves with the direction of the river's current, the boat will be moving downstream at a speed of 25 mph relative to the land*; if it opposes the current it would move downstream* [2] *at a speed of 5 mph* relative to the land. *If the boat were in a lake without any currents, it would be moving at 10 mph,* relative to the land, *regardless of the direction it traveled. In this last case, the time it takes to cross the lake in one direction it in the other.*

For the problem of the airplane, saying that there is no wind is like saying there is no current for the boat. In that case, regardless of the direction the plane travels, it will

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[2] The poor little boat is just not strong enough to fight the current! Woe is the boat!

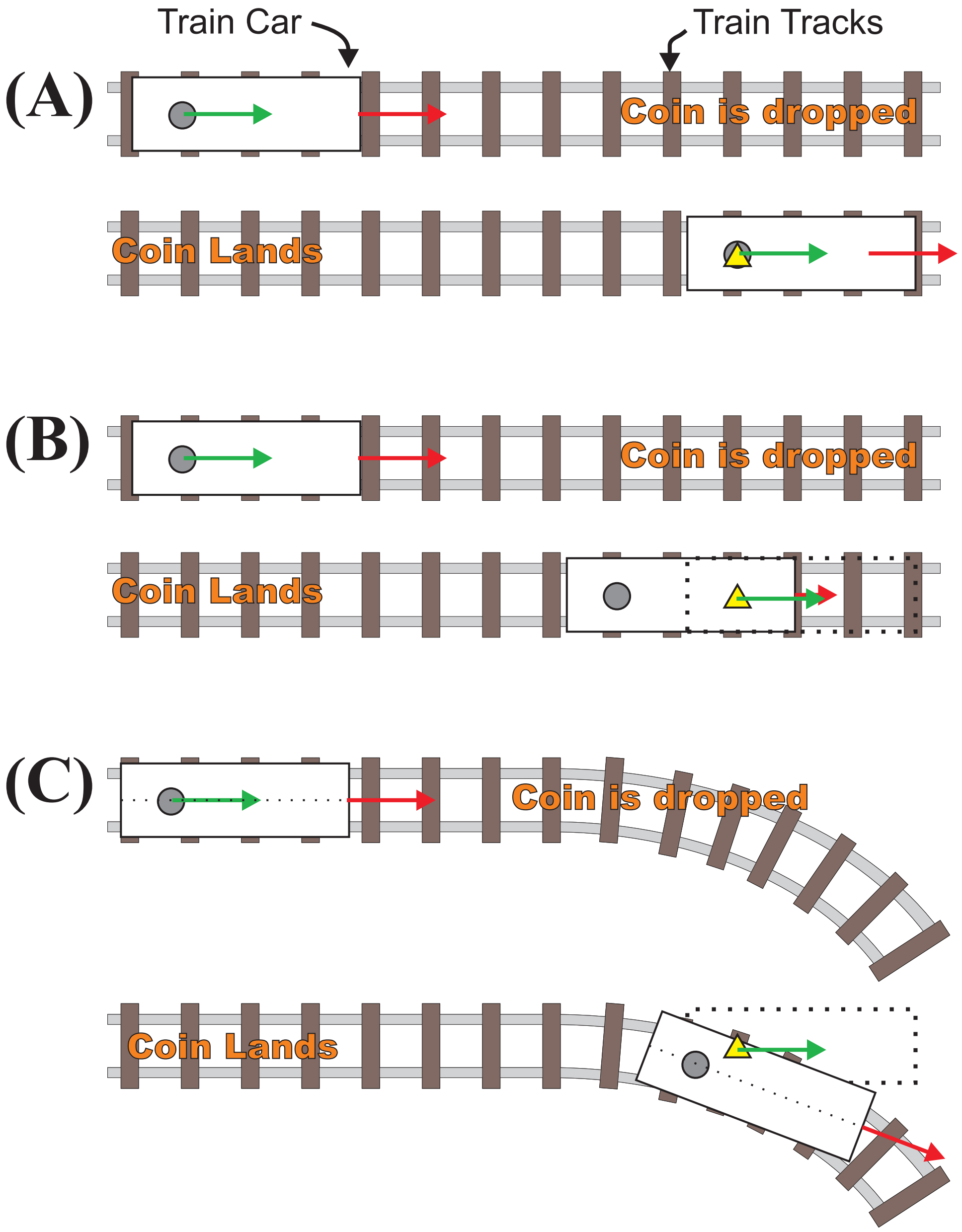

Figure 2: Diagram for Solution to Problem 10. The gray circles indicate where the coin was dropped (relative to the train), the yellow triangles where the coin lands, the green arrow represents the coins' velocity just after being dropped and the instant before it lands, the red arrow represents the train's velocity at those two times, and the dashed outline of the train car indicates where the car would be if it had continued in a straight line at constant speed, as in Part (A) of Problem 10. Note that the length of the velocity arrows are proportional to the speed of the coin/train so that a short arrow represents a slower speed than a long arrow.

appear to move at the same speed relative to the land, just like a boat in a lake. In reality, just as there are ocean currents that can vary the amount of time it takes a ferry to cross the SF bay, there are air currents, called jet streams [3]*, that can shorten or lengthen flight times, depending on the direction of the flight.*

Problem 12:

The first half of this semester, you will learn about Newtonian mechanics. This will give you a general understanding of motion and energy, allowing us as a class to discuss a wide variety of things (some may say things that are more interesting than Newtonian mechanics!). It is up to you, as a class, to decide what we learn about in the second half of the semester. For this problem, you need to *list four different topics/questions that you would be interested in learning about.* The curriculum for the second half will be determined by the classes suggestions. Possible topics include, but are not limited to:

- What causes rainbows?
- Why is the sky blue in the day and reddish at sunrise and sunset?
- How did the dinosaurs die and will the same thing happen to us?
- What's a black hole? A neutron star? A supernova?
- How do whales communicate across vast distances and how did this discovery help rescue stranded sailors in WWII?
- How does a pinhole camera work and how is that related to a desert gecko's eyes?
- What is the greenhouse effect and how do "greenhouse gasses" cause it?
- What is Einstein's theory of relativity? And why was he so interested in a pair of twin ducks?
- Outer space is only a few degrees above *absolute zero.* Why doesn't the Earth freeze?
- How does a laser work?
- What might have crashed near Roswell in 1947 and what does this have to do with whales?
- What are radio waves? And how can an airplane flying over a TV set cause interference (assuming the TV is using bunny ears)?
- What are earthquakes and how do seismometers work?
- Why do hot things get bigger and cold things get smaller?
- What is quantum mechanics, anyhow? And what's that Schrödinger guy got against cats?
- What is radioactivity and how do nuclear power plants work?
- What's the deal with tsunamis?
- How do musical instruments work?
- How can you predict hot weather by listening to distant traffic in the morning? And what's this got to do with desert mirages?

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[3] See Wikipedia's article for a nice explanation: `http://en.wikipedia.org/wiki/Jet_stream`

- How does GPS work?
- How can Lake Vostok, a lake the size of Lakes Ontario, exist under ~4 km of *ice* in *Antarctica*? How does this relate to my heating bill?
- How can light be slowed down so that a horse could outrun it?
- What's the Big Bang?
- What's dark matter?
- How does a digital camera's sensor work and why is that similar to a solar panel?
- What does it mean to say, "If you're not radioactive, you've been dead for a long, long time?"

  Answer: *There is, of course, no correct answer to this question so long as you provided four topics or questions that interest you.*