Name: _____________________________________________________________

(c) Randall Munroe, www.xkcd.com
Part I:
Answer all the questions in this section. Feel free to explain your reasoning to any question, even if the question does not directly ask you to.

You are interviewing for a job at Narbonics Labs, an organization of mad scientists obsessed with world domination. You have been up all night practicing your maniacal laugh. BWAHAHAHA!

* (all the Narbonics Lab comics are (c) Shaenon Garrity, www/narbonic.com)

**Question #1:**
In order to reach the interview room, you have to go down a hallway whose floor is perfectly frictionless. You see a convenient toboggan lying just inside the frictionless hallway. You get a running start, leap onto the toboggan, and slide forward across the frictionless floor. (You may neglect all forms of friction, including air resistance, while you are in this hallway.)

What do you expect to happen?

a) You will continue to move in a straight line at constant speed.
b) You will speed up gradually.
c) You will slow down and eventually stop.
d) You will move on a curved path, eventually completing a full circle.
e) You will speed up for a while, then begin to slow down.
f) You will slow to a stop, then reverse direction.
Your toboggan exits the frictionless hallway, and emerges into the interview room, where there is friction. The toboggan is now slowing down sharply.

**Question #2:**
As your toboggan slows down, what form of energy is it losing?

**Question #3:**
As the energy you described in Question #2 was lost, it was being transformed into which of the following forms? (Choose the BEST answer, even if you think it does not tell 100% of the story.)

a) It changed into gravitational potential energy.
b) It changed into thermal energy.
c) It changed into gravitational force.
d) It changed into kinetic energy
e) It changed into stopping Energy
f) The energy simply vanished; it was not transformed into anything else.

**Extra Credit:**
Can you think of any other form of energy which is also probably involved in this process? Briefly explain.

**Question #4:**
Your don't slow down quite fast enough, and you slam into the interviewer's very heavy oak desk. Think carefully about Newton's Laws of Motion while answering Questions #4 and #5.

Which is stronger: the force you exert on the desk during the collision, or the force the desk exerts on you? How do you know?
Question #5:
Who is more likely to be injured in the collision, you or the interviewer (who is sitting on that heavy oak desk, watching the chaos unfold.) Explain your reasoning, using one or more of Newton's Laws of Motion.
**Question #6:**
If your toboggan slows down TOO sharply at any point in this story, you may find that you are thrown off the front of it. Why does this happen? Did a force push you off the toboggan, and if so, what force? Briefly explain your reasoning, using one or more of Newton's Laws.

**Question #7:**
“Hi,” the interviewer tells you. “I'm Helen Narbon; I run this place.”

“Um, I didn't actually think of any interview questions,” she admits. “We didn't think you would get past the frictionless hallway.”

“So let's see...go to that whiteboard over there and draw a diagram of the solar system. Doesn't have to be to scale, but try to get the important stuff right.”

Show what you draw:
Question #8:
“Not a bad drawing,” Helen admits. “Our last applicant was a guy who just stepped out of a time machine from a thousand years ago, before Copernicus and Galileo. His diagram was crazy.”

How do you think Bob’s diagram differed from yours? *(There is more than one possible answer here!)*

Question #9:
What other mistaken beliefs it is likely that Bob the time traveller holds?  
(Reminder: Bob's home time, a thousand years ago, was before Copernicus, Galileo, or Newton, but after most of the other early astronomers and scientists we discussed. You can assume he is well-educated, according to the knowledge of his day.)

a) Bob probably believes the stars are much further away than they really are.  
b) Bob probably believes the Earth is flat.  
c) Bob probably believes the moon is larger than the Earth.  
d) Bob probably believes the moon is made of aether, not rock.  
e) Bob probably believes the Earth is much larger than it really is.  
f) All of the above.
Questions #10 - #12:
Back in the frictionless hallway, two of your colleagues, Mell and Dave, are fighting over a doomsday machine that they both want to use. They have each tied a rope to the machine; Mell's rope is pulling the machine west, while Dave's is pulling it to the east.

Again, you can assume no friction or air resistance is acting on the machine.

Question #10:
The machine is moving east, toward Dave, at a constant speed of 3 meters per second. Which of the two ropes is exerting a stronger force on the machine?

Question #11:
You notice that the machine is now slowing down, but is still moving toward Dave. Would your answer to Question #9 be different now?

Question #12:
Mel gets distracted and drops the rope she was holding. What has happened to the force she was exerting on the machine?

a) The force changed into kinetic energy.
b) The force changed into thermal energy.
c) The force changed into epicycles.
d) The force changed into chemical energy.
e) The force did not change into anything else; it simply vanished.

Extra credit:
What important difference between force and energy is illustrated by Questions #3 and #12?
Question #13:
You have figured out why Mel lost interest in the tug-of-war. She is now standing on a high ledge, dropping objects on you.

She drops a heavy anvil (with mass 50 kilograms) and a somewhat lighter bowling ball (with mass 5 kilograms.) You may ignore air resistance for this problem.

If she drops the two objects simultaneously, which one will hit the ground first?

Would Bob the pre-Copernican time traveler have answered this question differently? If so, how?

Question #14:
Which of the two objects in #13 has a greater kinetic energy just before it hits the ground? Briefly explain your reasoning.
Question #15:
“Mell!” Shouts Helen. “I don't want you dropping anvils on new employees like that!”
“Drop it again,” she continues, “but I want this one to hit with a lot more kinetic energy!”

Describe at least one way in which Mell could make sure the next anvil hits the ground with more kinetic energy than the last one she dropped.

Question #16:
Fortunately, Mell has become distracted again. (You suspect this is the main reason any of her coworkers survive.) “Huh,” she says, looking out a window. “Full moon out there tonight.”

Assuming she is correct, which of the following statements does that imply? (Circle all that apply; there may be more than one correct statement.)

a) The moon is closer to the Earth than on most other nights.
b) The tides will be slightly more extreme today than on most other days.
c) The earth, the moon, and the sun are aligned in a (very nearly) straight line.
d) There might be a solar eclipse tonight.
e) There might be a lunar eclipse tonight.
f) The Sun is further from the Earth than on most other nights.
g) This will be the longest night of the year.
h) Werewolves.

Question #17:
Helen sees you looking at the moon. “I might send you on a business trip there next week,” she mentions.

If she is not joking, what do you expect to be true when you are standing on the moon? (Circle all that apply; there may be more than one correct answer.)

a) You will have less mass than you do on Earth.
b) You will have more mass than you do on Earth.
c) You will have the same mass as you do on Earth.
d) You will have no mass at all.
e) The force of gravity pulling you downward will be weaker than it was on Earth.
f) The force of gravity pulling you downward will be the same as it was on Earth.
g) The force of air resistance will be stronger than it was on Earth.
h) There will be no force of gravity pulling you downward.
Dave is amusing himself by whirling a small tray containing a cup of water in a vertical circle. Your instructor will demonstrate, with a real cup of water.

**Question #18:**
At point A (the top of the arc) and at point B (the bottom of the arc), sketch vectors showing the velocity of the cup. Label these vectors “v”.
At these same two points, sketch vectors showing the acceleration of the cup. Label these vectors “a”.

**Question #19:**
Describe at least two forces which are acting on the cup of water at point B. Which direction does each of these forces point? Which force is stronger? Briefly explain your reasoning.
Part II: Short Essays

Choose any two of the following six topics, and write about them using the blank paper provided at the end of this test.

It will probably take at least a couple solid paragraphs to cover any of these topics. Make sure to pick topics that you feel you can make some interesting points about; an answer showing thought and insight will be worth more than one which simply provides some basic information.

If you want, you can write about additional topics as extra credit. If you do this, please decide which two topics are your “main” answers, and clearly label the others as “Extra Credit”.

**Topic #1:**
Bob the pre-Copernican time-traveler may have a lot to learn, but there are some topics he WILL understand well. Describe one or more of the great astronomical discoveries made by ancient civilizations. (Possible examples might be the size and shape of the Earth, the size and distance to the Moon, and the size and distance to the Sun.) What observations and lines of reasoning allowed people to make this discovery?

Also briefly describe at least one thing that these ancient civilizations did *not* understand about the solar system or the universe.

**Topic #2:**
Help bring Bob the pre-Copernican time traveler's knowledge up to date. Describe and explain one of the major discoveries made by Copernicus, Galileo, Newton, or any of the scientists who came after them. What evidence led to this discovery, and how did it fundamentally change our understanding of the universe?

**Topic #3:**
It would probably really piss Mell off to find that the energy she was using to try to injure you in Questions #13 to #15 was actually solar energy!

So make the argument. Can you trace the kinetic energy of Mell's anvil when it hit the ground back to processes taking place in the core of the sun? Give an explanation of what other forms the energy has probably taken along the way...

(Also: is there any way she could give those anvils their kinetic energy without using energy that came from our sun? If so, how?)
Topic #4:
You ask Helen why she wants you to visit the Moon next week. “To control the tides, of course!” she answers. “Whoever controls the tides controls the WORLD!”

You're not 100% sure that Helen understands how tides work. So you go back to that whiteboard and try to explain it. Why do tides exist at all? Why are there two high tides each day?

(For an even more impressive answer, can you explain why the tides occur a little later each day than the day before? And can you explain at least one mistaken idea people have had about tides?)

Topic #5:
Suppose Mel dropped those falling anvils from a much greater height. Eventually, they would reach “terminal speed” and not fall any faster.

Explain why there is such a thing as terminal speed for a falling object. What forces are important in understanding the phenomenon? Is terminal speed for an anvil the same speed as for a person, a ping-pong ball, or a feather? Why or why not?

Topic #6:
If there is another topic that you would rather write about, this is your chance!

Invent a topic of comparable complexity to the ones suggested here, drawing from this semester's lectures and readings so far. Please come discuss the topic with me before you start to write about it, so we can agree that it is a good topic for a short essay.