PHY 211 practice final exam

Spring 2020

Instructions – *Please read*

The exam will have a series of multiple choice questions, and then a few longer form exam questions like on the midterms. This practice is designed to give you an idea of what the final may look like and is not exhaustive of all topics. You should review the recitations, homework, and other problems you have received throughout the semester.

Multiple choice questions

The multiple choice questions on the final will not necessarily be about these topics, or take this format. These are just examples and practice.

1. Each of the following equations look like things that might appear in the solution to a physics problem. However, some of them can't possibly describe the real world, since they contain a dimensional mismatch (for instance, a length is added to a mass). Which of these equations **cannot possibly be** part of valid physics because their dimensions do not match? Choose as many as necessary.
All symbols have their conventional meaning. h is a height, d is a distance, F_T is a tension force, k is a spring constant, and so on.

(a) $\frac{1}{2}\mu g t^2 - v_0 \sin\theta = 0$

(b) $\frac{1}{2}m_1 v_1^2 - \mu m g d = \frac{1}{5}m_3 r\omega$

(c) $a = \frac{F_T - m_1 g}{m_1 + \frac{1}{2}m_2}$

(d) $t = \sqrt{m/k}$

(e) $v_f = v_0 + \sqrt{\mu_k g \cos\theta - mg\sin\theta}$

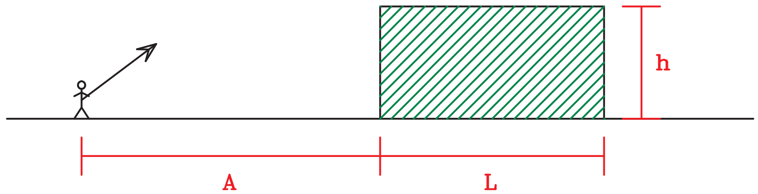
(f) $\omega = \frac{gt}{r}$

(g) $\frac{GM}{r^2} = \omega^2 r$

2. Indicate whether the following quantities are positive, negative, or zero. If there are multiple possible answers, check multiple boxes.

+	0	−	
			The work done by gravity on an airplane flying horizontally at a constant speed
			The work done by gravity on an airplane that is flying diagonally downward at a constant speed
			The rotational kinetic energy of a wheel
			The gravitational potential energy of a rock near Earth
			The elastic potential energy in a spring
			The work done by static friction on a car driving at a constant 120 km/hr
			The total work (rotational plus translational) done by static friction on a ball rolling downhill.
			The work done by the Earth's gravity on a rocket flying from Mars to the Moon
			The change in momentum in an inelastic collision
			The change in kinetic energy in an inelastic collision

An archer stands a distance A in front of a rectangular building. This building has a height h and a total length L. They shoot an arrow upwards at an initial speed v_0 at an angle θ above the horizontal. Treat the point at which the arrow is released as the origin, and upward and the direction toward the building as positive. (The archer's height is small compared to the height of the building and can be neglected.)



Here are some questions about this scenario. Each question may have more than one correct answer; indicate all correct answers.

3. Which set of equations correctly describes the arrow's motion?

(a)
$$x(t) = v_0 t$$
$$y(t) = v_0 t - \frac{1}{2}gt^2$$
$$v_x(t) = v_0$$
$$v_y(t) = v_0$$

(b)
$$x(t) = (v_0 \cos\theta)t$$
$$y(t) = (v_0 \sin\theta)t - \frac{1}{2}gt^2$$
$$v_x(t) = v_0 \cos\theta$$
$$v_y(t) = v_0 \sin\theta - gt$$

(c)
$$x(t) = (v_0 \sin\theta)t$$
$$y(t) = (v_0 \cos\theta)t - \frac{1}{2}gt^2$$
$$v_x(t) = v_0 \sin\theta$$
$$v_y(t) = v_0 \cos\theta - gt$$

(d)
$$x(t) = (v_0 \sin\theta)t - \frac{1}{2}gt^2$$
$$y(t) = (v_0 \cos\theta)t - \frac{1}{2}gt^2$$
$$v_x(t) = v_0 \sin\theta - gt$$
$$v_y(t) = v_0 \cos\theta - gt$$

(e)
$$x(t) = (v_0 \cos\theta)t - \frac{1}{2}gt^2$$
$$y(t) = (v_0 \sin\theta)t - \frac{1}{2}gt^2$$
$$v_x(t) = v_0 \cos\theta - gt$$
$$v_y(t) = v_0 \sin\theta - gt$$

4. Which question would allow you to determine whether the arrow strikes the left side of the building?

(a) "What is the value of x at the time that v_x is equal to 0?"

(b) "What is the value of y at the time that v_x is equal to 0?"

(c) "What is the value of y at the time that x is equal to A?"

(d) "What is the value of x at the first time that y is equal to h?"

(e) "What is the value of x at the second time that y is equal to h?"

5. If you ask the question "What is the value of x at the time that y is equal to h", you will get two results; call them x_1 and x_2, where x_1 is the smaller one. What must be true about these two results for the arrow to land on top of the building?

(a) $x_1 < A$ and $x_2 > A + L$

(b) $x_1 < A$ and $x_2 < A + L$

(c) $x_1 > A$; no condition on x_2

(d) $x_1 < A$; no condition on x_2

(e) $x_2 > A + L$; no condition on x_1

6. Suppose that you try to solve for the time that $y = h$ and get an imaginary answer (i.e. the square root of a negative). What does this indicate?

(a) This is nonphysical so it indicates that you have necessarily made an algebra error

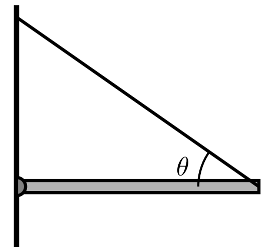
(b) The arrow will fly over the building without striking the roof

(c) The arrow will never make it to height h

(d) The arrow will always land in the ground to the left of the building

(e) The arrow will always strike the left wall of the building

7. An awning of mass m is attached to a hinge on the wall, with a wire holding it horizontal. The wire attaches at an angle θ with the awning (see diagram). What is the tension T in the wire?



(a) $T = mg/(\sin(\theta))$

(b) $T = mg/(\cos(\theta))$

(c) $T = mg/(2\sin(\theta))$

(d) $T = mg/(2\cos(\theta))$

8. An astronaut is floating in deep space with no external forces on her. She is initially at rest relative to you. A heavy piece of equipment is floating in a straight line past her, and she reaches her arm out to the side and catches it. After she does, which of the following describes her motion?

(a) She will remain at rest.

(b) She will start moving along the same direction the equipment was, without rotating.

(c) She will start rotating in place.

(d) She will move along the line while also rotating.

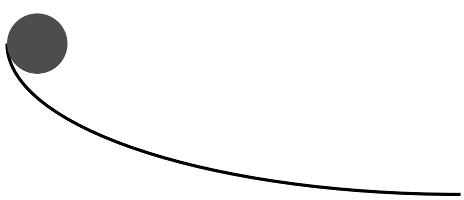
9. You have a toy car with a ball launcher on top of it, which shoots a ping pong ball straight up into the air. We know that if the car is rolling on flat ground, the ball will land back in the launcher because there is no horizontal forces changing its velocity. If the car is rolling down a hill when the ball is fired, where will the ball land?

(a) In front of the car.

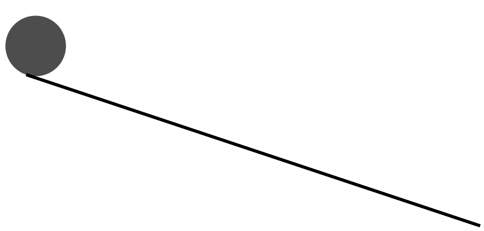
(b) Behind the car.

(c) In the car.

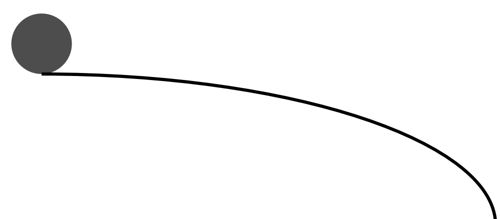
10. Three identical balls roll down three tracks. The balls all start at the same height and the tracks have the same horizontal length. Which ball will get to the end of the track first?



(a)



(b)

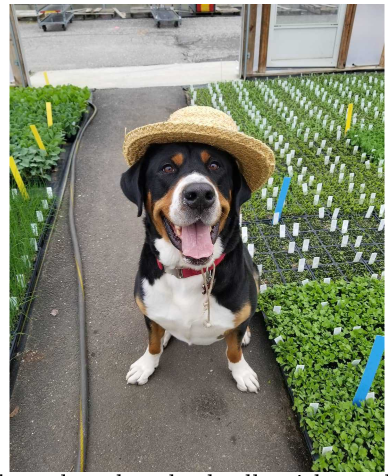


(c)

(d) They will tie.

11. For the same three tracks which has the highest speed *at the end*? (answer (d) is now “the same speed”)

Question 1



Last year's student Shannon Walsh has a massive dog name Bruin (55 kg / 120 lbs) who is trained to assist people with disabilities – and to pull heavy loads like a horse.

Suppose that, to give Bruin practice pulling things, Shannon attaches his harness to the axle of an old truck wheel of mass m and radius r. The truck wheel is standing up, so it can roll when Bruin pulls on it. It has a moment of inertia $I = \frac{1}{2}mr^2$; the coefficients of friction between it and the ground are μ_s and μ_k, respectively.

Bruin pulls on the rope with a tension T; this tension is small enough so that the wheel rolls without slipping.

a) Is the force of friction on the wheel equal to $\mu_k mg$, $\mu_s mg$, zero, or some other value? Explain briefly.

b) Draw a force diagram for the wheel, showing both the forces that act on it, and the positions where they act. Write an expression for the torque applied by each of these forces.

c) Without doing any mathematics and looking only at your force diagram, is the magnitude of the acceleration equal to T/m, less than this, or more than this? Explain briefly.

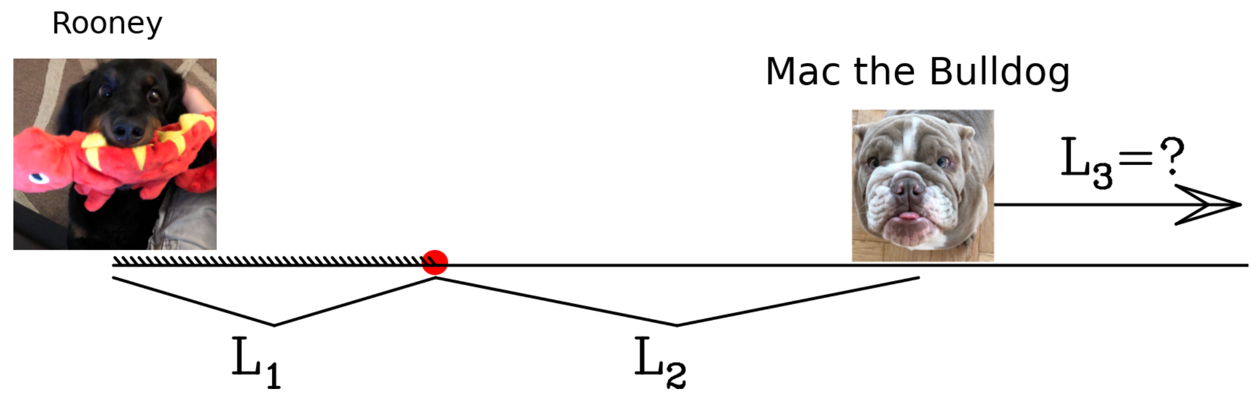
d) Write down an equation relating the forces on the wheel to its acceleration.

e) Write down an equation relating the forces on the wheel to its angular acceleration.

f) Referencing your force diagram in (b), calculate the acceleration of the wheel if Bruin pulls with a tension T.

Question 2

Last year's student David Fikhman's dog Rooney likes to chase laser-pointer dots.
Suppose that David has a carpeted room that is a length L_1 adjacent to a kitchen with a smooth floor.
Rooney is standing at the far end of his living room when David shines his laser pointer on the boundary between the carpeted room and the kitchen. Rooney accelerates as fast as his traction will allow toward the laser pointer dot, trying to catch it.
He zooms past it onto the kitchen, where he realizes his mistake. He tries to stop, but his furry feet have very little friction on the smooth floor. He skids into David's other dog Mac, who is asleep on the floor of the kitchen a distance L_2 away from the edge of the kitchen. Rooney falls onto Mac, and they skid a further distance L_3 before they come to a stop.
Mac has twice the mass of Rooney (since he's a big ol' bulldog).



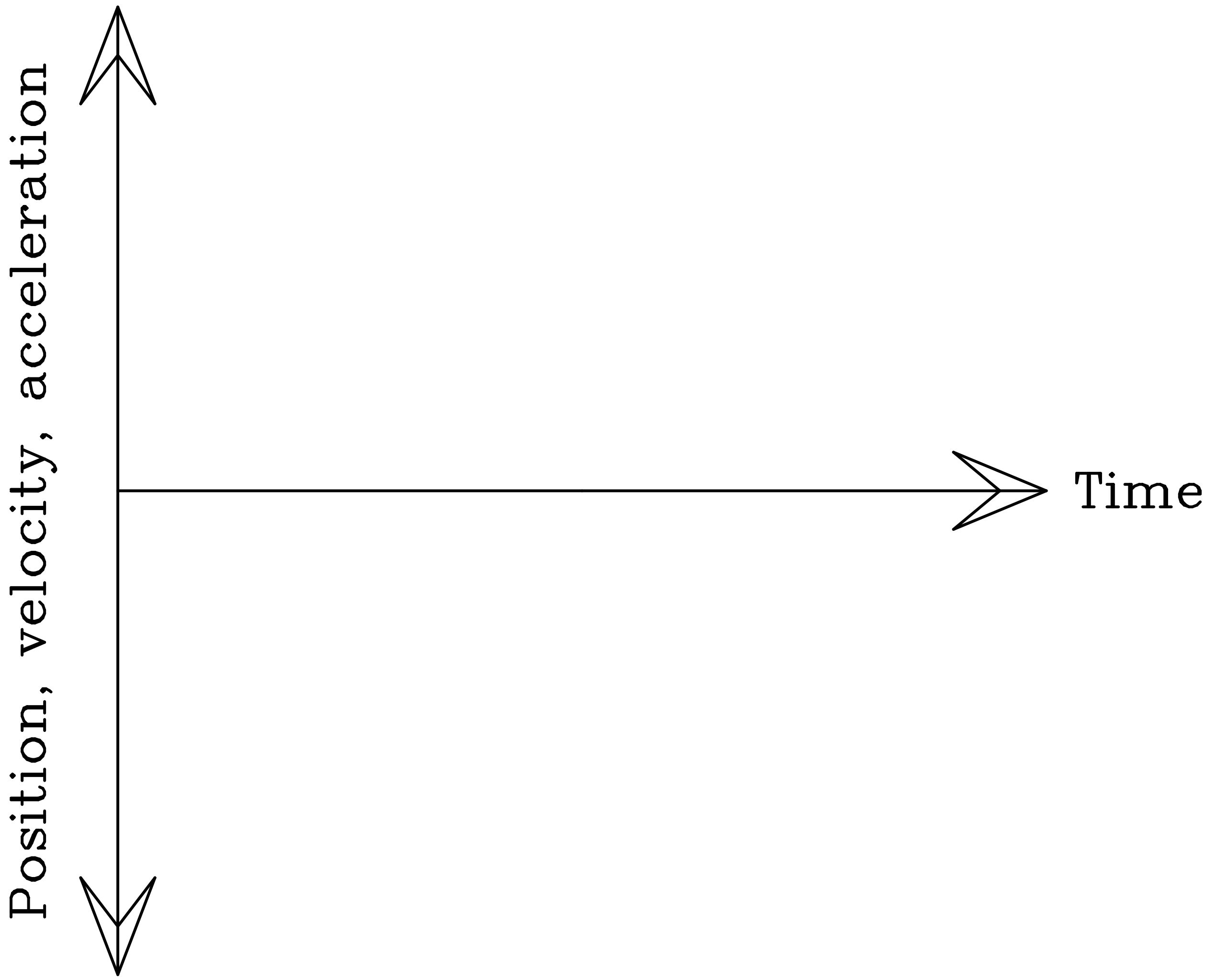
The coefficients of friction are:

- Dog and carpet: $\mu_s = 0.8, \mu_k = 0.6$
- Dog and floor: $\mu_s = 0.4, \mu_k = 0.2$

a) Find L_3 in terms of L_1, L_2, and g. (Your answer will also depend on the coefficients of friction; use the numbers for those.)

Question 2, continued

b) Sketch graphs of Rooney's position, velocity, and acceleration on the axes below. (You will draw three plots on the same axes.) We aren't looking for exact values, but slopes, signs, concavity, and relative magnitudes should be roughly correct.



Question 3

The top end of a spring is attached to a stationary point; a $m = 2$ kg mass hangs from the bottom end. It has spring constant $k = 200$ N/m; the mass is at rest. You may give your answers either numerically or in terms of m, k, and g.

a) How far below the spring's equilibrium point does the mass hang? (10 points)

Then, a second $2kg$ mass is added to the spring and released. When the mass is added, the extra weight stretches the spring out further, falling down an additional distance before the elastic force pulls it back up.

b) How far below the spring's equilibrium point do the masses fall in total? (30 points)

c) The masses bounce up and down for a while before eventually coming to rest (due to air drag, friction, and the like). Once they come to rest, how far below the equilibrium point will they be located? (10 points)

Question 4

A horizontal disk of mass m and radius R is freely rotating at angular velocity ω, spinning clockwise when seen from above. (The moment of inertia of a disk is $\frac{1}{2}mR^2$.) While it is rotating, someone drops a thin ring of mass m and also of radius R on top of it. When the ring lands, it is initially not rotating, but friction quickly causes it to rotate along with the disk, but the rotation of the disk slows down.

a) What principle of physics explains why the rotation slows down once the ring is dropped on top of the disk? (10 points)

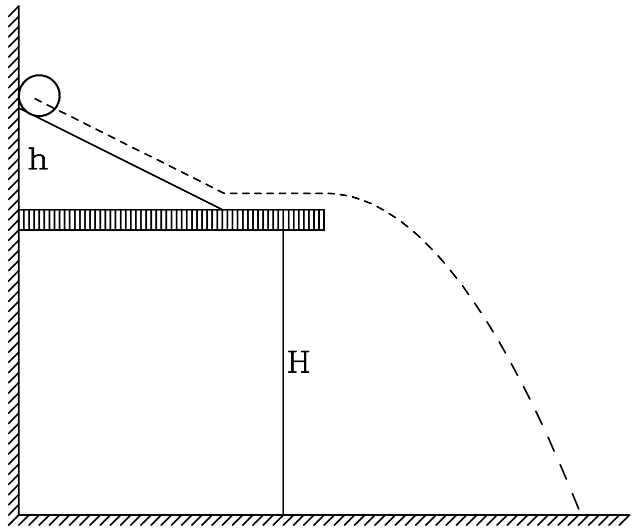
b) What is the final angular velocity of the disk and ring?

Now, suppose that a bird of mass $m/3$ flies in horizontally and lands on the disk. It lands a distance R/2 south of the center of the disk, and is flying eastward when it lands. The bird is flying at exactly the right speed to stop the platform from rotating once it lands.

c) Find the initial speed of the bird v_b in terms of m, R, and ω.

Question 5

In class, you saw a demonstration where a ball bearing (solid sphere, moment of inertia $I = \frac{2}{5}mr^2$) was rolled down a small ramp on top of a table. The ball rolled down the ramp, rolled across the table, and then fell off of the side of the table.



Suppose that the height of the ramp is h, the height of the table is H, and the radius of the ball is r.

a) How fast is the ball traveling when it reaches the edge of the table?

(This problem continues on the next page.)

b) How fast is the ball traveling when it strikes the floor? (Hint: What happens to the ball's angular velocity as it travels through the air?) (15 points)

c) How far past the edge of the table does the ball land?