Physics 211 Exam 3

Problem 1	Problem 2	Problem 3	Problem 4	Total
/25	/25	/25+10	/25	/100

Name: ______________________________

Recitation section number: ___________

(see back page)

- **The reference page is on the back of the exam; you may tear it off.**
- There are three questions and a set of short answer questions, worth a total of 100 points, with a possibility of 10 points extra credit.
- **You must show your reasoning to receive credit**. An answer with no logic shown will be treated as no answer.
- You are highly encouraged to use both pictures and words to show your reasoning, not just algebra.
- If you run out of room, continue your work on the scratch paper on the back, and indicate that on the main page of the exam.
- Remember, show your reasoning as thoroughly as possible for partial credit.
- You may use $g = 10\,\mathrm{m/s^2}$ throughout, except where indicated, to minimize arithmetic.

Recitation Schedule

M005	10:35-11:30A	Physics B129E	Bradley Cole
M013	10:35-11:30A	Physics 106	Emily Syracuse
M021	10:35-11:30A	Heroy 013	Xuan Zheng
M006	11:40A-12:35P	Physics B129E	Bradley Cole
M014	11:40A-12:35P	Physics 106	Kesavan Manivannan
M022	11:40A-12:35P	Heroy 013	Alexander Hartwell
M007	12:45-1:40P	Physics B129E	Merrill Asp
M015	12:45-1:40P	Physics 106	Emily Syracuse
M008	2:15-3:10P	Physics B129E	Bradley Cole
M016	2:15-3:10P	Physics 106	Kesavan Manivannan
M009	3:45-4:40P	Physics B129E	Ohana B. Rodrigues
M017	3:45-4:40P	Physics 104N	Kesavan Manivannan
M010	5:15-6:10P	Physics B129E	Julia Giannini
M018	5:15-6:10P	Physics 106	Emily Syracuse
M003	8:25-9:20A	Physics B129E	Merrill Asp
M011	8:25-9:20A	Physics 106	Julia Giannini
M004	9:30-10:25A	Physics B129E	Merrill Asp
M012	9:30-10:25A	Physics 106	Julia Giannini
M020	9:30-10:25A	Heroy 013	Xuan Zheng
M024	9:30-10:25A	Hall/Lang 205	Alexander Hartwell

Question 1

A large boulder has fallen onto the surface of a frozen lake. A mad engineer, whose desire to see things go boom is larger than their common sense, would like to remove it.

They drill a hole in it, insert a stick of dynamite, and light the fuse.

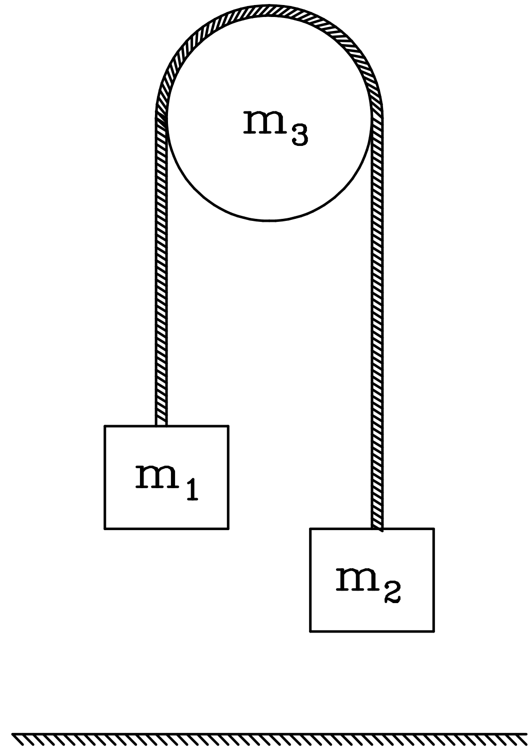
After the explosion the boulder splits into two pieces, which move in opposite directions after the collision. The larger piece has three times the mass of the smaller piece. The coefficient of kinetic friction is μ between both pieces and the ice; this friction eventually brings both of them to rest.

*The large piece travels a distance of 10 meters after the explosion before coming to rest. How far does the small piece travel? Your answer should be a numeric value (*i.e. *a number of meters). While it may not appear that you have enough information to solve the problem, you actually do! (25 points)*

Note: this problem requires you to consider several different concepts we have studied to solve it. If you take some time to explain your approach and plan what ideas you will use to understand each thing that is happening, this will both help you and earn you partial credit even if you make math errors.

(You may continue your work on the next page.)

Question 2



Previously in the semester, when we considered the "Atwood machine" (a pulley with two weights hanging on either side), we used Newton's second law to analyze it, and worked only in the approximation where the pulley's mass was so small that it did not matter.

Now you will use energy methods, and consider the mass of the pulley as well.

Suppose that an Atwood machine has two hanging masses with masses m_1 and m_2, where $m_2 > m_1$, and the pulley has mass m_3. The pulley is a solid disk with radius r; the moment of inertia of a solid disk is $\frac{1}{2}mr^2$.

The masses are initially at heights h_1 and h_2 above the ground when they are released.

In this problem, you will calculate the speed at which m_2 is moving when it hits the ground. Note that you can add up all the energies for the different objects, and the work done on different components of the system.

a) The total work done by the tension forces on this system taken as a whole is zero. Make a brief argument why this must be true. (Since it is zero, you may neglect it.) (2 points)

(This question continues on the next page.)

b) Write down an expression of the work-energy theorem for the entire system as a whole as m_2 falls to the ground. Label your equation, very briefly telling me what each term represents in words (e. g. "work done by gravity on mass 1") (6 points)

c) How do the final velocities of the blocks relate to each other, and how do they relate to the final angular velocity of the pulley? (4 points)

(This question continues on the next page.)

d) Calculate the velocity with which m_2 hits the ground. (8 points)

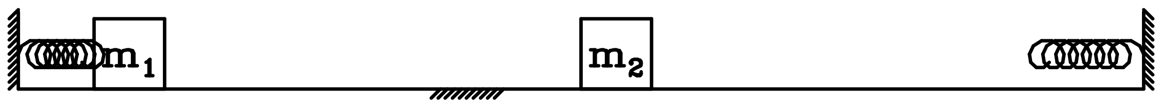
e) If the pulley were replaced with a spoked wheel (like a bicycle wheel) of the same mass, would your answer to (c) increase, decrease, or stay the same? Explain briefly in words. (5 points)

Question 3

A spring of spring constant k is compressed by a distance d by a mass m_1 and released. This propels the mass down a flat track. Another spring, also of spring constant k, is on the other side.

Another object of mass m_2 is sitting in the middle of the track. The first mass strikes it and sticks to it.

The entire track is frictionless, except for a small region of the track to the left of m_2, of width b, with a coefficient of kinetic friction μ. (This is indicated by diagonal lines on the track in the diagram.)



(The space below is for you to draw other diagrams, if you so choose, or to do scratch work.)

(This part continues on the next page.)

a) How fast is the first mass moving right before it collides with the second block? (5 points)

b) How fast are the two masses moving right after the collision? (5 points)

c) When the two blocks reach the spring on the other side, they will bounce off of it, compressing it in the process. What is the maximum distance that this spring is compressed? (15 points)

(An extra credit part of this question continues on the next page.)

Suppose that the numeric quantities in this problem are as follows:

- $m_1 = 2$ kg; $m_2 = 1$ kg
- $k = 1000$ N/m
- $d = 0.1$ m
- $b = 0.1$ m
- $\mu = 0.2$

d) How many times will the blocks cross the track before they come to rest? (10 points extra credit) Hint: There is an easy way and a hard way to do this!

Part 4: Short Answer

A small cylindrical spacecraft (mass of a few hundred kilograms) has run out of fuel, and is tumbling slowly but uncontrollably at angular velocity ω, clockwise when seen from the front. The astronaut on board needs to stop it from rotating in order to keep its antenna lined up with Earth, so she can send a distress call.

Since the engines are out of fuel, she removes one of the engines from the spacecraft, climbs out on the side, and throws it off of the spacecraft.

a) Explain briefly how this will help her stop her spacecraft from tumbling. (4 points)

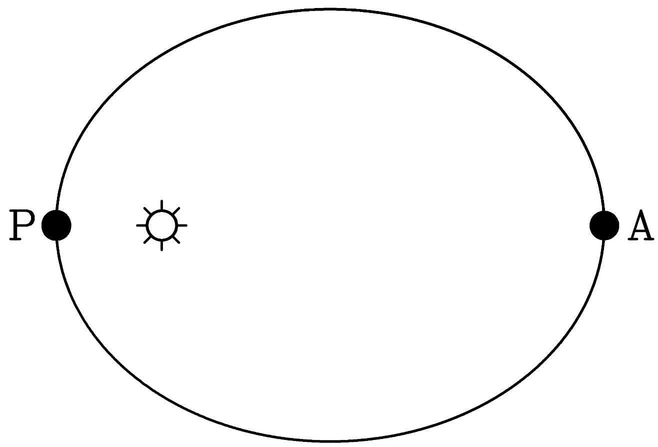
b) Draw an arrow in the direction she should throw the engine, if her goal is to stop the spacecraft from rotating. (3 points)

c) Explain briefly (using symbols and/or words) how the conservation of momentum is a consequence of Newton's second and third laws of motion. (5 points)

d) Explain briefly (using symbols and/or words) how the work-energy theorem in one dimension is a consequence of Newton's second law of motion and the third kinematics relation $v_f^2 - v_i^2 = 2a\Delta x$. (5 points)

(This part continues on the next page.)

A comet orbits the Sun in an elliptical orbit, as shown. (The only force acting on the comet is the Sun's gravity.) The point of closest approach, called "perihelion", is labeled **P**; the point where the comet is furthest away, called "aphelion", is labeled **A**.



Kepler's second law of orbital motion (which we have not studied specifically) says that the comet must be moving faster at perihelion (point P) than aphelion (point A).

e) Explain why this must be true by invoking the work-energy theorem. (4 points)

f) Explain why this must be true by invoking the conservation of angular momentum. (4 points)

Scratch Paper

Scratch Paper

Scratch Paper

Reference

The work-energy theorem: $KE_i + W_{\text{all}} = KE_f$

Translational kinetic energy is $\frac{1}{2}mv^2$; rotational kinetic energy is $\frac{1}{2}I\omega^2$.

If you treat some forces as associated with a potential energy, then the work-energy theorem becomes

$$KE_i + PE_i + W_{\text{others}} = KE_f + PE_f$$

The potential energy associated with gravity is $PE_g = mgy$; the potential energy associated with a spring is $PE_e = \frac{1}{2}k(\Delta L)^2$.

A force $\vec{F}$ acting on an object does work $W = \vec{F} \cdot (\Delta\vec{s}) = F(\Delta s)_\parallel = F_\parallel(\Delta s)$.

A force applied to an object moving at velocity $\vec{v}$ exerts a power $P = \vec{F} \cdot \vec{v}$. If a spring's equilibrium length is L_0, but it is stretched to a length L, the force it applies to an object connected to it is $F_e = -k(L - L_0)$. Here the minus sign indicates that the force is opposite the stretch or compression.

The moment of inertia of a rotating object is, in general, $I = M\left\langle R^2 \right\rangle$, where $\left\langle R^2 \right\rangle$ is the average squared distance from the axis.

- For a hollow ball: $I = \frac{2}{3}mr^2$
- For a disk or cylinder: $I = \frac{1}{2}mr^2$
- For a solid ball: $I = \frac{2}{5}mr^2$

The standard kinematics relations for constant acceleration in one dimension are:

$$v(t) = v_0 + at \qquad x(t) = x_0 + v_0 t + \frac{1}{2}at^2 \qquad v_f^2 - v_0^2 = 2a\Delta x$$

(The reference material continues on the reverse of this page.)

$$\text{Conservation of momentum: } \sum \vec{p}_i = \sum \vec{p}_f$$

where the momentum of an object is $\vec{p} = m\vec{v}$.

$$\text{Conservation of angular momentum:} \sum L_i = \sum L_f$$

where $L = I\omega$ (extended rotating object) or $L = mvr_\perp$ (small object).

Newton's second law of motion relates the net force on an object to its acceleration: $\sum \vec{F} = m\vec{a} = \frac{\partial \vec{p}}{\partial t}$, where $m\vec{a} = \frac{\partial \vec{p}}{\partial t}$ if the mass is constant.

Newton's third law of motion: $\vec{F}_{BA} = -\vec{F}_{AB}$

Rum the Physics Dog is very disappointed that the conservation of bleps does not appear on this exam.

He would, however, be happy to eat your homework for you.