Physics 211 Exam 3

()

Your name: ______________________________

Your recitation section: ____________________

(see next page for a list)

Dog		/25
Car		/25
Skateboard		/25
Astronaut		/25
Exam 2 Total		**/100**

Instructions

- There are four questions worth 25 points each. I expect that the skateboarder question and the dog question will take you more time, and that the astronaut question and the car question will take you less.
- **You must show your reasoning to receive credit**. A numerical answer with no logic shown will be treated as no answer.
- You are encouraged to use both pictures and words to show your reasoning, not just algebra. Show your reasoning as thoroughly as possible for partial credit.
- Do not attempt to communicate with anyone other than teaching staff during the exam.
- You may use an ordinary scientific or graphing calculator, but not one that will do algebra for you. If you do not have a calculator, leave your answers in symbolic form.
- Other electronic devices (laptops, smartphones, smartwatches) are not allowed during the exam.
- You may use $g = 10\,\mathrm{m/s^2}$ throughout, except where indicated, to minimize arithmetic.

Recitation Schedule

Section	Day / Time	Room	TA
M025	TTh 5:00-5:55	Bowne Hall 105	Chad
M009	TTh 5:00-5:55	Physics B129E	Kelly
M017	TTh 5:00-5:55	Physics 106	Byron
M018	TTh 6:30-7:25	Physics 106	Byron
M010	TTh 6:30-7:25	Physics B129E	Mingwei
M003	WF 8:25-9:20	Physics B129E	Chad
M011	WF 8:25-9:20	Physics 106	Mingwei
M012	WF 9:30-10:25	Physics 106	Trent
M004	WF 9:30-10:25	Physics B129E	Chandler
M020	WF 9:30-10:25	Life Sciences 156	Byron
M005	WF 10:35-11:30	Physics B129E	Aklima
M013	WF 10:35-11:30	Physics 106	Chad
M006	WF 11:40-12:35	Physics B129E	Aklima
M014	WF 11:40-12:35	Physics 106	Manabputra
M022	WF 11:40-12:35	765 Irving 221	Trent
M007	WF 12:45-1:40	Physics B129E	Chandler
M015	WF 12:45-1:40	Physics 106	Manabputra
M023	WF 12:45-1:40	Newhouse 2 355	Kelly
M016	WF 3:45-4:40	Physics 106	Aklima
M008	WF 3:45-4:40	Physics B129E	Kelly
M024	WF 3:45-4:40	Tolley 204	Trent

Question 1

Finn is a water-loving and very strong dog who has gotten good at jumping off of a boat to catch a Frisbee floating in the water. He's got a mass of $m = 25$ kg. When he jumps, his muscles are able to produce 450 J of energy. For simplicity, let's think about Finn jumping horizontally from the side of a boat, just so we don't have to do any trigonometry. You may approximate Finn as a single point, even though that's not quite realistic.

a) Suppose that Finn jumps horizontally from a very massive boat (so massive that it will not move) as fast as he can from a height of $h = 1$ meter. What velocity v_0 will Finn have once he jumps? *(5 points)*

b) If this boat is floating 2.5 m away from a Frisbee in the water, will Finn be able to jump on top of it? *(5 points)*

c) Now, suppose that Finn jumps horizontally from a much lighter canoe that has the same mass as Finn (25 kg), also from a height of $h = 1$ meter. (The canoe is floating in the water, and is free to move.) Recall that Finn's muscles can only produce $E = 450$ J of energy in a jump, which must be shared between the canoe and Finn.

Determine the velocities of Finn and the canoe after he jumps. *(10 points)*

d) If this canoe is floating 2.5 m away from the same Frisbee, and Finn is again jumping from a height of $h = 1$ m, will Finn be able to jump on top of the Frisbee? *(5 points)*

Question 2

An electric car has the following attributes:

- Maximum speed $v_{\max}$: 50 m/s (with no wind)
- Motor maximum power $P_{\max}$: 180 kW
- Battery capacity U_b: 250 MJ (250×10^6 J)

In this problem, we're going to imagine this car driving at a constant speed along a flat highway with no wind. Under these conditions, the main retarding force on the car is air drag pointing opposite the car's motion, given by the formula

$$F_{\text{drag}} = \gamma v_r^2.$$

Here γ is a coefficient that depends on the shape and size of the car, and v_r is the relative speed of the car with respect to the air. (If the wind is not blowing, this is just the speed of the car.)

You may give your answers in terms of $v_{\max}$, $P_{\max}$, and U_b or as numerical values.

a) What units might γ be measured in? *(5 points)*

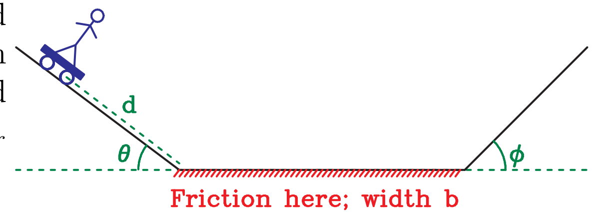
b) Determine the value of γ. (Once you have found it, it will stay the same for the whole problem.) *(5 points)*

c) Suppose that the driver wants to travel 300 km (driving at a constant speed on a flat highway with no wind blowing) before recharging their batteries. At what speed could the driver accomplish this? *(7 points)*

d) Suppose that the manufacturer wanted to build a high-performance version of this car that could travel 70 m/s instead (increasing the top speed by 1.4x). How powerful would the motor need to be to achieve this? *(8 points)*

Question 3

A skateboarder of mass m is standing on the edge of a drainage channel, as shown. The left side, where the skateboarder starts, is elevated at an angle θ; the right side is elevated at an angle ϕ. The slopes on either side are smooth, and the skateboard moves over them with essentially no friction, but the flat bottom of width b is covered with a little sand, and the skateboard experiences a small amount of rolling friction there, with μ_r known.



The skateboarder starts a distance d up the left-hand side. They roll down the left side, across the sand-filled bottom, and up the right side.

(*Give your answers to the first two parts in terms of the variables above, along with g.*)

a) Determine the maximum distance d_2 that the skateboarder makes it up the right side. (This is the diagonal distance, not the height.) *(10 points)*

b) After rolling up and back down the right side, the skateboarder will come back to the left side. How far will they travel back up the left side? *(5 points)*

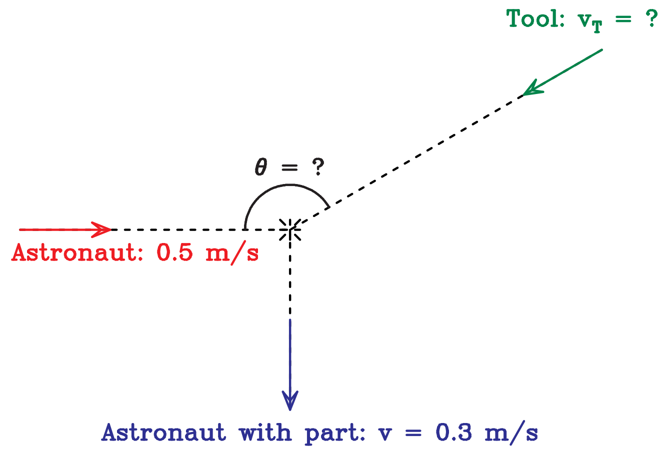
c) Suppose that you know numeric values as follows:

- $m = 75$ kg
- $\theta = 30°$
- $\phi = 40°$
- $\mu_k = 0.05$
- $d = 4$ m
- $b = 7$ m

How many times will the skateboarder travel across the sandy bottom of the channel before coming to rest? Explain the approach behind your solution fully. *(Hint: It will help you to think qualitatively about the conversion of energy between different types before calculating anything. There is an easy way and a hard way to do this!) (10 points)*

Question 4

An astronaut is drifting in space while working to repair a space station that has broken down.
She is drifting at a velocity of 0.5 m/s when another astronaut throws a spare part to her as shown. The spare part has one-quarter of the astronaut's mass.
She catches the spare part and observes that the angle between her velocity before and after she caught it is 90°, as shown in the figure.



Determine, in any order you wish: *(25 points)*

- The initial speed of the part that was thrown to her
- The angle between the part's initial velocity and hers

Reference

The work-energy theorem:

$$\frac{1}{2}mv_0^2 + W_{\text{all}} = \frac{1}{2}mv_f^2 \tag{1}$$

The work-energy theorem incorporating potential energy:

$$\frac{1}{2}mv_0^2 + PE_0 + W_{\text{other}} = \frac{1}{2}mv_f^2 + PE_f \tag{2}$$

The definition of work:

$$W = \vec{F} \cdot \Delta\vec{s} \equiv F(\Delta s)_{\parallel} = F_{\parallel}(\Delta s) = F\Delta s\cos\theta \tag{3}$$

Expressions for potential energy:

$$U_{\text{grav}} = mgy(\text{where +y points upward}) \tag{4}$$

$$U_{\text{spring}} = \frac{1}{2}k(\Delta x)^2 \tag{5}$$

Power applied by a force:

$$P = \vec{F} \cdot \vec{v} \tag{6}$$

Conservation of momentum:

$$\sum m\vec{v}_i = \sum m\vec{v}_f \tag{7}$$