Physics 8, Fall 2017, Homework #5.
Due at start of class on Friday, October 13, 2017

Problems marked with (*) must include your own drawing or graph representing the problem and at least one complete sentence describing your reasoning.

Remember **online response** at `positron.hep.upenn.edu/wja/jitt/?date=2017-10-13`

(Chapter 9 problems.)

1*. One day I get the foolish idea to jump off a bridge with an elastic bungee cord tied to my waist. The bridge deck is 130 m above the water, and the spring constant of the bungee cord is 35 N/m. Since I must fall the length of the unstretched cord before it begins to stretch, I realize that the unstretched length, which is adjustable, has to be adjusted based on my inertia. What must the maximum unstretched length of the cord be if I am to stop falling just above the water surface? Take my inertia to be 65 kg and treat my body like a particle (i.e. a mass that is concentrated at a single point).

2*. A motor must lift a 900 kg elevator cab. The cab's maximum occupant capacity is 410 kg, and its constant "cruising" speed is 18.5 m/s. The design criterion is that the cab must achieve this speed within 2.0 s at constant acceleration beginning from rest. (a) When the cab is carrying its maximum capacity, what power must the motor deliver to get the cab up to cruising speed? (b) What constant power must the motor supply as the fully loaded cab rises after attaining cruising speed?

(Chapter 10 problems.)

3. A package is dropped from an airplane traveling at 110 m/s at an altitude of 190 m, but the parachute attached to the package fails to open. (a) How long does it take for the package to reach the ground? (b) How far does the package travel horizontally before it lands? (c) What is the velocity of the package just before it lands? Give the velocity both in rectangular coordinates (v_x, v_y) and in polar coordinates (i.e. speed $|\vec{v}|$ and angle θ w.r.t. horizontal).

4. The archer fish shown in the figure, peering from just below the surface of the water, spits a drop of water at the grasshopper and knocks it into the water. The grasshopper's initial position is 0.45 m above the water surface and 0.25 m horizontally away from the fish's mouth. If the launch angle of the drop of water is 63° with respect to the horizontal water surface, how fast is the drop moving when it leaves the fish's mouth?
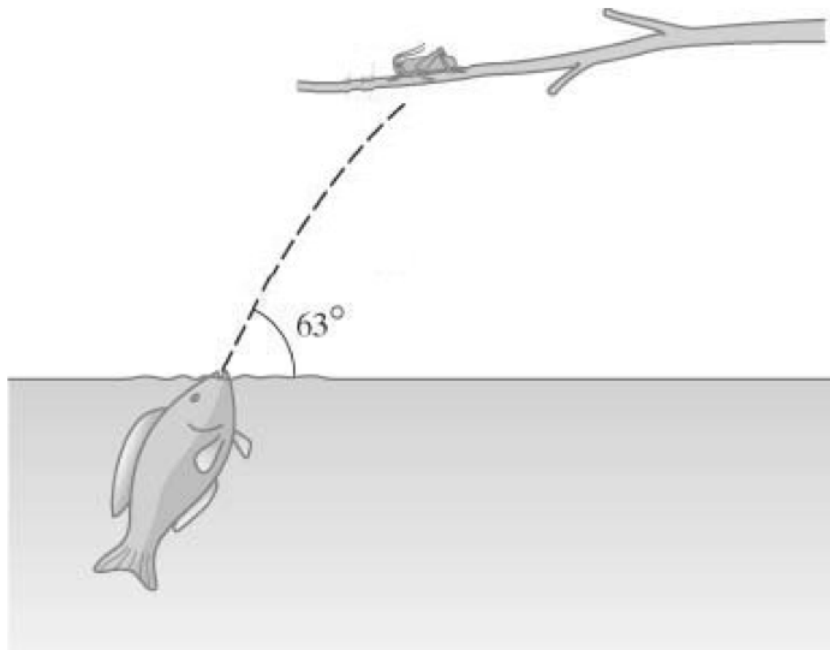
5. A resort uses a rope to pull a 45 kg skier up a 35° slope at constant speed for 90 m. The tow rope is parallel to the ski slope. (a) Find the tension in the rope if the snow is slick enough to allow you to ignore any frictional effects. (b) How much work does the rope do on the skier? (c) Now find the tension in the rope if the coefficient of kinetic friction between snow and skis is $\mu_k = 0.20$. (d) Now how much work does the rope do on the skier?

6*. You have to specify the power output of a motor for a ski tow rope that will carry twenty passengers at a time, each having an average inertia of 55 kg. The grade of the ski slope is 29° above horizontal, and the average coefficient of kinetic friction between skis and snow is 0.15. You decide that 2.5 m/s is a safe speed to be towed up the slope. What must the minimum power output of the motor be?

7*. A 1.10 kg block on a horizontal tabletop is pushed against the free end of a spring (whose other end is attached to a wall) until the spring is compressed 0.220 m from its relaxed length. The spring constant is $k = 110$ N/m, and the coefficient of kinetic friction between block and tabletop is 0.25. When the block is released from being held against the compressed spring, how far does the block travel before coming to rest?

8. A woman applies a constant force to pull a 45.0 kg box across a floor at constant speed. She applies this force by pulling on a rope that makes an angle of 36.9° above the horizontal, and for the box-floor interface, $\mu_k = 0.12$. (a) Find the tension in the rope. (b) What is the work done by the woman as she moves the box 9.0 m?

(More Chapter 8 conceptual questions. These questions require no calculations. Just think about them and write your answer as either (a) a sentence, or (b) a few words and a quick drawing — whichever is more appropriate for the problem. Very short answers are fine, as long as your reasoning is clear. You will probably learn a lot by discussing these questions with your fellow students. To make our job easier, please try to make these answers as clear and succinct as possible.)

9. You push on a crate, and it starts to move but you don't. Draw a free-body diagram for you and one for the crate. Then use the diagrams and Newton's third law of motion to explain why the crate moves but you don't.

10. A delivery person in an elevator is holding a package by an elastic cord. (Don't ask why.) (a) What happens to the length of the cord when the elevator accelerates upward? Draw the free-body diagram for the package in this case. (b) What happens to the cord's length when the elevator slows to a stop after its ascent? Draw the free-body diagram for the package in this case.

11. Walking beside a pasture, you and a fellow student see a farmer pulling a mule with a rope and getting nowhere. Your friend says, "The force with which the mule is pulling on the rope has the same magnitude as the force with which the farmer is pulling on the rope, but the two forces point in

opposite directions. Because the two forces cancel, the tension in the rope is zero." How do you respond?

12. The design strength of the couplings used in connecting railroad cars is determined by the maximum tension or compression that any coupling in a given train will likely feel. (a) If a locomotive is pulling ten cars and speeding up, in which coupling is the force greatest? (b) Is this force a tension force or a compression force? (c) If the locomotive is slowing the train down, which coupler feels the greatest force? (d) Is this force a tension force or a compression force?

13. (Here's a Chapter 9 conceptual question.) You are lifting a ball at constant velocity. (a) When the system is the ball, is work done on the system? If so, by what agent(s)? (b) Describe the potential energy of this system during the lift. (c) When the system is ball+Earth, is work done on the system? If so, by what agent(s)? (d) Describe the potential energy of this system during the lift.

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XC1*. Optional / extra-credit. (From Chapter 9.) A 1000 kg car starting at the bottom of a 20 m hill at 5.0 m/s almost comes to a complete stop as it crests the hill, barely making it over the top. (See figure below.) The power rating of the engine is 67 kW. (a) Assuming the engine's delivery of power just accounts for the change in the car's potential and kinetic energies as it moves from the bottom of the hill to the top, how long does it take the car to make it up the hill under full power? (b) Does your answer to (a) seem reasonable? (c) If not, what do you think is going on?
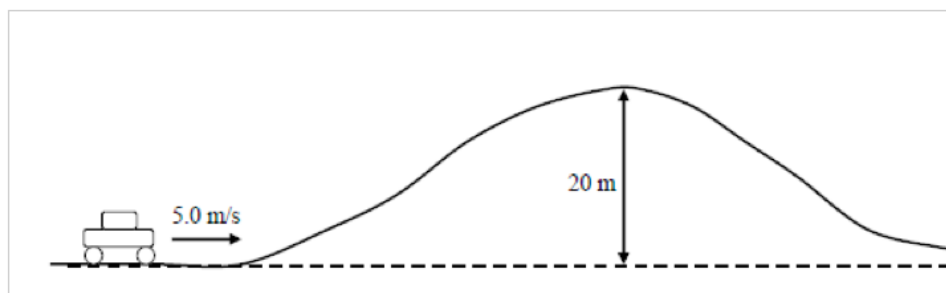
XC2*. Optional / extra-credit. (From Chapter 10.) A book of inertia m is resting on a table. You push down on the book with a force directed at an angle φ w.r.t. vertical. (So in this case $\varphi = 0$ would mean pushing vertically, and $\varphi = 90°$ would mean pushing horizontally.) If φ is smaller than some minimum value $\varphi_{\min}$, you cannot get the book to slide no matter how hard you push. What is that minimum angle?

XC3*. Optional/extra-credit. (From Chapter 10.) You have just inherited property in Vermont that would make an excellent ski resort. One of the ski slopes has a cliff on the other side of the hill, and this gives you a money-saving idea. Instead of a chair lift or motorized tow-rope, you decide to attach a pulley to the top of the cliff and then drape the tow-rope over the pulley, with one end of the rope temporarily secured at the base of the ski slope and a counterweight attached to the end that hangs over the edge of the cliff. The plan is to release the rope and pull two skiers (with the inertia for the pair kept between 100 and 200 kg) up the 400 m slope, which has an incline angle of 35°. You guess that customers get nervous if they move faster than 5.0 m/s, and you begin immediately to calculate the required properties of the counterweight. (I guess a 200 kg pair must make it up the hill, and a 100 kg pair must reach the top at final speed less than 5.0 m/s.)

XC4*. Optional/extra-credit. (From Chapter 10.) The figure below shows a friend standing on the flat roof of a building that is 51.8 m tall. The roof is square and measures 20 m on a side. You want to launch a water balloon so that it lands on the roof and startles your friend, using a spring-loaded device that shoots water balloons at a launch speed of 42 m/s. The only problem is a slim billboard 67.5 m high between you and the roof, 20 m in front of the building. You are sitting somewhere in front of the billboard such that when you launch the water balloon it just barely gets over the billboard at the highest point in its trajectory. (The figure shows you standing, but let's say that you are sitting, so that your own height can be neglected.) (a) At what angle above the horizontal do you need to aim the balloon to clear the billboard? (b) What is your horizontal distance from the billboard? (c) How long does the water balloon take to move from the highest point in its trajectory to the height of the roof? (d) Does it strike the roof? (e) What is the speed of the balloon when it strikes?
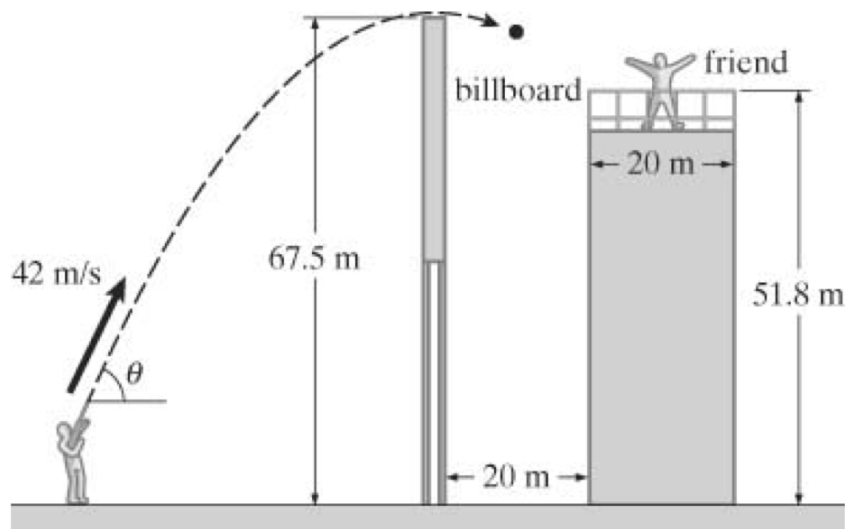
Physics 008 2017 homework #5 score sheet

Problem 1: _____   /4   Problem 8: _____   /4

Problem 2: _____   /4   Problem 9: _____   /4

Problem 3: _____   /4   Problem 10: _____   /4

Problem 4: _____   /4   Problem 11: _____   /4

Problem 5: _____   /4   Problem 12: _____   /4

Problem 6: _____   /4   Problem 13: _____   /4

Problem 7: _____   /4

The following 4 points reflect your maintaining good habits for all of the above problems:

Reasonable number of significant digits reported in answers: _____   /2

Sufficient level of explanation for reasoning behind answers: _____   /2
(You can earn 3 out of 2 for consistently clear presentation/explanation of your answers.)

Total (out of 56): _____

+ Extra credit (if any): _____

scoring guideline (for each problem):
4 = complete and correct solution
3 = good but minor error or minor omission
2 = serious error or omission but shows decent effort
1 = we can't make sense of what is written down
0 = no serious attempt to solve problem

Please write your name only on the bottom edge of this sheet (not on your own solutions), and staple the sheet to your own solutions, so that we don't know whose paper we are grading until after we have finished grading it.

Name: _____