Physics 8, Fall 2019, Homework #5.

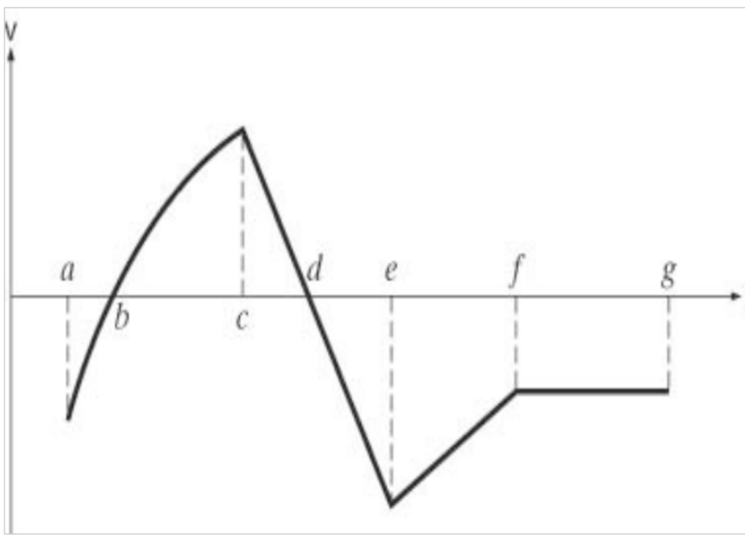
Due at start of class on Friday, October 4, 2019

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/q008/?date=2019-10-04`

(Chapter 9 problems.)

1. The velocity of an object as a function of time is shown in the figure below. Over what intervals is the work done on the object (a) positive, (b) negative, (c) zero? (Hint: make a table showing sign of acceleration (hence sign of net force), sign of displacement, and sign of their product, for each segment.)



2*. 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 145 m above the water, and the spring constant of the bungee cord is 42.0 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 72.0 kg and treat my body like a particle (i.e. a mass that is concentrated at a single point).

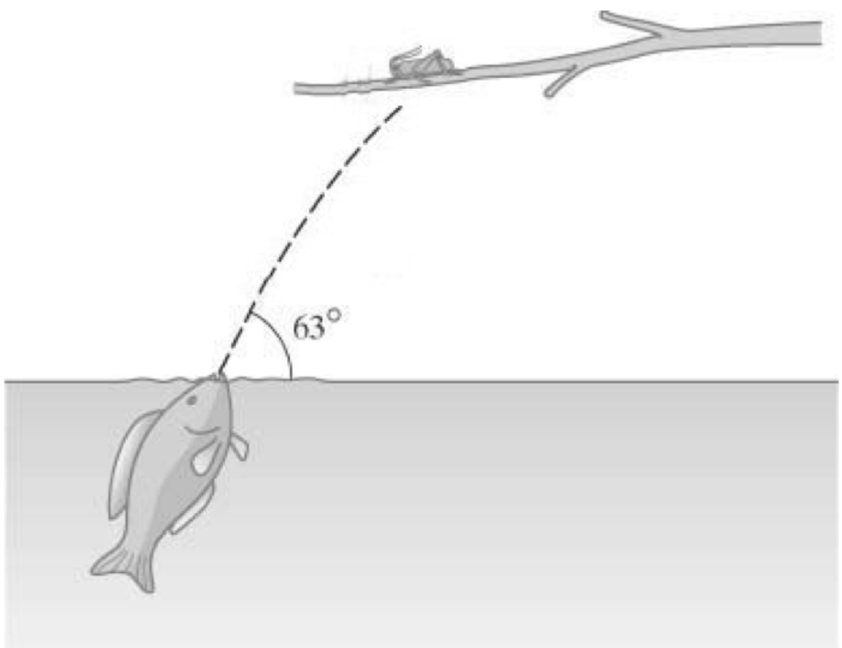
3*. A motor must lift a 950 kg elevator cab. The cab's maximum occupant capacity is 450 kg, and its constant "cruising" speed is 19.5 m/s. The design criterion is that the cab must achieve this speed within 2.0 s at constant acceleration beginning from rest. (a) When the cab is carrying its maximum capacity, 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?

4. An object is said to be in *stable equilibrium* if a displacement in either direction requires positive work to be done on the object by an external force. What is **(i.e. draw)** the shape of the potential energy curve (as a function of position) in the region of stable equilibrium? (Hint: think of a spring at its relaxed length.)

5. A 49 kg woman climbs a 12 m rope in 32 s. What is her average power output?

(Chapter 10 problems.)

6. 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?



7. A package is dropped from an airplane traveling at 105 m/s at an altitude of 175 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).

(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.)

8. 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.

9. A delivery person in an elevator is holding a package by a spring-like 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.

10. 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?

11. 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. Assume that friction between the track and the railcars can be neglected (but of course friction between the track and the locomotive cannot be neglected). (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 ten-car train down, which coupler feels the greatest force? (d) Is this force a tension force or a compression force?

12. (Here's a Chapter 9 conceptual question.) You are lifting a ball at constant velocity. (a) When the system is the ball, how many agents (external forces) are doing work on the system? Name the external forces (if any). Is the combined work done on the system by the agent(s) (if any) nonzero? (b) Describe the potential energy (if any) 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 (if any) of this system during the lift. In parts (b) and (d), if there is no relevant potential energy, explain why.

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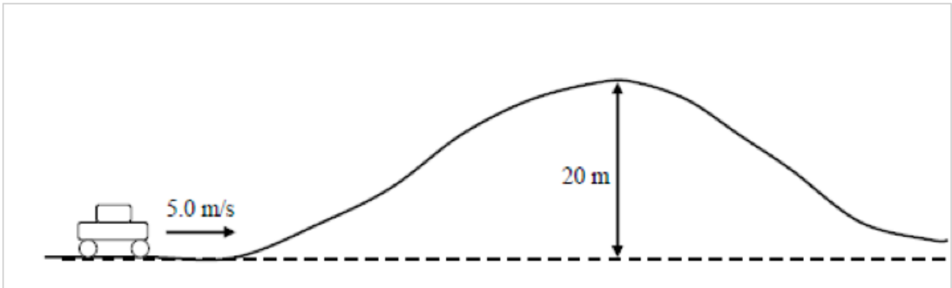
XC1*. Optional / extra-credit. (From Chapter 9.) A 1000 kg car starting at the bottom of a 20 m hill at 5.0 m/s almost comes to a complete stop as it crests the hill, barely making it over the top. (See figure below.) The power rating of the engine is 67 kW. (a) Assuming the engine's delivery of power 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.) 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?