Your Name: ______________________________

Teammates: ____

Physics 8, Fall 2023, Worksheet #11.

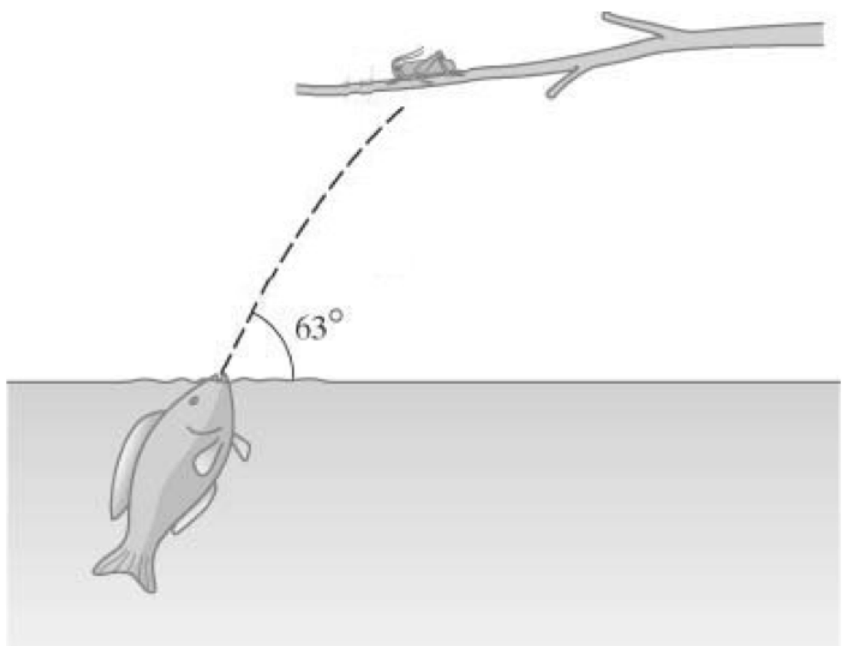
`http://positron.hep.upenn.edu/p8/files/ws11.pdf`

Upload PDF (smartphone scan or tablet edit) to Canvas shortly after class on Mon, Oct 9, 2023.

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

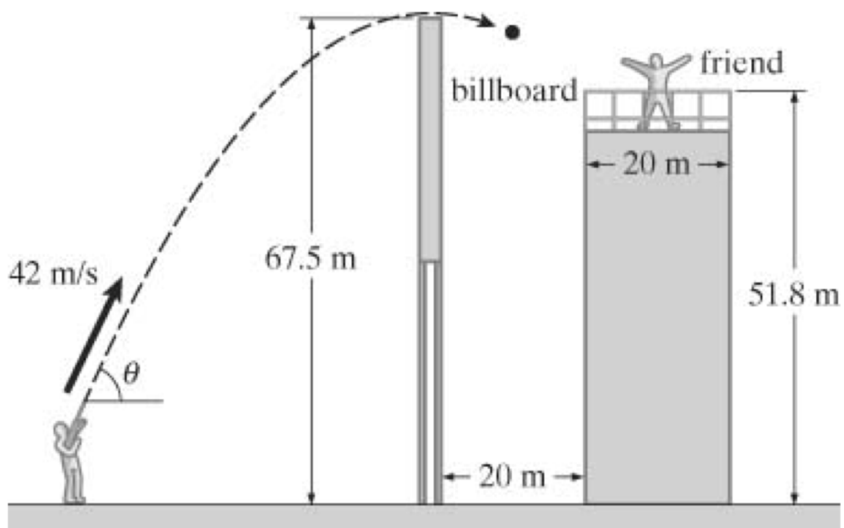
Discuss each problem with your teammates, then write up your own solution. Be sure to compare final results with your teammates, as a way to catch mistakes. It can also be very interesting when you and a teammate use different methods to arrive at a result. Do not hesitate to ask for help from other students or from the instructors — but don't just copy down other people's results!

1. 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?



2. A package is dropped from an airplane traveling at 100 m/s at an altitude of 200 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).

3*. *(This problem is longer, so it counts double: 8 points instead of 4 points.)* 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?



4*. Optional/XC. This XC problem (such as it is; I just made it up on my train commute, to answer a question in someone's chapter 9 reading response) follows up on the question on slide 23 of `phys8_notes_09.pdf`. That question, paraphrased, is: "You drop a rock from a height h above the ground. When it hits, how much force does the rock exert on the ground?" The answer is: "Impossible to determine without knowing over what distance the rock slows when it impacts the ground." Intuitively, the maximum force is bigger if the ground is very stiff, like concrete, but is not so large if the ground is quite flexible, like a rubber mat or a trampoline. Let's explore that by modeling the ground as a spring of spring constant k. The top end of the spring compresses a displacement d before bringing the rock's velocity (for an instant) to zero. Using energy balance, show that in slowing the rock to a stop, the maximum force exerted by a stiff spring (large k) is larger than the maximum force exerted by a more flexible spring (small k). To show this, derive an expression for d in terms of m, g, h, and k, and then use that expression to find the force between the rock and the spring. There are two complications that you can ignore here. First, to simplify the math, assume that $d \ll h$, ie that the change in G.P.E. while compressing the spring is negligible. Second, if you've studied physics before, you will know that the rock will bounce (oscillate) up and down on the spring for a while after landing; this subsequent oscillation (and how that motion is eventually dissipated into thermal energy) is not so relevant to our calculation of the maximum force exerted by the rock on the "ground" (spring). If you follow my guidance, I think you will find that if you reduce the stiffness k of the ground by a factor of 100, the corresponding maximum force will be reduced by a factor of 10. But there are no numbers in this problem: it's entirely symbolic math.