Problem 1

Suppose Mete Gazoz, who won the gold medal in archery in the Olympics this summer, comes to Northwestern for a demonstration on a calm afternoon with little to no wind. You challenge him to shoot an arrow in the air and hit it mid-air by shooting another one. Confident in himself, he accepts the challenge and immediately shoots the first arrow. Drawing the second arrow as fast as he can, he shoots the second arrow almost without thinking about it and hits the first one mid-air. Later, you ask him how he did the math. He tells you the following: The first arrow was shot at an angle 53° from the horizontal with a speed of 40 m/s. One can draw and shoot the second arrow right after the first one in 2.0 s fastest. The second arrow was shot with a speed of 75 m/s. Take $g = 10$ m/s^2 and ignore air resistance.

Treating the arrows to be point-like objects, find the shooting angle for the second arrow. (Hint: $\sin(53°) = 0.8$ and $\sin(37°) = 0.6$.)

Problem 2

In the Season 3 Episode 3[1] of Game of Thrones, Catelyn mourns her father's death. They have this ceremonial tradition in which the relatives place the dead in a small boat, let it go down the river, and shoot a flaming arrow to hit the boat and burn it. Edmure, Catelyn's brother, attempts with no luck to hit the boat — three times. Then, his uncle pushes him aside, grabs the bow and the arrow, draws his arrow, takes a look at the flag to estimate the wind velocity, and releases the arrow, performing a perfect shot[2]. In this problem, you will work out the math.

Suppose the map is given as in Fig. 1. Assume the bow shoots at 80 m/s and the wind blows with a speed of 5 m/s at 37° to the north of east so it supports the uncle. Assume the boat is so heavy that it is not affected by the wind or waves in the river and that it calmly keeps going due east at a speed of 1 m/s. Assume the boat is 250 m to the east and 10 m to the north of the uncle when he takes the shot, standing at the edge of the pier. Take $g = 10$ m/s^2. Ignore air resistance. Neglect the height of the uncle and the boat and assume both are at the ground level. Treating the arrow and the boat to be point-like objects, compute the angle from the horizontal at which the uncle shoots the arrow for a perfect shot.

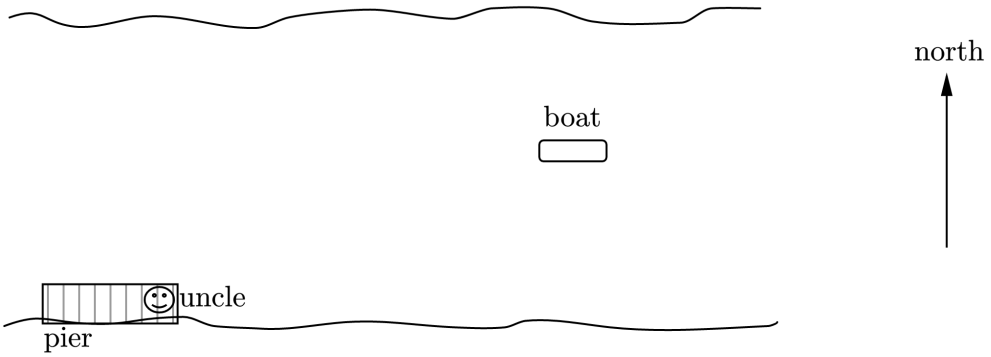

Figure 1:

[1] Scan for the link in the printout version:

[2] Imagine he misses it, too.

Problem 3

Suppose you catch a fly, sedate it, put it in a medium-size balloon, breath into the balloon, and put the balloon on a scale. When the fly regains consciousness, it realizes it's been trapped and suddenly decides to take off straight up with a constant acceleration until it reaches the center of the balloon. Then, it maintains its maximum flying speed until it reaches the top of the inside. Just before it touches the surface of the balloon, you feel sorry for the fly and pop the balloon so that the fly becomes free again. Sketch the values on the scale as a function of time from the beginning to the point where you pop the balloon.