Coaching the Physics of On-Target

The Simple Balance

Balance works on principle of torque -torque = gravity * mass * distance from pivot
Force at a distance from the pivot. (force is caused by gravity acting on the mass on the balance)

More mass on one side causes the balance to tilt due to the higher torque (turning force).

The distance from the pivot as well as the mass of the weight determines the torque (turning force).

For the simple balance that means that they two masses are hung at approximately the same distance from the center.

You can do some experiments with the balance to show this relationship. Use paper clip to hang some mass 2 inches from pivot and a another mass 4 inches from pivot. You will see that twice the mass at half the distance away will be (close) to balancing. You can use coins or beads for the masses in this test.

See if the balance is fair. Get two masses to balance, and then switch them and see if they balance. (they will likely not balance exactly the same, but some of the balances might be more fair than others)

See how sensitive the balance is. Mark the balance point on empty. Hang a light weight craft bead (like the one on the pivot)
on one side and mark where the balance line is. This is how sensitive it is to a single bead of mass.

Determine the impact of this mass on the launch distance for a single rocket.

Balance your rocket with a reference mass (lump of clay or other weight). Launch it 5 times the same way and record how far it goes. (record the launch settings, leave the launcher there for 2nd test) Then add a single bead to the reference mass and add enough clay to your rocket nose to rebalance it. Then do 5 more identical launches with the new, slightly heavier rocket. Record the distance.

What does this tell you about the impact on launch distance of being out of balance by this amount?

How precise will you need to be with the balance in order to get consistent launch distances? Is the balance sensitive enough to help you do well?

Mass

The acceleration of the rocket is inversely proportional to the mass of the rocket.
$a = F/m$

The force applied to the rocket is proportional to the drop height of the launch piston.

F ~ drop height

Force is provided by the piston being dropped, more height means more force, and so more force means more acceleration for the same mass.. (this is what proportional means)
You can vary the mass and see the result, more mass means less acceleration. (inversely proportional)

From your balance experiments, how can you make a rocket that has about twice the mass of another?

With twice the mass, what is the effect on the magnitude of the acceleration? (half?)

How far a rocket goes

The faster a rocket goes, the farther it will go in a given amount of time. Distance traveled is proportional to velocity. Distance traveled is proportional to time that it flies.

distance = velocity * time

So, you can get a rocket to go farther by making it go faster, or giving it more time (or both)

The amount of time in the air is dependent on how high and fast the rocket is directed upward.

Getting the rocket to a certain distance is determined by controlling the launch angle *and* the speed that the rocket comes off of the launcher. Togther they determine the time in the air and that determines how far the rocket goes.

Magnitude of acceleration

The larger the acceleration, the faster the rocket goes. Bigger a means bigger v.
Velocity (how fast it goes) is proportional to how much it accelerates.

$v = at$

The drop height determines the magnitude of the force applied to the rocket, and we know that is proportional to the acceleration.

Launch a rocket with drop heights in increments of 5 and graph the resulting distances.

Pick a range of drop heights and do the experiment in increments of 1 between those two.

Look at the graphs and see if you can see the trend in the data. (does it make a neat line?)

Duration of acceleration

The longer the rocket accelerates, the faster it goes.

The amount of time that the rocket is being pushed by the puff of air from the launcher determines how fast the rocket goes.

Do some experiments with the o-ring (stop ring) on the brass launch tube. Use same rocket, same angle, and same drop height, but adjust the position of the o-ring. Try it 1, 2, 3, and 4 cm from the end of the tube. Record the launch distances. Plot them on a graph.

See if you can see the impact of the length of acceleration.

velocity = acceleration * time ($v = at$)

Because the the rocket is getting a push from a puff of air there may not be a simple linear trend in your data, but your students should be able to see the difference and know how to explain. The longer you accelerate, the faster you go.

Aiming the launcher

Two points determine a line.

See if you can find two points on the launcher that represent the line for the launch of the rocket.

Lie down on the floor if you need to line them up. (gym floor will be relatively clean)

Make tools to help you (out of index cards, straws?) Play an aiming game where the target is a line running away from the target. Object is to land as close to the line as possible.

Vectors

The acceleration and velocity are vector quantities, they have magnitude and direction. Note that getting the rocket to spend lots of time in the air and travel a long distance in the air might not get the rocket to travel far down range. This is because the *direction* of the movement is important as well as the magnitude.

Need an experiment to show that launch force and angle adjustment can achieve the same distance.

Density of materials

The straws are manufactured products and so probably have the same mass, and the mass is evenly distributed throughout the straw. This means that you can use the length of the straw to control the mass of the straw. (for example, you can expect 6” of straw to have the same mass) Maybe even twice the mass of a 3” straw? (this is because the mass per unit length is constant) Does a 10 foot tree have one tenth the mass of a 100 foot tree?

Use a balance experiment to see if two straws have a mass about twice that of a single straw. Try it with straws of a different color to see. Does ½ of a straw have ½ the mass of a full straw?

How does the sensitivity of the balance compare to measuring the length of the straw? What is the easiest way to get the most accurate mass for a straw?

Does the clay also have a uniform density? Can you measure a “length” of clay (new stuff) and expect that to be a good measure (maybe estimate) of the mass of the clay? What other ways could you estimate the mass of some clay? Does a measure of one color of clay have the same mass as a measure of another color?