KLiC Activity Scenario Template – Informal Setting

Activity title:

Practical Mechanics: Projectiles in motion

Subject:

Informal Physics

Student age:

16+

Estimated duration:

50 minutes (excluding setup time)

Learning content

- Learning Newton's second law of motion, $F = ma$.
- InLOT system.
- Learning details about different motion formulas involving acceleration (a), Initial velocity (u), final velocity (v), time (t) & distance (s).
- Seeing how these formulas can be adapted to measure the variables for a projectile.

Learning objectives

The aim of the lesson is to teach students the basics of motion using rudimentary physics. The following points will be covered:

- Explanation for the origin of the formula of $F = ma$
- Comparison of $a = F/m$ with $a = (u - v)/t$
- Understanding how an accelerometer works
- How gravity is related to the mass and weight of an object
- Practical demonstration of the KLIC accelerometer

Inquiry-based character (if applicable)

The instructor explains the basics behind the maths and physics and through the experiments the participants are charged to find if what they have been taught is correct. This is both a Teaching-guided and a Discovery-based learning approach.

Applied technology (if any)

KLiC SensBall and communication base station, with an equivalent number of Laptops and a single projector.

Materials needed (if applicable)

Trebuchet, open sports' field classroom.

Description of Activities

Knowledge Building

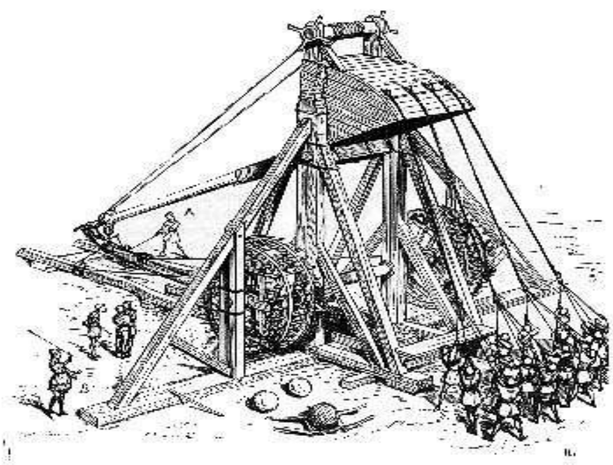
At the start of the lesson the participants will be brought to a demonstration in an open space (sports' field) where a Trebuchet is available. This demonstration is designed to have the SensBall launched by the Trebuchet, so this should be of a real life size.

At the start of the demonstration, the instructor will give a brief talk to explain briefly the reason for the informal lesson being given. The aim of the lesson is to introduce, in an informal way, the KLiC technology to participants as an informal learning tool. It will be explained to the participants that the technology works through wireless communication. The SensBall which is turned on and connected wirelessly, transmitting its data to the SensVest base station. The information read out at the receiving end is represented as a graph which plots 4 lines, X, Y, Z and G. When the ball moves in a direction the force applied can be measured as a signal output across the graph. The problem is that the X, Y & Z data can change dramatically due to rotational forces applied to the SensBall as the X, Y & Z data are respective to the balls orientation.

The SensBall will then be launched by the Trebuchet, measurements will be made and the rest of the lesson's content will be taken into the classroom.

Trebuchet

The trebuchet was developed to be one of the first long range artillery weapons which originated in china during the 6th century. However this design of trebuchet wasn't built with a counter weight system, instead it was designed with people pulling on the short arm by means of rope. This uses leverage, where the closer you are to the pivot point, the more force is required to turn but a shorter distance is travelled where as the further away you are from the pivot point the less force is applied but the greater the distance travelled.



In the 12th century the first counterweight trebuchet was developed. With this design the trebuchet could launch a projectile over much larger distances, as the force of the counter weight pulling down could put a lot more acceleration into the long arm of the trebuchet.

Because the trebuchet would launch projectiles at great distances they would require some accuracy in firing, otherwise they could fall too short of the target or over shoot. Back in the medieval times people would use best guess in order to position and aim the trebuchet at. But in today's artillery based weapons we use maths and physics to calculate the distance and speed of the projectile.

Health & Safety

Safety is an important aspect of this experiment; any and all observers must be perpendicular to the direction of the launch. This is because if the trebuchet misfires and launches the ball behind the trebuchet, it could seriously injure someone. Only the people operating the trebuchet are permitted to be near it and then they're only there to set up, after which they must be stood clear away from the trebuchet similar to the observers. During the time of preparation, an expert is required to make sure the setup is correct. He or she will be required to go under the counter weight to line up the sling correctly to make sure it doesn't twist and the projectile misfire. At this time participants are not allowed to go under the counter weight, under any circumstances, unless there are two people of adequate strength holding the launching arm down. This is a health and safety risk, this individual is at risk of losing their life.

The Physics

Initially a building of background knowledge involving motion formulas will be covered in loose detail to the students and observers so they have a basic understanding. It will be proposed that for a battle re-enactment a trebuchet is needed to hit a target army which is 200 meters away. First the base formulas are required so the unfamiliar observer can understand what's going on.

The simplest of formulas is: $speed = distance \times time$

Also to note that Speed ≠ Velocity. Velocity is speed in a given direction.

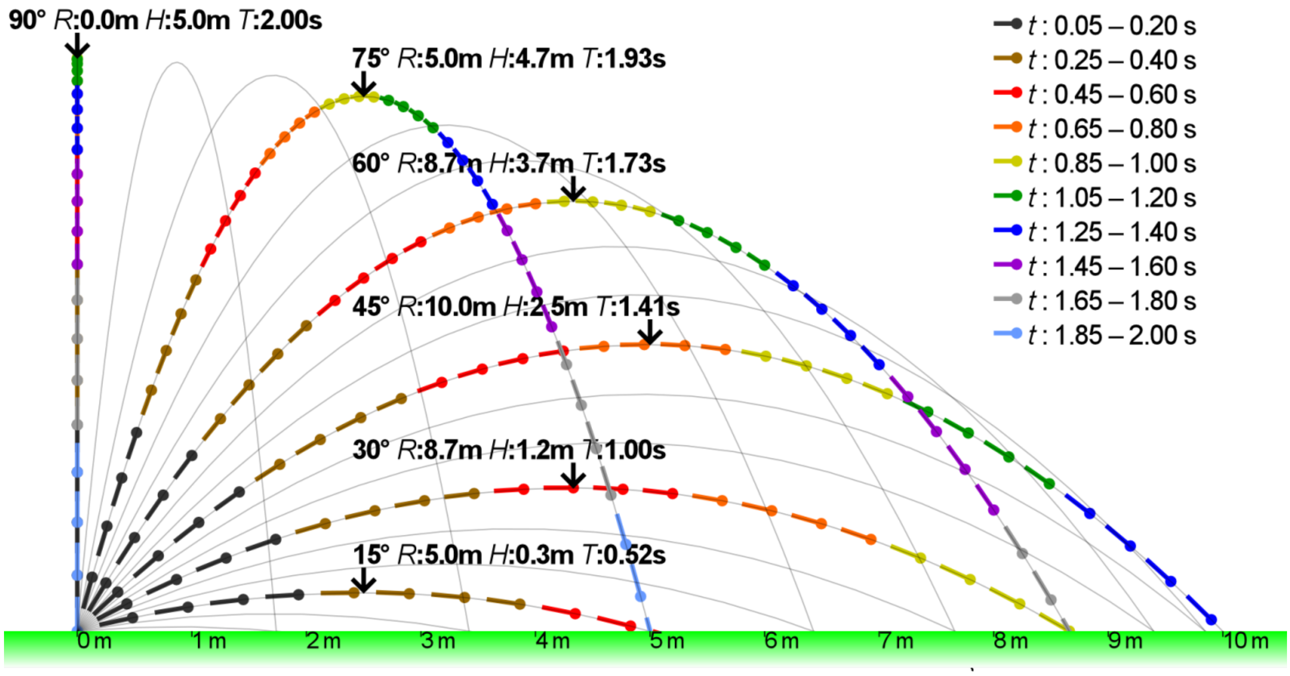
So to work out the acceleration of a car you need to know: $a = \frac{v-u}{t}$ which is the difference in velocity over time using acceleration (a), initial velocity (u), final velocity (v) and time (t). We can also use acceleration to determine how much force is applied to an object to make it move but for this we need the mass of the object. So to work out mass we use: $weight = mass \times gravity$

So Sir Isaac Newton determined that: $force = mass \times acceleration$ and this became Newton's second law of motion.

A lot of different factors come into effect when performing such an action as launching a projectile over a large distance, some of these includes air resistance and wind. For the maths involved at this point we won't be taking these into account and we shall always consider gravity to be the same throughout the journey of the ball. Thus the formula we shall use are:

$$Range = \frac{v^2 \sin 2\theta}{g}$$

$$height = \frac{v^2 \sin^2 \theta}{g}$$



For the purposes of this experiment we shall say gravity is 9.81N. We can work out V by using the force measured by the SensBall and work backwards to find V. So if:

$$F = m \times a \quad \& \quad a = \frac{v-u}{t}$$

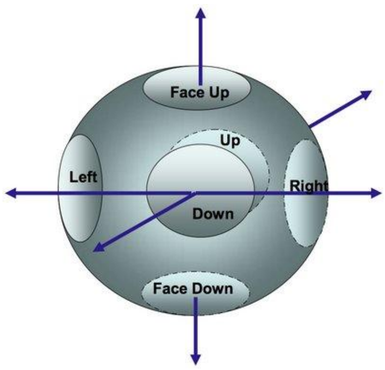
$$F = m \times \left(\frac{v-u}{t}\right)$$

$$\frac{F}{m} = \frac{v-u}{t}$$

$$\left(\frac{F}{m}\right) \times t + u = v$$

So the Mass of the SensBall is approx. 700g, time t is approx. 1 second and the initial velocity u is 0. So taking the force output by the SensBall we can determine the initial velocity and enter it into our range and height equations to calculate the approximate location of impact.

SensVest Technoloy



The SensBall is designed to use a three axis accelerometer to calculate the force applied to the ball. The accelerometer is designed with the concept of being able to measure the voltage across six separate plates. Each opposite plate belongs to the same axis but will produce a different voltage due to its direction.

In between all these plates is a crystalline structure designed to conduct a voltage, in the micro volts range, When the crystalline structure makes contact with one or more of the plates it reduces a current through the device completing the circuit and allowing us to know what direction the device is travelling.

This does mean that if the accelerometer is at rest that the crystalline structure will be making contact with one of the surfaces and show the downward force of gravity being applied. It is common misconception that all accelerometers measure acceleration, most of them measure force instead.

References

http://upload.wikimedia.org/wikipedia/commons/6/61/Ideal_projectile_motion_for_different_angles.svg
http://www.google.co.uk/url?sa=t&source=web&cd=2&ved=0CCIQFjAB&url=http%3A%2F%2Fwww.algarcia.org%2FTalks%2FTrebuchet.ppt&rct=j&q=trebuchet.ppt&ei=xWwETpaZA4Wr8QP2uNjeDQ&usg=AFQjCNGZCIVkeejBJEofo2em81CBgRmfmw&sig2=jwn1X1fsH4MJ-JCAbP2OAg
http://smarticle.co.uk/wordpress/wp-content/plugins/wp-o-matic/cache/190c1_rcjAccelerometer.jpg

Assessment (if applicable)

The purpose of this informal scenario is to encourage the basic understanding movement, acceleration and force. No specific assessment recommendation is given, as the technology is there to support the trainer in illustrating the physics of projectile motion in an empirical way.