KLiC Activity Scenario Template – Informal Setting

Activity title:
Mechanics in Practice: Friction

Subject:
Informal Physics

Student age:
16+

Estimated duration:
50 minutes (excluding setup time)

Learning content

- Learning Newton's second law of motion, F = ma.
- Seeing how this formula can be adapted to measure the variables for a moving object (i.e. Friction).

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
- 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 wrist accelerometer and base station, with an equivalent number of Laptops and a single projector

Materials needed (if applicable)

1 large wooden block & 1 thin wooden block, both having equal weight; classroom space.

Description of Activities

Knowledge Building

At the start of the lesson the participants will be brought to a demonstration in the classroom. This demonstration is designed to have a SensVest wrist accelerometer attached to a small weighted cube on an incline plane.

At the start of the demonstration, a talk will be given to explain briefly the reason for the informal lesson being given. The aim of the lesson is to introduce, in an informal way, the SensVest technology to the participants as a learning tool. It will be explained to the participants that the technology works through wireless communication. The KLiC wrist accelerometer, which is turned on and connected to wirelessly, transmits its data to the KLiC 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 accelerometer 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. This needs to be conveyed to the participants. Furthermore, the instructor needs to convey the sensitivity of the accelerometers to noise.

The accelerometer will then be attached to a weight with rough surfaces, which will then be moved around either on a surface, or between the participants (various directional movements as the weight is passed between the hands of different participants) so the class can see the output of the data collected via a projector. The rest of the lesson's content will be delivered after the demonstration.

Instances where friction is important(informal expalnations)

In the world of engineering, friction is taken into account during a large number of different products. Within the design of a bicycle, friction can be considered to be one of the most important features. For example, if one was to cycle on smooth roads for a race they'd often choose a racing bike over a mountain bike, because the tires have less friction. If an individual, is cycling they don't want the chain of their bike to seize up as this will cause the gears to stop turning. From cars to computers, friction plays a key part in most machinery. In order for friction forces to be worked out, a series of different formula are required.

Figure 1: Road & Mountain Tyres

Charles-Augustin de Coulomb approximated that the force of friction is less than or equal to the coefficient of friction multiplied by the normal force: $F_f \leq \mu N$. This means that, if an object is placed on a surface, the force of friction can stop it from moving, but it can't make it move. The coefficient of friction is the empirical property of two materials making contact. For example, the coefficient of friction between concrete and rubber on a dry day is 1.0, whereas on a wet day the value is 0.3. In the instance of having a 100 Newton normal force on a bicycle pushing down during a dry day, we have the force of friction being 1 x 100 = 100N. If the same instance is presented but it's on a wet day, the force of friction is 0.3 x 100 = 30N. Additionally, if a cyclist wants to increase their speed they will use a road bike, where there is less surface area on the wheel, in order to reduce the friction. If the cyclist wants to be able to ride there bike off road and be able to climb steep hills they will choose a mountain bike because it has more surface area and thus increases the friction.

The Physics

As previously mentioned, Friction plays a large part in the development of various mechanical devices. With a smooth frictionless surface an object placed on an incline plane will always slide down due to gravity. When an object is placed on an incline plane the only force acting upon the object is gravity (mg on figure 2).

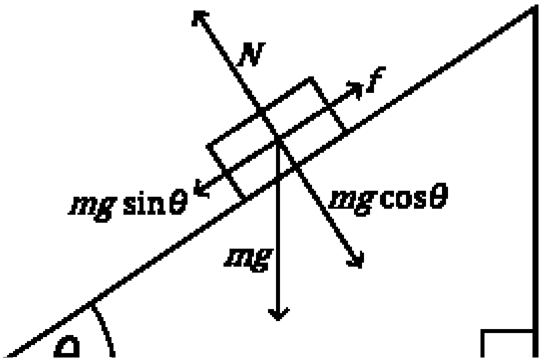

Figure 2: Forces on an incline plane

First we take the formula $f = m \times a$ to determine the force applied on the object. Because the object is moving due to being on a frictionless surface the acceleration of the object is equal to gravity, but only if it was to move vertically. This would also mean that the force of the object going into the incline plane is the same as the normal force as the object only slides down the plane. In order to determine the force of the object moving down the incline plane we need to treat the force of the object as two separate entities that make the whole. This can be done by using Pythagoras' theorem using trigonometric identities:

$$\sin\theta = \frac{o}{h}$$

$$\cos\theta = \frac{a}{h}$$

$$\tan\theta = \frac{o}{a}$$

For this example, we will treat mg as the hypotenuse (h) meaning we can use sin theta or cos theta. Additionally, we know that theta is the angle of the plane from horizontal which is the same as the angle between mg and the force going into the incline plane. So we can rearrange the cos element of the formula to give:

$$\mathrm{h} \times \cos\theta = a$$
$$N = mg \times \cos\theta$$

We can also work out the force of the object pushing the object down the incline plane to be:

$$F = mg \times \sin\theta$$

Take the example of an object with mass 100g and acceleration is 9.81 m/s^2 down on an incline plane of 45^o. We can determine that the force is 981N. From there we can work out the force of the object moving down the slope to be:

$$F = mg \times \sin\theta$$
$$= 981 \times \sin 45$$
$$F = 693.67N\ (to\ 2\ d.p.)$$

Now we take into consideration what happens when we have a 100g rubber wheel on an incline plane made of concrete at a 45^o, this means it has a force of friction of 100N going in the opposite direction. So adapting the formula:

$$F = (mg \times \sin\theta) - f$$
$$F = 693.67 - 100$$
$$F = 593.67N$$

Demonstration

After the explanation of the physics principles, in a simple and graphical manner, the participants will be demonstrated an experiment where the wrist accelerometer is attached to a large wooden block on a wooden incline plane. The data output from the accelerometer is displayed on the projector for the class to see. As the large wooden block is released, the block should move down the slope slowly and then stop. After this action, the wrist accelerometer is then placed in a thin wooden block and placed on the incline plane. When the thin block is released, the block will travel down the incline plane further than the large one before coming to a stop.

Doing simple calculations (as described above) on outputs of the accelerometer data will comparatively show to the participants that the larger the surface area the more friction will have an effect regardless of the mass of the object.

Image References

http://cyclinginsider.com/wp-content/uploads/2011/05/03/new-geax-sturdy-29er-mountain-bike-tire-vittoria-open-corsa-road-tires/wpid-soc2011-geax-sturdy-29er-mtb-open-corsa-road-bike-tires01-600x450.jpg
http://upload.wikimedia.org/wikipedia/commons/thumb/8/85/Free_body.svg/300px-Free_body.svg.png

Assessment (if applicable)

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