

Physics Lab Report: How to make machines more efficient?

Background Study:

A simple machine is a tool that makes our work easier. Work, in science, is any force acting on an object to move it from its position. Simple machines make our work easier by helping in small things such as an inclined plane that would be used to move heavy items into a truck, a pulley that helps in carrying construction items, a shovel that helps scoop up items such as sand, dirt, leaves etc. Simple machines can also be used for leisure purposes such as the see-saw. There are six very common simple machines that we utilize in our daily life; Inclined Plane, Wedge, Screw, Lever, Wheel and Axle, and Pulley.

An Inclined Plane is slanted flat surface that helps in sliding things down or even pushing a wheelchair up instead of using the stairs. An inclined plane can be used to vary the energy and distance involved in doing the work. A wedge is similar to the inclined plane as instead of using a smooth surface the wedge uses the pointed edges to push things apart. Wedges are, essentially, two inclined planes stuck together, side by side. Chisels, knives and axes are all types of wedges but the most common is a door wedge. It provides friction rather than separating things but they are still considered as a wedge.¹

The third simple machine is a screw which is a machine with an inclined furrow on its surface. This works by applying a torque (twisting force that causes rotation) perpendicular to the furrow thus making it a linear one. Screws are used to join two objects together and fasten them. When we are trying to pull out weeds from underground, instead of using our hands, we could use a lever. A lever is an arm that turns from its fulcrum and it is curved against a point on its surface. Therefore, when you rotate the level the nails in the wall become loose and come out. The wheel and axle is also part of this as the wheel is another kind of lever as it helps in moving an object to a specific distance. The wheel helps in moving heavy objects as you do not need to push the object you just have to apply force on the carrier, such as a wagon. The last example of the simple machine is a pulley and we see these multiple times in construction sites. In a puller, a cord or string is wrapped around a wheel and as the wheel rotates the cord moves in that direction. On one end a hook is attached that carries a weight. In construction sites a pulley is used to carry the material from one place to another.¹

Although these simple machines make life easier, some measures need to be taken to improve the efficiency of the machine. Fundamentally, efficiency is the ratio of what work was been put in (force/energy) and what work has been produced as the outcome of the effort. This is due to the fact that when a machine does work it is restricted to things such as drag and **friction**. The output is always smaller than the inputs as there are many barriers. This is proved when reflecting on the Second Law of Thermodynamics. The Law states that “The entropy of an isolated system never decreases, because isolated systems spontaneously evolve toward thermodynamic equilibrium”. This basically means that the quality of energy in anything will decrease as it becomes heat. Therefore, efficiency is never 100 % as some of it is always lost.²

Objectives:

- To improve the efficiency of a simple machine by manipulating a factor that restricts the outcome from being equal to input (friction)
- To prove that lubricants can increase the efficiency of a machine

Hypothesis:

If lubricant, such as butter or grease, is applied to a surface then the efficiency of that machine will increase. This is because lubricants reduce the amount of **friction** that resides in parts of the machines that touch a surface. This also prevents heat from being produced and allows the machine to work faster.

¹ <http://www.fi.edu/ga97/spotlight3/>

² http://www.ftexploring.com/energy/2nd_Law.html

Variables:

| Dependant Variable | Why/How? |
|-------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| The efficiency of the machine | This experiment is designed to improve the efficiency therefore while conducting this experiment I expect this to be my dependant variable as this is a desired outcome. The efficiency should increase as this is what the objective is. |
| Force applied to pull up the wooden block | The force applied will vary every time as the surface changes. This is due to the fact that a slippery surface will not take more force than a hard surface as slippery surfaces minimize the chance of friction being a restriction whereas harder or rougher surfaces maximize the chance. |
| Independent Variable | Why/How? |
| Type of lubricant applied on surface | The surface that the lubricant was applied on changed as this would contribute as a major factor that would affect the efficiency. We used a flat board for this so that our results are more reliable. |

| Controlled Variable | Why/How? |
|--------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Distance which is covered by the lubricant | The distance that the lubricant and the other surface will cover will be maintained at 10cm so that the results will be reliable. If the distance is not covered and an average is found the results are less likely to be trusted as they are just estimated and cannot be trusted completely. After doing three trials of every experiment and average will later be found as every trial will not give us the same results. This will decrease the reliability and validity of the results to an extent but it will not change the phase of the whole experiment. |
| General materials | The general materials used in this experiment were constantly kept the same in order to keep the results fair and trustworthy as if in one experiment I use a pulley and the next I use an inclined plane I would be using two different machines, that would have different jobs and I'd have to improve both. |
| Angle of the pulley | The angle of the pulley was constantly kept at 87 degrees in order to increase the reliability of the results. If the angle is changed that means that would be a manipulating variable as well and this would affect the results severely as one varied variable is already being tested if another was tested then different procedures would be used to test other factors. |

| | |
|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Amount of Lubricant | The amount of lubricant will be the same as we will weigh it and let it cover the same distance which is 10 cm by 10 cm on the wooden board to make it fair and have accurate and valid results. |
| Length and Width of wooden block | The wooden block will always be of the same size (5cm by 10 cm by 5 cm) as the experiment was set up in such a way that it only allowed space for that wooden block with those measurements or else the results cannot be applied in every situation as the machine is only built for one purpose as it is simple. |

Materials/Apparatus:

| | |
|-------------------|-----------------------|
| Materials: | |
| Wooden Board | 12 pc- 12 cm by 12 cm |
| CD | 2 pc |
| Toilet Roll | 1 pc |
| String | 60 cm |
| Butter | 1 block |
| Grease | 1 can |
| Sand paper | 2 papers |
| Duct Tape | 1 roll |
| Glue (PVA) | 1 bottle |
| Pencil | 1 pc |
| Apparatus: | |
| Newton Meter | 1 pc |
| Weighing Scale | 1 pc |

Procedure/Set up:

Part 1- Constructing the pulley

1. Take a toilet roll and cut it in half.
2. Place a pencil through the two holes and use tape to stabilize it in one position
3. Place a CD through each side of pencil and use more duct tape to uphold one position.

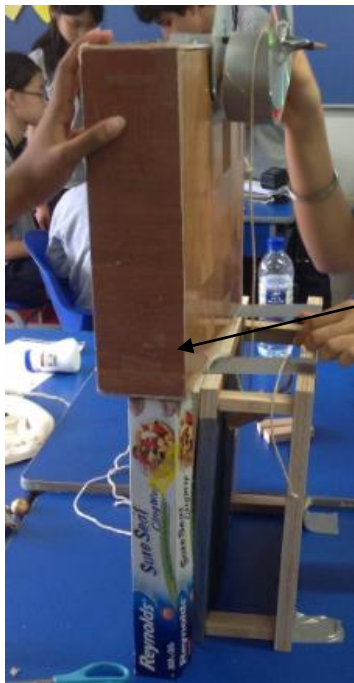
Part 1- Designing the experiment

1. Cut two pieces of 10 cm by 10 cm sandpaper and glue them onto two wooden boards
2. Place the two boards parallel to each other and use thick books to help them stand
3. Use 6 wooden boards to then make a box which measure 12 cm by 4 cm by 12 cm
4. Attach one side of the pulley to the wooden box
5. Use the remaining boards to build a support for one side of the sand paper board.
6. Place the pulley box on top of the sandpaper board and make it stable by using the help of additional supports (the extra boards)
7. Thread a string through the pulley
8. Attach a Newton meter to the outer part of the pulley and a wooden block to the part that is facing downwards toward the sandpaper
9. Keep the wooden block in horizontal position. It should measure as 5 cm by 10 cm by 5 cm
10. Using the length of the wooden block (10 cm) create that space between the two sand paper boards (about 10.2 cm to allow movement of wooden block)
11. Pull on Newton meter and note how much force is used to pull the wooden block up till 10 cm.
12. Record results
13. Repeat step 11 by changing the sand paper to grease, butter and the plain wood

14. Analyze data



The structure of the pulley and the wooden box should look like this



What the whole experiment should look like. The Newton meter will be attached to the outside part of the pulley (where arrow is pointing and the wood block should go inside between the two boards

Data Analysis:

Table 1.0 Data showing the variation in force from trials one to three while the surface used is Sandpaper

| Trial | Mass (kg) ± 0.001 kg | Gravitational pull (m/s^2) | Height (m) ± 0.01 m | Distance (m) ± 0.01 m | Force (N) ± 0.01 N |
|-------|----------------------|----------------------------|---------------------|-----------------------|--------------------|
| 1 | 0.25 kg | 9.8 m/s^2 | 0.1 m | 0.15 m | 3.6 N |
| 2 | 0.25 kg | 9.8 m/s^2 | 0.1 m | 0.15 m | 3.4 N |
| 3 | 0.25 kg | 9.8 m/s^2 | 0.1 m | 0.15 m | 3.7 N |

Table 2.0 Data showing the variation in force from trials one to three while the surface used is Butter

| Trial | Mass (kg) \pm 0.001 kg | Gravitational pull (m/s ²) | Height (m) \pm 0.01 m | Distance (m) \pm 0.01 m | Force (N) \pm 0.01 N |
|-------|--------------------------|----------------------------------------|-------------------------|---------------------------|------------------------|
| 1 | 0.25 kg | 9.8 m/s ² | 0.1 m | 0.15 m | 1.9 N |
| 2 | 0.25 kg | 9.8 m/s ² | 0.1 m | 0.15 m | 2 N |
| 3 | 0.25 kg | 9.8 m/s ² | 0.1 m | 0.15 m | 1.7 N |

Table 3.0 Data showing the variation in force from trials one to three while the surface used is Grease

| Trial | Mass (kg) \pm 0.001 kg | Gravitational pull (m/s ²) | Height (m) \pm 0.01 m | Distance (m) \pm 0.01 m | Force (N) \pm 0.01 N |
|-------|--------------------------|----------------------------------------|-------------------------|---------------------------|------------------------|
| 1 | 0.25 kg | 9.8 m/s ² | 0.1 m | 0.15 m | 1.5 N |
| 2 | 0.25 kg | 9.8 m/s ² | 0.1 m | 0.15 m | 1.8 N |
| 3 | 0.25 kg | 9.8 m/s ² | 0.1 m | 0.15 m | 1.7 N |

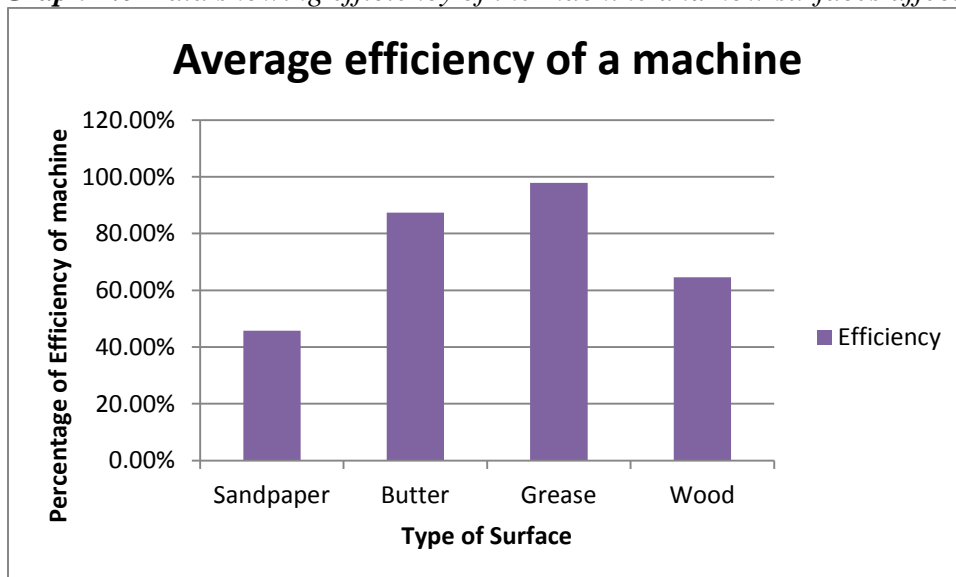
Table 4.0 Data showing the variation in force from trials one to three while the surface used is Wood

| Trial | Mass (kg) \pm 0.001 kg | Gravitational pull (m/s ²) | Height (m) \pm 0.01 m | Distance (m) \pm 0.01 m | Force (N) \pm 0.01 N |
|-------|--------------------------|----------------------------------------|-------------------------|---------------------------|------------------------|
| 1 | 0.25 kg | 9.8 m/s ² | 0.1 m | 0.15 m | 2.5 N |
| 2 | 0.25 kg | 9.8 m/s ² | 0.1 m | 0.15 m | 2.4 N |
| 3 | 0.25 kg | 9.8 m/s ² | 0.1 m | 0.15 m | 2.7 N |

Table 5.0 Data showing the average force applied on each surface. The table also shows the efficiency of each surface in percentage.

| Surface | Mass (kg) | Height (m) | Distance (m) | Gravitational pull (m/s ²) | Force (N) | Energy | Work | Efficiency |
|-----------|-----------|------------|--------------|----------------------------------------|-----------|---------|-------|------------|
| Sandpaper | 0.25 | 0.1 | 0.15 | 9.8 | 3.567 | 0.53505 | 0.245 | 45.79% |
| Butter | 0.25 | 0.1 | 0.15 | 9.8 | 1.87 | 0.2805 | 0.245 | 87.34% |
| Grease | 0.25 | 0.1 | 0.15 | 9.8 | 1.67 | 0.2505 | 0.245 | 97.80% |
| Wood | 0.25 | 0.1 | 0.15 | 9.8 | 2.53 | 0.3795 | 0.245 | 64.56% |

Graph 1.0 Data showing efficiency of the machine and how surfaces affect the percentage.



*Explanation of Graph and average table in Conclusion

Calculations:

1. To calculate the Distance (m) we applied our Trigonometry formula of sin, cos and tan. We used cosine as we had to look for our hypotenuse and the two figures we had was the angle between the adjacent and hypotenuse and our adjacent line. Our calculations looked something like this:
 - $\cos \theta = d/x$
 - $x = d/\cos \theta$
 - $x = 0.1/\cos 47$
 - $x = 0.15 \text{ m}$
2. To calculate Work we used the formula mgh or mass in kg * gravitational pull in m/s^2 * height. Our mass was 0.250 kg, the gravitational pull is 9.8 m/s^2 and our height is 0.1m. Therefore the working would look like this:
 - mass in kg * gravitational pull in m/s^2 * height
 - $0.250 * 9.8 * 0.1$
 - 0.245 j
3. To calculate Energy output we use the formula force * distance. The above calculated the energy input and from the research done in the beginning the output is always less than the input as work is always lost by restrictions such as friction, even if it is at its minimum. The force used in this varied every time therefore we look at the example of Sandpaper out force 3.567 N on average and our distance is 0.15 m and our working appears as shown below:
 - Force * distance
 - $3.567 * 0.15$
 - 0.53505 j
4. Our last formula used was efficiency is equal to work divided by energy multiplied by 100. The work used in Sandpaper was 0.245 j and energy that came out was 0.53505 j and we calculated like this:
 - $(\text{Work}/\text{energy}) * 100$
 - $(0.245/0.53505) * 100$
 - $0.4579 \text{ j} * 100$
 - 45.79%

Evaluation:

The experiment was conducted well and done cautiously. We were slow and careful and the experiment proved that different surfaces do affect the efficiency of our machine. However, some human errors were definitely unavoidable as accurate measurements depend on how well the materials were used. The following points describe what the human errors are and recommendations on improving them:

- The Distance between the two wooden boards that had the lubricant on it was to be 10.2 cm and we tried our best to maintain the distance but there would have definitely been a bit of shaking as we used supports such as heavy books to make the boards stand. Also, we used tape to mark where the board should stand and plotted it out as well but not intentionally the board could have moved to about 10.25 cm. The way we could improve is to have a base and glue the two vertical wooden boards to the horizontal base in order to prevent distance issues.
- The second human error would be the reading of the force on the Newton Meter. When a weight or anything pulls on the Newton meter we are to read the Newton's according to the lines drawn on it. Due to the fact that we had to read quickly or else it would cross 10 cm we read it only once and therefore had to do 3 trials to get close results. After averaging it we get rough figures and this affects validity and reliability of the results. Reliability and Validity is not exactly the same thing; validity is the degree of accuracy of how a study reflects a concept that is experimented on while reliability is the consistency of the acquired results. When reading, we saw, supposedly 1.9 N, it could have, in fact, been 1.92 N but due to the shortage of time we read to the nearest 1 decimal place and those were our final results. Next time, when the wooden block reaches 10 cm we could hold the Newton meter at its position and read the results accurately instead of reading it to the nearest decimal.

- When finding the final efficiency of each surface, the formula had the averaged force as the responding variable. Therefore, there could have been a slight difference if we found the efficiency of each trial and then averaged it, the efficiency would have been less in my opinion as when finding the average, it is bigger than a few trials and smaller than a few trials. In order to prevent these types of variations in results both efficiency's should be found out of both, the average of force and the average of every trials efficiencies.
- The angle at which the pulley was maintained at was 47 degrees but while the experiment was being conducted the string could have moved out of place a little due to the weight exerted on it. In order to correct this error we could have placed some object that would maintain the gap between the angle (area of 47 degrees) thus, preventing the angle from being changed even if it was by ± 1 degree.
- The last identifiable human error was the volume of lubricant applied. When the sandpaper was attached it covered 10 cm and so did the butter and grease. However, Grease is thick and although it covered 10 cm it could have been more in weight and volume and this effect the results as the efficiency may have decreased if less grease was put on. Similarly, the butter could have been of a less volume compared to the grease therefore needing more force for the wooden block to rise with. This error could have been corrected if we weighed the amount of lubricant put on to have equal and none would be biased results.

Conclusion:

The results showed how efficient the machine we designed was and how much the output was compared to the input (100 %). In *Table 5.0* we notice that the average force is different for all four surfaces as two surfaces reduce friction while two surfaces increase the friction. The two surfaces that reduce friction are Grease and Butter. Due to their smooth and slippery texture friction minimizes increasing the speed of its travel. The force manipulated and this showed that less force was needed when pulling on a slippery surface compared to that of a rougher surface. Wood and Sandpaper have very rough and rigid surfaces and these increase the friction present. This is due to the fact that roughness includes a little bit of bumpiness due to bigger particles and these are the tiny obstacles/restrictions that prevent the machine from moving properly hence, decreasing it's speed and increasing the amount of force used to pull on the wooden block. In the *Graph 1.0* we can deduce that rougher surfaces result in less efficiency and in this case the roughest surface was sandpaper and that resulted in the output or efficiency of the machine being only 47 %, roughly. There was a loss of 53 % of the energy as friction had lessened the speed and increased the force. On the other hand, the most slippery surface was Grease due to its thickness and its soft texture. Friction was reduced and this allowed almost 97% of output, only 3% was lost, and this showed us that our machine was very efficient as we acquired our desired results. Our results are reliable as the results in all three trials of all four surfaces were consistent, when rounding off to the nearest 5 N. This is because after three trials if the it did not all round off to the nearest 5 N then we conducted another trial and used the better results. I am very confident on my results as if another student carried out the same experiment and used the same way of calculation then they would acquire similar results, not exactly the same, there may be a difference of ± 5 %. Our data is also valid as validity is essentially the degree of accuracy of how our results reflect our concept or aim of experiment. Our objectives were to improve the efficiency of a machine by manipulating its surface and to prove that lubricants reduce the frictional force and lessen the amount of force applied in order to pull the object upwards. Both these objectives were answered and proved as we do see that by manipulating our surface (Butter, Grease, Sandpaper and Wood) we acquired dissimilar results; two in favor of our objective 1 and two not in favor. But when a 'because' statement was given in our hypothesis all four of the results were in favor. Our hypothesis "If lubricant, such as butter or grease, is applied to a surface then the efficiency of that machine will increase. This is because lubricants reduce the amount of **friction** that resides in parts of the machines that touch a surface. This also prevents heat from being produced and allows the machine to work faster" is proven to be accurate as friction was reduced due to the texture of the lubricants and helped the machine work faster. Heat was not a factor that we tested but could have been another factor to experiment on. Other than that, I feel as though our experiment was well conducted albeit having to repeat the whole experiment twice due to miscommunication and overall I feel that I have accomplished what I desire and will improve on the human errors that took place if I were to conduct the same experiment again.

References:

1. "Simple Machines." *"inQuiry Almanack" - Spotlighting*. The Franklin Institute, Mar. 1997. Web. 26 Nov. 2013. < <http://www.fi.edu/ga97/spotlight3/> >.
2. Watson, David. "The Second Law of Thermodynamics." *FT Exploring- Science and Technology*. FT Exploring, n.d. Web. 26 Nov. 2013. < http://www.ftexploring.com/energy/2nd_Law.html >.