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Efficiency of a Motor

Aim: To investigate the relationship between the efficiency of a motor and the load it is lifting.

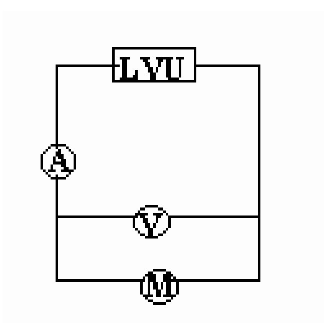
Apparatus:

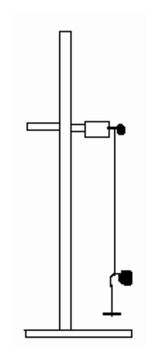
- Motor
- Blue tack
- Clamp
- Ammeter
- Low Voltage Unit
- Sellotape
- Mass hook
- 50cm length of cotton
- 0.01Kg plasticine
- Boss
- Voltmeter
- 0.01Kg masses
- Wires
- Stopwatch

Safety

You should not use an electrical source with wet hands. Sockets should have nothing inserted into them other than plugs. This is because the voltage of a mains supply is 240V and this is enough to kill a human being. Water should be kept away from sockets, as water is a good conductor of electricity and therefore could potentially be lethal. For the same reason all wires should be insulated. As a general safety rule there should be no running in the laboratory and all bags should be placed under desks to avoid tripping.

Diagrams

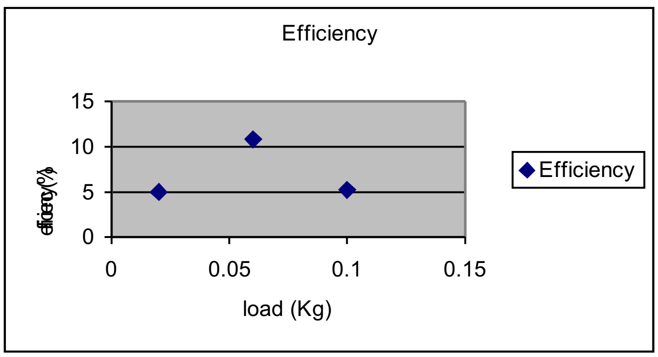




Preliminary Results

From my preliminary experiments I discovered that the cotton would not fix itself to the spindle of the motor in such a way that it would wind up without the addition of blue tack to secure it. It is vital therefore that I use blue tack in this experiment or the efficiency of the motor cannot be calculated because the load would not move any distance whatsoever. I attempted to gain results for 0.01 Kg but this proved to be too difficult as the time taken for the motor to lift the mass was too quick to measure with any degree of accuracy. In addition, the load tended to swing whilst being lifted and this would have affected the results in an unfair way. The largest load I will use will be 0.1 Kg as beyond this I discovered that the cotton found it difficult to support the load and this would have affected my results. I will use the following loads because they will produce results which are close enough together to draw an accurate graph: 0.02 Kg, 0.04 Kg, 0.06 Kg, 0.08 kg and 0.1 Kg. I plan on using a distance of 0.5 M as this gives a large enough distance for measuring the time it takes for the load to be lifted. Equally it is a suitable length to easily wind around the spindle of the motor and be used in conjunction with the clamp. The voltage I shall use will be 2V as this allows the motor to work at a good, suitable speed for us to measure the time it takes for the load to be lifted. Using this voltage results in the amperage remaining at 1.36 A

Load (Kg)	Time Taken (s)	Efficiency
0.02	0.74	4.968203
0.06	1.02	10.81315
0.1	3.53	5.207465



This shows that the efficiency increases and then decreases again. This gives me an indication of what the results for my experiment shall be like and will help me to write my hypothesis.

<u>Fair Testing</u>

- The voltage must be kept the same. This is because the motor will turn at a different speed depending on the voltage and the rate of the motor affects the time it takes for a load to be lifted.
- The length of cotton must be kept the same as the distance affects the kinetic energy. The shorter the cotton is the faster the load will lifted, such a change will therefore produce results that are not relevant to each other. Also the cotton itself must be kept the same as different thicknesses of cotton could wind up differently and affect the results.
- The same person should be used to time how long it takes for the load to reach the motor so that the reaction times are all the same. This will ensure that the times are all proportionate to each other.
- The experiment should be repeated for the same load three times so that we can be sure that any inaccurate results can be identified.

Step by Step Method

1. Connect the motor to the ammeter, voltmeter and LVU. The ammeter should be placed in series and the voltmeter in parallel. The voltage should be set to 2 volts so as not to blow the motor but still allow the motor to function sufficiently. After checking that the motor is functioning the LVU should then be switched off.
2. The motor should be clamped tightly approximately 60cm above the ground.
3. Cotton should be attached the spindle of the motor. To do this you should tightly tie the cotton into a double knot and the cover this in blue tack. In addition a small piece of blue tack should be placed onto the end of the spindle to prevent the cotton from slipping off.
4. The other end of the cotton should be attached to the mass hook. To do this a double knot should be tied around the hook with a 0.01Kg mass of plasticine should be placed on the end of the mass hook to ensure that the cotton remains attached.
5. The LVU should be switched on and at the same time the stop clock should be started.
6. As the load is being lifted the amps recorded on the ammeter should be recorded.
7. As soon as the mass has reached the motor the stopwatch should be stopped and the time recorded.
8. Steps 4-7 should be repeated a further 2 times so we are sure that the results we have gained are accurate.
9. Steps 4-8 should then be repeated again for the different masses.

Hypothesis

All energy must be transferred. Energy cannot be created or destroyed. Energy efficiency is how much of the energy that has been input is transferred into a useful energy output. In this case the motor is given electrical energy this is then transferred to rotational kinetic energy this rotational kinetic energy is then transferred into gravitational potential energy when the load is lifted.
To calculate energy efficiency we use the following formula:

$$\frac{\text{Useful energy output}}{\text{Total energy input}} \times 100$$

The useful energy output is gravitational potential energy. The formula for this is:

$$\text{Mass} \times g \times \text{change in height}$$

G is gravity. We measure this as 10N. The total energy input is the power put into the motor. We calculate this using the formula:

$$\text{Voltage} \times \text{current} \times \text{time}$$

This means that to find the energy efficiency the formula I will need to use overall is:

$$\frac{\text{Mass} \times g \times \text{change in height}}{\text{Voltage} \times \text{current} \times \text{time}} \times 100$$

The voltage, mass, gravity, height and current should all remain the same. This means that the results of our energy efficiency should greatly depend on the mass and on the time.
When a heavier load is being lifted this adds strain onto the cotton which creates friction. This friction creates heat and a little sound. The principle of conservation of energy states that "energy can be changed from one to another but it cannot be created or destroyed" The sound and heat energy must therefore come from the electrical energy that has been inputted. The more sound and heat energy produced, therefore, reduces the efficiency of the motor. This is as, whilst the gravitation potential energy will only be affected by the load, the overall efficiency will become lower as the more energy transferred into heat and sound the less energy is used for lifting the load and the time taken will therefore be greater.
The efficiency may also be lower for a light load as there will be little strain on the cotton and it may therefore slip on the spindle making the motor appear inefficient.
If the motor was 100% efficient, then the

total energy input = total energy output

In the case of the motor this would mean that

electrical energy = gravitational potential energy

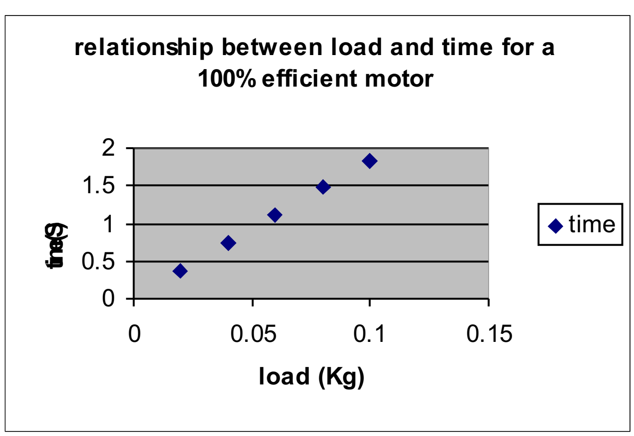
$$\frac{\text{Mass} \times g \times \text{change in height}}{\text{Voltage} \times \text{current} \times \text{time}} \times 100$$

If I was to calculate what my results would be, should my motor be 100% efficient, I could use the formula for efficiency which is
And times both sides by time to get the formula

$$\frac{\text{mass} \times g \times \text{change in height}}{\text{voltage} \times \text{current}} = \text{time}$$

By using the set masses, distance, voltage and current I can gain a table of results for a 100% efficient motor.

Load (Kg)	Time (s)
0.02	0.37
0.04	0.74
0.06	1.10
0.08	1.47
0.10	1.84



There is a direct positive correlation between the mass and the time. I would not, however, expect to see a graph like this with my experiment because I predict that the motor will lose energy in the form of heat and sound. Therefore I think that a similar graph for my experiment would produce a curve as the time will increase for the weight to be lifted as the load increases due to theses loses of energy.

Results

Load (kg)	Time 1 (s)	Time 2 (s)	Time 3 (s)	Average time (s)	Efficiency 1 (%)	Efficiency 2 (%)	Efficiency 3 (%)	Average Efficiency (%)
0.02	0.70	0.62	0.70	0.67	5.25	5.93	5.25	5.60
0.04	0.82	0.74	0.90	0.82	8.97	9.94	8.17	9.24
0.06	1.19	1.01	1.22	1.14	9.27	10.92	9.04	9.97
0.08	1.65	1.46	1.88	1.66	8.91	10.07	7.82	9.18
0.10	2.96	3.53	3.74	3.41	6.21	5.21	4.92	5.55

Analysis

The graph for time shows that as the mass increases so does the time taken for the mass to be lifted. The increase becomes greater for greater masses, for example, the increase of time between 0.02 Kg and 0.04 Kg is 0.15s, whereas, the increase between 0.08 Kg and 0.1 Kg is 1.75s. We see a greater mass taking a longer amount of time to be lifted as larger masses create more friction therefore producing more heat and potentially a little sound.

The motor uses electrical energy to turn into rotational kinetic energy. This energy is then transferred to gravitational potential energy when the load is lifted. All energy must be transferred it cannot be destroyed or created. Therefore, the rotational kinetic energy transfers itself not only to the gravitational potential energy but also to heat and sound energy as the load increases. Heat and sound energy are produced as a result of the friction created by using a heavier load. This use of energy means that it takes longer to lift the load as not all of the energy available is used to lift the load, the less energy transferred to gravitational potential energy the longer it takes for the load to be lifted.

We find the efficiency of the motor using the formula:

$$\frac{\text{Useful energy output}}{\text{Total energy input}} \times 100$$

This is equivalent to:

$$\frac{\text{gravitational potential energy}}{\text{electrical energy}} \times 100$$

This is:

$$\frac{\text{Mass} \times \text{g} \times \text{change in height}}{\text{Voltage} \times \text{current} \times \text{time}} \times 100$$

The gravitational potential energy is affected solely by the mass in our experiment the components of the formula are mass, height and gravity. Height and gravity are kept the same throughout the experiment. The time, however, is the part of the formula which affects the experiment the most. A greater time in the equation produces a smaller answer and we see the time greatly increase as a result of the increase in mass. This means that as more heat and sound energy are produced and the time increases the motor becomes less and less efficient.

The graph also showed that whilst the efficiency decreased as the load increased it did, in fact, increase up to 0.04 kg. This was due to the small mass not producing enough strain on the cotton to stay on the spindle of the motor as well as it should have done. As the cotton was slipping, the motor itself was not inefficient it was just the way that the graph made it appear due to the load took to be lifted. As the load increased up to 0.04 Kg the cotton stopped slipping and the efficiency therefore decreased, as I had predicted.

If I had taken more results, I predict that the efficiency would have continued to decrease at the same pace although I believe that there would be a point at which the motor was no longer able to lift the load.

Evaluation

The graph agreed with my prediction, which showed that the results were fairly accurate, as there were no results that were obviously incorrect. However, there was a larger error bar on the time graph for the 0.1-kg load, which showed that the results could have been more precise. The trouble in obtaining our data was that our results greatly depended on both the reaction time and the hand-eye co-ordination of the person in charge of the stopwatch. This meant that our results could not be presumed to be accurate even to the nearest 0.1s. To eliminate this problem a solution could be to set up a circuit using pressure pads so the stopwatch was activated when the load started to be lifted and stop when the load had reached the top. This would cancel all human error.

Another inaccuracy was that the motor appeared to be inefficient before the load reached 0.04 Kg when, in fact, it was not the inefficiency of the motor but instead the inability of the cotton to stay on the spindle efficiently. This problem is difficult to combat, as there appears to be no obvious solution. It is hoped that the blue tack reduced this problem but there does not seem to be any other way to aid the grip on the motor.

Also the cotton may have stretched as more mass was attached to it, this would have increased the time taken for the motor to lift the load as there was a further distance to lift and therefore decreased the efficiency. Nevertheless, I believe that if the cotton did stretch the difference would have been so little that it would have very little bearing on the results. To be convinced of this, the cotton should have been measured regularly to check this was not the case and if it was this should have been taken into account in the equation.

Another problem was that we could not control the ‘stickiness’ of the blue tack and this ‘stickiness’ decreased the more the experiment was repeated. Replacing the blue tack, however, would have been difficult and altered the set-up of the cotton the spindle which may have influenced the results more than the state of the blue tack would have done.

I feel that the results we used were well space, however, I think that it may have been a good idea to continue adding masses until the motor could no longer lift them. There would have been more to conclude from the graph, for example, to see if the efficiency continued to decrease at the same rate.