Royal Academy of Engineering

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THIS IS ENGINEERING

8 Calculating power and energy

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Technique sheet

Problem-based learning resources

Introduction

A few lights at Christmas are always cheering, but how much power is needed to light them all and how much does it cost? Engineers are always having to balance the need for power to drive machines and systems with cost. You want just enough to make the machine work but not so much that it overheats or becomes too expensive. How do power calculations work?

What is energy?

A system has energy when it can do something. So, a stretched elastic band has energy because when you release it the band shrinks back – it creates movement and can pull on something. A charged electric battery contains energy because if you connect it to a bulb, electricity will flow, and the bulb will light. Even a falling weight has energy – so water flowing downhill can generate electricity in a hydroelectric power station. Energy can be confusing because we cannot see it or hear it – we can only detect its effects when it does something. Physicists state this formally when they say energy is the ability of a system to do work.

- Make sure you understand that energy is something we detect when it causes changes in the world around us. Energy is the ability to do something.

How do we measure energy?

Since we can only detect energy when it does something (e.g. moves an object, lights a bulb, heats a filament) we have lots of different meters to measure it. A light meter can measure the energy in light. A thermometer can tell you the temperature – which can be used to calculate the energy stored as heat in the water in a swimming pool. This all involves some mathematical work to convert the observations into a measure of energy in Joules. It takes about 100 Joules of energy to boil enough water for a cup of coffee. It takes roughly the same amount to watch a large flatscreen TV for the 3 minutes it takes to make a cup of coffee! A Joule is quite a small unit so you will also come across a thousand Joules called a kilojoule(kJ) or a million Joules called a megajoule(MJ).

- Make sure you understand that energy is measured in Joules. kilojoules (KJ) and megajoules (MJ) are also used for large values.

Are power and energy the same thing?

Power is the rate at which energy is transferred. The unit to measure power is called the Watt and if you supply 1 joule every second to a system you

are giving it 1 Watt of power. A typical electric kettle delivers 3kW of power when it is on. A large modern wind turbine might produce nearly 10 MW of power in optimum conditions.

- Make sure you can convert between energy in Joules and power in Watts. Remember that 1 Joule per sec is the same as 1 Watt.

What about Amps and Volts?

The flow in an electric circuit is called the current (symbol I) and measured in amps (A). This current flow occurs because two areas with different charges are connected by a conductor. The difference in charge is called the potential difference (p.d.) and is measured in Volts. The current and potential difference are linked – large potential differences produce higher currents in the same circuit. The power transferred by a circuit is calculated by multiplying the potential difference in Volts by the current in Amps. This tells you how much energy is transferred every second because 1 Watt is the same as 1 Joule per second.

- Make sure you can calculate power by multiplying the potential difference in Volts by the current in Amps. This will tell you the energy supplied by the circuit every second.

So, is more powerful better?

To increase the output energy from a device it makes sense to increase the input energy. If you want the bulb to glow more brightly turn up the current to deliver more power. This makes sense, but different bulbs are better than others at converting electricity to light. LEDs convert energy in electricity into light much better than incandescent lightbulbs with a hot wire filament in them. So, an LED that uses 7 Joules per second (7 Watts) gives out as much useful light as an old lightbulb did when it used 150 Joules per second (150W)! Efficiency is measured by dividing the energy we want (e.g. light) by the energy we put in (the electricity) and multiplying the result by 100 to give a percentage.

Efficiency = (useful energy output / energy input) × 100

- Make sure you can calculate efficiency by dividing useful energy output by total energy input and multiplying the result by 100 to give a percentage.

Why is efficiency important?

The more efficient our devices the less input energy is wasted. That means they are cheaper to run! Most domestic appliances now come with efficiency ratings (A+ to E) which show the ones that do their job (e.g. washing clothes, keeping foods frozen) for the lowest electricity input. Efficiency is important in all mechanisms that transfer energy. A streamlined car can slip through the air more quickly than a chunky van of the same weight – so the car is more efficient because you get more useful energy out as movement compared with the van.

- Make sure you can recognise things which might increase the efficiency of machines and mechanisms – either by selecting more efficient versions in the first place or by designing the mechanism to reduce the factors that will cut down efficiency.

Check yourself

You should be able to answer these questions easily after reading this sheet.

1. What is the definition of energy used by engineers and scientists?
2. What is the unit of energy?
3. Why's energy efficiency so important? (think about the cost of running your TV!)?

Taking it further

These activities will deepen your understanding of this topic.

1. Review the power consumption of a variety of devices at college, work, or home. A plate on the back of most devices shows the appropriate voltage and the power consumption in Watts. Which types of devices use the most energy?
2. How much energy could you save by converting all the lightbulbs in your classroom or workshop into LED bulbs? Work out the energy savings even if you had the same light levels. Then work out the saving in energy costs. Taking this into account, how long would it take to repay the cost of LED purchase and installation?
3. Solar panels have now reached 40% efficiency. Research the available systems and work out how long it would take for a solar panel system for a house would take to pay for itself. Assume the house is in Leicester and has a south-facing roof. Annual consumption for the people in the house is 2,750 kWh.