

Episode 115: Energy and power

In this episode, students find that the energy transferred by an electrical component depends on the potential difference across it, the current through it and the time for which it operates.

Summary

Demonstration and discussion: Lamp and joulemeter. (10 minutes)

Student experiment: Power of a lamp. (30 minutes)

Student questions: Electrical power. (20 minutes)

Demonstration + discussion:

Lamp and joulemeter

Start by reviewing the effect of increasing the voltage across a filament lamp. The current through the lamp increases and the lamp gets brighter.

TAP 115-1: Energy transferred by a lamp

Remind your students that the pd is defined as the energy transferred per coulomb and that the current is the number of coulombs per second. If the lamp is connected to a joulemeter you can show that the number of joules transferred increases with time and that the rate increases when voltage and current increase. This should lead to the word equation:

energy transferred = no. of joules per coulomb \times number of coulombs
= pd across lamp \times current through lamp \times time

ending up with the equation:

energy transferred = $V I t$

Now remind them that power is rate of transfer of energy leading to $P = I V$ (they may also need to be reminded of the S.I. units, watts).

This exercise can be rounded off by calculating power and showing that (at the rated voltage) it is equal to the quoted power of the lamp.

Student experiment:

Power of a lamp

At this stage, students should investigate the way power depends on pd across the lamp. Ask them to predict the effect of doubling the voltage. Some will expect the power to double. More able students may suggest that it quadruples (arguing that both I and V double). In fact neither answer is correct in practice. At higher currents the filament is hotter so the resistance is higher and the current does not double when the voltage doubles.

The results of the experiment will lead to useful discussion about energy, power, voltage, current and resistance.

TAP 115-2: The filament lamp: The relationship between power and applied potential difference.

Student questions:

Electrical power

Applying the above ideas.

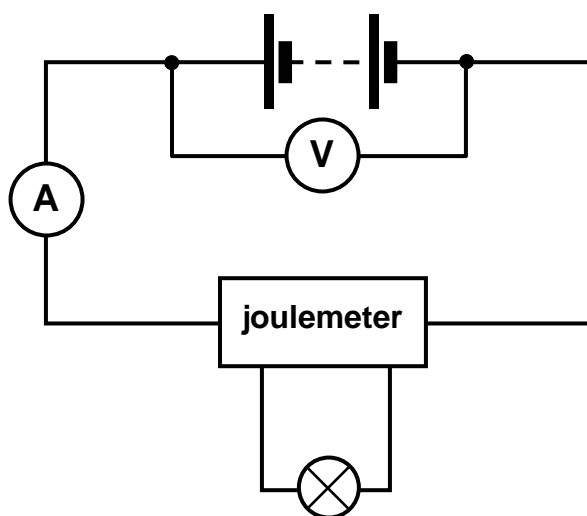
TAP 115-3: Types of light bulb

TAP 115- 1: Demonstration: Energy transferred by a lamp.

Requirements

- ✓ 4 mm leads
- ✓ stopwatch
- ✓ filament lamp 12 V, 24 W in holder
- ✓ display ammeter, voltmeter and joulemeter
- ✓ power supply, 0–12 V dc

The outputs of the ammeter, voltmeter and joulemeter should be visible to the class.



Set-up:

Show the effect of increasing the voltage across a filament lamp. The current through the lamp increases and the lamp gets brighter.

If the lamp is connected to a joulemeter you can show that the number of joules transferred increases with time and that the rate increases when voltage and current increase.

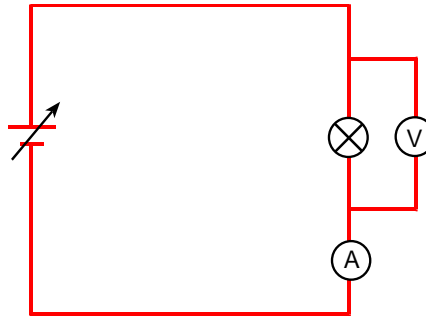
TAP 115- 2: The filament lamp: The relationship between power and applied potential difference

Power dissipation in the filament lamp

How does the electrical power dissipation in a filament lamp vary with the potential difference across it? Remember that the filament has to heat up to a very high temperature before it gives off any light. The filament resistance changes with temperature, and so with the applied potential difference. In this activity you will find out how the power consumption is related to the applied pd

Requirements

- ✓ 4 mm leads
- ✓ stopwatch
- ✓ filament lamp 12 V, 24 W
- ✓ 2 of digital multimeter
- ✓ power supply, 0–12 V dc



What you have to do

1. Set up the circuit shown.
2. Select 0 V on your power supply before switching on the power supply. Switch on the power supply and adjust to a value between 0 V and the maximum voltage rating of the bulb. Warning: you must not exceed the voltage rating of your bulb. Ask for help if in doubt.
3. Record the ammeter and voltmeter readings.
4. Repeat for different potential differences (use at least 6 different voltages between 0 V and 12 V).
5. Record your results in the table, or enter them directly into a spreadsheet.
6. Take steps to check your readings.

Potential difference	Current	Power	Resistance
V / V	I / A	P / W	R / Ω

Using your results

Plot a graph of power against voltage. By what factor does the power increase when the voltage doubles? Can you explain this?

Alternative method using a joulemeter

Instead of using an ammeter and voltmeter, connect a filament bulb in a lamp holder to the joulemeter which measures the power dissipated in the lamp.

Reset the joulemeter if applicable. Select 0 V on your power supply. You will select different voltages each time. Warning: you must not exceed the voltage rating of your bulb. Ask for help if in doubt.

Switch on the power supply and adjust to the value required. Switch on the stop clock and reset the joulemeter at the same time. Record the voltmeter reading and also ensure the voltage remains constant. Switch off after 30 seconds or longer, record the time and the joulemeter reading.

Repeat for different voltages (potential differences).

Practical advice

For the first version of this experiment you may like to use smoothing units, if available. However purchase is not justified for this occasional use. Similarly, the alternative method is only for those who already own joulemeters.

The experiment itself is very easy but students should be encouraged to check their readings.

Alternative method using a joulemeter: Many joulemeters come with dual ranges and a scaling of the reading. Most students will not have used a digital joulemeter and will need careful supervision. There is a class joulemeter on the market, but that requires 9–12 V.

External references

This activity is taken from Advancing Physics Chapter 2, 140E

TAP 115- 3: Kinds of light bulb

People use electric light bulbs for many purposes, from a torch used to light up a path home, to aircraft searchlights. These lamps differ tremendously in the power they use.

- All bulbs are stamped with two different values, for instance 36 W, 12 V. What do these numbers tell you?
- You can also use these values to calculate the current and the resistance of the bulb filament. The table below shows these values for five different bulbs. Use a suitable formula to calculate the missing values.

Bulb	Power / W	pd / V	Current / A	Resistance / Ω
Headlamp	36	12		4
Torch bulb	0.09	3	0.03	
Filament bulb	100	230		529
Flashlight bulb	4.5	9	0.5	
Energy Saving bulb	24	230		

Fuse protection

- Explain why appliances are protected by a fuse and explain how the fuse provides this protection.
- The table shows the power rating and voltage as marked on a number of appliances. Calculate the operating current of each appliance. Suggest a suitable fuse value for each appliance choosing from the fuse values given.

Appliances	Power rating	pd / V	Operating current / A	Suggested fuse values choosing from 3 A; 5 A, 13 A
Iron	1200 W	230		
Vacuum cleaner	900 W	230		

Headlamp	48 W	12		
Jug kettle	2.4 kW	230		
Radio	100 W	230		
Travel kettle	340 W	120		
Microwave cooker	1.4 kW	230		

Practical advice

These are a set of mainly pre-16 level revision questions. Some could be used as 'warm-up' exercises after the summer break. The use of real numbers, including the mains voltage of 230 V provides an opportunity to think about the use of calculators and significant figures in answers.

Answers and worked solutions

1. Power in watts – rate of energy use; operating potential difference in volts, pd at which it is designed to work.

2.

Bulb	Power / W	pd / V	Current / A	Resistance / Ω
Headlamp	36	12	3.0	4.0
Torch bulb	0.09	3	0.03	100
Filament bulb	100	230	0.43	530
Flashlight bulb	4.5	9	0.5	18
Energy Saving bulb	24	230	0.10	2200

3. To prevent too much power passing through the cable (the fuse is to protect the cable not the appliance) - the fuse melts.

4.

Appliances	power rating	pd / V	operating current / A	Suggested fuse values choosing from 3 A; 5 A, 13 A
Iron	1200 W	230	5.2	13
Vacuum cleaner	900 W	230	3.9	5
Head lamp	48 W	12	4.0	13
Jug kettle	2.4 kW	230	10	13
Radio	100 W	230	0.43	3

Travel kettle	340 W	120	2.8	3*
Microwave cooker	1.4 kW	230	6.1	13

*The surge that takes place when you switch on any kettle *might* cause the fuse to blow, due to the lower cold resistance of the element when you first switch on, if you fit a 3 A fuse. In real life (not exams) fuses blow at roughly twice the rated value!

External references

This activity is adapted from Advancing Physics Chapter 2, 30S