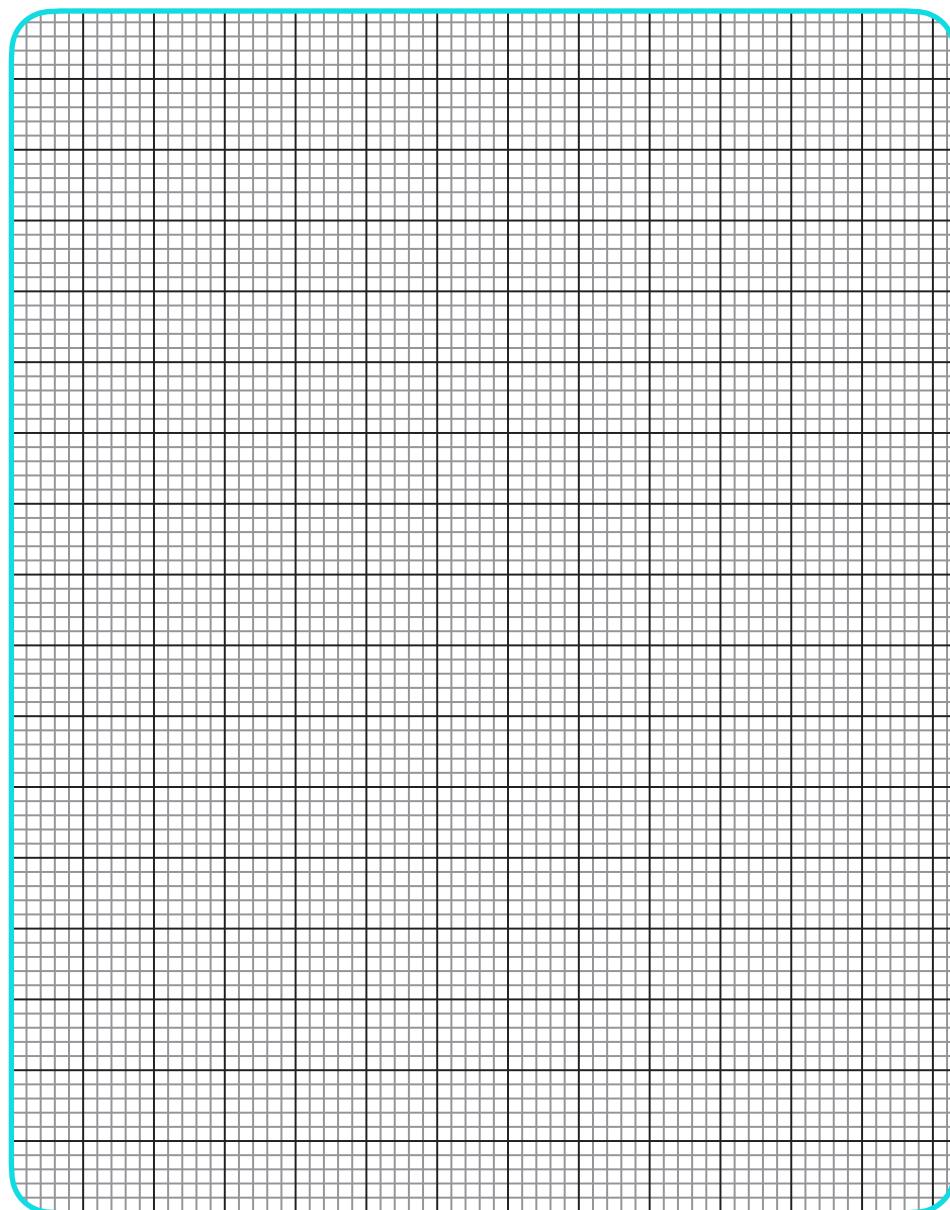
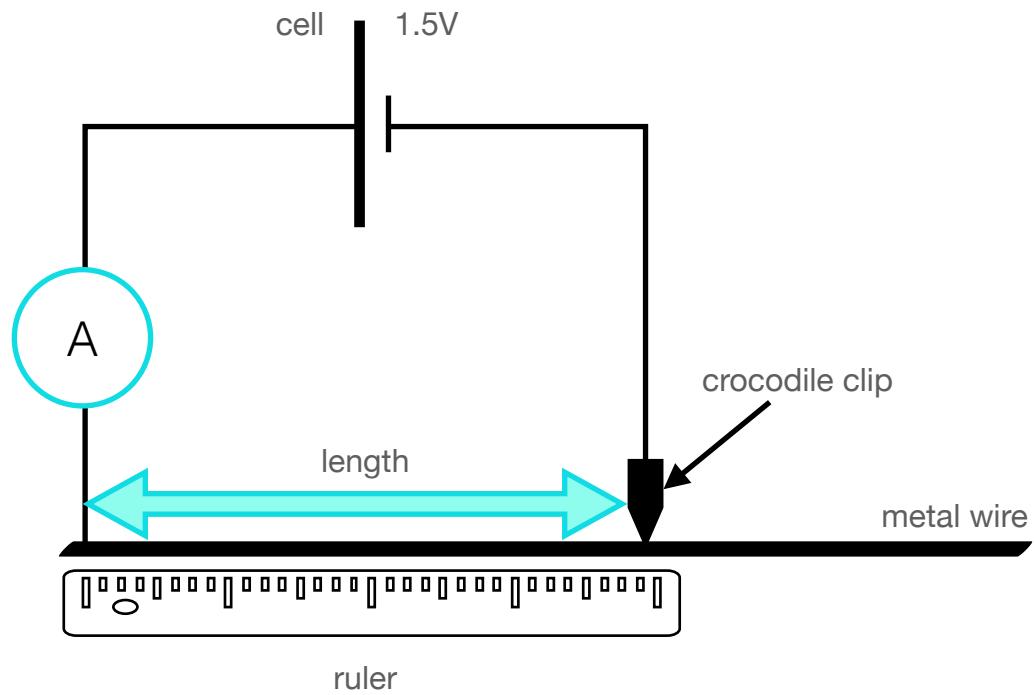


# resistance vs length



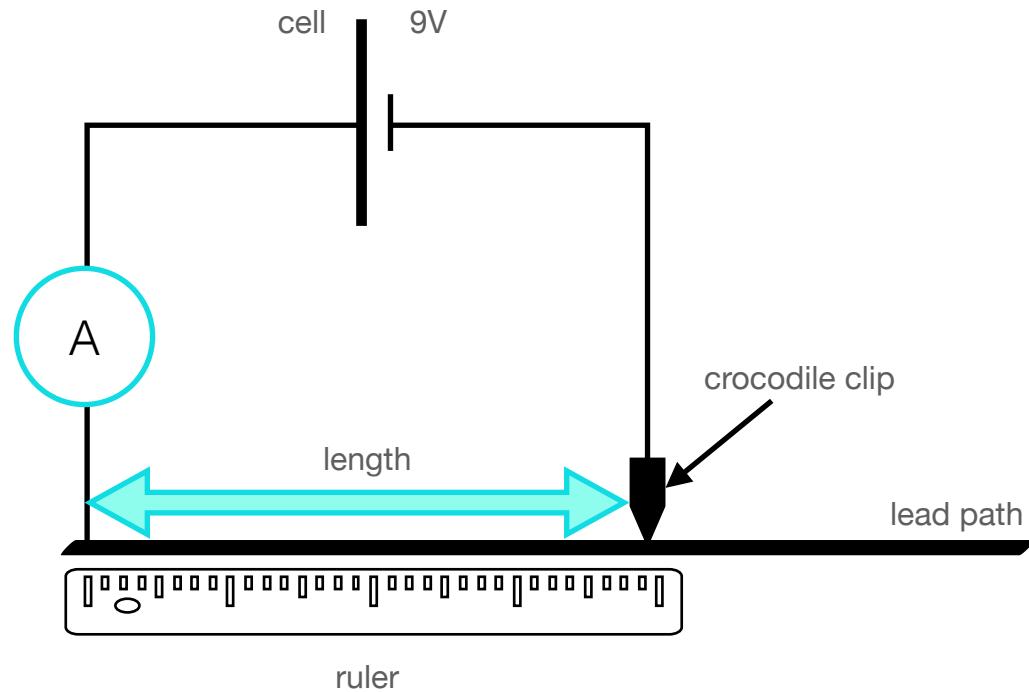
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# pencil lead resistance



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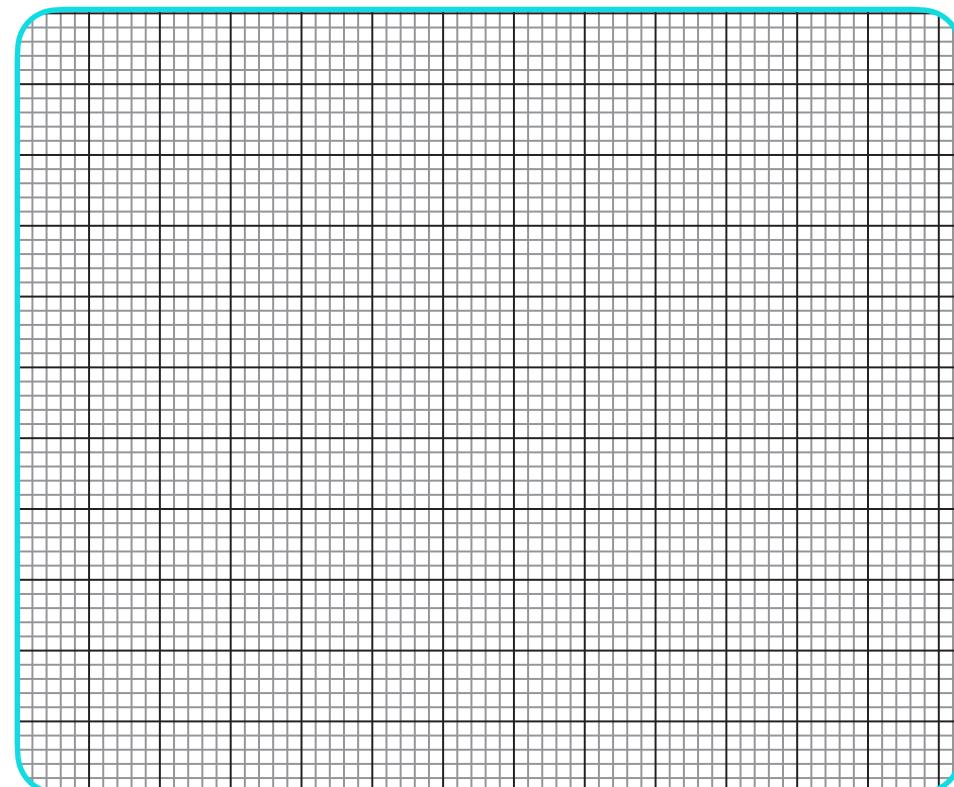
## equipment

1. multimeter, ideally with micro Amp precision
2. x3 test leads a.k.a crocodile leads
3. ruler
4. 9V battery

lead type: shade in these lines with different leads

lead type:

lead type:



# Questions



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## pencil lead resistance

1. Convert 400 micro Amps ( $\mu\text{A}$ ) into Amps.
2. If the current through a wire is 250 micro Amps at a voltage of 9V what resistance is the wire?
3. Use a spreadsheet to record all my measurements and find the resistance for each current value. Plot resistance vs length for each lead type. Be careful with your units.
4. Describe how you could determine the type of pencil lead used to draw a line.
5. Have a look at the page on series and parallel resistors. Can you do that experiment using pencil lead on paper like in this experiment?

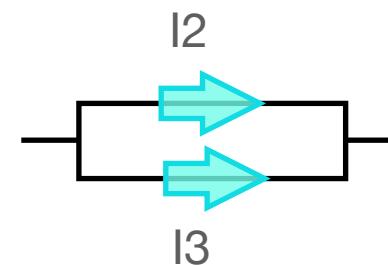
# Answers



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## pencil lead resistance

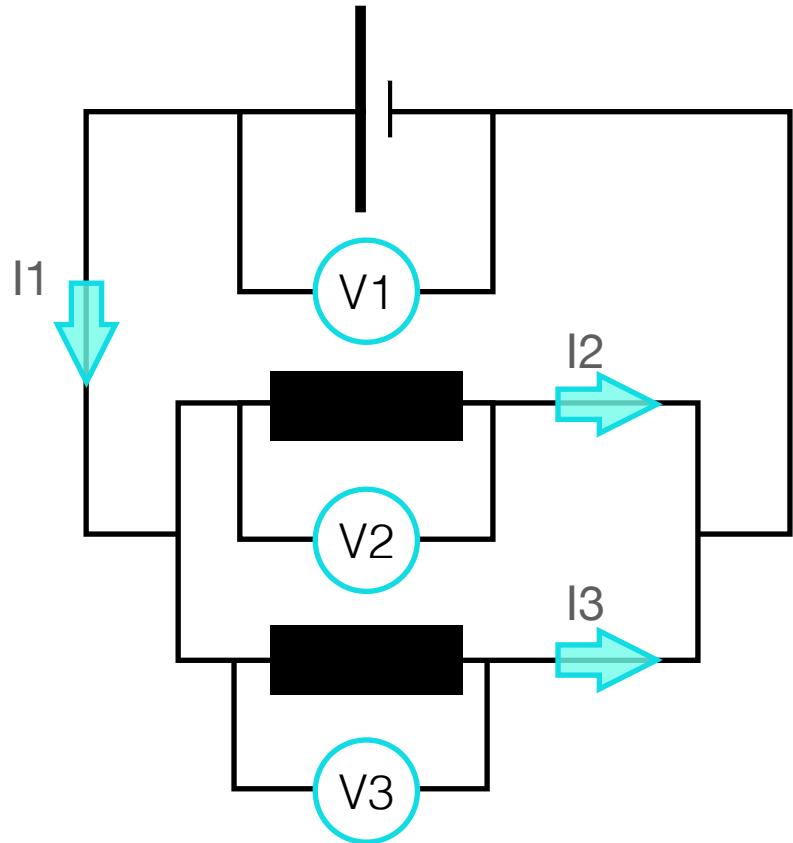
1. Convert 400 micro Amps ( $\mu\text{A}$ ) into Amps.  $1\mu\text{A} = 1 \times 10^{-6}\text{A} = 0.000001\text{A}$ . So divide by 1 million.  $400\mu\text{A} = 0.0004\text{A}$
2. If the current through a wire is 250 micro Amps at a voltage of 9V what resistance is the wire?  $\mathbf{V=IR \text{ so } R = V/I}$   $9/(0.00025) = 36000\Omega$
3. Use a spreadsheet to record all my measurements and find the resistance for each current value. Plot resistance vs length for each lead type. Be careful with your units.
4. Describe how you could determine the type of pencil lead used to draw a line. **Using the data from the video our your own experiment you can figure out the resistance of 1cm of each type of pencil lead. Measure the resistance of the line and then divide by its length. The number you get should match the value for one of the types of lead.**
5. Have a look at the page on series and parallel resistors. Can you do that experiment using pencil lead on paper like in this experiment? **The series example is very simple, a pencil line 5cm long is just a 2cm in series with a 3cm and so on. The parallel example should be doable but remember that in physics most of the time we use wires with very low resistance whereas in this experiment every length of lead has a high resistance. we could draw patterns like this to test the parallel resistance equation, but remember to measure the whole length of each path the current can take.**



# series and parallel circuits



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$I_1 =$  \_\_\_\_\_

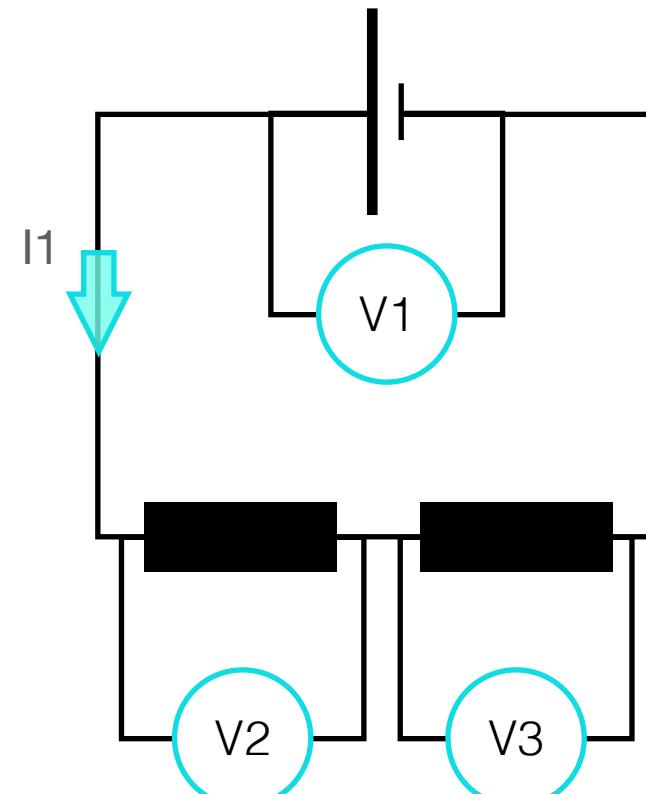
$V_1 =$  \_\_\_\_\_

$I_2 =$  \_\_\_\_\_

$V_2 =$  \_\_\_\_\_

$I_3 =$  \_\_\_\_\_

$V_3 =$  \_\_\_\_\_



$I_1 =$  \_\_\_\_\_

$V_1 =$  \_\_\_\_\_

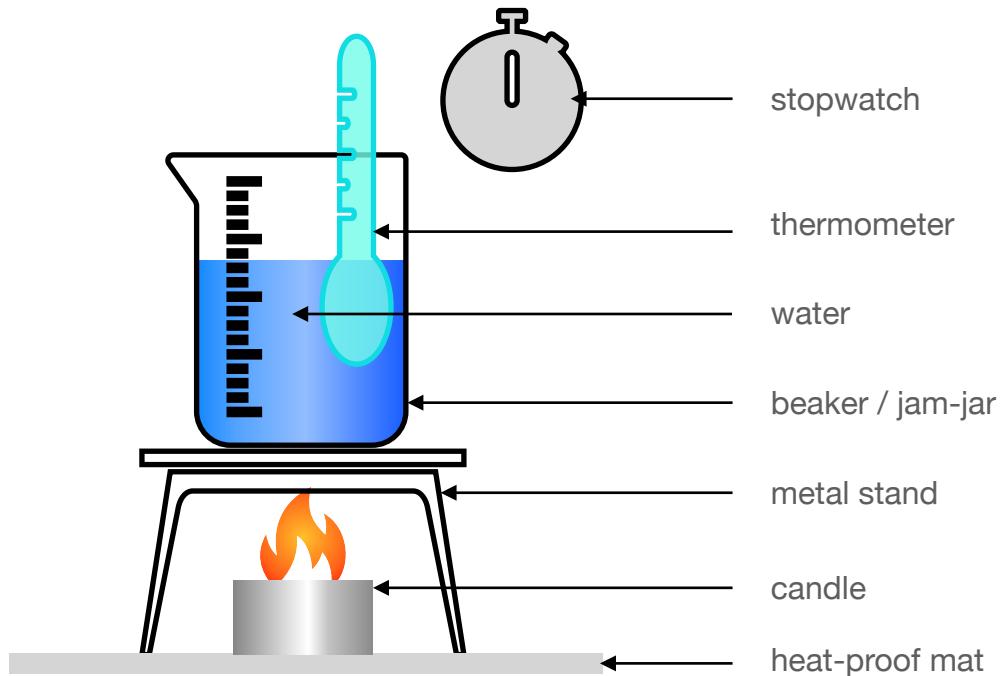
$V_2 =$  \_\_\_\_\_

$V_3 =$  \_\_\_\_\_

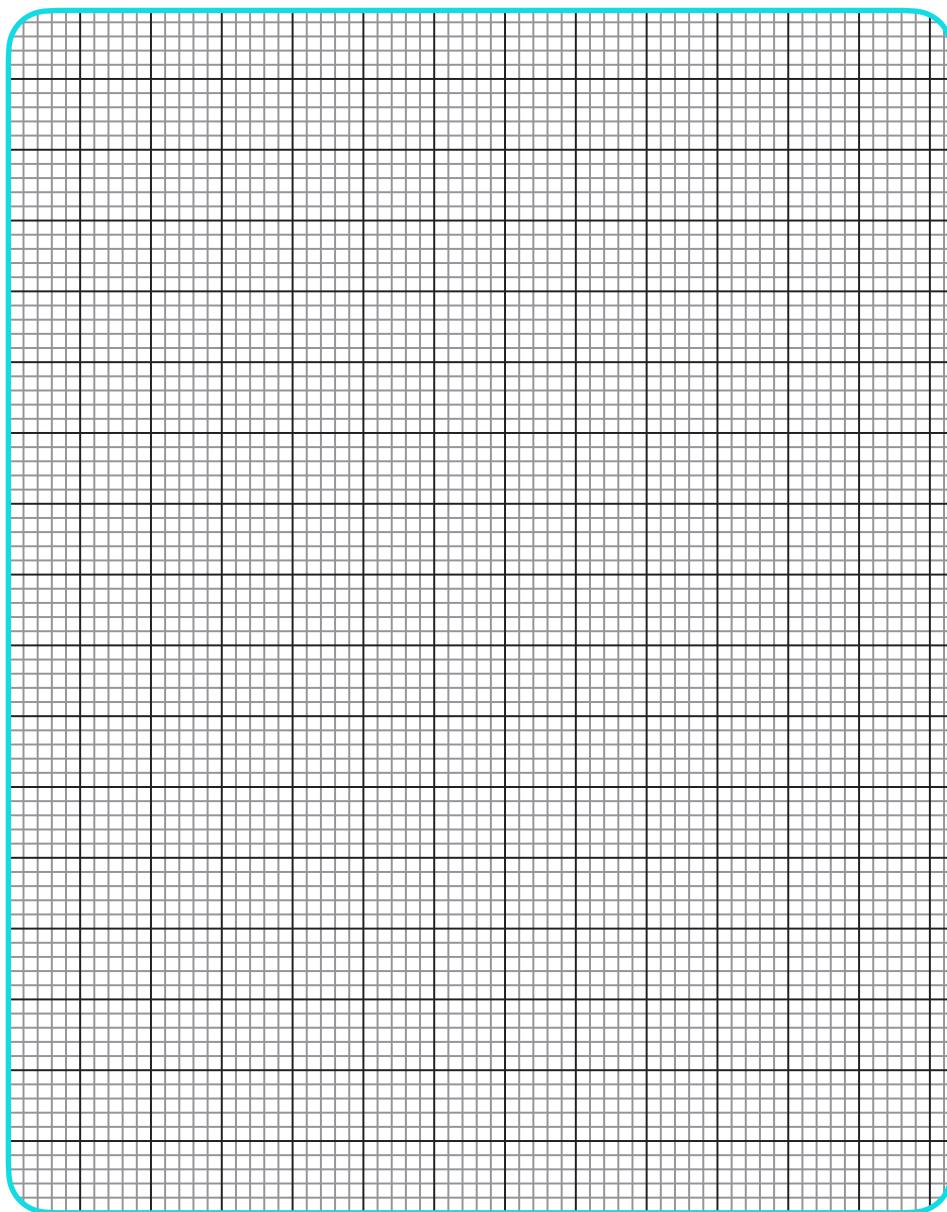
# specific heat capacity



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amount of water	
time ( )	temperature ( )



# Questions



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## specific heat capacity candle power

1. Plot a graph of temperature vs time for this experiment.
2. Why did I drill a hole in the lid to hold the thermometer instead of just standing the thermometer in the water?
3. There are many sources of error in this experiment. Describe 3 of them and say whether they will cause me to over or under-estimate the power output of the candle.

## Fail! Specific heat capacity of 2 materials

1. Plot a graph of temperature vs time for this experiment.
2. Take the specific heat capacity of steel to be 420J/Kg K. How much energy should it take to heat the steel nuts in this video by 30K?
3. Do the same calculation for the water in this video.
4. Why do you think my result was so far off?

# Answers



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## specific heat capacity candle power

1. Plot a graph of temperature vs time for this experiment.
2. Why did I drill a hole in the lid to hold the thermometer instead of just standing the thermometer in the water?  
**To reduce heat loss to the air**
3. There are many sources of error in this experiment. Describe 3 of them and say whether they will cause me to over or under-estimate the power output of the candle.

**The candle loses a lot of heat to the air and the glass jar causing us to underestimate the candle's power.**

**The water will loose heat through the walls of the jam jar by conduction, also causing us to underestimate the candle's power.**

**The candle may not burn at a uniform rate, introducing a random error into the power output.**

**The jam jar lid will conduct heat to the air causing an underestimate of the candle's power.**

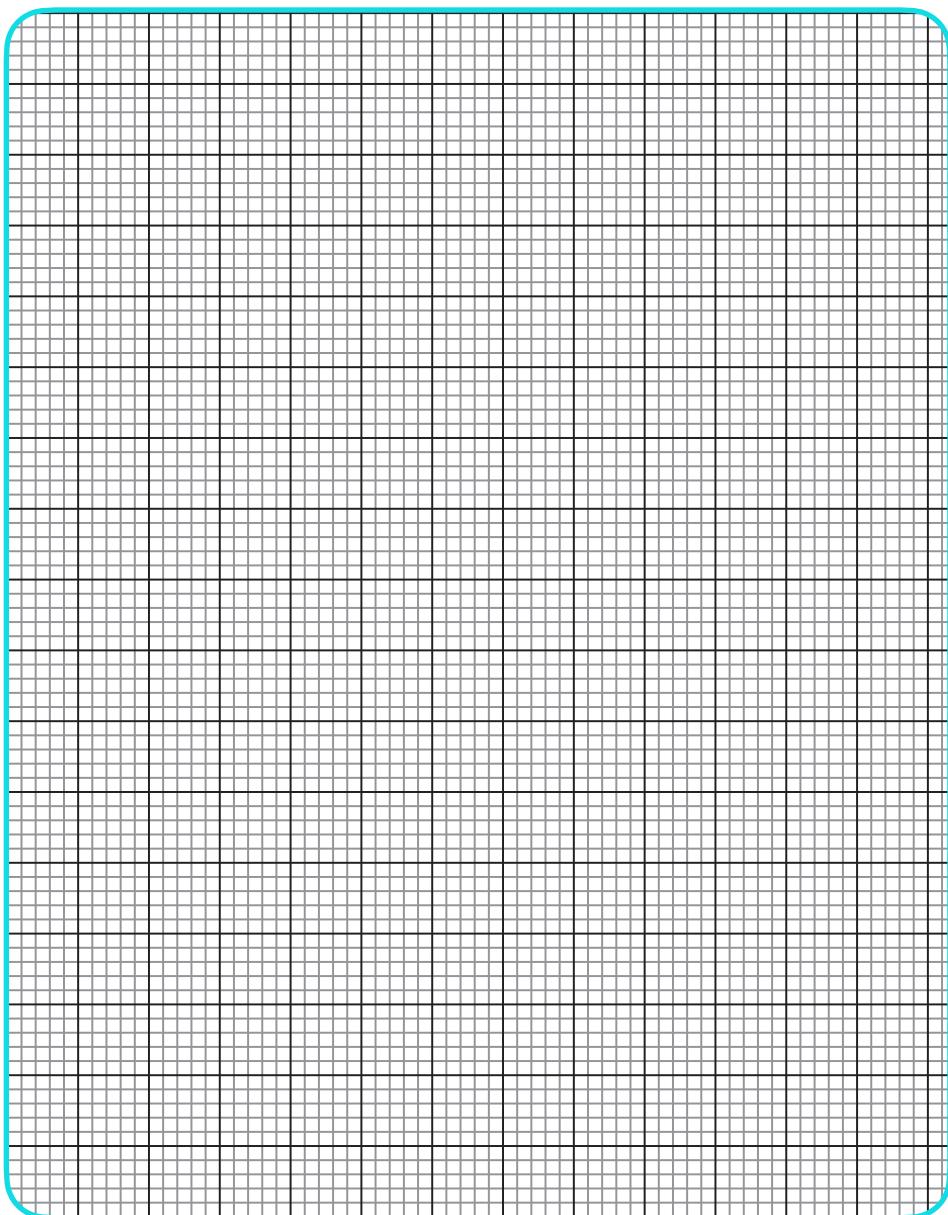
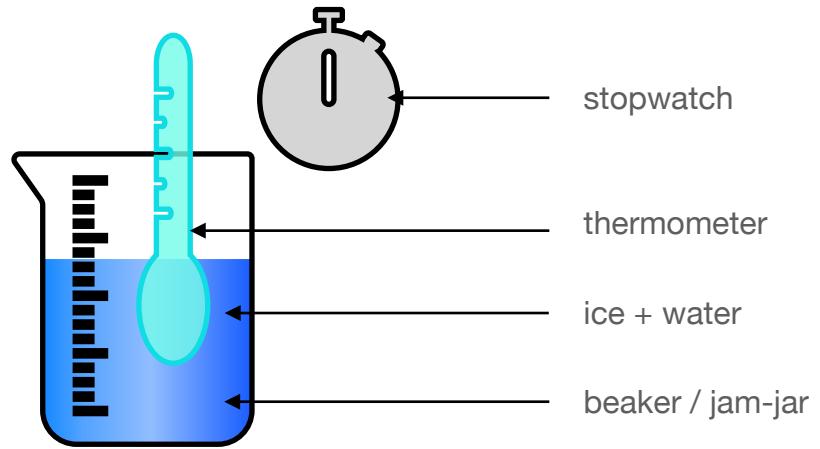
## Fail! Specific heat capacity of 2 materials

1. Plot a graph of temperature vs time for this experiment.
2. Take the specific heat capacity of steel to be 420J/Kg K. How much energy should it take to heat the steel nuts in this video by 30K?  $E = m c \Delta T = 0.08513 * 420 * 30 = 1072J$
3. Do the same calculation for the water in this video.  $E = m c \Delta T = 0.0731 * 4182 * 30 = 9171J$
4. Why do you think my result was so far off? **Since the experiment is set up the same as the other video the sources of systematic error mentioned on the left should all be in-play in this experiment too but this means the value of 11W remains a good estimate of how rapidly the jam jar and its contents absorb heat energy in these circumstances, therefore they cannot be reasons for the current error. Compare the flame at 0:34 and then 1:36 (video time) and I think the most likely reason is actually the non-uniform burn rate of the candle, if it burned slower because it was running out of wax we would have over estimated the heat capacity of steel which is what happened.**

# latent heat of water



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# Questions



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## latent heat ice melting experiment

1. Play from 0:26 Why do I say "It's not important?"
2. What temperature does the ice water start at (0:33)?
3. At what time does the temperature begin to rise?
4. At around 44 mins the reading on the thermometer drops a bit, why do you think that is?
5. What mass of ice did I use?
6. The latent heat of fusion for water is 333KJ per Kg. How much energy would it take to melt the ice in this video if the ice's temperature is 0°C?

## the frozen thermometer experiment

1. How long does it take the ice to heat up to 0°C?
2. At around 0:29 we can see condensation disappearing from the side of the test tube, why?
3. The temperature reading drops at one point in this video, too. What time (stopwatch or video) does this happen and why do you think it happens? (2:18:48 or 1:22)
4. The specific heat capacity of ice is 2.04KJ per Kg. Suppose we have 60g of water in this video. How much energy did it take to heat the ice up to 0°C?
5. How long did warming up take? And so how rapidly was heat flowing through the walls of the test tube during this time? Your answer should be in Watts.

# Answers



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## latent heat ice melting experiment

1. Play from 0:26 Why do I say "It's not important?" **it's just there to speed up the process. The ice would melt anyway.**
2. What temperature does the ice water start at (0:33)? **We would expect 0°C but the thermometer reads ~2°C perhaps because of the water I added.**
3. At what time does the temperature begin to rise? **0:41mins wall time or 0:52sec video time**
4. At around 44 mins the reading on the thermometer drops a bit, why do you think that is? **Perhaps because as the ice repositions itself it gathers around the thermometer more closely. Remember the thermometer takes a reading along its length, not at a single point.**
5. What mass of ice did I use? **118g**
6. The latent heat of fusion for water is 333KJ per Kg. How much energy would it take to melt the ice in this video if the ice's temperature is 0°C?  **$E = m L = 0.118 * 333 = 39KJ$**

## the frozen thermometer experiment

1. How long does it take the ice to heat up to 0°C? **Hard to judge! Anywhere from 8:00-10:30 wall time. N.B you can skip forward and back in videos using the ,. keys.**
2. At around 0:29 we can see condensation disappearing from the side of the test tube, why? **The test tube is no longer cold enough to cause condensation to form and then freeze, instead it probably forms as a liquid and runs down the sides.**
3. The temperature reading drops at one point in this video, too. What time (stopwatch or video) does this happen and why do you think it happens? **(2:18:48 wall time or 1:22 video)**
4. The specific heat capacity of ice is 2.04KJ per Kg. Suppose we have 60g of water in this video. How much energy did it take to heat the ice up to 0°C? **It's hard to measure the start temp in °C because it's off the scale but it is clearly about 10°F which is -12.2°C so  $dT = 12.2°C$ .  $E = m C dT = 0.06 * 2.04 * 12.2 = 1.49KJ$**
5. How long did warming up take? And so how rapidly was heat flowing through the walls of the test tube during this time? Your answer should be in Watts. **From Q1 let's say 8 minutes. Power = Energy transferred / time taken = 1.49KJ / 490 sec = 3W**