Leaving Cert Physics Long Questions 2018 - 2002

5. *Temperature and Heat*

Please remember to photocopy 4 pages onto one sheet by going A3→A4 and using back to back on the photocopier

Contents

Specific heat capacity of copper = $390\ J\ kg^{-1}\ K^{-1}$;

Specific heat capacity of water = $4200\ J\ kg^{-1}\ K^{-1}$

Specific heat capacity of aluminium = $910\ J\ kg^{-1}\ K^{-1}$;

Specific latent heat of fusion of ice is $3.3 \times 10^5\ J\ kg^{-1}$

Specific latent heat of vaporisation of water = $2.3 \times 10^6\ J\ Kg^{-1}$

Temperature: ordinary level questions

2014 Question 7 (a) [Ordinary Level]

The temperature of an object can be measured using a thermometer which is based on a suitable thermometric property.

(i) What is heat?

(ii) What is meant by temperature?

(iii) Give an example of a thermometric property.

(iv) The SI unit of temperature is the kelvin. Give another temperature scale.

(v) Express 310 K in the units of the scale you have named in part (*iv*).

2013 Question 9 [Ordinary Level]

(i) When heat is transferred to or from an object the temperature of the object changes. What is heat?

(ii) Name the three ways in which heat can be transferred.

(iii) Describe an experiment to show how heat is transferred in a liquid.

(iv) The water in an electric kettle is heated by the element and its handle is made from an insulating material.
How does the method of heat transfer in a liquid affect the positioning of the heating element in a kettle?

(v) Why is the handle of a kettle made of an insulating material?

(vi) Name an insulator suitable for use in the handle of a kettle.

2011 Question 8 (a) [Ordinary Level]

(i) What is meant by a thermometric property?

(ii) Name two different thermometric properties.

(iii) Name two different thermometers.

(iv) Describe how to calibrate a thermometer.

(v) Why is there a need for a standard thermometer?

2009 Question 12 (b) [Ordinary Level]

(i) What is meant by the temperature of a body?

(ii) Name two scales that are used to measure temperature.

(iii) What is the boiling point of water on each of these scales?

(iv) The diagram shows a laboratory thermometer, what is its thermometric property?

(v) Name one other type of thermometer and state its thermometric of property.

(vi) Why is there a need for a standard thermometer?

2008 Question 7 (a) [Ordinary Level]

The temperature of an object is measured using a thermometer, which is based on the variation of its thermometric property.

(i) What is meant by temperature?

(ii) What is the unit of temperature?

(iii) Give an example of a thermometric property.

2005 12 (a) [Ordinary Level]

To calibrate a thermometer, a thermometric property and two fixed points are needed.

(i) What does a thermometer measure?

(ii) What are the two fixed points on the Celsius scale?

(iii) Explain the term thermometric property.

(iv) Name the thermometric property used in a mercury thermometer.

(v) Give an example of another thermometric property.

Temperature: higher level questions

2003 Question 12 (b) [Higher Level]

(i) What is the difference between heat and temperature?
(ii) The emf of a thermocouple can be used as a thermometric property.
Explain the underlined terms.
(iii) Name a thermometric property other than emf.
(iv) Explain why it is necessary to have a standard thermometer.

2015 Question 12 (c) [Higher Level]

(i) A thermometer uses a thermometric property to measure temperature.
The thermometric property of a thermocouple thermometer is emf.
Explain the underlined terms.
(ii) What is the SI unit of temperature?
(iii) Give an advantage of using this unit in scientific measurements.
(iv) Describe a laboratory experiment to demonstrate the principle of operation of a thermocouple.
(v) Give an advantage of using a thermocouple thermometer instead of a mercury-in-glass thermometer.

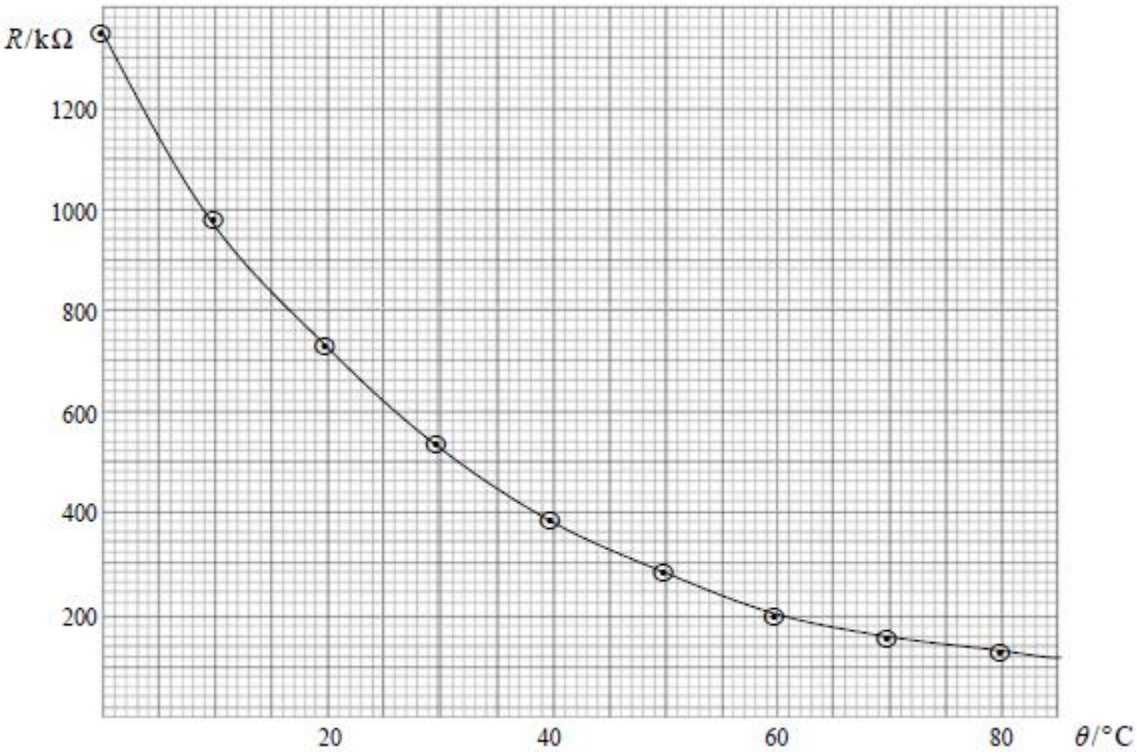
2011 Question 7 (c) [Higher Level]

(i) A thermocouple is used to measure the temperature of the steam.
How would you demonstrate the principle of operation of a thermocouple?
(ii) Describe how to establish a calibration curve for a thermocouple.

2013 Question 12 (d) [Higher Level]

(i) What is meant by the term thermometric property?

This graph was obtained during an experiment where the resistance R of a thermistor was measured as its temperature θ was raised from 0 °C to 100 °C (as measured by a mercury-in-glass thermometer).



The thermistor is used in a circuit to keep the water in a tank at a constant temperature.

(ii) What is the temperature of the water when the resistance of the thermistor is 420 kΩ?

(iii) A thermocouple thermometer has emf values of 0 μV at 0 °C and 815 μV at 100 °C.
When the thermocouple thermometer was placed in the tank of water, its emf was found to be 319 μV.
What is the temperature of the water in the tank as measured by the thermocouple thermometer?

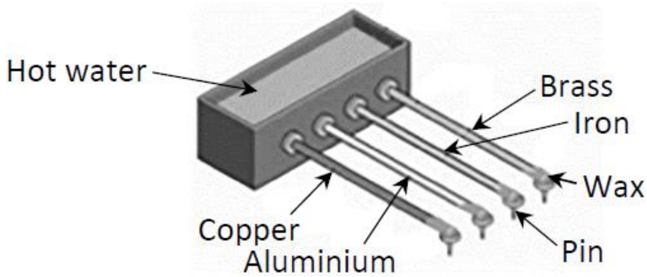
(iv) Why do the thermistor and the thermocouple thermometer give different temperature readings for the water in the tank?

Heat: ordinary level theory questions

2018 Question 7 [Ordinary Level]

The temperature of an object can be measured using a thermometer.

(i) What is heat?
(ii) What is meant by the temperature of an object?
(iii) What is the unit of temperature on the SI scale?
(iv) Express 20 °C in the units you have named in part (iii).



The diagram shows an apparatus used to compare heat transfer in different metals.

(v) Name the method by which heat is transferred in metals.
(vi) Name the two other methods of heat transfer.
(vii) How can this experiment be used to find out which metal is the best at allowing heat transfer?
(viii) State two ways of making sure that this investigation is fair.
(ix) Metals are good conductors. Name a good insulator.

2014 Question 7 (b) [Ordinary Level]

The photograph shows an experiment to compare the heat transfer in different metals. A piece of wood is placed in a drop of wax at the end of each piece of metal and a heat source is used to heat the metals at the centre of the apparatus.

(i) How is heat transferred in metals?
(ii) Name the two other methods of heat transfer.
(iii) How can this experiment be used to find out which of the metals is best at allowing heat transfer?
(iv) State one way to make sure that this is a fair test.

2012 Question 9 (a) [Ordinary Level]

(i) The temperature of an object is a measure of its hotness or coldness.
What is the SI unit of temperature?
(ii) The Celsius scale is the practical temperature scale.
How is the degree Celsius (°C) related to the SI unit of temperature?
(iii) When heat is transferred to a substance, it causes a rise in temperature or a change in state of the substance, or both.
What is heat?
(iv) Name the three methods of heat transfer.
(v) What is meant by the change in state of a substance?
(vi) Define specific latent heat.

2010 Question 8 (a) [Ordinary Level]

(i) What is heat?
(ii) Explain how heat is transferred in a solid.
(iii) Describe an experiment to compare the rates of heat transfer through different solids.
(iv) Explain the term U-value
(v) How can the U-value of the walls of a house be reduced?

2010 Question 8 (b) [Ordinary Level]

The diagram shows a solar heating system.

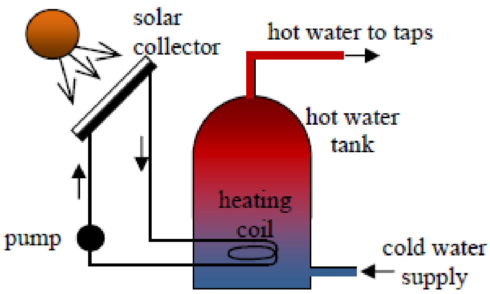
(i) How is the sun's energy transferred to the solar collector?

(ii) Why is the solar collector normally painted black?

(iii) How is the heat transferred from the solar panel to the hot water tank?

(iv) The heating coil for the hot water tank are placed at the bottom, explain why.

(v) Give an advantage and a disadvantage of a solar heating system.



2008 Question 7 (c) [Ordinary Level]

The rise in temperature of an object depends on the amount of heat transferred to it and on its specific heat capacity.

(i) What is heat?

(ii) Name three ways in which heat can be transferred.

(iii) Define specific heat capacity.

2006 Question 7 (a) [Ordinary Level]

(i) Heat can be transferred in a room by convection.

(ii) What is convection?

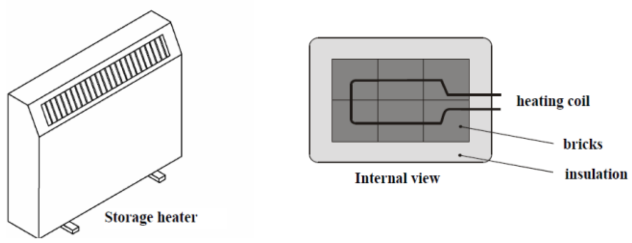
(iii) Name two other ways of transferring heat.

(iv) Describe an experiment to demonstrate convection in a liquid.

(v) In an electric storage heater, bricks with a high specific heat capacity are heated overnight by passing an electric current through a heating coil in the bricks.
The bricks are surrounded by insulation.
Why is insulation used to surround the bricks?

(vi) Name a material that could be used as insulation.

(vii) Explain how the storage heater heats the air in a room.



2004 Question 7 [Ordinary Level]

(i) Heat can be transferred by conduction. What is meant by conduction?

(ii) Name two other ways of transferring heat.

(iii) Describe an experiment to show how different solids conduct heat at different rates.

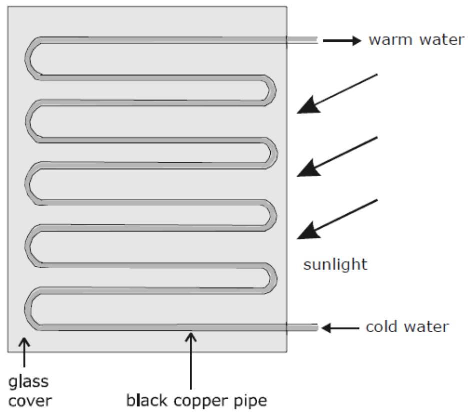
(iv) The *U*-value of a house is a measure of the rate of heat loss to the surroundings.
Give two ways in which the *U*-value of a house can be reduced.

(v) The diagram shows a solar panel (solar heater) which can be used in the heating of a house.
What energy conversion takes place in a solar panel?

(vi) Why are the pipes in the solar panel usually made from copper?

(vii) Why are the pipes in the solar panel usually painted black?

(viii) Why does warm water rise to the top of the solar panel?



Heat: ordinary level maths questions

2002 Question 12 (b) [Ordinary Level]

(i) Define specific heat capacity.

(ii) An electric kettle contains 1.5 kg of water. The specific heat capacity of water is 4180 J kg^{-1} K^{-1}.
Calculate the amount of energy required to raise the temperature of the water from 15 ^{0}C to 100 ^{0}C.

(iii) The kettle takes 4 minutes to heat the water from 15 ^{0}C to 100 ^{0}C.
Calculate the power of the kettle. (Assume all the energy supplied is used to heat the water).

(iv) Why is the heating element of an electric kettle near the bottom?

2013 Question 9 (b) [Ordinary Level]

A kettle contains 1.3 kg of water with a specific heat capacity of 4200 J kg^{-1} K^{-1}.
The temperature of the water rises from 10 °C to 80 °C during a three-minute period.

(i) Calculate the energy gained by the water.

(ii) Calculate the power rating of the kettle, assuming all of the electrical energy is used to heat the water.

2011 Question 8 (b) [Ordinary Level]

An electric kettle is filled with 500 g of water and is initially at a temperature of 15 ^{0}C.
The kettle has a power rating of 2 kW.

(i) Calculate the energy required to raise the temperature of the water to 100 ^{0}C.

(ii) How much energy is supplied by the kettle every second?

(iii) How long will it take the kettle to heat the water to 100 ^{0}C?

(iv) Name a suitable material for the handle of the kettle. Justify your answer.
(specific heat capacity of water = 4180 J Kg^{-1} K^{-1})

2018 Question 12 (c) [Ordinary Level]

The diagram shows a water boiler which is filled with 0.7 kg of water which is initially at 20 ^{0}C.
The boiler has a power rating of 3 kW.

(i) Calculate the energy needed to raise the temperature of the water from 20 ^{0}C to 90 ^{0}C.

(ii) How many joules of energy are supplied per second by the boiler?

(iii) Calculate how long it will take the boiler to heat the water to 90 ^{0}C.

(iv) Where should the manufacturer place the heating element of the boiler? Explain your answer.
(specific heat capacity of water = 4200 J kg^{-1} K^{-1})

2015 Question 9 [Ordinary Level]

(i) Distinguish between heat and temperature.

The diagram shows a kettle which is filled with 500 g of water which is initially at a temperature of 20 °C.
The heating element of the kettle has a power rating of 0.8 kW.
We assume all the heat is transferred to the water.

(ii) Find the energy required to raise the temperature of the water to 100 °C.

(iii) What is the energy supplied by the element per second?

(iv) How long will it take the kettle to heat the water to 100 °C?

(v) Why are handles of kettles often made of plastic?

(vi) How is the heat transferred throughout the liquid in the kettle?

(vii) Why is the heating element of a kettle made of metal?

(viii) The heat source for a kettle is placed at the bottom. Suggest why this is the case.

(specific heat capacity of water = 4180 J $kg^{-}1$ K^{-1})

2008 Question 7 (c) [Ordinary Level]

A saucepan containing 500 g of water at a temperature of 20 °C is left on a 2 kW ring of an electric cooker until it reaches a temperature of 100 °C.

All the electrical energy supplied is used to heat the water.

(i) Calculate the rise in temperature of the water;

(ii) Calculate the energy required to heat the water to 100 °C;

(iii) Calculate the amount of energy the ring supplies every second;

(iv) Calculate the time it will take to heat the water to 100 °C.

2006 Question 7 (b) [Ordinary Level]

The total mass of the bricks in a storage heater is 80 kg and their specific heat capacity is 1500 J kg^{-1} K^{-1}.
During a ten-hour period the temperature of the bricks rose from 15 ^oC to 300 ^oC.

(i) Calculate the energy gained by the bricks;

(ii) Calculate the power of the heating coil.

2012 Question 9 (b) [Ordinary Level]

20 g of ice cubes at 0 °C are added to a glass of warm water.

All the ice melts quickly and cools the water to 5 °C.

Assuming no heat transfer to the surroundings or to the glass,

(i) Calculate the energy required to melt the ice.

(ii) Calculate the energy required to warm the melted ice to 5 °C.

(iii) Why is it important to stir the mixture?

(specific heat capacity of water = 4180 J kg^{-1} K^{-1} ;
specific latent heat of fusion of ice = 3.34×10^5 J kg^{-1})

2017 Question 12 (b) [Ordinary Level]

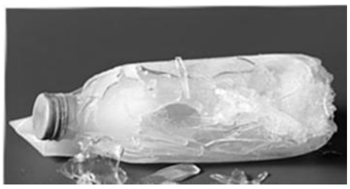
(i) The <u>heat pump</u> in a fridge uses a fluid with a high <u>specific latent heat</u>.
Explain the underlined terms.

(ii) A fridge lowers the temperature of 2 kg of water from 30 °C to 5 °C in 840 s.
Calculate the energy removed from the water.

(iii) Calculate the power of the fridge.

(*specific heat capacity of water = 4200 J kg^{-1} K^{-1}*)

2016 Question 9 [Ordinary Level]



(i) What is meant by latent heat?

(ii) Name an instrument used to measure temperature.

A glass bottle is filled with 0.75 kg of water at a temperature of 20 ^0C.
The bottle is then placed in a freezer, which freezes the water and cools it to −15 ^0C.

(iii) Calculate the energy removed from the water to reduce its temperature to 0 ^0C.

(iv) Calculate the energy removed from the water to convert the water at 0 ^0C to ice at 0 ^0C.

(v) Calculate the energy removed from the water to cool the ice at 0 ^0C to ice at −15 ^0C.

Specific heat capacity of water = 4200 J kg^{-1} K^{-1}
Specific latent heat of fusion of water = 3.3 x10^5 J kg^{-1}
Specific heat capacity of ice = 2200 J kg^{-1} K^{-1}

(vi) The power rating of the freezer is 300 W.
How long will it take for the freezer to remove 9000 J of energy from the water?

(vii) As the water freezes, the glass bottle cracks and shatters. Explain why this occurs.

(viii) The freezer is an example of a heat pump. Outline the operation of a heat pump.

Heat: higher level maths questions

2006 Question 12 (c) [Higher Level]

(i) Define power.
(ii) Define specific heat capacity.
(iii) 400 g of water at a temperature of 15 °C is placed in an electric kettle.
The power rating of the kettle is 3.0 kW.
Calculate the energy required to raise the temperature of the water to 100 °C.
(iv) Calculate the energy supplied by the kettle per second.
(v) Calculate the least amount of time it would take to heat the water to 100 °C.
(vi) In reality, the time taken to heat the water will be greater. Explain why.
(specific heat capacity of water = 4200 J kg^{-1} K^{-1})

2014 Question 12 (c) [Higher Level]

(i) Define specific latent heat.
(ii) A drinking glass contains 500 g of water at a temperature of 24 °C.
Three cubes of ice, of side 2.5 cm, are removed from a freezer and placed in the water.
The temperature of the ice is –20 °C.
Calculate the mass of the ice.
(iii) Calculate the minimum temperature of the water when the ice has melted.
density of ice = 0.92 g cm^{-3}
specific heat capacity of water = 4200 J kg^{-1} K^{-1}
specific heat capacity of ice = 2100 J kg^{-1} K^{-1}
specific latent heat of fusion of ice = 3.3×10^5 J kg^{-1}

2011 Question 7 (a) [Higher Level]

(i) When making a hot drink, steam at 100 °C is added to 160 g of milk at 20 °C.
If the final temperature of the drink is to be 70 °C, what mass of steam should be added?
You may ignore energy losses to the surroundings.
(ii) A metal spoon, with an initial temperature of 20 °C, is then placed in the hot drink, causing the temperature of the hot drink to drop to 68 °C.
What is the heat capacity of the spoon?
You may ignore other possible heat transfers.

($c_{milk} = 3.90 \times 10^3$ J kg^{-1} K^{-1}, $c_{water} = 4.18 \times 10^3$ J kg^{-1} K^{-1}, $c_{hot\ drink} = 4.05 \times 10^3$ J kg^{-1} K^{-1}
specific latent heat of vaporisation of water = 2.34×10^6 J kg^{-1})

2004 Question 7 [Higher Level]

(i) Define specific heat capacity.
(ii) Define specific latent heat.
(iii) 500 g of water at a temperature of 15 ^{0}C is placed in a freezer.
The freezer has a power rating of 100 W and is 80% efficient.
Calculate the energy required to convert the water into ice at a temperature of –20 ^{o}C.
(iv) How much energy is removed every second from the air in the freezer?
(v) How long will it take the water to reach a temperature of –20 ^{o}C?
(vi) Allowing a liquid to evaporate in a closed pipe inside the freezer cools the air in the freezer. The vapour is then pumped through the pipe to the outside of the freezer, where it condenses again.
Explain how this process cools the air in the freezer.
(vii) The freezer causes the room temperature to rise. Explain why.

specific heat capacity of ice = 2100 J kg^{-1} K^{-1};
specific heat capacity of water = 4200 J kg^{-1} K^{-1};
specific latent heat of fusion of ice = 3.3×10^5 J kg^{-1}

2011 Question 7 (b) [Higher Level]

(i) Name two processes by which a hot drink cools.
(ii) How is the energy lost by each of these processes reduced for a hot drink supplied in a disposable cup?

2016 Question 7 [Higher Level]

At a lecture in Cork in 1843, James Joule, while describing his work on heat and temperature, suggested the principle of conservation of energy. Later in the nineteenth century, the work of Joule and Lord Kelvin led to the invention of the heat pump.
(i) Distinguish between heat and temperature.
(ii) State the principle of conservation of energy.

(iii) As part of his presentation, Joule proposed that the temperature of the water at the bottom of the Niagara Falls would be 0.12 °C greater than that at the top, due to gravitational potential energy being converted into heat energy.
Calculate the height of the Niagara Falls.

(iv) In reality the increase in temperature will be much smaller.
Suggest a reason for this.

(v) In a heat pump, a fluid is used to transfer energy from a cold body to a warmer body.
Describe the operation of a heat pump and explain how a heat pump can be used to reduce the temperature of a cold region, for example the interior of a refrigerator.
(vi) State two desirable physical properties of the fluid used in a heat pump.

The fluid in the heat pump of a refrigerator has a specific latent heat of vaporisation of 4.6 MJ kg^{-1}.
The internal volume of the refrigerator is 0.6 m^3.
The heat pump removes 12 kJ of energy from the air in the refrigerator as the fluid evaporates.
(vii) Calculate the mass of fluid that has evaporated
(viii) Calculate the fall in temperature of the air in the refrigerator.

(specific heat capacity of water = 4200 J kg^{-1} K^{-1}; acceleration due to gravity = 9.8 m s^{-2}; density of air = 1.23 kg m^{-3}; specific heat capacity of air = 1005 J kg^{-1} K^{-1})

2012 Question 12 (c) [Higher Level]
The graph shows the variation in temperature θ of 150 g of crushed ice when it was supplied with energy ΔE at a constant rate.

(i) Explain the shape of the graph.
(ii) Describe how energy could have been supplied at a constant rate.
(iii)Using the graph, estimate the specific latent heat of fusion of ice.

2009 Question 11[Higher Level]

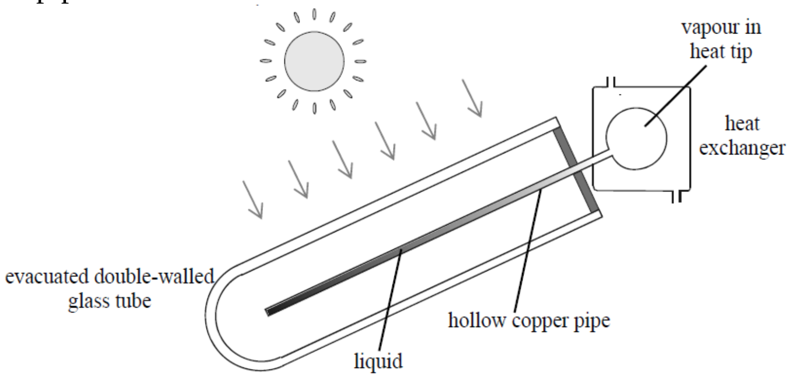
Read the following passage and answer the accompanying questions.

The sun is a major source of 'green' energy. In Ireland solar heating systems and geothermal systems are used to get energy from the sun.

There are two main types of solar heating systems, flat-plate collectors and vacuum-tube collectors.

1.

A flat-plate collector is usually an aluminium box with a glass cover on top and a blackened plate on the bottom. A copper pipe is laid on the bottom of the box, like a hose on the ground; water is passed through the pipe and transfers the absorbed heat to the domestic hot water system.



2.

In a vacuum-tube collector, each tube consists of an evacuated double-walled silvered glass tube in which there is a hollow copper pipe containing a liquid. The liquid inside the copper pipe is vaporised and expands into the heat tip. There the vapour liquefies and the latent heat released is transferred, using a heat exchanger, to the domestic hot water system. The condensed liquid returns to the copper pipe and the cycle is repeated.

In a geothermal heating system a heat pump is used to extract solar energy stored in the ground and transfer it to the domestic hot water system.

(*a*) What is the maximum energy that can fall on an area of 8 m^2 in one hour if the solar constant is 1350 W m^{-2}?

(*b*) Why is the bottom of a flat-plate collector blackened?

(*c*) How much energy is required to raise the temperature of 500 litres of water from 20 ^{0}C to 50 ^{0}C?

(*d*) The liquid in a vacuum-tube solar collector has a large specific latent heat of vaporisation. Explain why.

(*e*) Name the three ways that heat could be lost from a vacuum-tube solar collector.

(*f*) How is the sun's energy trapped in a vacuum-tube solar collector?

(*g*) Describe, in terms of heat transfer, the operation of a heat pump.

(*h*) Give an advantage of a geothermal heating system over a solar heating system.

(specific heat capacity of water = 4200 J kg^{-1} K^{-1}; density of water = 1000 kg m^{-3}; 1 litre = 10^{-3} m^3)

Solutions to ordinary level *maths* questions

2018 Question 12 (c)

(i) **Calculate the energy needed to raise the temperature of the water from 20 ^{0}C to 90 ^{0}C.**

Q = mcΔθ = (0.7)(4200) (90-20) = 205800 J

(ii) **How many joules of energy are supplied per second by the boiler?**

3000

(iii) **Calculate how long it will take the boiler to heat the water to 90 ^{0}C.**

Pork = Work/time so t = Work/Power t = 205800/3000 = 68.6 secs.

(iv) **Where should the manufacturer place the heating element of the boiler? Explain your answer.**

At the bottom, because cold water is more dense and will sink down

2017 Question 12 (b)

(i) Explain the underlined terms.

heat pump: means of transferring heat from a cold region to a warm region

specific latent heat : heat needed to change the state of 1 kg of a substance

(ii) **Calculate the energy removed from the water.**

$E = mc\Delta\theta = 2 \times 4200 \times 25 =$ 210 000 J

(iii) **Calculate the power of the fridge.**

$$power = \frac{W}{t} = \frac{210000}{840} = 250\ W$$

2016 Question 9

(i) **What is meant by latent heat?**

Latent heat is the heat energy required to change the state of a substance (without changing temperature)

(ii) **Name an instrument used to measure temperature.**

Thermometer

(iii) **Calculate the energy removed from the water to reduce its temperature to ^{0}C**

$Q = mc\Delta\theta$ $= 0.75 \times 4200 \times 20$ $= 63000$ J

(iv) **Calculate the energy removed from the water to convert the water at ^{0}C to ice at ^{0}C**

$Q = ml$ $= 0.75 \times (3.3 \times 10^5)$ $= 247500$ J

(v) **Calculate the energy removed from the water to cool the ice at ^{0}C to ice at −15 ^{0}C.**

$Q = mc\Delta\theta$ $= 0.75 \times 2200 \times 15$ $= 24750$ J

(vi) **How long will it take for the freezer to remove 9000 J of energy from the water?**

$P = \frac{Work}{time}$ $time = \frac{Work}{power}$ $time = \frac{9000}{300}$ time = 30 s

(vii) **As the water freezes, the glass bottle cracks and shatters. Explain why this occurs.**

The water expands (and the glass contracts).

2015 Question 9

(ii) E = mcΔθ = (5×4180×80) = 167 200 J

(iii) The energy is supplied by the kettle which has a power rating of 0.8 kW = 800 Watts which corresponds to 800 Joules per second.

(iv) 167 200 Joules are required to heat the water, and energy is supplied at a rate of 800 Joules per second
So time taken is 167200/800
= 209 s

2013 Question 9

(i) E = *mcΔθ* = (1.3)(4200)(80-10) = 3.8×10^5 J

(ii) *P* = Energy/time = 3.8×10^5 / 180 = 2123.3 W

2012 Question 9

(ii) *t* = *T* - 273(.15)

(i) *E* = *ml* = $(20 \times 10^{-3})(3.34 \times 10^5)$ = 6.68×10^3 J

(ii) *E* = mcΔθ = $(20\times 10^{-3})(4.18 \times 10^3)(5)$ =) 418 J

2008 Question 7

(v) 100 – 20 = 80 °C

(vi) Q = m cΔθ = 0.5 × 4200 × 80 = 168 000 J

(vii) 2 kW = 2,000 W = 2,000 J per second.

(viii) P = W/t so t = W/P t = 168 000/2,000 = 84 secs.

2006 Question 7

(i) Q = mcΔθ ⇒ Q = (80)(1500)(285) = 34 200 000 J = 4.2 MJ

(ii) P = W/ t ⇒ P = 34 200 000 / (10×60×60) = 950 W

2002 Question 12 (b)

(ii) Q = mcΔθ Q = 1.5 × 4180 × 85 = 532 950 J.

(iii) P=W/t P = 532 950/240 P = 2221 W.

Solutions to all higher level questions

2016 Question 7

(i) Distinguish between heat and temperature.
Heat is a measure of energy. Temperature is a measure of hotness

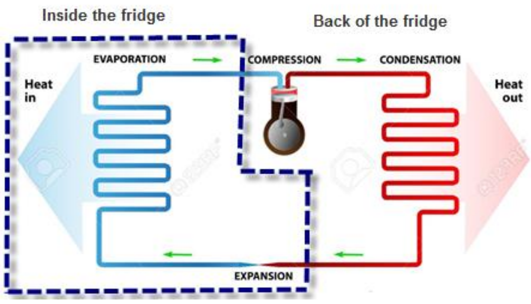
(ii) State the principle of conservation of energy.
Energy cannot be created or destroyed, it can be changed from one form into another

(iii) Calculate the height of the Niagara Falls.
The key phrase here is "due to gravitational potential energy being converted into heat energy."
Mathematically mgh = mcΔθ

$h = \frac{(c)(\Delta\theta)}{g}$ $h = \frac{(4200)(0.12)}{9.8}$ h = 51.4 m

(iv) Suggest a reason for this.
Much of the heat energy will be lost to the environment as the water falls

(v) Describe the operation of a heat pump
A special liquid is pumped around the pipe as shown.
Inside the dotted section the liquid expands quickly, and in going from a liquid to a gas it takes in energy from around the pipe.
Outside the dotted section a pump is used to *compress* the gas which causes it to go back into the liquid state, and in the process it gives heat energy back out to the surroundings.



(vi) State two desirable physical properties of the fluid used in a heat pump.
High (specific) latent heat of vaporisation
Low boiling point

(vii) Calculate the mass of fluid that has evaporated.

$Q = ml$ Q = 12 ×10^3 J $l = 4.6 \times 10^6$ J kg^{-1}

$m = \frac{E}{l}$ m = $\frac{12 \times 10^3}{4.6 \times 10^6}$ = 0.0026 kg

(viii) Calculate the fall in temperature of the air in the refrigerator.
Any time there is a change in temperature it means we need to use the formula Q = mcΔθ.
But note that we are now interested in the air in the fridge itself, not the fluid in the pipes of the heat pump.
First we need to work out the mass of the air

$\rho = \frac{m}{V}$ m = (ρ)(V) m = (1.23 kg m^{-3})(0.6 m^3) m = 0.74 kg

The heat pump removes 12 kJ of energy from the air in the refrigerator as the fluid evaporates.
So Energy removed = 12000 J.
c_{air} = 1005 J kg^{-1} K^{-1}

Q = mcΔθ 12000 = (0.74)(1005)(Δθ)

$$\Delta\theta = \frac{12000}{(0.74)(1005)}$$

Δθ = 16.1 °C

2015 Question 12 (*c*)

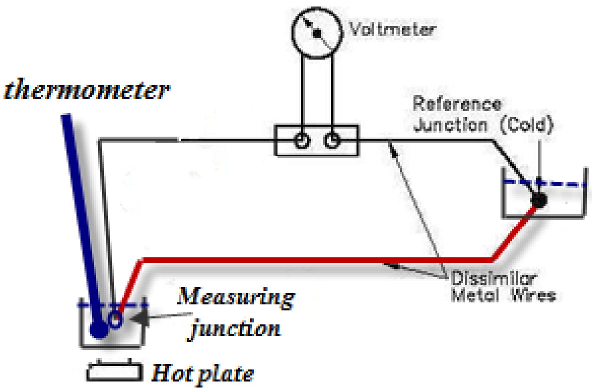
(i) Explain the underlined terms.
Thermometric property: one that changes (measurably) with temperature
Emf: A voltage when applied to a full circuit is called an emf (electromotive force).

(ii) What is the SI unit of temperature?
Kelvin / K

(iii)Give an advantage of using this unit in scientific measurements.
Temperature is always positive

(iv)Describe a laboratory experiment to demonstrate the principle of operation of a thermocouple.

- A thermocouple is comprised of two different metals joined together at both ends to form two junctions.
- One junction is connected to a liquid of known temperature like ice-water which would be at 0 ^{0}C; this is the cold or reference junction.
- The other junction is connected to the liquid whose temperature is to be measured.
- An emf /voltage is produced (as seen in the diagram).
- Increase the temperature of the heat source and note the new temperature (using an existing thermometer) and new voltage.
- Plot a graph of emf against temperature.
- You can now use the graph with this thermocouple to establish the temperature of the liquid in the future (dip the measuring junction into the liquid note the voltage and use the graph to get the corresponding temperature).



(v) Give an advantage of using a thermocouple thermometer instead of a mercury-in-glass thermometer.
Less fragile, wider temperature range, mercury is toxic etc**.**

2014 Question 12 (c)

(i) Define specific latent heat.

This is the heat needed to change the state of 1 kg of a substance without a change in temperature.

(ii) Calculate the mass of the ice.

$Density = \frac{mass}{volume}$

Mass of one cube of ice = (density)(volume)

Mass of one cube of ice = (0.92 g cm^{-3})(2.5×2.5×2.5 cm^3) = 14.375 g

Mass of *three* cubes of ice = 43.125 g = 0.043125 kg

(iii) Calculate the minimum temperature of the water when the ice has melted.

Heat gained by the ice = heat lost by the water

Heat gained: the ice gains heat in three stages:

1. Ice heating from –20 °C to 0 °C
2. Ice changing state (to water)
3. Melted ice (now water – obviously) heating up from 0 °C to some final temperature of the system T.

Heat lost: the heat lost by the water = $mc\Delta\theta_3$, where $\Delta\theta_3$ is the difference between the initial temperature of the water (which was 24 °C) and the final temperature of the system T.

So $\Delta\theta = (24 – T)$

Heat gained by the ice = heat lost by the water

$$m_{ice}c_{ice}\Delta\theta_1 + m_{ice}l_{ice} + m_{ice}c_{water}\Delta\theta_2 = m_{water}c_{water}\Delta\theta_3$$

$$(0.043125)(2100)(20) + (0.043125)(3.3\times10^5) + (0.043125)(4200)(T-0) = (0.5 \times 4200 \times (24 – T))$$

$$1811.25 + 14231.25 + 181.125T = 50400 – 2100T$$

$$2281.125T = 34357.5$$

$$T = 15.06 \text{ °C}$$

2013 Question 12 (d)

(i) What is meant by the term thermometric property?

A property that changes measurably with temperature.

(ii) What is the temperature of the water when the resistance of the thermistor is 420 kΩ?

.Read directly from the graph to get approximately 37^0 C

(iii) What is the temperature of the water in the tank as measured by the thermocouple thermometer?

As the temperature goes from ^{0}C to 100 ^{0}C, the emf goes from 0 V to 815 μV

So an increase of 1μV corresponds to a temperature difference of $\frac{100}{815}$ or 0.1227 ^{0}C

319 μV therefore corresponds to a temperature of $\frac{100}{815} \times 319 = 39.14$ ^{0}C

(iv) Why do the thermistor and the thermocouple thermometer give different temperature readings for the water in the tank?

Each of the thermometers has a different thermometric property which changes differently with temperature

2012 Question 12 (c)

(i) Explain the shape of the graph.

Temperature of ice increased from –3^o to 0^o as energy is added.
Ice temperature stays at 0 ^{0}C while ice is melting / changing state - the heat taken in at this stage is known as *latent heat*.
Once all the ice has melted the water temperature increases to 1^{o}C.

(ii) Describe how energy could have been supplied at a constant rate.

Using a heating coil (ideally with a joulemeter and rheostat to monitor and adjust the energy supplied).

(iii) Using the graph, estimate the specific latent heat of fusion of ice.

From the graph we can see that the energy required to melt 0.15 kg of ice = (59 kJ – 10 kJ) = 49 kJ
Q = m*l*

$l = \frac{E}{m} = \frac{49 \times 10^2}{0.15}$ $\qquad$ $l = 3.27 \times 10^5$ J Kg^{-1}

2011 Question 7 (a)

(a)

(i) If the final temperature of the drink is to be 70 °C, what mass of steam should be added?

Energy gained by the milk = energy lost by the steam when condensing + energy lost by this condensed water cooling down

$$(mc\Delta\theta)_m = (ml)_{steam} + (mc\Delta\theta)_{condensed\ steam}$$

$$(0.160)(3.90\times10^3)(50) = (m_{steam})(2.34\times10^6) + (m_{steam})(4.18\times10^3)(30)$$

$$31.2\times10^3 = (2.4654\times10^6)m_{steam} \qquad m_{steam} = \frac{31.2\times10^3}{2.4654\times10^6} = 12.655\times10^{-3}\text{ kg} \qquad = 12.66\text{ g}$$

(ii) What is the heat capacity of the spoon?

The hot drink now consists of 160 grams of hot milk plus 12.66 grams of steam.

Total mass = 17.266 grams = 0.17266 kg

{It looks like we are missing a value for the mass of the spoon, but we are being asked to calculate the heat capacity (C), not the specific heat capacity (c). The relationship between C and c is: C = mc

Energy gained by the spoon = energy lost be the hot drink

$$(C\Delta\theta)_{spoon} = (mc\Delta\theta)_{hot\ drink}$$

$$48C = (0.17266)(4.05\times10^3)(2)$$

$48C = 1.3985\times10^3$ $\quad$ $C = 29.14\text{ J K}^{-1}$

(b)

How is the energy lost by each of these processes reduced for a hot drink supplied in a disposable cup?

Conduction – The material the cup is made from is a good insulator

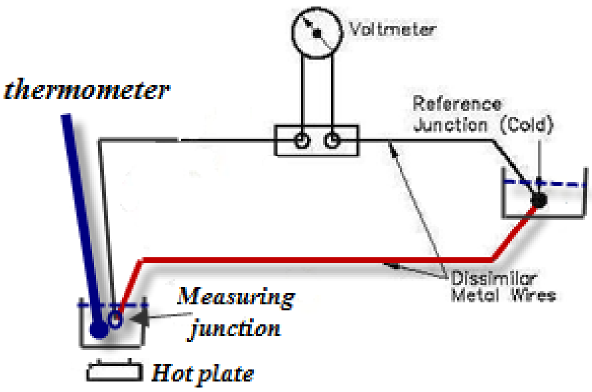
Evaporation – use a lid

Convection – Use a lid /insulation

(c)

(i) How would you demonstrate the principle of operation of a thermocouple?

- A thermocouple is comprised of two different metals joined together at both ends to form two junctions.
- One junction is connected to a liquid of known temperature like ice-water which would be at 0 ^{0}C; this is the cold or reference junction.
- The other junction is connected to the liquid whose temperature is to be measured.
- An emf /voltage is produced (as seen in the diagram).
- Increase the temperature of the heat source and note the new temperature (using an existing thermometer) and new voltage.
- Plot a graph of emf against temperature.
- You can now use the graph with this thermocouple to establish the temperature of the liquid in the future (dip the measuring junction into the liquid note the voltage and use the graph to get the corresponding temperature).



(ii) Describe how to establish a calibration curve for a thermocouple.

- Hold one junction at constant temperature (eg °C)
- Hold the other junction in water beside an (already calibrated) thermometer.
- Heat the water (in steps of 10 °C approx) and note temperature and emf values each time.
- Plot a graph of emf vs. temperature.

2009 Question 11

(a) What is the maximum energy that can fall on an area of 8 m^2 in one hour if the solar constant is 1350 W m^{-2}?

1350 joules of energy fall on one m^2 every second.

So the amount of energy falling on **8 m^2** in **one hour** corresponds to $1350 \times 8 \times 60 \times 60 = 3.9 \times 10^7$ J

(b) Why is the bottom of a flat-plate collector blackened?

Dark surfaces are good absorbers of heat/energy/radiation

(c) How much energy is required to raise the temperature of 500 litres of water from 20 ^{0}C to 50 ^{0}C?

{There are one thousand litres in one cubic metre, so 1 litre = 1×10^{-3} m}

$density = \frac{mass}{volume}$ ⇒ mass = (density)(volume) ⇒ mass = $(1000)(500 \times 10^{-3}) = 500$ kg.

$Q = mc\triangle\theta = (500)(4200)(30) = 6.3 \times 10^7$ J

(d) The liquid in a vacuum-tube solar collector has a large specific latent heat of vaporisation. Explain why.

So that the liquid can absorb a lot of energy per kg in the heat exchanger during a change of state.

(e) Name the three ways that heat could be lost from a vacuum-tube solar collector.

Conduction, convection, radiation

(f) How is the sun's energy trapped in a vacuum-tube solar collector?

Silvered walls prevent radiation and evacuated walls prevent conduction and convection

(g) Describe, in terms of heat transfer, the operation of a heat pump.

Energy is taken from one place (making it colder) by allowing the liquid to change state to a gas.

Then in another place the gas condenses to a liquid releasing the heat to another place making it hotter.

(h) Give an advantage of a geothermal heating system over a solar heating system.

Geothermal system functions all the time whereas a solar heating system works only during sunshine.

2006 Question 12 (c)

(i) Define power.

Power is defined as energy divided by time.

(ii) Define specific heat capacity.

The specific heat capacity of a substance is the heat energy needed to change one kilogram of the substance by one Kelvin.

(iii) Calculate the energy required to raise the temperature of the water to 100 ^{o}C.

$Q = mc\Delta\theta$

$Q = (0.40)(4200)(85) = 1.428 \times 10^5$ J

(iv) Calculate the energy supplied by the kettle per second.

3000 J per second = 3000 W

(v) Calculate the least amount of time it would take to heat the water to 100 ^{o}C.

$time\ taken = \frac{Energy\ required\ to\ heat\ the\ water}{rate\ at\ which\ energy\ is\ supplied}$ $time = \frac{1.428 \times 10^5}{3000}$ time = 47.6 seconds

(vi) In reality, the time taken to heat the water will be greater. Explain why.

Energy will be lost to the surroundings.

2004 Question 7

(i) Define specific heat capacity

The specific heat capacity of a substance is the heat energy needed to change one kilogram of the substance by one Kelvin.

(ii) Define specific latent heat

The specific latent heat of a substance is the amount of heat energy need to change the state of 1 kg of the substance without a change in temperature.

(iii) Calculate the energy required to convert the water into ice at a temperature of –20 ^oC.

There are 3 separate stages here:

Cooling from 15 ^0C to 0 ^0C: $Q = mc\Delta\theta$ = (0.5)(4200)(15) = 31500 J

Change of state: Q = ml = (0.5)(3.3 × 105) =165000 J

Cooling ice from 0 ^oC to -20 ^oC: $Q = mc\Delta\theta$ = (0.5)(2100)(20) =21000 J

Total energy required = $Q_t = Q_1 + Q_2 + Q_3$ =217500 = 2.2×10^5 J

(iv) How much energy is removed every second from the air in the freezer?

{Power rating = 100W = 100 Joules per second.

But 80% efficiency means that the useful power is actually 80 W}

So 80 J of energy is removed every second.

(v) How long will it take the water to reach a temperature of –20 ^oC?

$$time\ required = \frac{energy\ which\ needs\ to\ be\ removed}{number\ of\ joules\ of\ energy\ removed\ per\ second} \qquad t = \frac{217500}{80} = 2700 \text{ s}$$

(vi) Explain how this process cools the air in the freezer.

This change of state which takes place inside the pipe requires energy (latent heat). This energy is available from the air surrounding the pipe which is inside the freezer; this therefore lowers the temperature of the freezer.

(vii) The freezer causes the room temperature to rise. Explain why.

When the vapour condenses inside the pipe (at the back of the freezer) latent heat energy is released to the surroundings. This causes the air outside the pipe (the air in the room) to increase in temperature.

2003 Question 12 (b)

(i) What is the difference between heat and temperature?

Heat is a form of energy, temperature is a measure of hotness.

(ii) Explain the underlined terms.

An emf is a voltage applied to a full circuit.

A thermometric property is any property which changes measurably with temperature.

(iii) Name a thermometric property other than emf.

Length, pressure, volume, resistance, colour

(iv) Explain why it is necessary to have a standard thermometer.

Two different types of thermometer will give slightly different readings at the same temperature