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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 1 Physics, Earth and Space Science RAS 2023

92047 Demonstrate understanding of energy in a physical system

EXEMPLAR

Excellence

TOTAL 22

You may find the following formulae useful.

$$E_k = \frac{1}{2}mv^2 \qquad \Delta E_p = mg\Delta h \qquad g = 10 \text{ N kg}^{-1} \qquad W = Fd$$

$$E(\text{thermal}) = mc\Delta T \qquad E(\text{thermal}) = mL$$

$$P = VI \qquad V = RI \qquad \Delta E = P\Delta t$$

QUESTION ONE

Jamie plays with his football while he waits for his bus. He throws the ball vertically up. The ball has a mass of 0.150 kg and reaches a height of 3.4 m. As it falls back down, its speed just before it hits the ground is 7.8 m s^{-1}.

(a) In the box below, write an equation to show the energy changes taking place when the ball falls back down from its highest point.

gravitational potential → kinetic + heat

(b) Calculate the size of the average force of friction between ball and air.

Begin your answer by showing that, on its way down from the highest point, 0.537 J of mechanical energy are changed into other forms of energy.

Ep = mgh

0.150 × 10 × 3.4   5.1 − 4.563 = 0.537 J

Ep = 5.1 J

Ek = 1/2 mv²

Ek = 1/2 × 0.150 × 7.8²

Ek = 4.563 J

(c) While falling, 80% of the 0.537 J converted to other types of energy is absorbed by the ball. The specific heat capacity of the ball is 8200 J kg^{-1} °C^{-1}.

Calculate the rise in temperature of the ball as it falls.

E = mcΔt   0.537 × 0.8 = 0.4296

0.4296 = 0.150 × 8200 × Δt $\frac{0.4296}{1230}$ = 0.00035 °C

0.4296 = 1230 × Δt

(d) After some time, Jamie's bus did not arrive. Jamie shoulders his backpack and walks to the train station. On his way to the platform, he climbs a flight of stairs.

In terms of work and/or energy, explain why each of the following three statements given below is true.

No calculations are needed.

(i) No work is done on Jamie's backpack when Jamie is standing at the bus stop.

The backpack is not moving therefore W=fxd does not apply as the back pack is not moving a distance.

(ii) No work is done on Jamie's backpack when Jamie walks at constant speed on horizontal ground.

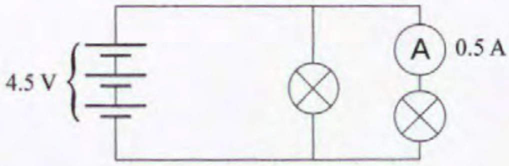
Although Jamie is moving no work is done on the backpack as it is not moving itself. No energy is transferred into the backpack.

(iii) Work is done on Jamie's backpack when Jamie climbs up a flight of stairs.

the backpack moves a vertical distance up the stairs, gaining gravitational potential energy so the equation W=fxd is applicable.

QUESTION TWO

Jake has a torch that uses three 1.5 V batteries in series. The torch has two lamps, each rated at 4.5 V, connected as shown in the circuit diagram below. The current through each lamp is 0.50 A.



(a) Calculate the resistance of each lamp.

$\frac{V}{I|R}$

$V = IR$

$R = V/I$ $\quad 4.5/0.5 = 9\ \Omega$

(b) The batteries power both lamps simultaneously.

Explain why both lamps glow with their rated brightness if connected as shown above.

Begin your answer by identifying what type of connection the above diagram shows.

Both lamps glow with thier rated brigntness as they are connected in paralell. This means that every ~~pathy~~ pathway has the full 4.5v from the three batteries. ~~the~~ Each bulb is rated at 4.5 v, therefore needing 4.5v to glow at thier full brightness.

(c) Calculate the amount of electrical energy used by both lamps in two hours.

Begin your answer by calculating the power output of each lamp.

$P = VI$

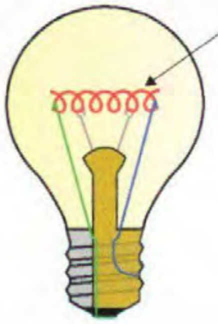
$4.5 \times 0.5 = 2.25$ w for each bulb

$\Delta E = P\Delta t$

$E = (2.25 + 2.25) \times 7200$ s

$E = 32400$ J

(d) Jake's torch uses incandescent lamps. These lamps have a very thin tungsten wire called a 'filament'. When a current passes through such a filament, it heats up and glows.



Tungsten is a metal with a very high melting point and a relatively small specific heat capacity. The very small diameter of the filament means that the filament has a large resistance.

Explain why the high melting point, small specific heat capacity, and large resistance of the filament are important for the incandescent lamps to work well in a circuit.

Begin your answer by describing the energy changes that occur in the filament when a current passes through it.

When a current passes through the fillament the electrical energy is converted to ~~the~~ light and heat. The high melting point of tungsten means that it will not melt when heated as it needs a high temperature to melt. However, the small specific heat capacity means it requireds a smaller amount of energy to heat ~~it~~ up one kg by 1°C. This means that it doesn't need a lot of energy (compared to some other metals) to heat up and glow, but will not melt. The filament has a large resistance as it has a small diameter. Resistance is inversely related to current so if $\hat{V} = \downarrow I R \uparrow$ The small diameter slows the flow of charges allowing for the transfer of energy from electrical to heat and ~~th~~ light. The incandescent lamps work well in a circuit as they do not melt, require less energy to generate heat and light and have a large resistance

QUESTION THREE

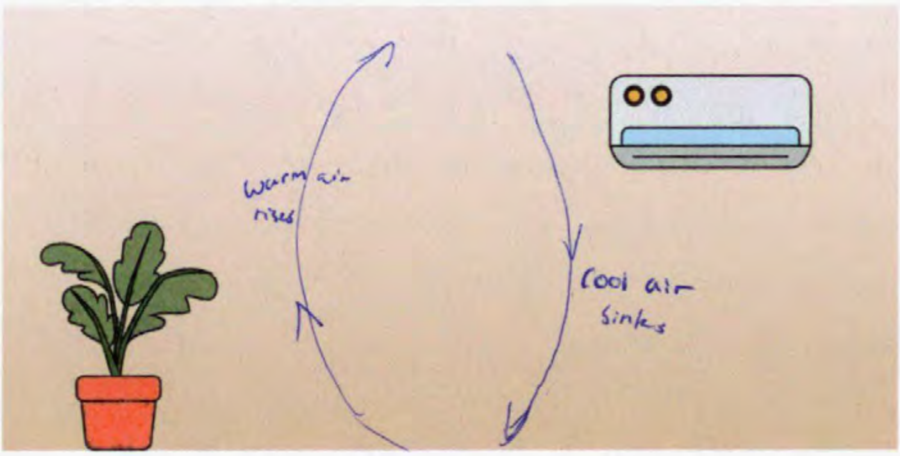
Pearl has had an air conditioning (AC) unit installed in her room. The AC unit uses electricity to cool down air and blow cooled-down air into her room. This way, Pearl's room is comfortably cool although it is hot outside.

AC units are typically mounted high up on a wall.

https://flitemechanical.com/mini-split/

(a) In the diagram below, draw labelled arrows to show the movement of warm air and cool air in the room.

Disregard effects of air being pushed out of the AC unit.

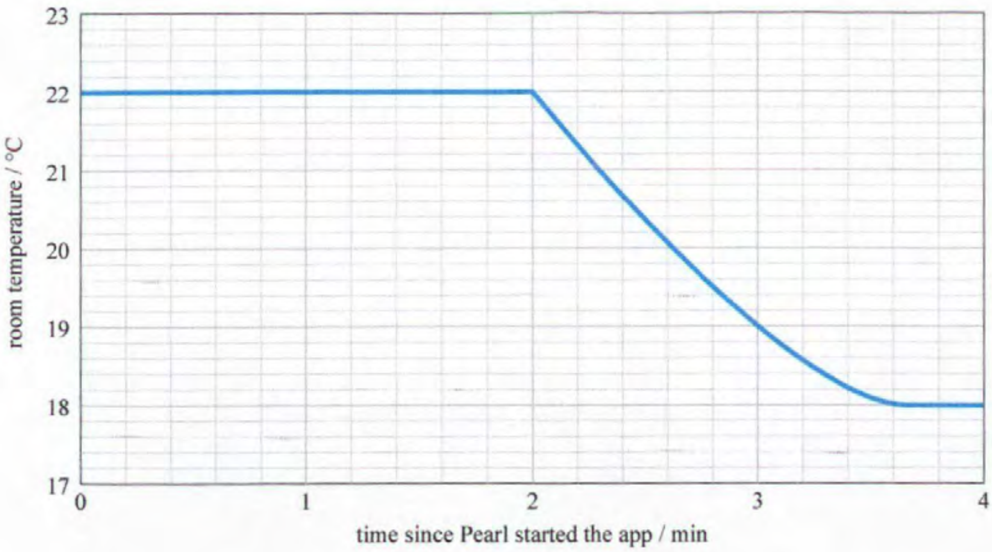


(b) The volume of space occupied by a given amount of air depends on the temperature of the air. This is the reason for the movement of warmer and cooler air around the room.

Explain, in terms of particle theory of matter, why a given amount of cooler air occupies a slightly smaller volume of space than the same mass of warmer air.

Cooler air occupies a smaller volume of space than warmer air because the particles have less energy. This means that they are moving around less and are closer together meaning that cooler air particles are more dense than warm air particles and thus take up less volume.

(c) One summer morning, Pearl checks the room temperature on her phone. Two minutes after she starts the app, she sets the AC unit to 18 °C and switches it on. The temperature in her room drops as shown in the graph below.



Pearl's room contains 41.4 kg of dry air; the specific heat capacity of dry air is 718 J kg^{-1} °C^{-1}.

Using information from the graph above, **calculate the average power** of the AC unit in the two minutes after Pearl sets it to 18 °C.

Begin your answer by calculating the amount of thermal energy drawn from the air in Pearl's room.

$Q = mc\Delta t$

$Q = 41.4 \times 718 \times 4$

$Q = 118900.8$ J

$\Delta E = P\Delta t$ $\quad \frac{118900.8}{240} = 495.42$ W

$118900.8 = P \times 240$

Question Three continues on the following page.

(d) At night, when it gets cold outside, Pearl closes the curtains on the window in her room. Pearl's curtains reach down to the floor and are close to the wall.

Explain why the layer of air between the curtain and the window reduces heat transfer by conduction through the glass of the window pane.

In your answer, you should:

- explain, in terms of particle theory of matter, how heat transfer by conduction works
- compare and contrast conduction through air and glass.

conduction transfers heat through particles. As the ~~outward~~ particles close to the heat source heat up, they gain more energy so begin to vibrate more. The vibrating particles bumped into neighbouring particles and transfer on the heat, thus allowing heat transfer all through the object. Glass is a solid, so has a rigid structure and particles close together, this enables good conduction as the particles are close together, the bump into each other more ~~rapid~~ frequently. Air, however, is a gas and is a poor conductor this is because ~~there~~ it's particles are far apart and freely move, so the particles do not bump into each other as often as in a solid, like glass. The layer of air between the curtain and the glass reduces heat transfer from the room through the glass as it doesn't effectively transfer heat to the window pane, so not all the ~~heat~~ energy in the room is transferred through conduction to the window.

Excellence

Subject: Physics, Earth and Space Science RAS

Standard: 92047

Total score: 22

Q	Grade score	Marker commentary
One	M6	• Correct description of energy changes. • Correct calculations of GPE and KE to show the quantity of energy changed into other forms but no calculation to find the average force of friction. • Correct calculations to find the proportion of energy converted to heat and then the change in temperature of the ball. • Use of $W = Fd$ in (i) showing since $d = 0$ then ¼ = 0. Incorrect understanding of the physical system in (ii). Correct explanation in (iii) that changes in GPE mean work is being done.
Two	E8	• Correct use of $R = V/I$ • Correct identification of the parallel circuit and that each pathway in the circuit has a PD of 4.5 V. • Correct use of $P = VI$ to calculate the power of a single bulb and conversion of 2 hours into 7200 seconds. The candidate also recognised that they needed to account for the energy used by both bulbs. • Correct energy changes in the filament lightbulb and analysis of why the given features of a filament lightbulb are important to its function.
Three	E8	• Correctly describes convection. • Describes density in terms of cooler air having lower particle energy linked to less movement and reduced spacing compared to warmer air. • Correct calculation of energy used in four minutes but incorrect conversion of time to seconds. • Good description of conduction and analysis of how conduction is less effective in air compared with solids due to comparative particle spacing and that the layer of air slows heat transfer between the curtain and the glass.