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

Merit TOTAL 16

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 Energy → Kinetic Energy + Mechanical Energy

(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.

$E_P = mg\Delta h$, $m = 0.150$ kg, $g = 10$ N, $\Delta h = 3.4$ m, $E_P = 0.150 \times 10 \times 3.4$, $E_P = 5.1$ J

$E_K = \frac{1}{2}mv^2$, $m = 0.150$ kg, $v = 7.8\text{ms}^{-1}$, $E_K = \frac{1}{2} \times 0.150 \times 7.8^2$, $E_K = 4.563$ J,

$E_P - E_K = 5.1 - 4.563$, $= 0.537$ J of mechanical is changed into other forms of energy as gravitational potential energy changes to kinetic energy on the way down from the highest point the ball reaches,

Forces acting on the soccer ball are unbalanced - soccer ball is accelerating, weight force greater than force of gravity.

(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.

$E = mc\Delta t$, $E = 0.537\,J$, $m = 0.150\,kg$, $c = 8200\,Jkg^{-1}$, $\Delta t = ?$, $0.537 = 0.150 \times 8200 \times \Delta t$

$\Delta t = \frac{mc}{E}$, $\Delta t = \frac{0.150 \times 8200}{0.537}$, $\Delta t = \frac{E}{mc}$, $\Delta t = \frac{0.537}{0.150 \times 8200}$, $\Delta t = \frac{0.537}{1230}$

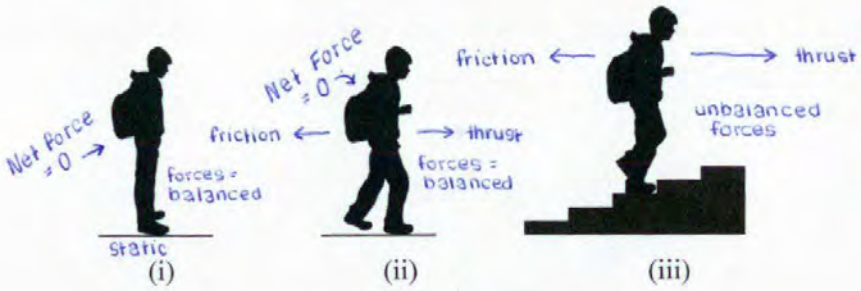
$\Delta t = 0.00044°C$

The rise in temperature as the ball falls is 0.0004°C.

(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.

No work is done because Jamie is standing still - as he is not moving, so or the backpack is not moving so no energy is required, because he is not doing and work. - he is static, net force is 0, forces acting on Jamie are balanced

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

No work is done because at a constant speed, friction and thrust acting on Jamie are equal (opposite forces are equal), meaning forces acting on Jamie are balanced, so his net force is 0,

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

Work is done because Jamie is moving, so energy is required to climb the flight of stairs, increased mass of Jamie (including mass of backpack) = increased amount of work needed to be done to climb the flight of stairs, thrust is greater force than friction, forces are unbalanced net force = greater than 0 Jamie is accelerating

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.

$V = RI$, $V = 4.5V$, $R = ?$, $I = 0.5$, $4.5 = R \times 0.5$, $R = V/I$

$R = \frac{4.5}{0.5}$, $R = 9$, Resistance of each lamp is $9\ \Omega$

(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.

This diagram is a parallel ~~series~~ circuit meaning that there is more than one route for the current (flow of electrons) to go. In a parallel circuit, if one component ~~(lamp 1~~ (lamp 2 in jakes case) breaks, the circuit will still work because there is more than one route for the current to take. In a parallel circuit, there is increased current, so increased ~~function.~~ less resistance. Both lamps glow with their rated brightness when connected through a parallel circuit because of how the function of the circuit increases when the current increases, ~~so~~ allowing for both lamps to glow with their rated brightness of 4.5V each. - ~~so~~ there isn't as much resistance acting against the current (flow of electrons).

(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.

$P = VI$, ~~P=~~ $V = 4.5$, $I = 0.5$, $P = 4.5 \times 0.5$, $P = 2.25\ W$

$\Delta E = P\Delta t$, $P = 2.25w$, $\Delta t = 2h$, ~~$\Delta t = 2.25 \times 2$, $\Delta E = 4.5J$~~ 2h in min = 120

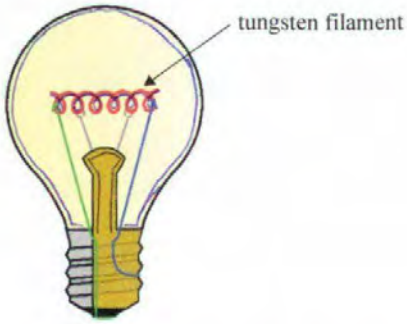
$\Delta t = 120$, $\Delta E = 2.25 \times 120$, $\Delta E = 270J$

~~Electrical energy used by both lamps in 2 hours is 4.5J each.~~

Electrical energy used by both lamps in 2 hours is **270J each**

$(270 \times 2 = 540)$, Total electrical energy = **540J in 2 hours.**

(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 filament, the energy changes from ~~electrical~~ mechanical energy to ~~mechanical~~ electrical energy.

High melting point because the torch is a parallel circuit

High melting point, small specific heat capacity and large resistance make incandesecent lamps work well in a circuit because it causes for there to ~~be increased current, therefore also increasing the function of the lamp~~ be a decreased current, slowing down the flow of electrons.

~~large increase in resistance, low current~~ increased current, when current increases, function also increases

~~current is the flow of electrons~~

resistance counter-acts against current

↑ resistance = ↓ current, ↓ function.

QUESTION THREE

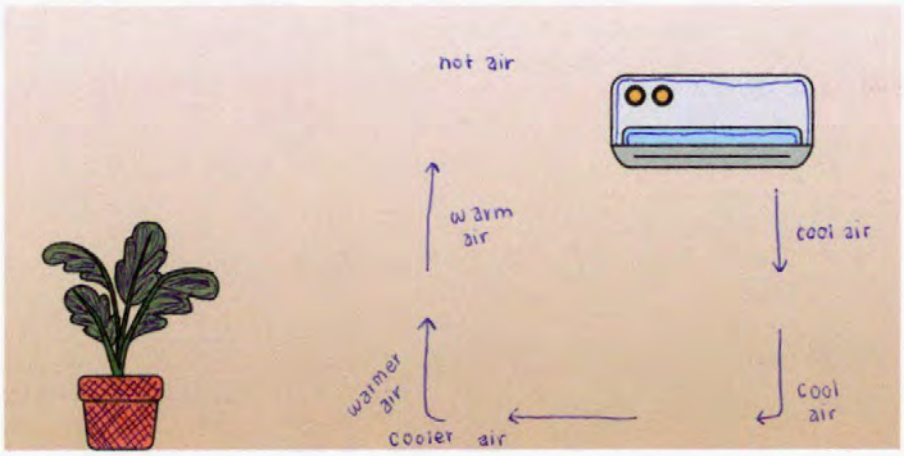
Pearl has had an air conditioning (AC) unit installed in her room. The AC unit uses electricity to cool down air and blow cooled-down air into her room. This way, Pearl's room is comfortably cool although it is hot outside.

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.

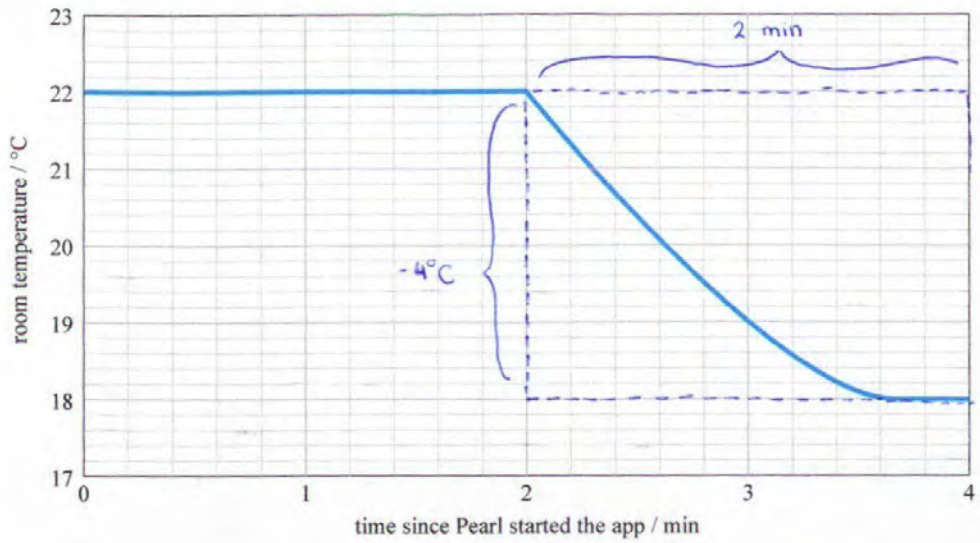
When air is heated, the air particles vibrate causing for them to expand, causing for volume of space of air particles to become less dense - air particles take up greater volume of space when less dense*

cooler particles = more dense, take up smaller volume of space.

Hot air rises - particles move around more freely in the room as they are less dense

* ~~able to move~~ greater ~~more~~ space between each particle when heated

(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.

E (thermal) = mcΔT. m = 41.4 kg, c = 718 Jkg^{-1}, ΔT = 4°C, E = 41.4 × 718 × 4

E = 118 900.8 J of ~~on~~ thermal energy drawn from air in Pearl's room

$\Delta E = P\Delta t$, E = 118900.8, Δt = 2, $P = \frac{\Delta E}{\Delta t}$, $P = \frac{118900.8}{2}$, P = 59 450.4 w

average power of AC unit in 2 minutes = 59 450.4 w

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.

~~Curtains (fabric) is a good insulator~~

Seem as the curtains in Pearl's room are both, close to the wall and reach down to the floor, it means that the air particles are closer together - more dense

Heat transfer through conduction occurs ~~mainly in~~ more effectively in solids - done through when two materials ~~are touching~~ make contact with each other - as particles heat up, they vibrate and bump into each, causing for them to expand and heat transfer to occur.

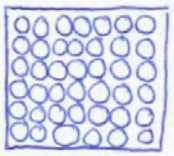
Conduction in air: particles further apart, able to move around more freely, slower to heat up, ~~more~~ because of space between each particle Slows down heat transfer between curtain and window ~~because~~

curtain and glass of window pane are not making physical contact with each other

Conduction through glass: partides are much closer together, generally ~~take~~ in smaller volume of space

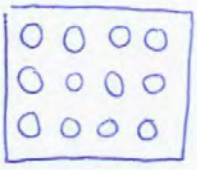
when heated, they vibrate, bump into the next particle, heat up all particles in the glass. thus making glass become warm

air becomes warm as particles expand when heated.



when heated: vibrate, expand

particles in glass



particles move more freely

particles in air

Merit

Subject: Physics, Earth and Space Science RAS

Standard: 92047

Total score: 16

Q	Grade score	Marker commentary
One	M6	• Candidate did not demonstrate a clear understanding of energy transfers in falling objects. • The candidate correctly found the difference between GPE and KE but did not then complete the final calculation to find the average force of friction ($F = W/d$). • The candidate used the correct formula but did not apply the 80% to 0.537 before completing the calculation. • The candidate showed a clear understanding of W=Fd and that when "net" forces are zero no work is done in (i) and (ii). The candidate also recognised that to climb the stairs forces must be unbalanced so work is done.
Two	A3	• Correct use of formula $R = V/I$. • Correct identification of the parallel circuit but no clear link to each pathway in the circuit having a PD of 4.5 V • Correct use of P=VI to calculate the power of a single bulb. Incorrect conversion of 2 hours into 7200 seconds resulting in a error to calculate total energy used by a single bulb. The candidate also recognised that they needed to account for the energy used by both bulbs. • The candidate did not demonstrate understanding of energy changes in a filament lightbulb and was not able to link the described features of a filament lightbulb with their benefits.
Three	E7	• Showed understanding of convection. • Describes density in terms of particle movement and spacing. • Correct calculation of energy used in four minutes but no conversion of time to seconds. • Good description of conduction and explaining how conduction is less effective in air compared with solids due to particle spacing and that the layer of air slows heat transfer between the curtain and the glass.