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

Achievement TOTAL 10

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 pot. → kinetic energy + heat 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 = 0.537J

m = 0.150kg

h = 3.4m

v = 7.8ms^{-1}

$E_k = \frac{1}{2}mv^2$

$= \frac{1}{2} \times (0.150) \times (7.8)$

$E_k = 0.585$

$E_p = mg\Delta h$

$E_p = 0.150 \times 10 \times 3.4$

$= 5.1$ J

$W = Fd$

$F = \frac{W}{d}$

$F = \frac{0.537}{3.4} = F = 0.158$N

(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.

$E = mc\Delta T \quad \Delta T = \frac{E}{mc}$

$T = \frac{0.537}{(0.150 \times 8200)}$

$T = 0°C$

(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) (ii) (iii)

work done/ is time taken to do work.

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

True. Jamie is shouldering his backpack. That takes energy for Jamie. The backpack is hanging from his shoulders but not moving.

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

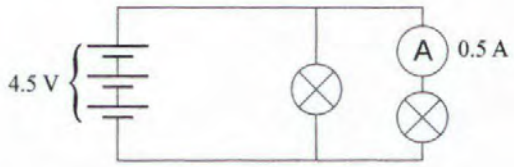
False. Jamie is in motion at constant speed. The person's energy is being used up. So the backpack is moving with Jamie.

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

True. Jamie's backpack is moving as he climbs the stairs. It bounces off his back.

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.

$V = RI$ $\quad R = \frac{4.5}{0.50}$ $\quad R = 9\ \Omega$

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

(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 is a parallel circuit where the current for the lamp is used up in different paths. If the lamps were placed in the same path of the circuit, the light would be dimmer as the current has to be shared. But since its parallel, the light lamps will be brighter but the batteries will be finished faster.

(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.

$P = VI$

$P = (4.5 \times 0.50)$

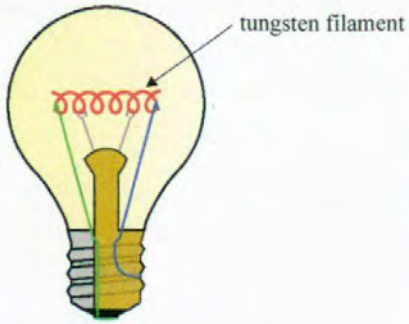
Power output of each lamp = 2.25W

$\Delta E = P\Delta t$ $\quad (2 \times 60 \times 60 = 7200\ sec)$

$\Delta E = (2.25 \times 7200)$

$E = 16200\ J$

(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.

chemical → electrical → heat
→ light
→ sound

Incandescent lamps works well with high melting point, small specific heat capacity and large resistance in the filament. With large resistance due to small diameter in the filament, too much current won't be used up but will shine bright. Saves electricity. The filament turns chemical energy into electrical and then converts to thermal energy to heat it up and make it glow with light energy and due to that, sound energy will be produced. This lamp won't finish fast and lasts longer because of small specific heat capacity and large resistance.

QUESTION THREE

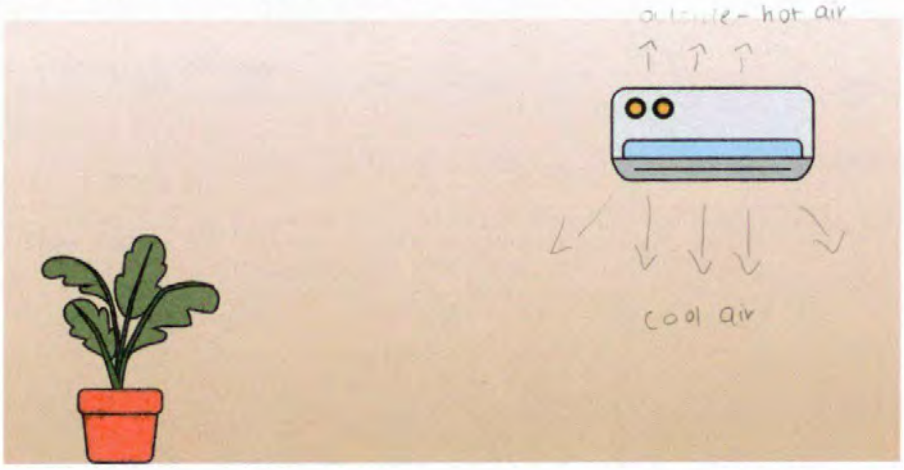
Pearl has had an air conditioning (AC) unit installed in her room. The AC unit uses electricity to cool down air and blow cooled-down air into her room. This way, Pearl's room is comfortably cool although it is hot outside.

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.

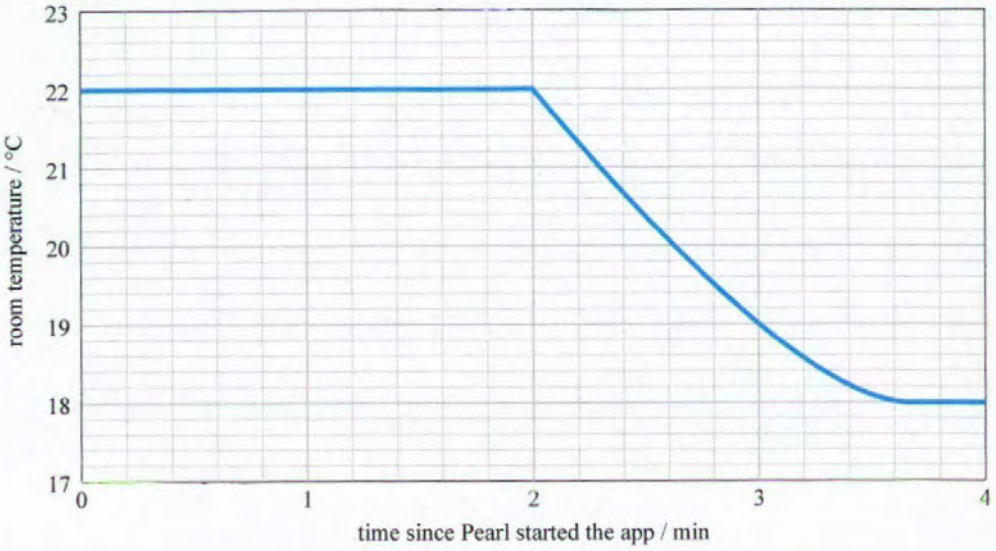


(b) The volume of space occupied by a given amount of air depends on the temperature of the air. This is the reason for the movement of warmer and cooler air around the room.

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.

Warmer air usually stays at the top. When warmer air takes over a space, the cooler air moves away. Volume of space occupied by air depends on the temperature of air. Since air is gas, the particles can be moved freely unlike solid & liquid and are not bonded. Warm air holds more weight than cool air.

(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.

$E = mc\Delta T$

$E = (41.4) \times (718) \times (18)$

E (thermal) $= 535053.6$ J

$\frac{E}{\Delta t} = \frac{P\Delta t}{\Delta t}$

$\frac{E}{t} = P$

$(2 \times 60) = 120$ sec

$P = \frac{535053.6}{120}$

Average $P = 4458.78$ 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.

Conduction is a way of heat transfer. Cool air usually moves to spaces with more volume. Since there is not much space between the wall and the curtain, heat energy is transferred. Warm air particles is not bonded. Conduction through air and glass. Heat energy from air transfers to glass, making it warmer. Glass is usually cold. Air makes glass warmer

Achievement

Subject: Physics, Earth and Space Science RAS

Standard: 92047

Total score: 10

Q	Grade score	Marker commentary
One	A3	• Correct description of energy transfers. • Correct calculation of the average friction force without the required difference between KE and GPE. • Correct formula selected but inferred final value and no accounting for only 80% of the energy going to heat. • Unable to explain or analyse the energy changes in the given context. No recognition of $W = Fd$ or valid changes in energy.
Two	A4	• Correct use of $V = IR$ and change of subject to find R. • Correct identification of the circuit type but explanation to justify the same level of brightness – the same PD across both bulbs. • Correct power for a single lamp and then conversion of time into seconds to give a correct energy for a single lamp. • Correct description of the energy changes in a filament lightbulb. Incorrect explanation or analysis of why the given features of a filament lightbulb are important to its function.
Three	A3	• Demonstrates understanding of convection. • Demonstrates understanding of low bonding between gas particles compared with solids and liquids. No explanation of relative energy of particles at different temperatures. • Correct formulae selections and conversion of minutes to seconds but incorrect change in temperature.