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National Qualifications 2016

X757/75/01

Physics
Section 1 — Answer Grid and Section 2

TUESDAY, 24 MAY

INSTRUCTIONS TO CANDIDATES

Candidates should enter their surname, forename(s), date of birth, Scottish candidate number and the name and Level of the subject at the top of their first answer sheet.

Total marks — 110

SECTION 1 — 20 marks
Attempt ALL questions.

SECTION 2 — 90 marks
Attempt ALL questions.

Reference may be made to the Data Sheet and to the Relationships Sheet X757/75/11.

Questions marked with an asterisk differ in some respects from those in the printed paper.

An OW in the margin indicates a new question.

SECTION 1 — 20 marks

1. The answer to each question is **either** A, B, C, D or E. Decide what your answer is, then write the letter at the end of each question.

2. There is **only one correct** answer to each question.

Sample Question

The energy unit measured by the electricity meter in your home is the:

A ampere

B kilowatt-hour

C watt

D coulomb

E volt.

The correct answer is **B** — kilowatt-hour. You write: Question 7. B

Changing an answer

If you decide to change your answer, cancel your first answer by brailling it out and write the answer you want.

SECTION 2 — 90 marks

Attempt ALL questions

* **1.** Electrical storms occur throughout the world.

During one lightning strike 24 C of charge is transferred to the ground in 0·0012 s.

(a) Calculate the average current during the lightning strike. [3 marks]

(b) The charge on an electron is $-1{\cdot}6 \times 10^{-19}$ C.

Determine the number of electrons transferred during the lightning strike. [1 mark]

Refer to the diagram for Question 1(c).

* (c) Many tall buildings have a thick vertical strip of metal attached to the side of the building.

This strip is used to protect the building from damage during electrical storms.

Explain how this strip protects the building from damage. [2 marks]

Refer to the diagram for Question 2(a).

* **2.** A student investigates the resistance of a resistor using the circuit shown.

(a) Describe clearly where a voltmeter must be connected to measure the voltage across resistor R. [1 mark]

(b) Describe how the student obtains a range of values of voltage and current. [1 mark]

* (c) The results of the student's investigation are shown in the following table.

Voltage across resistor R (V)	*Current in resistor R* (A)
1·0	0·20
2·5	0·50
3·2	0·64
6·2	1·24

Use **all** these results to determine the resistance of resistor R. [4 marks]

Refer to the diagram for Question 2(d).

* (d) The student now replaces resistor R with a filament lamp and repeats the investigation. A sketch graph of the student's results is shown.

State a conclusion that can be made about the resistance of the filament lamp. [1 mark]

* **3.** A washing machine fills with water at a temperature of 15·0 °C.

The water is heated by a heating element.

(a) The mass of the water in the washing machine is 6·00 kg.

Show that the minimum energy required to increase the temperature of the water from 15·0 °C to 40·0 °C is 627 000 J. [2 marks]

(b) The heating element has a power rating of 1800 W.

(i) Calculate the time taken for the heating element to supply the energy calculated in (a). [3 marks]

(ii) Explain why, in practice, it takes longer to heat the water from 15 °C to 40 °C than calculated in (b)(i). [1 mark]

Refer to the diagram for Question 3(c).

* (c) The temperature of the water in the washing machine is monitored by a circuit containing a thermistor.

As the temperature of the water increases, the resistance of the thermistor decreases.

The heating element is switched off when the temperature of the water reaches 40 °C.

Explain how the circuit operates to **switch off** the heating element. [3 marks]

Refer to the diagram for Question 4.

* **4.** The diagram shows some parts of the electromagnetic spectrum in order of increasing wavelength.

(a) State a detector of infrared radiation. [1 mark]

(b) State which radiation in the electromagnetic spectrum has a wavelength shorter than X-rays. [1 mark]

(c) (i) An electromagnetic wave has a frequency of 1·2 GHz.

Show that the wavelength of this wave is 0·25 m. [2 marks]

(ii) Identify the part of the spectrum that this wave belongs to. [1 mark]

* **5.** A Physics textbook contains the following statement.

"Electromagnetic waves can be sent out like small water waves, called ripples, on a pond."

Using your knowledge of physics, comment on the similarities and/or differences between electromagnetic waves and the ripples on a pond. [3 marks]

Refer to the diagram for Question 6.

* **6.** A student directs a ray of red light into a Perspex block to investigate refraction.

(a) Describe clearly where the following should be shown on the diagram:

(i) the normal; [1 mark]

(ii) the angle of incidence *i* and the angle of refraction *r*. [1 mark]

Refer to the diagram for Question 6(b).

* (b) The student varies the angle of incidence and measures the corresponding angles of refraction. The results are plotted on a graph.

(i) Determine the angle of refraction when the angle of incidence is 30°. [1 mark]

(ii) Comment on the shape of the graph as the angle of incidence increases from 0° to 70°. [1 mark]

(c) Suggest why it would be good practice for the student to repeat the investigation a further three or four times. [1 mark]

* **7.** A spacecraft uses a radioisotope thermoelectric generator (RTG) as a power source.

The RTG transforms the heat released by the radioactive decay of plutonium–238 into electrical energy.

(a) In 15 minutes, $7{\cdot}92 \times 10^{18}$ nuclei of plutonium-238 decay.

Calculate the activity of the plutonium-238. [3 marks]

(b) Each decay produces heat that is transformed into $4{\cdot}49 \times 10^{-14}$ J of electrical energy.

Determine the power output of the RTG. [2 marks]

(c) Plutonium-238 emits alpha radiation.

Explain why a source that emits alpha radiation requires less shielding than a source that emits gamma radiation. [1 mark]

* **8.** During medical testing a beta source is used to irradiate a sample of tissue of mass 0·50 kg from a distance of 0·10 m.

The sample absorbs $9{\cdot}6 \times 10^{-5}$ J of energy from the beta source.

(a) (i) Calculate the absorbed dose received by the sample. [3 marks]

(ii) Calculate the equivalent dose received by the sample. [3 marks]

(b) The beta source used during testing has a half-life of 36 hours.

The initial activity of the beta source is 12 kBq.

Determine the activity of the source 144 hours later. [3 marks]

Refer to the diagram for Question 9.

* **9.** A student walks around a building from point X to point Y, as shown in the diagram.

From point X he walks 54 m due North, then 75 m due East, then 14 m due South and finishes at point Y. The diagram is not to scale.

(a) By scale diagram, or otherwise, determine:

(i) the magnitude of the displacement of the student from point X to point Y; [2 marks]

(ii) the direction of displacement of the student from point X to point Y. [2 marks]

(b) The student takes 68 s to travel from point X to point Y.

(i) Determine the average velocity of the student from point X to point Y. [3 marks]

(ii) The student states that their average speed between point X and point Y is greater than the magnitude of their average velocity between point X and point Y.

Explain why the student is correct. [2 marks]

* **10.** An air descender is a machine that controls the rate at which a climber drops from a platform at the top of a climbing wall.

A climber, attached to the air descender by a rope, steps off the platform and drops towards the ground and lands safely.

Refer to the graph for Question 10.

The graph shows how the vertical velocity of the climber varies with time from the instant the climber leaves the platform until landing.

(a) Calculate the acceleration of the climber during the first 2·0 s of the drop. [3 marks]

(b) Calculate the distance the climber drops during the first 3·5 s. [3 marks]

* (c) During part of the drop the forces on the climber are balanced.

Describe all the forces acting vertically on the climber during this part of the drop.

You must name these forces **and** state their directions. [3 marks]

* **11.** The length of runway required for aircraft to lift off the ground into the air is known as the ground roll.

The ground roll of an aircraft varies for each take-off.

Use your knowledge of physics to comment on why the ground roll of an aircraft varies for each take-off. [3 marks]

*12. On 12th November 2014, on a mission known as Rosetta, the European Space Agency successfully landed a probe on the surface of a comet.

The main structure of the Rosetta spacecraft consists of an orbiter, a lander and propellant. It also has solar arrays attached to the main structure.

Rosetta spacecraft data		
Launch mass	Orbiter Lander Propellant	$1{\cdot}23 \times 10^3$ kg $0{\cdot}10 \times 10^3$ kg $1{\cdot}67 \times 10^3$ kg
	Total	$3{\cdot}00 \times 10^3$ kg
Energy source	Solar array output Solar array output	850 W at 3·4 AU 395 W at 5·25 AU
Trajectory control	24 Thrusters	10 N of force each

(a) Calculate the total weight of the spacecraft on Earth. [3 marks]

(b) The solar arrays contain photovoltaic cells.

(i) State the energy change in a photovoltaic cell. [1 mark]

(ii) Suggest why the solar arrays were designed so that they can rotate. [1 mark]

(iii) AU is a measure of the amount of sunlight absorbed.

Calculate the total energy output of the solar arrays when operating at 5·25 AU for 2 hours. [3 marks]

(c) At a point on its journey between Earth and the comet, the spacecraft was travelling at a constant velocity.

(i) The spacecraft switched on four of its thrusters to accelerate it in the direction of travel.

The four thrusters exerted a force on the spacecraft in the same direction.

Determine the total force produced by these thrusters. [1 mark]

(ii) At this point, the spacecraft had used $1{\cdot}00 \times 10^3$ kg of propellant.

Calculate the acceleration of the spacecraft. [4 marks]

* **13.** Read the passage and answer the questions that follow.

Supernova explosion

The average temperature of the surface of the Sun is 5778 K. In the core of the Sun energy is produced by nuclear fusion. Once the Sun has used all its nuclear fuel it will collapse to form a white dwarf.

A star with a mass much larger than that of the Sun will end its life in an enormous explosion called a supernova. The energy released in a supernova explosion is more than a hundred times the energy that the Sun will radiate over its entire 10 billion year lifetime.

In our galaxy, the star Betelgeuse is predicted to explode in a supernova. Betelgeuse has a mass of around 8 times the mass of the Sun. Even though Betelgeuse is 640 light-years from Earth, the supernova will be as bright as a full moon at night in our sky.

(a) State what is meant by the term *nuclear fusion*. [1 mark]

(b) Determine the average temperature of the surface of the Sun in degrees Celsius. [1 mark]

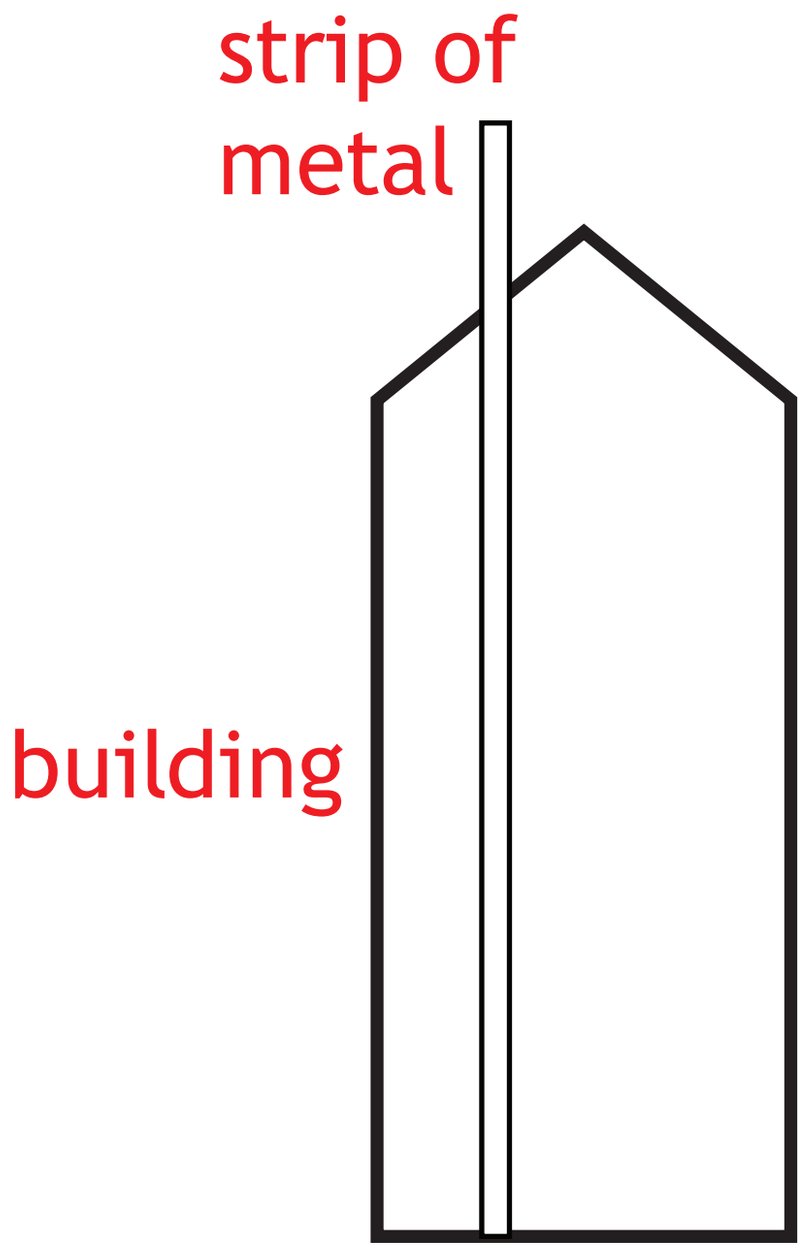
(c) Show that the distance from Earth to Betelgeuse is $6{\cdot}1 \times 10^{18}$ m. [3 marks]

(d) Betelgeuse may have already exploded in a supernova.

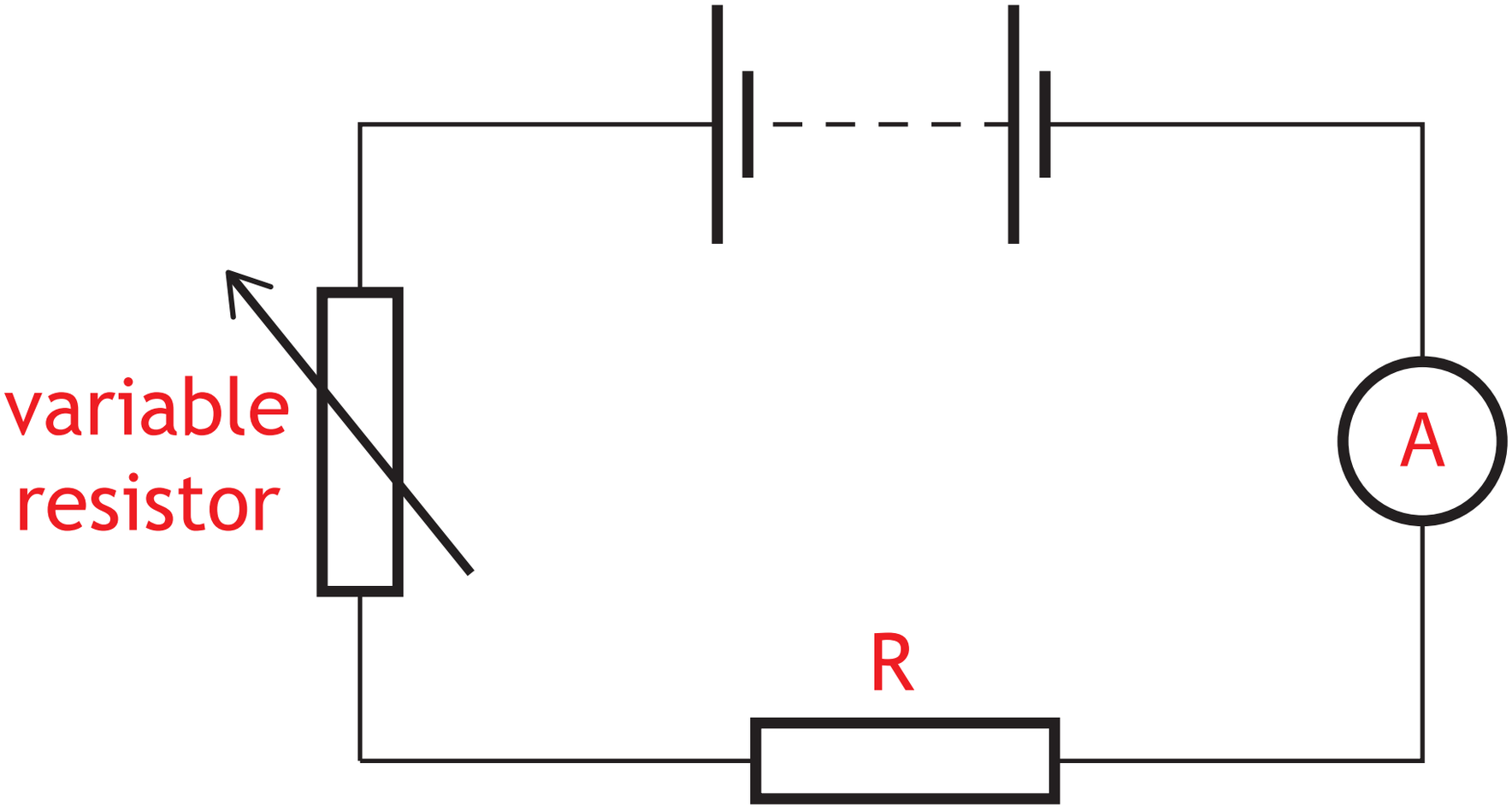
Explain this statement. [1 mark]

[END OF QUESTION PAPER]

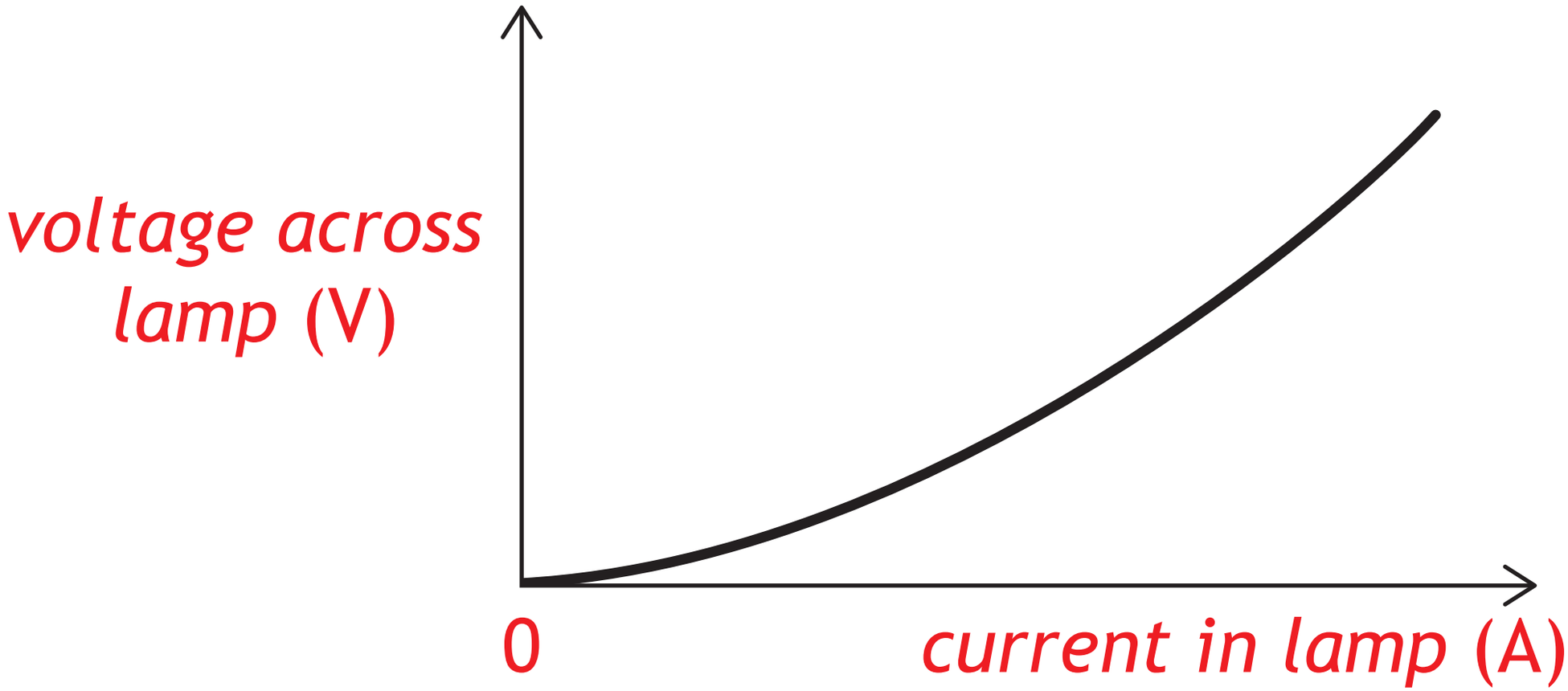
Q1c



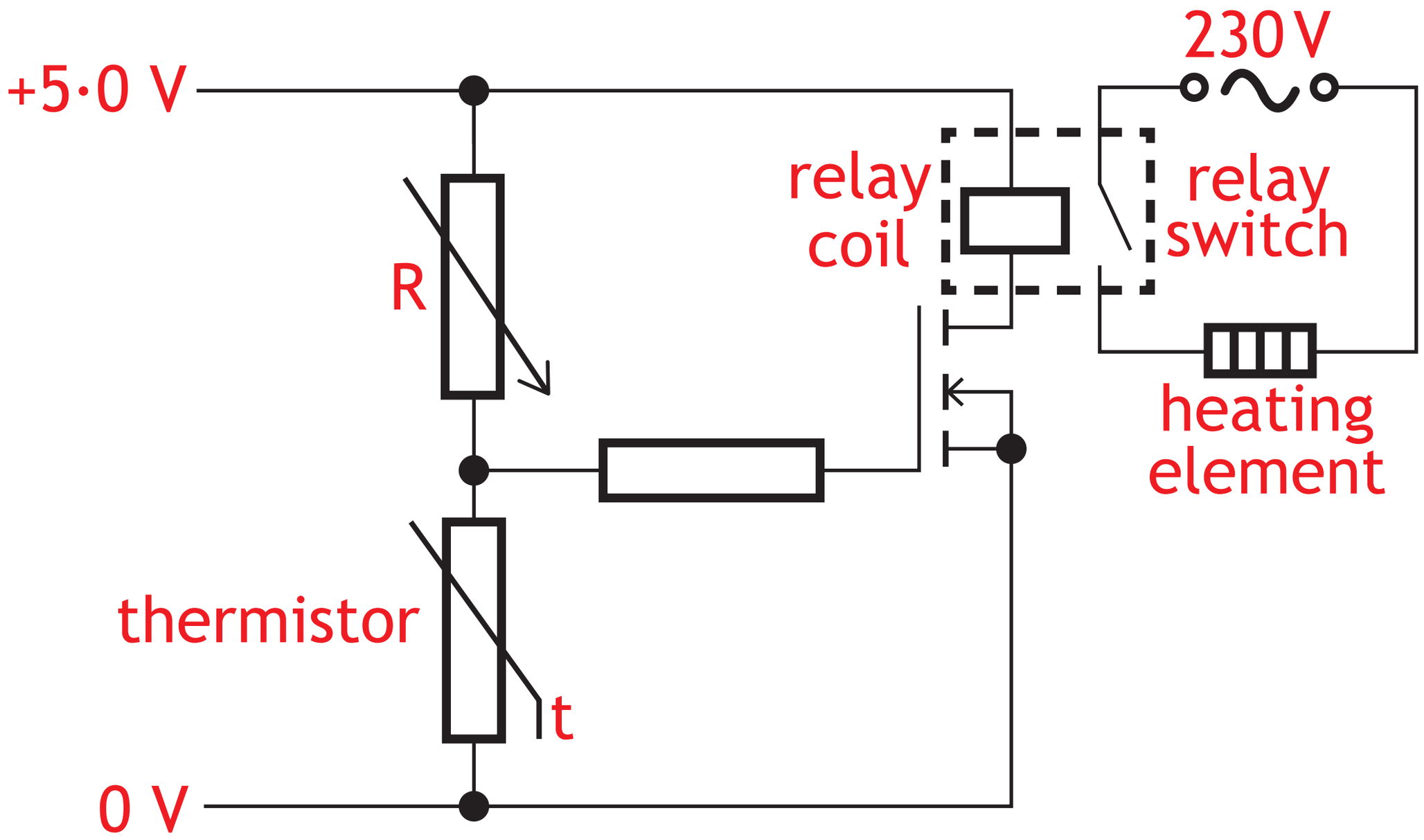
Q2

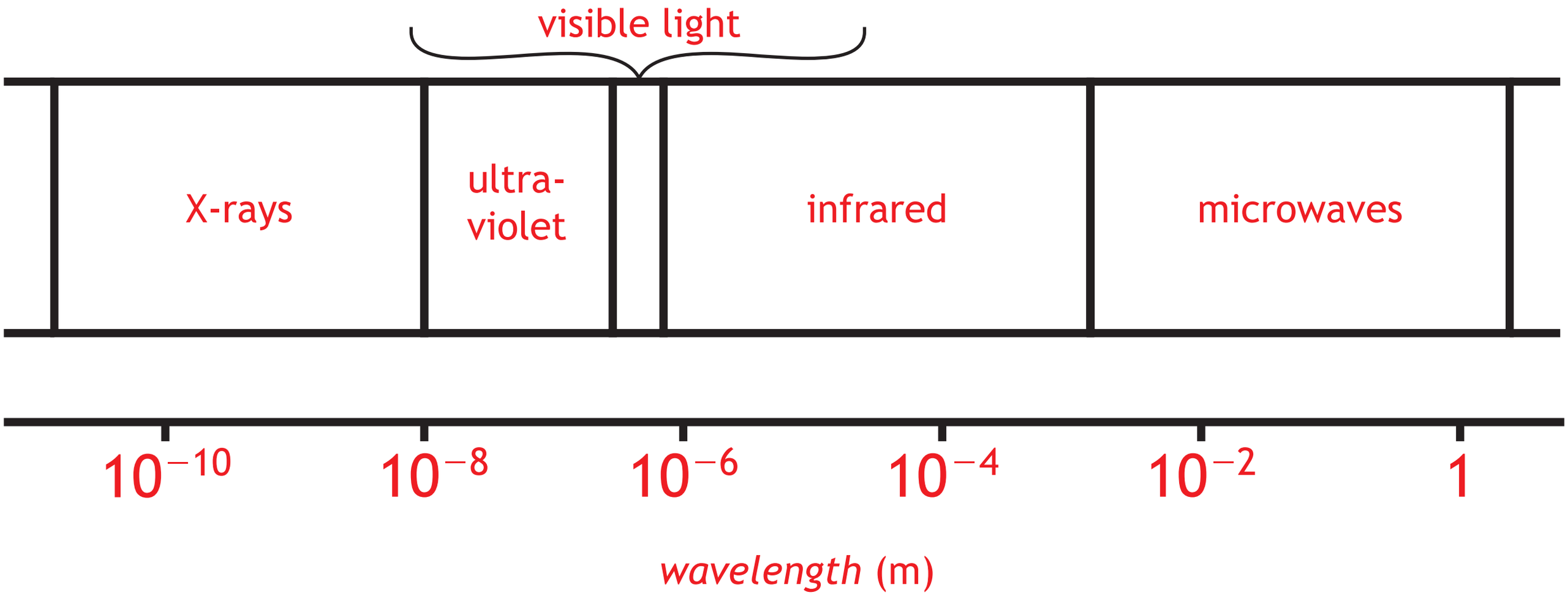


Q2d

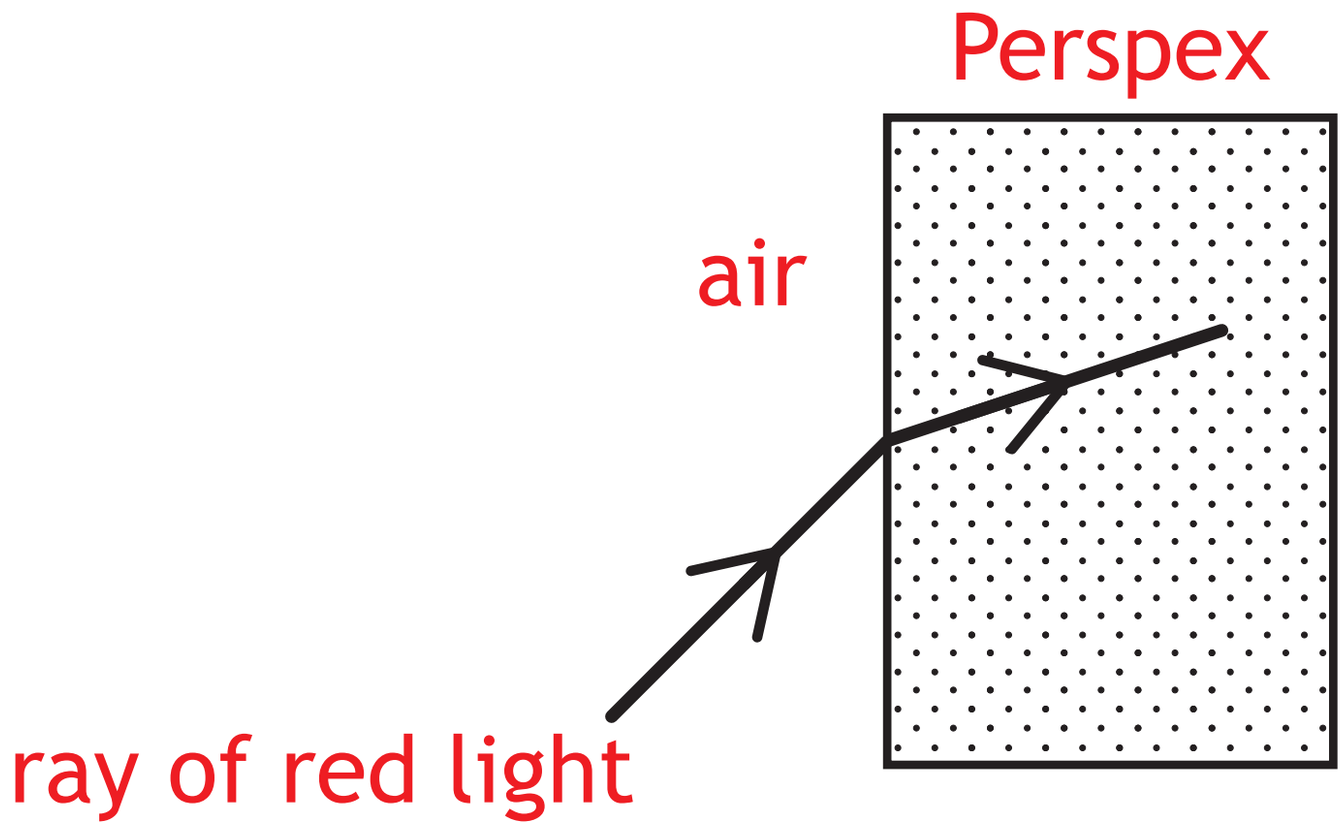


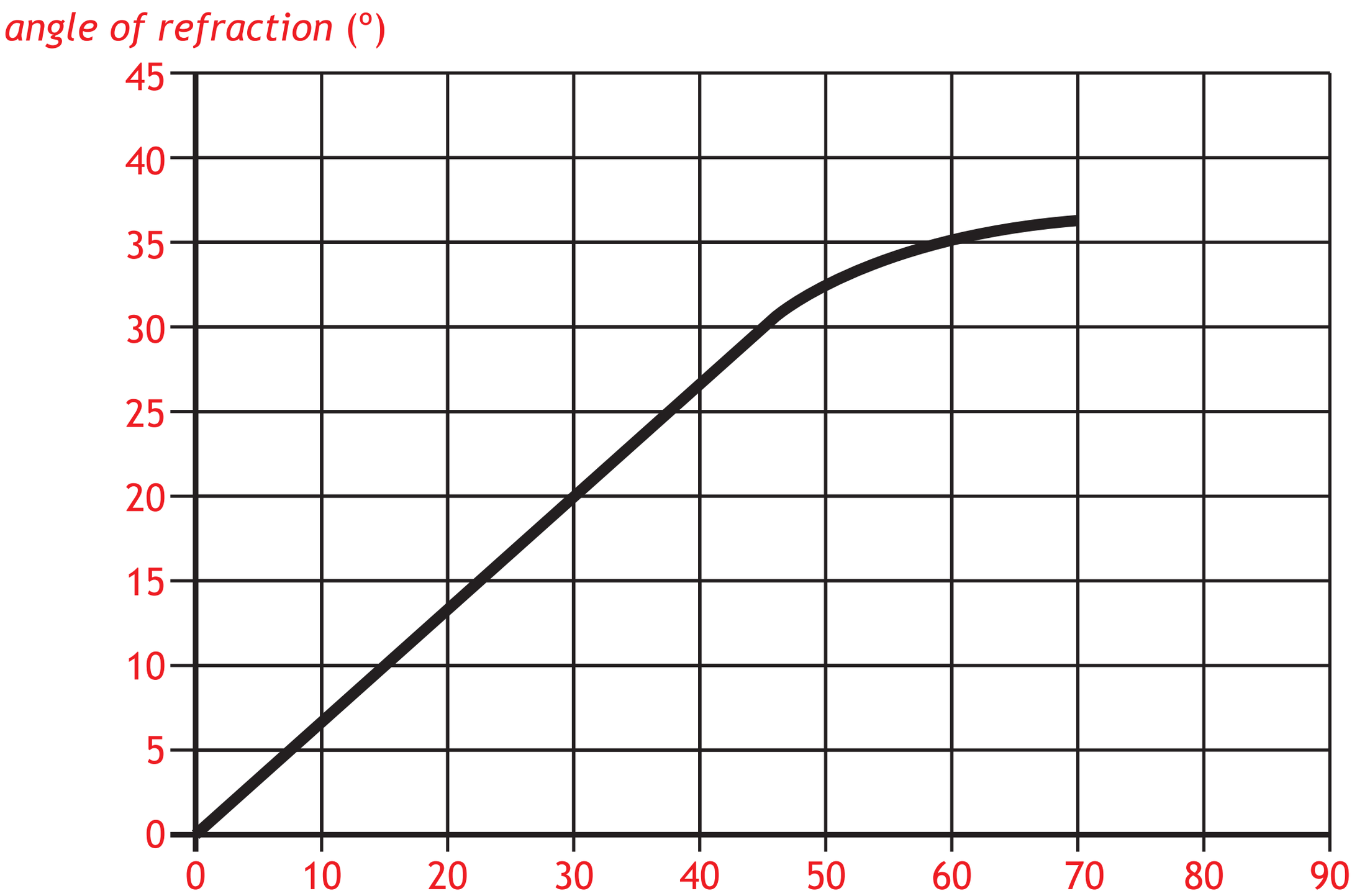
Q3c


+5·0 V
230 V
relay coil
relay switch
R
heating element
thermistor
t
0 V

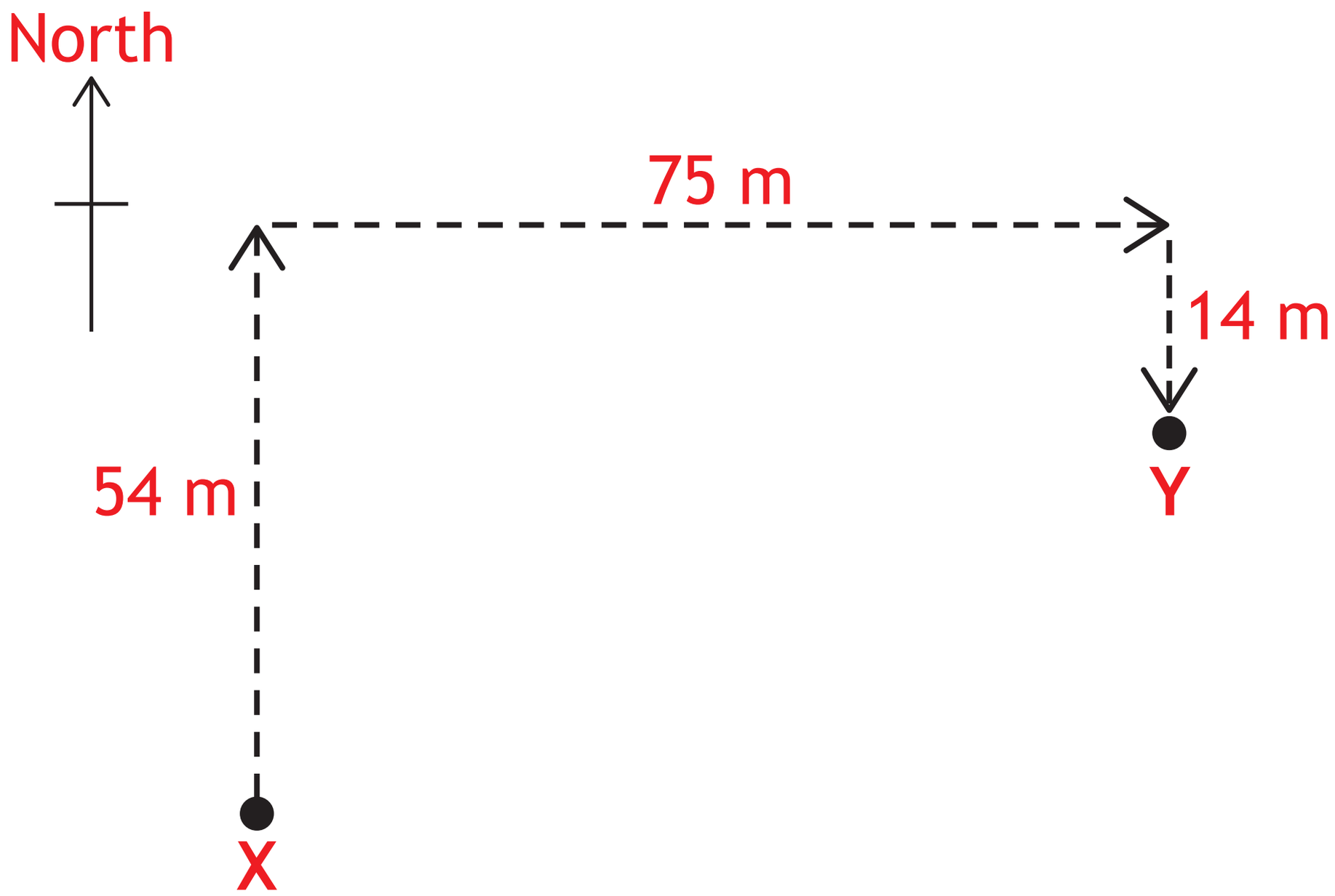

visible light
X-rays
ultra-violet
infrared
microwaves
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
1
wavelength (m)

Q6

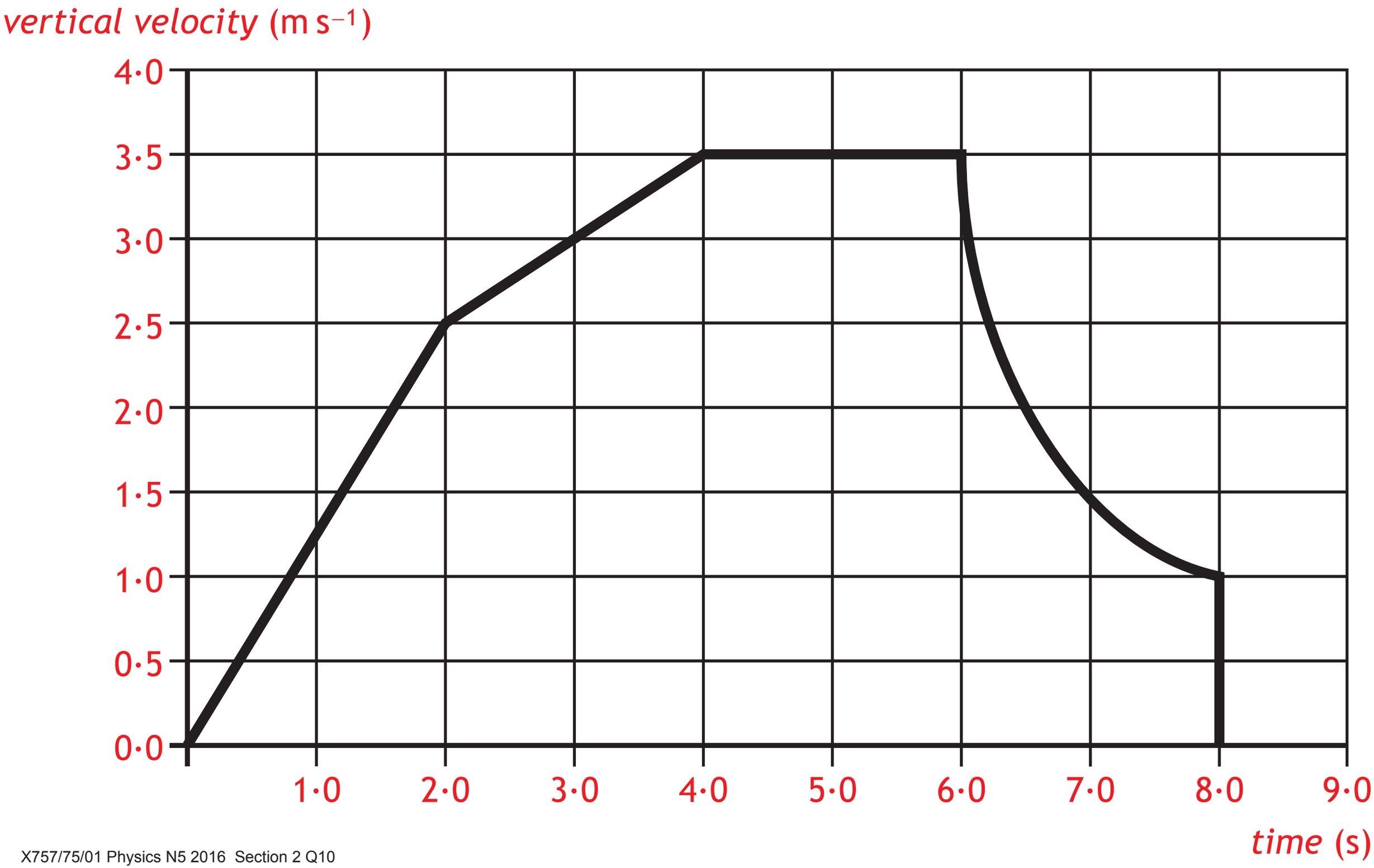



angle of refraction (°)
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
angle of incidence (°)

Q9



Q10


vertical velocity (m s−1)
4·0
3·5
3·0
2·5
2·0
1·5
1·0
0·5
0·0
1·0
2·0
3·0
4·0
5·0
6·0
7·0
8·0
9·0
time (s)