



GCE A LEVEL



A420U20-1

FRIDAY, 9 JUNE 2023 – MORNING

PHYSICS – A LEVEL COMPONENT 2

ELECTRICITY AND THE UNIVERSE

2 hours plus your additional time allowance

Surname: _____

First name(s): _____

Centre Number: _____

Candidate Number: 2 _____

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	9	
2.	12	
3.	17	
4.	15	
5.	13	
6.	11	
7.	9	
8.	14	
Total	100	

(Turn over)

ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a DATA BOOKLET (provided by WJEC).

ITEMS INCLUDED WITH QUESTION PAPER

A separate Diagram Booklet.

The Diagram Booklet MUST be handed in to the invigilators and sent for marking.

INSTRUCTIONS TO CANDIDATES

Use black ink, black ball – point pen, black felt tip or your usual method.

Write your name, centre number and candidate number in the spaces on the front cover.

Answer ALL questions.

Write your answers in the spaces provided.

If you run out of space use the additional pages at the back of the booklet taking care to number the question(s) correctly.

(Turn over)

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part – question.

The assessment of the quality of extended response (QER) will take place in question 5 (a).

ANSWER ALL QUESTIONS.

- 1. (a) Define the potential difference between two points in an electric circuit.**

[1 mark]

continued on the next page . . .

(Turn over)

Question 1 continued

- 1. (b) Look at the diagram for Question 1 (b) in the separate Diagram Booklet.**

The diagram shows a simple control circuit for a garden water feature, which is also shown. It consists of a 9.0 V battery with negligible internal resistance connected in series with a light dependent resistor (LDR) and a $10\text{ k}\Omega$ fixed resistor. The voltmeter and water feature circuit have very high resistances. The LDR has a resistance of $200\text{ k}\Omega$ IN THE DARK and $200\text{ }\Omega$ IN FULL SUNLIGHT.

continued on the next page . . .

Question 1 (b) continued

- 1. (b) (i) The circuit allows the water feature to operate during daylight. State and explain what happens to the reading on the voltmeter when the intensity of the light incident on the LDR increases.**

[illegible]

[3 marks]

continued on the next page . . .

(Turn over)

Question 1 (b) continued

1. (b) (ii) The water feature is activated when the reading on the voltmeter reaches **2.0 V**. Calculate the resistance of the LDR at this activation point.

[2 marks]

- (iii) A gardener notes that, on some days, the water feature is activated throughout the day. He wishes to control the circuit manually so that he can turn the feature off if required. He intends to include an additional component, a **0 – 40 k Ω** variable resistor, in the circuit.

continued on the next page . . .

(Turn over)

Question 1 (b) (iii) continued

- 1. (b) (iii) I. Sketch the modified circuit with the variable resistor appropriately positioned.**

Space for sketch:

[1 mark]

continued on the next page . . .

(Turn over)

Question 1 (b) (iii) continued

- 1. (b) (iii) II. Determine whether this modification will allow him to switch the water feature off IN FULL SUNLIGHT.**

[2 marks]

(Total for Question 1 = 9 marks)

(Turn over)

2. (a) The size of a current in a wire, for a given **pd**, depends on its resistance. State, in terms of free electrons, how this resistance arises.

[1 mark]

continued on the next page . . .

(Turn over)

Question 2 continued

2. (b) (i) A 2.0 m length of copper wire has a mass of 36.0 g and a cross – sectional area, A , of $2.0 \times 10^{-6} \text{ m}^2$
- Each copper atom has a mass of $1.05 \times 10^{-25} \text{ kg}$ and contributes, on average, one free electron per atom. Show that the number of free electrons per unit volume, n , is approximately $9 \times 10^{28} \text{ m}^{-3}$

[2 marks]

continued on the next page . . .

(Turn over)

Question 2 (b) continued

2. (b) (ii) A pd, V , is applied across the wire.

Show that the drift velocity, v , can be given by:

$$v = \frac{V}{\rho l n e}$$

where ρ is the resistivity of copper
and l is the length of the wire.

[3 marks]

continued on the next page . . .

(Turn over)

Question 2 (b) continued

2. (b) (iii) Calculate V when a **1.2 V** pd is applied across the wire.
(Resistivity of copper,
 $\rho = 1.7 \times 10^{-8} \Omega \text{ m}$)

[2 marks]

continued on the next page . . .

(Turn over)

Question 2 continued

- 2. (c) A second copper wire has the same volume as part (b) but is longer. Matthew considers how some properties in the longer wire compare with the original when a 1.2 V pd is applied across the longer wire. He determines whether the properties are BIGGER, SMALLER or THE SAME for the longer wire.**

Look at the table for Question 2 (c) in the separate Diagram Booklet. His conclusions are given in the table. Determine to what extent he is correct.

[2 marks]

(Turn over)

Question 2 continued

- 2. (d) Many scientists from around the world are searching for a superconducting material which has a critical temperature above 273 K. Discuss the benefits to society if this were achieved.**

[2 marks]

(Total for Question 2 = 12 marks)

(Turn over)

- 3. Look at the diagram for Question 3 in the separate Diagram Booklet. The diagram shows a circuit.**

Laura uses the circuit shown to investigate the discharging of a capacitor of unknown capacitance, C , through a $6.8 \text{ k}\Omega$ resistor.

During the discharging she uses a stopwatch and a voltmeter to take measurements for 1 minute.

continued on the next page . . .

Question 3 continued

- 3. (a) Briefly outline the experimental steps
Laura should take to obtain her results.**

[3 marks]

continued on the next page . . .

(Turn over)

Question 3 continued

3. (b) Laura rearranges the equation

$$V = V_0 e^{-\frac{t}{CR}} \text{ into the form:}$$

$$\ln V = -\frac{t}{CR} + \ln V_0$$

Look at the diagram for Question 3 (b) in the separate Diagram Booklet.

The diagram is a grid.

She plots a graph of $\ln V$ against t , as shown in the diagram.

Look at the table for Question 3 (b) in the separate Diagram Booklet.

She plots all points apart from the point at $t = 60$ s, the measurements for which are given in the table.

continued on the next page . . .

Question 3 (b) continued

**Complete the table AND plot the point
on the grid provided along with the
horizontal and vertical error bars.
Space is provided for calculations.**

Space for working:

[2 marks]

continued on the next page . . .

(Turn over)

Question 3 continued

- 3. (c) (i) Draw lines of maximum and minimum gradients and determine the gradients of both lines.**

[3 marks]

continued on the next page . . .

(Turn over)

Question 3 (c) continued

- 3. (c) (ii) Hence calculate the mean gradient and the PERCENTAGE uncertainty in its value.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 3 continued

- 3. (d) (i) Determine a value for the capacitance, C , of the capacitor along with its ABSOLUTE uncertainty. Assume that the resistor has a tolerance (uncertainty) of 5%. Give your answer to an appropriate number of significant figures.**

[5 marks]

3. (d) (ii) Determine the **pd**, **V** , of the power supply along with the **ABSOLUTE** uncertainty in its value.

[2 marks]

(Total for Question 3 = 17 marks)

(Turn over)

4. (a) Look at the diagram for Question 4 (a) in the separate Diagram Booklet.

The diagram shows how a gap can be bridged using a concrete beam.

- (i) Inserting a pre – stressed steel bar into the concrete would strengthen the beam.

ON THE DIAGRAM, draw a pre – stressed steel bar in an appropriate position.

[1 mark]

- (ii) Explain how the steel bar strengthens the beam.

[2 marks]

continued on the next page . . .

(Turn over)

Question 4 continued

- 4. (b) Look at the diagram for Question 4 (b) in the separate Diagram Booklet.**

Stress (σ) versus strain (ϵ) curves for three kinds of steel are shown.

- (i) All three steels have the same Young modulus. State how the graphs support this statement.**

[1 mark]

continued on the next page . . .

(Turn over)

Question 4 (b) continued

- 4. (b) (ii) Compare the physical properties of high carbon steel with low carbon steel and explain these properties in terms of their molecular structure.**

[3 marks]

continued on the next page . . .

(Turn over)

Question 4 continued

- 4. (c) Look at the diagram for Question 4 (c) in the separate Diagram Booklet.**

The diagram is NOT drawn to scale.

A tugboat uses a cable made of quenched steel to tow a large ship at constant speed.

- (i) Use information from the diagram and the data below to show that the extension in the cable is approximately 2 mm.**

Young modulus of steel = 210 GPa

Length of cable = 40.0 m

Diameter = 2.4 cm

(Turn over)

[4 marks]

4. (c) (ii) Calculate the energy stored in the extended cable.

[2 marks]

continued on the next page . . .

(Turn over)

Question 4 (c) continued

- 4. (c) (iii) The tugboat operator decides to replace the quenched steel cable with a cable made from low carbon steel of the same length and diameter. Using the graphs in part (b) as guides, suggest why this may be a mistake. (No further calculations are required.)**

[2 marks]

(Total for Question 4 = 15 marks)

(Turn over)

5. (a) Look at the diagram for Question 5 (a) in the separate Diagram Booklet.

Curves of gravitational potential versus distance from the surfaces of the Earth and Moon are shown along with the curve for the combined potential due to the Earth and Moon. Explain the shape of each curve and give a full account of the information which could be obtained from them if numerical scales were provided on the axes.

continued on the next page . . .

(Turn over)

Question 5 continued

- 5. (b) Look at the image for Question 5 (b) in the separate Diagram Booklet.**

The image represents a robotic lander to be used in the 'MARS SAMPLE RETURN PROGRAMME'.

The 'MARS SAMPLE RETURN PROGRAMME' is a proposed joint mission by NASA and the European Space Agency to return a sample of Martian soil to the Earth for analysis. The mission would involve the robotic lander collecting a sample of the soil, loading it onto a small rocket, which would then be launched vertically to link with an orbiting spacecraft. The spacecraft, with sample on board, would then return to Earth.

continued on the next page . . .

Question 5 (b) continued

5. (b) (i) Use the following data to calculate the speed with which the rocket must be launched from the surface of Mars to reach the height of the orbiting spacecraft. Ignore any resistive forces due to the Martian atmosphere.

Mass of Mars: 6.4×10^{23} kg

Radius of Mars: 3.4×10^6 m

Height of spacecraft above surface: 300 km

[4 marks]

5. (b) (ii) Look at the diagram for Question 5 (b) (ii) in the separate Diagram Booklet.
- The diagram is NOT drawn to scale.
- When the rocket has reached a height of **300 km**, it is given a sideways thrust so that it can ‘catch up’ with the orbiting spacecraft. This is illustrated in the diagram. Show that the orbital speed, V , of the rocket must be approximately **3500 m s^{-1}** or greater for it to successfully catch up and link with the spacecraft.
-
-

(Turn over)

[3 marks]

(Total for Question 5 = 13 marks)

6. Look at the diagram for Question 6 in the separate Diagram Booklet.

Point **P** is the centre of a circle of radius **0.3 m**. Charges are placed as shown.

- (a) Calculate the magnitude and direction of the resultant electric field strength at **P**.

[5 marks]

continued on the next page . . .

(Turn over)

Question 6 continued

6. (b) Calculate the potential at P.

[illegible]

[3 marks]

continued on the next page . . .

(Turn over)

Question 6 continued

6. (c) An electron released from rest from a point where the potential is **+50 V** follows a path that takes it through point **P**. John calculates that, at **P**, the electron's speed is nearly **2%** of the speed of light. Determine whether he is correct.

[3 marks]

(Total for Question 6 = 11 marks)

(Turn over)

7. (a) Look at the diagram for Question 7 (a) in the separate Diagram Booklet.

Part of the line absorption spectrum for light from the Sun is shown.

A star, similar to our Sun, is detected in a nearby galaxy which is moving away from the Earth. **SKETCH A POSSIBLE SPECTRUM** for this star in the blank spectrum provided.

[2 marks]

continued on the next page . . .

Question 7 continued

- 7. (b) Cepheid variables are types of stars that ‘pulsate’ regularly, varying in luminosity, diameter and temperature as they change. At a particular time, one such star has a diameter of 6.3×10^{10} m and a surface temperature of 6000 K.**

- (i) Calculate the wavelength at which the greatest spectral intensity is emitted by the star AND state in which part of the electromagnetic spectrum this wavelength lies.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 7 (b) continued

7. (b) (ii) Calculate the star's luminosity.

[2 marks]

continued on the next page . . .

(Turn over)

Question 7 continued

7. (c) During the evolution of a star, its diameter **DOUBLES** and its luminosity increases by a factor of **THREE**. Show that this change decreases the temperature by less than **10%**

[3 marks]

(Total for Question 7 = 9 marks)

(Turn over)

- 8. (a) (i) Use the Principle of Conservation of Energy to show that the critical density, ρ_c , of the universe is given by:**

$$\rho_c = \frac{3H_0^2}{8\pi G}$$

[illegible]

[4 marks]

continued on the next page . . .

(Turn over)

Question 8 (a) continued

- 8. (a) (ii) The critical density of the universe corresponds to about 5 atoms of hydrogen per m^3**

Evaluate whether this agrees with the value of the Hubble constant given in the Data Booklet.

[3 marks]

continued on the next page . . .

(Turn over)

Question 8 continued

8. (b) The Comet galaxy is 3.2×10^9 light years from Earth.

(i) Show that the galaxy is receding at approximately $65\,000 \text{ km s}^{-1}$

(1 light year = $9.5 \times 10^{12} \text{ km}$)

[2 marks]

continued on the next page . . .

(Turn over)

Question 8 (b) continued

8. (b) (ii) One of the lines in the hydrogen spectrum has a wavelength of **656.3 nm** when measured in a laboratory on Earth. Calculate the wavelength of the same line in the observed spectrum of the Comet galaxy.

[3 marks]

continued on the next page . . .

(Turn over)

Question 8 continued

8. (c) The Hubble space telescope can detect a portion of the infra – red and ultraviolet spectrum, as well as the visible spectrum. It has been used to study the Comet galaxy. Explain why it is more useful to use the Hubble telescope than to attempt to study the galaxy using telescopes sensitive only to visible light.

[2 marks]

(Total for Question 8 = 14 marks)

END OF PAPER

TOTAL 100 MARKS

(Turn over)

Question number	Additional pages, if required. Write the question number(s) in the left - hand margin.

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PHYSICS – A LEVEL COMPONENT 2

ELECTRICITY AND THE UNIVERSE

**The Diagram Booklet MUST be handed in
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Diagram Booklet

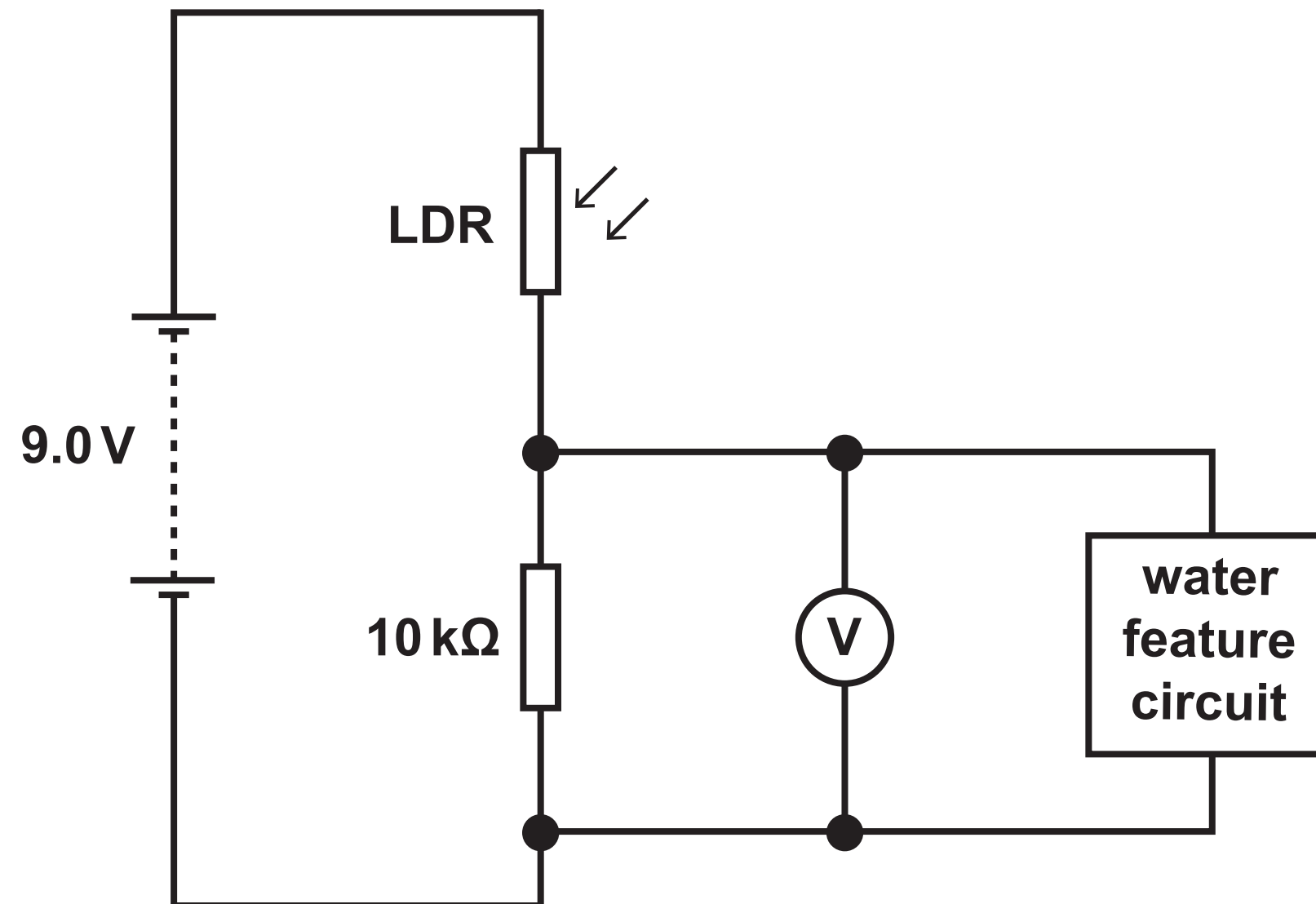
Surname: _____

First name(s): _____

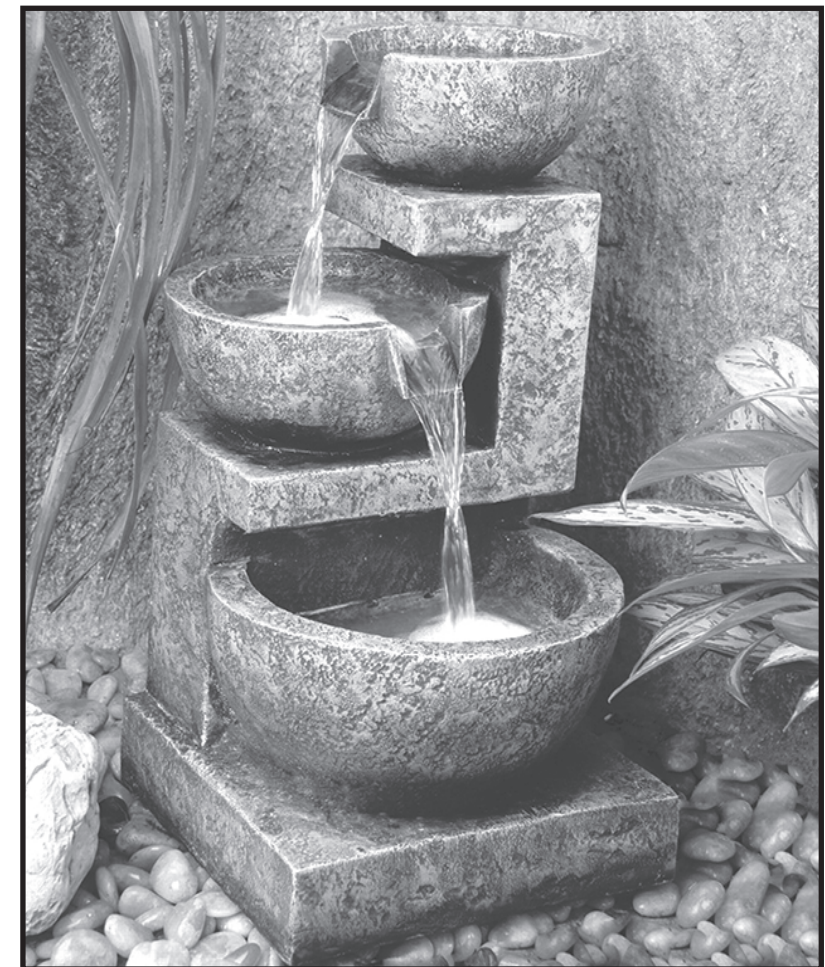
Centre Number: _____

Candidate Number: 2 _____

Question 1 (b)



Water feature

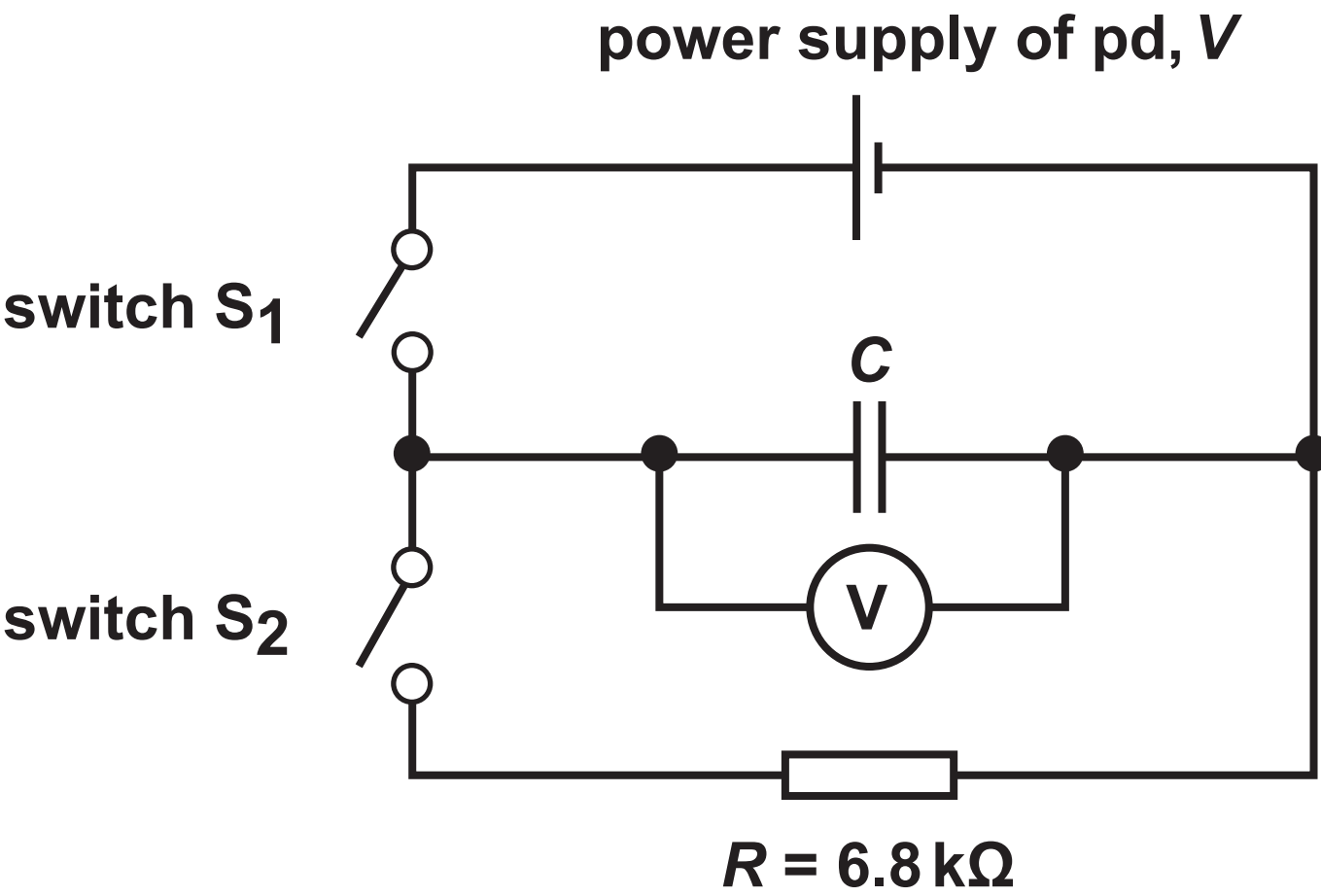


Question 2 (c)

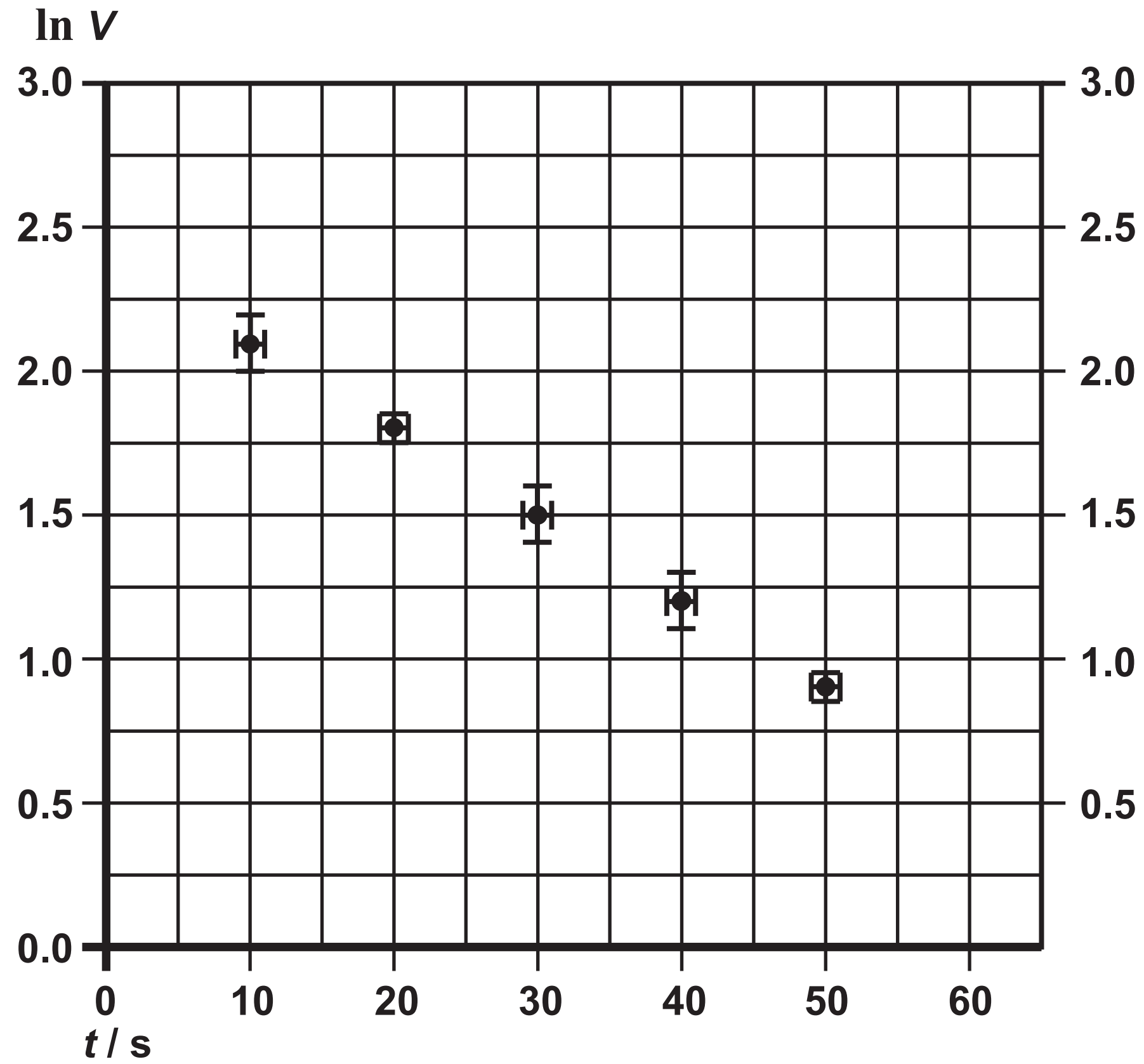
Table

Property	Matthew concludes that for the longer wire, this property is ...
A	smaller
n	bigger
ρ	the same
v	the same

Question 3



Question 3 (b)



Question 3 (b)

Table

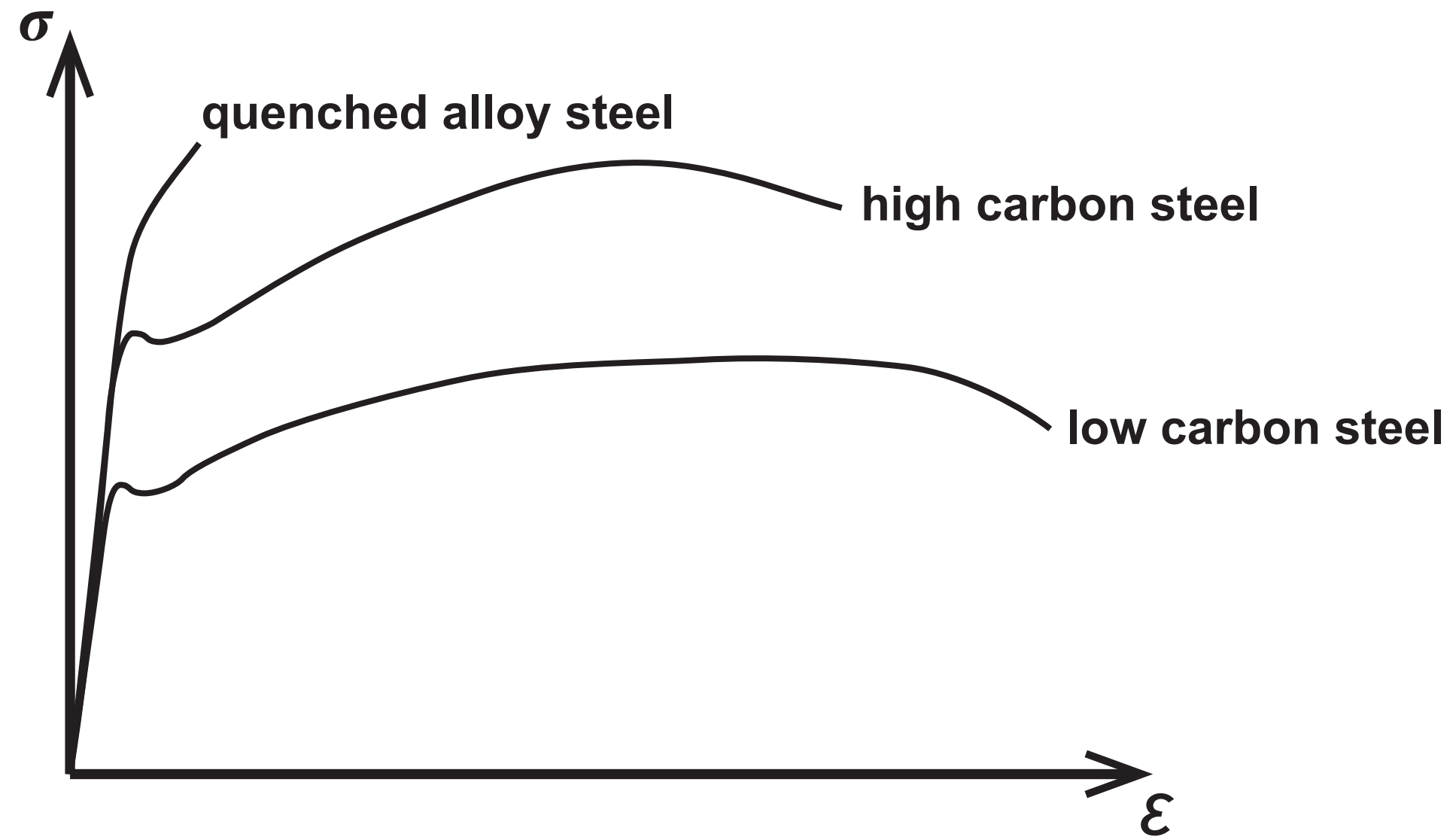
t / s	$V_{\text{reading 1}} / \text{V}$	$V_{\text{reading 2}} / \text{V}$	$\ln (V_{\text{reading 1}} / \text{V})$	$\ln (V_{\text{reading 2}} / \text{V})$	Mean $\ln (V / \text{V})$
60 ± 1	1.73	1.92	0.55		

Question 4 (a)

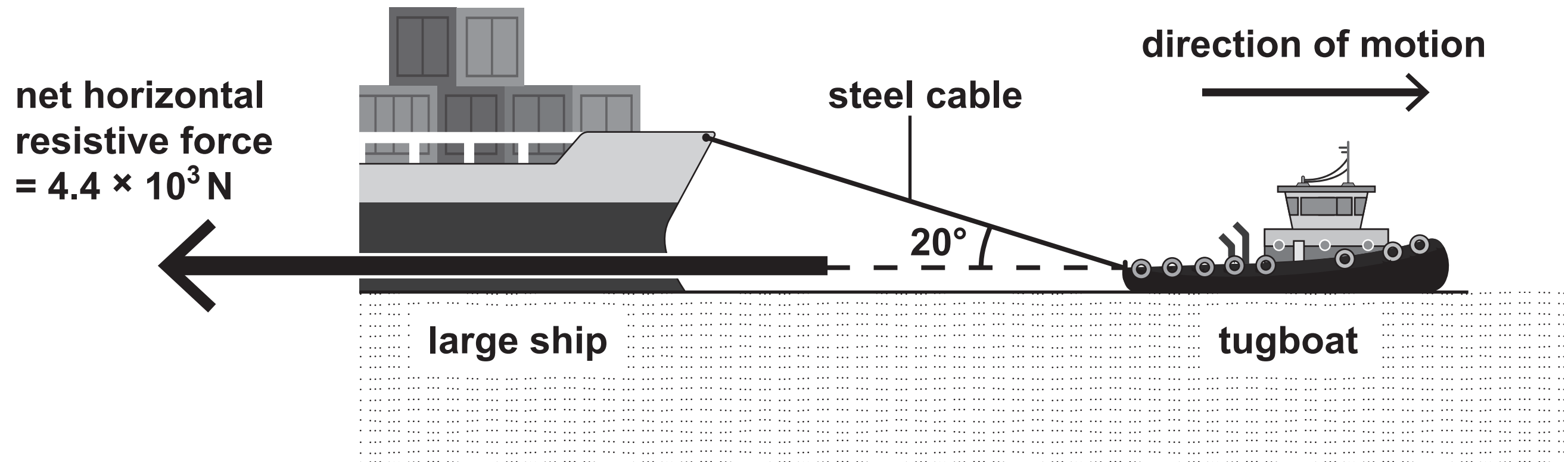
concrete beam



Question 4 (b)



Question 4 (c)



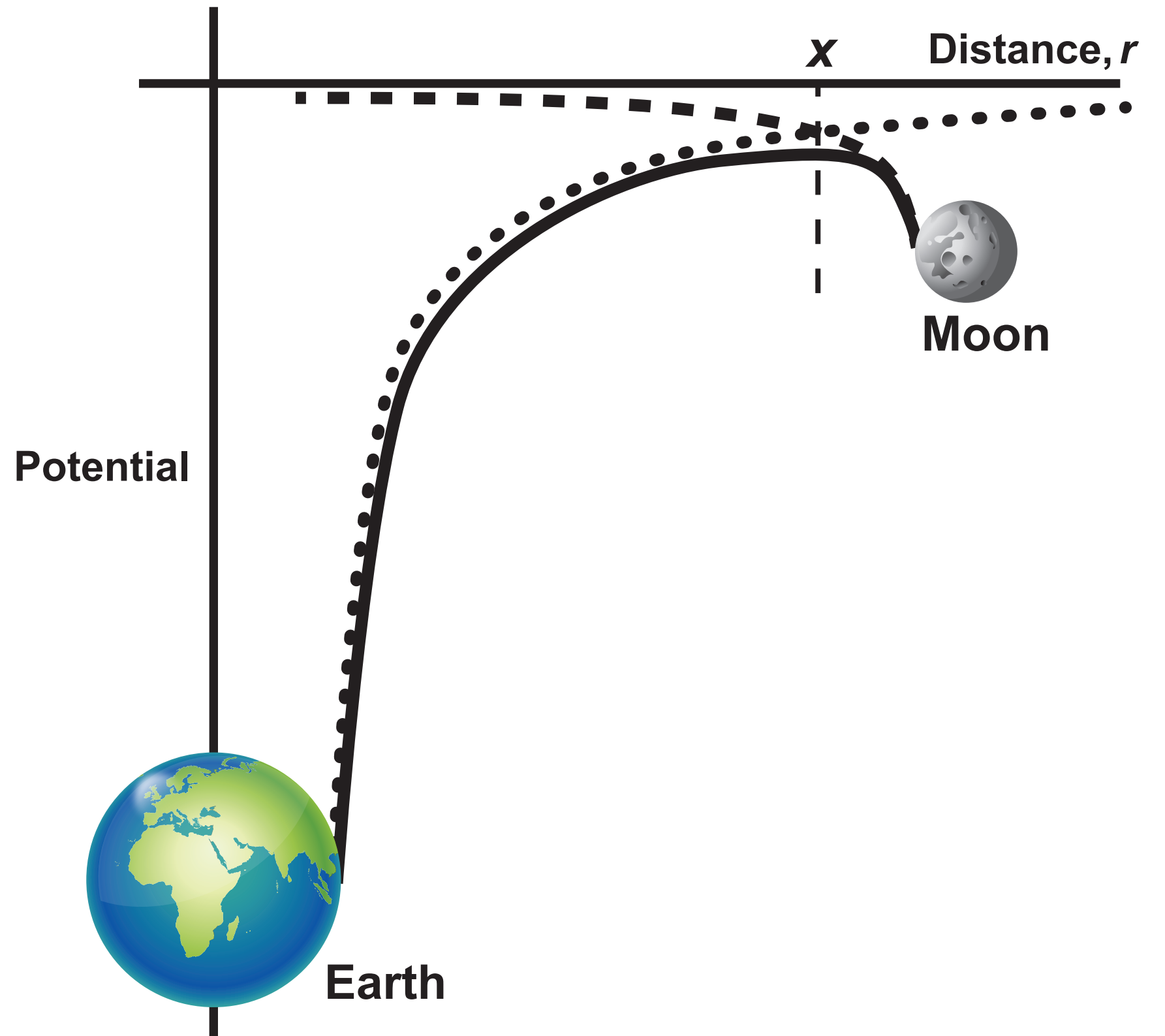
Question 5 (a)

Key: Gravitational Potential

..... = Earth

----- = Moon

———— = Earth and Moon
combined



Question 5 (b)

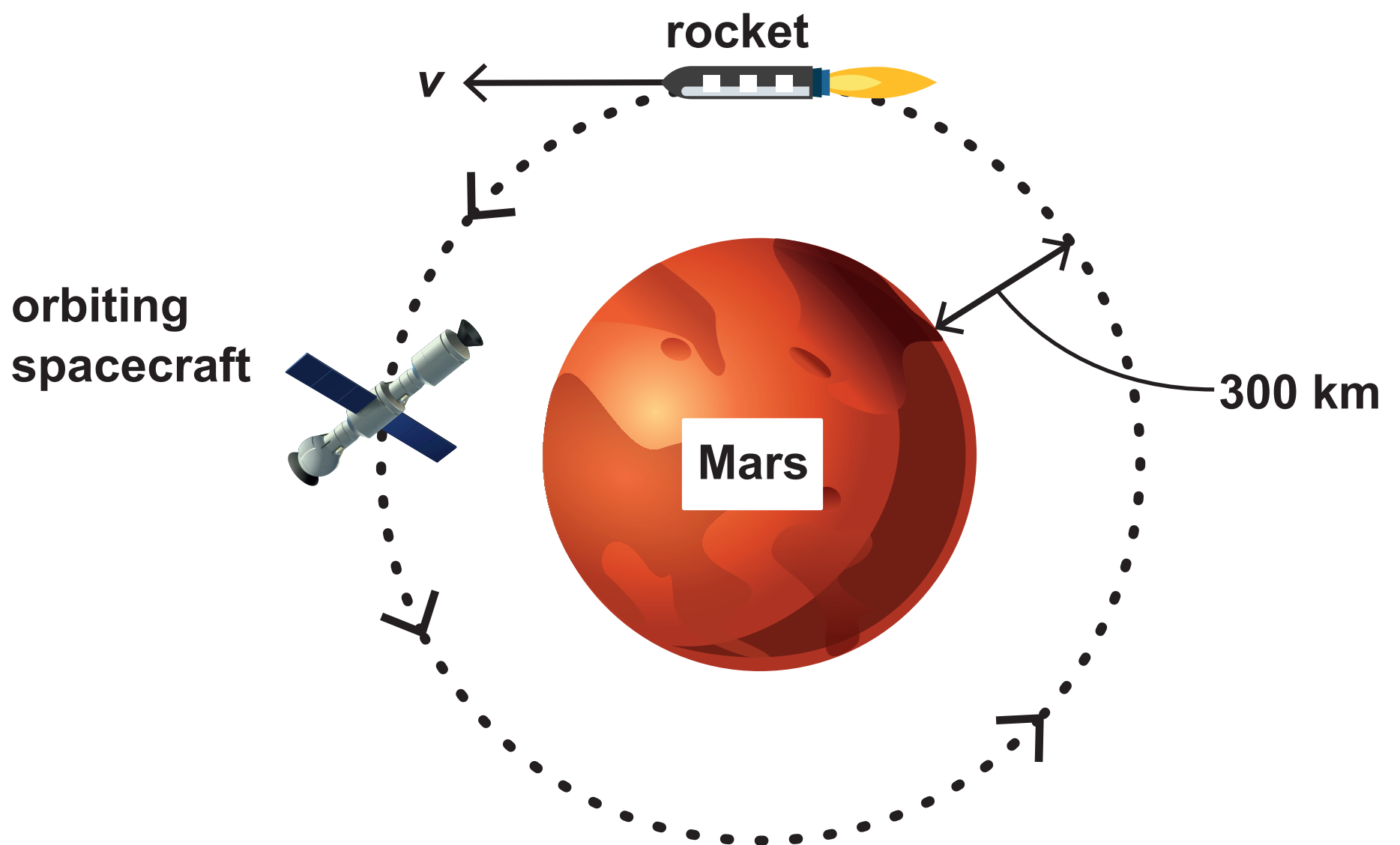
small rocket launched
vertically from the
robotic lander to link
with an orbiting
spacecraft

robotic lander

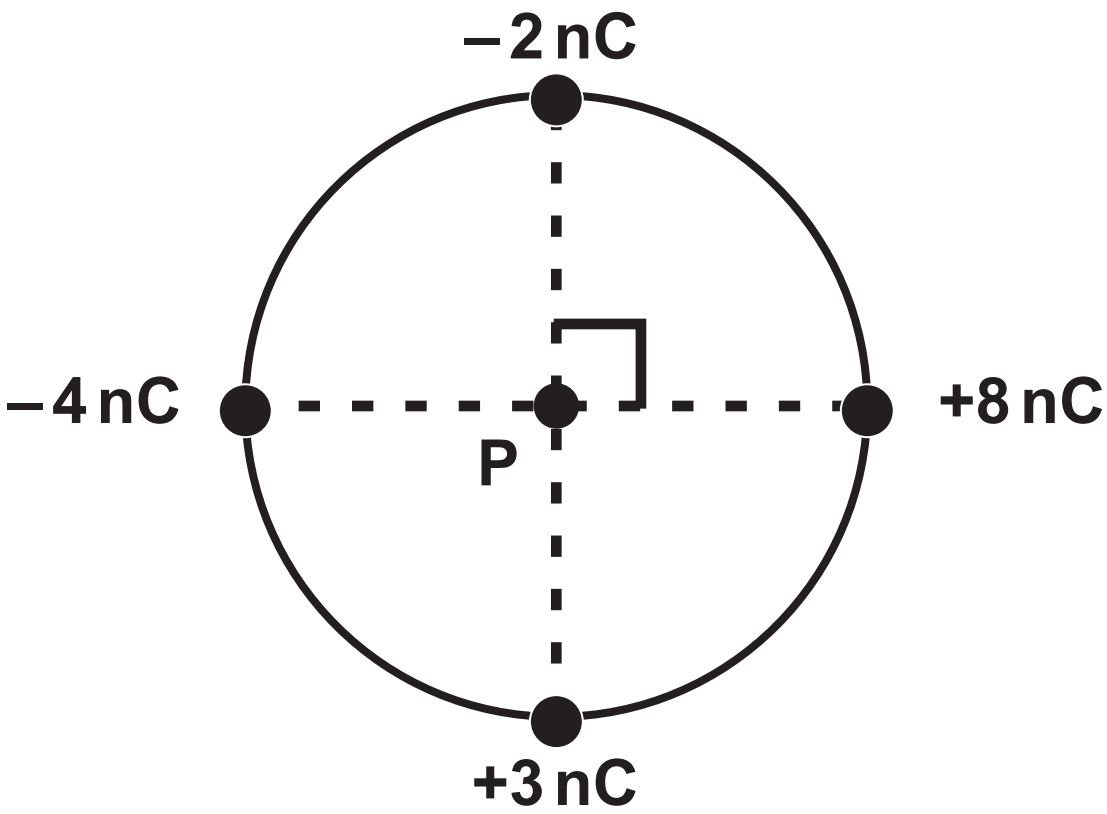


Question 5 (b) (ii)

Diagram NOT drawn to scale



Question 6



Question 7 (a)

