Time: 2 hours **Total: 85 marks**

Physics – A-level – Paper 1 (Mark Scheme) May 2023

Section A (Multiple Choice Questions): 40 marks

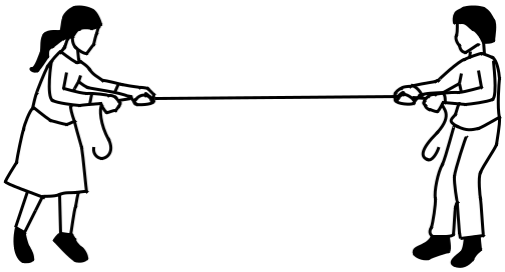
Section B (Short and Long Answer Questions): 30 marks

Section C (Practical Based Skills): 15 marks

***Note: There is a data and formulae sheet at the end of this examination**

Section A: Multiple Choice

1. Two students pull on opposite ends of a rope, as shown in the diagram below. Each student pulls with a force of 400 N.

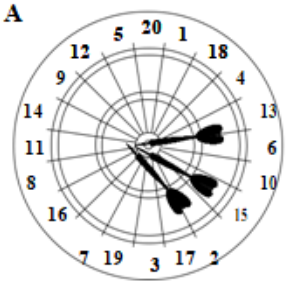


Which one of the following is closest to the magnitude of the force of the rope on each student?

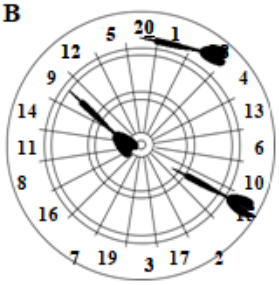
A) 0 N
B) **400 N**
C) 600 N
D) 800 N

2. The aim of darts is to hit the bullseye at the centre of a dartboard. Four darts players (A, B, C and D) each threw three darts. The results of their throws are shown below. Which player is precise and very accurate? **Player A**

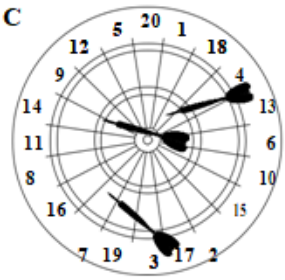
Player A



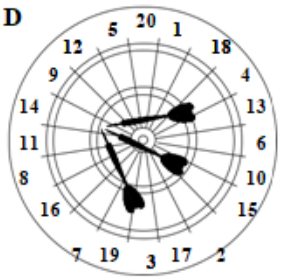
Player B



Player C



Player D



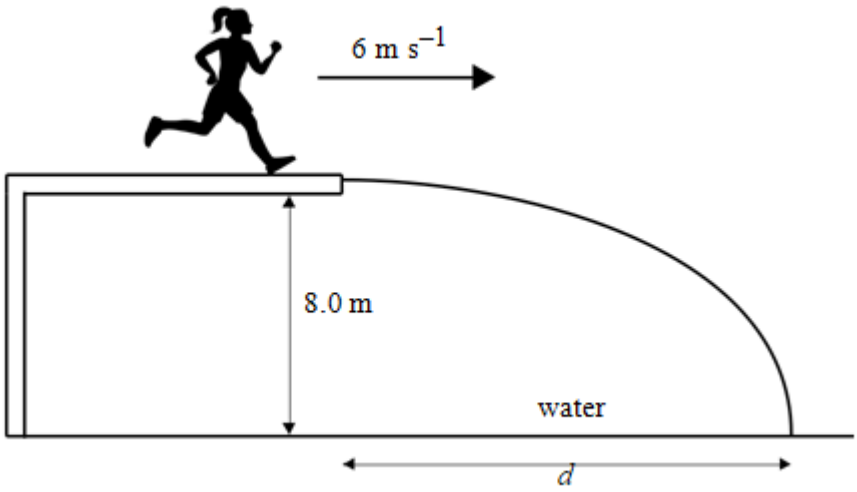
3. Which one of the players produced a set of attempts that could be described as being precise but inaccurate?
   A) Player A
   B) Player B
   C) Player C
   D) **Player D**

4. The experimental uncertainty of a measurement is best understood as
   A) an estimate of the validity of the data.
   B) a mistake in the experimental method used.
   C) a mistake in the recording of a measurement.
   D) **an estimate of the maximum likely difference between the measurement and the true value.**

For questions 5 & 6, use the below information:

Lucy is running horizontally at a speed of 6 m s^{-1} along a diving platform that is 8.0 m vertically above the water.

Lucy runs off the end of the diving platform and reaches the water below after time *t*.
She lands feet first at a horizontal distance *d* from the end of the diving platform.



5. Which one of the following expressions correctly gives the distance *d*?
   A) 0.8*t*
   B) **6*t***
   C) $5t^2$
   D) $6t + 5t^2$

6. Which one of the following is closest to the time taken, *t*, for Lucy to reach the water below?
   A) 0.8 s
   B) 1.1 s
   C) **1.3 s**
   D) 1.6 s

7. A cyclist is riding at a steady speed on a level road. According to Newton's third law of motion, what is equal and opposite to the backward push of the back wheel on the road?

   A) the force exerted by the cyclist on the pedals
   B) the total air resistance and friction force
   C) the tension in the cycle chain

D) the forward push of the road on the back wheel

8. A resultant force causes a body to accelerate. What is equal to the resultant force?

A) the acceleration of the body per unit mass

B) the change in kinetic energy of the body per unit time

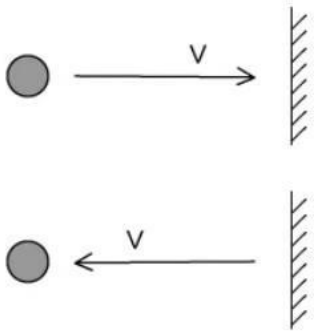
C) the change in momentum of the body per unit time

D) the change in velocity of the body per unit time

9. What is meant by the mass and by the weight of an object on the Earth?

	Mass	Weight
A	its momentum divided by its velocity	the work done in lifting it one metre
B	the gravitational force on it	the property that resists its acceleration
C	**the property that resists its acceleration**	**the pull of the Earth on it**
D	the pull of the Earth on it	its mass divided by the acceleration of free fall

10. An object travelling with velocity ***v*** strikes a wall and rebounds as shown



Which property of the object is not conserved?

A. momentum

B. mass

C. kinetic energy

D. speed

11. An egg is dropped from the top of a three-storey building. It falls through air until it reaches the ground. What remains constant throughout the fall?

A. acceleration of the egg

B. weight of the egg

C. velocity of the egg

D. air resistance on the egg

[1 mark]

12. The gravitational field strength on the surface of planet R is one eighth of that on the surface of planet S. On the surface of R, a body has its mass measured to be 2.5 kg and its weight measured to be 12.5 N

What results are obtained for measurements of the mass and weight of the same body on the surface of planet S?

	Mass on S	Weight on S
A	2.5 kg	20 N
B	20 kg	100 N
C	**2.5 kg**	**100 N**
D	20 kg	160 N

13. Which is not one of Newton's laws of motion?

A. If body A exerts a force on body B, then body B exerts an equal and oppositely-directed force on body A

B. The rate of change of momentum of a body is directly proportional to the external force acting on the body and takes place in the direction of the force

C. The total momentum of a system of interacting bodies remains constant, providing no external force acts

D. A body continues in a state of rest or of uniform motion in a straight line unless acted upon by some external force

14. As a car accelerates uniformly, its momentum is measured at regular intervals

A graph of the momentum of the car is plotted against time

What is evaluated by finding the gradient of the graph at a particular time?

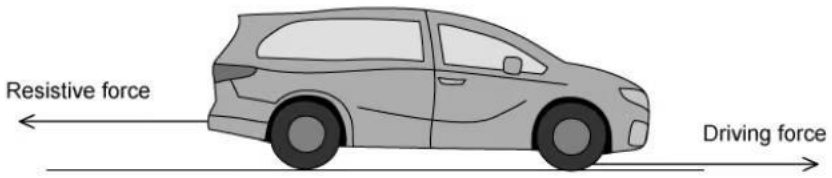
A. the acceleration of the car

B. the resultant force on the car

C. the kinetic energy of the car

D. the velocity of the car

15. A car has a horizontal driving force of 2.0 kN acting on it and a resistive force a quarter of this size. It has a forward horizontal acceleration of 2.0 m s^{-2}



What is the mass of the car?

A. 500 kg

B. 750 kg

C. 1250 kg

D. 2000 kg

16. A Sprinter runs a 200m race in a straight line. He accelerates from the starting block at a constant acceleration of 2.5 m s^{-2} to reach his maximum speed of 10 m s^{-1}. He maintains this speed until he crosses the finish line.

Which time does it take the sprinter to run the race?

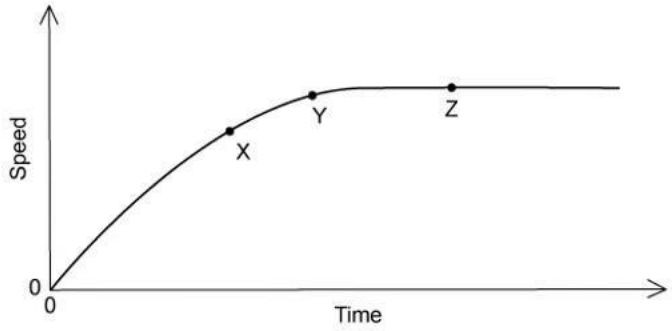
A. 8 s

B. 20 s

C. 22 s

D. 40 s

17. A raindrop falls vertically from rest in air. The variation with time of the speed of the raindrop is shown in the graph.



Which statement about the raindrop is correct?

A. at point X, the raindrop has an acceleration of 9.81 m s^{-2}

B. at point Z, the force on the raindrop due to air resistance has reached its maximum value and so the acceleration of the raindrop has also reached its maximum value

C. at point Z, the force due to air resistance is equal and opposite to the weight of the raindrop and so the speed of the raindrop is zero

D. the resultant force on the raindrop at point Y is less than the resultant force on the raindrop at point X

18. An aeroplane travels at an average speed of 700 km h^{-1} on an outward fight and at 300 km h^{-1} on the return fight over the same distance.

What is the average speed of the whole fight?

A. 400 km h^{-1}

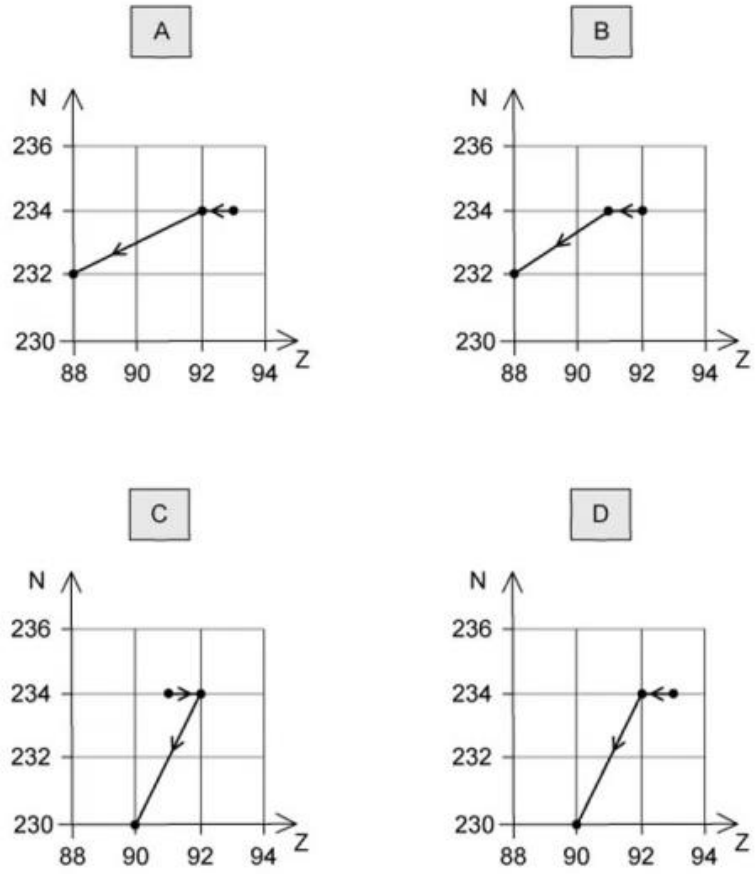
B. 420 km h^{-1}

C. 480 km h^{-1}

D. 500 km h^{-1}

19. A radioactive nucleus is formed by β-decay. This nucleus then decays by α-emission.

The graph below show the nucleon number N plotted against proton number Z. Which one shows the β-decay followed by the α-emission? B



20. An element emits an alpha particle from its radioactive nucleus.

The daughter nucleus then emits a beta particle, and then the daughter nucleus of that reaction emits another beta particle. Which statement describes the final nuclide that is formed?

A) it is a nuclide of the same element but with different proton number

B) it is a nuclide of a different element of higher proton number

C) it is a different isotope of the original element

D) it is identical to the original nuclide

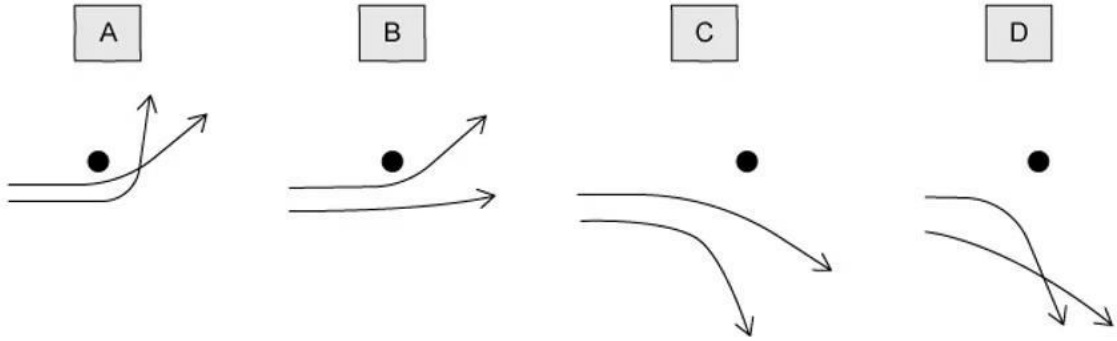
21. A thorium isotope has a nucleon number of 232 and a proton number of 90. It decays to form another isotope of with a nucleon number of 228.

How many alpha particles and beta particles are emitted during this decay?

	Alpha particles	Beta particles
A	0	4
B	**1**	**2**
C	1	1
D	2	1

22. Two α-particles with equal energies are defected by a gold nucleus.

Which diagram best represents their paths? A



23. Thorium $^{232}_{90}\mathrm{Th}$ decays through a series of transformations. The particles emitted in successive transformations are: α β β γ α

The resulting nuclide may be represented by

A) $^{230}_{82}Pb$

B) $^{227}_{85}At$

C) $^{227}_{85}Fr$

D) $\mathbf{^{224}_{88}Ra}$

24. Which of the following equations correctly shows an α-particle causing a nuclear reaction?

A) $\mathbf{^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}n}$

B) $^{17}_{8}O + ^{4}_{2}He \rightarrow ^{20}_{9}F + ^{1}_{1}p$

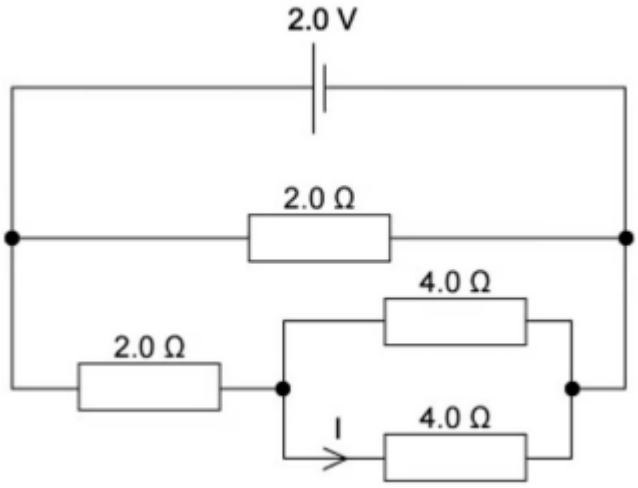
C) $^{17}_{8}O + ^{0}_{-1}e \rightarrow ^{13}_{5}B + ^{4}_{2}He$

D) $^{14}_{7}N + ^{1}_{1}p \rightarrow ^{11}_{6}C + ^{4}_{2}He$

25. Two lamps are connected in series to a 250 V power supply. One lamp is rated 240 V, 60 W and the other is rated 10 V, 2.5 W. Which statement most accurately describes what happens?

A) Both lamps light at less than their normal brightness
B) Both lamps light normally
C) Only the 60 W lamp lights
D) The 10 V lamp blows

26. A cell of e.m.f. 2.0 V and negligible internal resistance is connected to a network of resistors as shown.



What is the current *I* ?

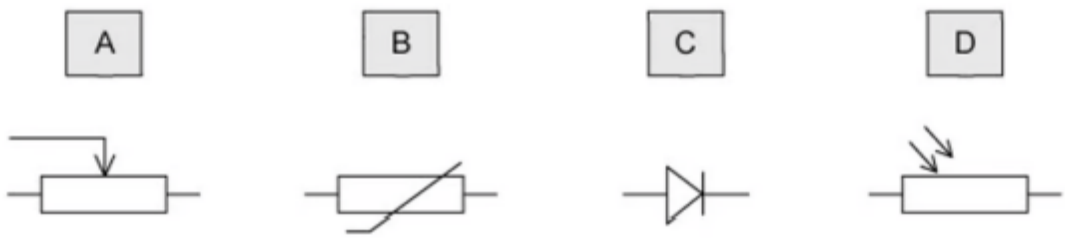
A) 0.25 A
B) 0.33 A
C) 0.50 A
D) 1.5 A

27. A battery is marked 9.0 V.

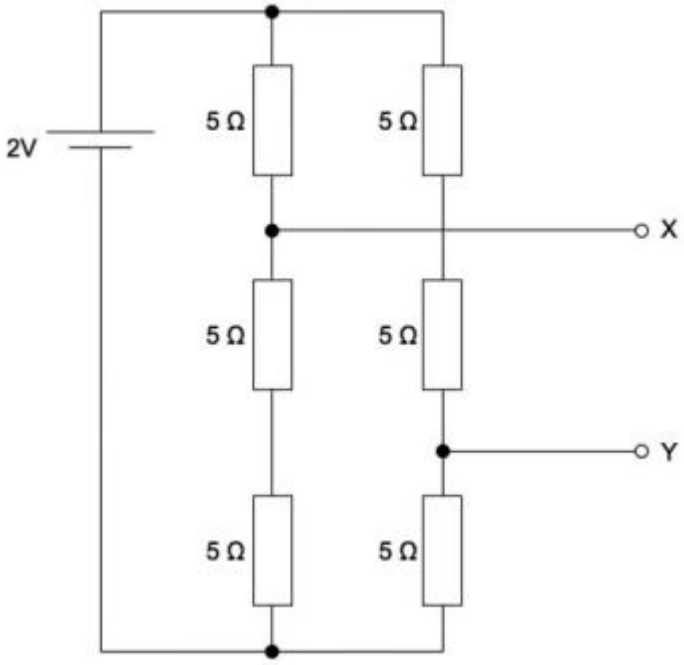
What does it mean?

A) Each coulomb of charge from the battery supplies 9.0 J of electrical energy to the whole circuit
B) The battery supplies 9.0 J to an external circuit for each coulomb of charge
C) The potential difference across any component connected to the battery will be 9.0 V
D) There will always be 9.0 V across the battery terminals

28. Which symbol represents a component whose resistance is designed to change with temperature? B



Six resistors, each of resistance 5 Ω, are connected to a 2 V cell of negligible internal resistance.



29. What is the potential difference between terminals X and Y?

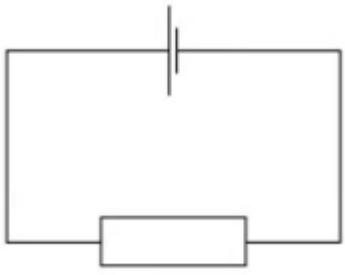
A) $\frac{3}{3}$ V

B) $\frac{8}{9}$ V

C) $\frac{4}{3}$ V

D) 2 V

A cell is connected to a resistor. At a given moment, the potential difference across the cell is less than its electromotive force.



30. Which statement explains this?

A) The cell is continually discharging
B) The connecting wire has some resistance
C) Energy is needed to drive change through the cell
D) Power is used when there is a current in the resistor

31. The combined resistance R_T of two resistors of resistances R_1 and R_2 connected in parallel is given by the formula

$$\frac{1}{RT} = \frac{1}{R1} + \frac{1}{R2}$$

Which statement is used in the derivation of this formula?

A) The currents through the two resistors are equal
B) The potential difference across each resistor is the same
C) The supply current is split between the two resistors in the same ratio of their resistances
D) The total power dissipated is the sum of the powers dissipated in the two resistors separately

32. An object, immersed in a liquid in a tank, experiences an upthrust.

What is the physical reason for this upthrust?

A) The density of the body differs from that of the liquid
B) The density of the liquid increases with depth
C) The pressure in the liquid increases with depth
D) The value of g in the liquid increases with depth

33. The density of mercury is 13.6×10^3 kg m^{-3}. The pressure difference between the bottom and the top of a column of mercury is 100 kPa. What is the height of the column?

A) 0.75 m
B) 1.3 m
C) 7.4 m
D) 72 m

34. A ball is falling at terminal speed in still air. The forces acting on the ball are upthrust, viscous drag and weight.

What is the order of increasing magnitude of these three forces?

A) Upthrust → viscous drag → weight
B) Viscous drag → upthrust → weight
C) Viscous drag → weight → upthrust
D) Weight → upthrust → viscous drag

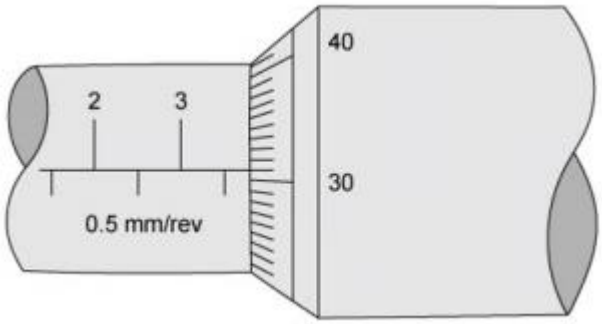
35. A steel wire is stretched in an experiment to determine the Young modulus for steel. The uncertainties in the measurements are given below.

Measurement	Uncertainty
Load on wire	± 2%
Length of wire	± 0.2%
Diameter of wire	± 1.5%
Extension	± 1.0%

What is the percentage uncertainty in the Young modulus?

A) 1.3 %
B) 1.8 %
C) 4.7 %
D) 6.2 %

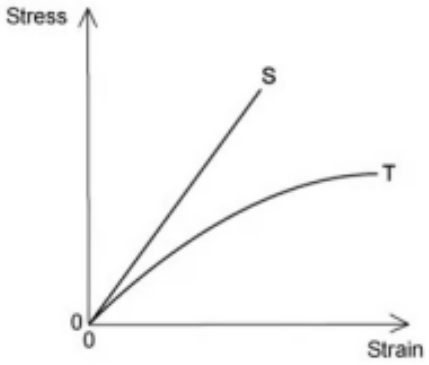
36. The diameter of a cylindrical metal rod is measured using a micrometer screw gauge. The diagram below shows an enlargement of the scale on the micrometer screw gauge when taking the measurement.



What is the cross-sectional area of the rod?

A) 3.81 mm^2
B) 11.4 mm^2
C) 22.8 mm^2
D) 45.6 mm^2

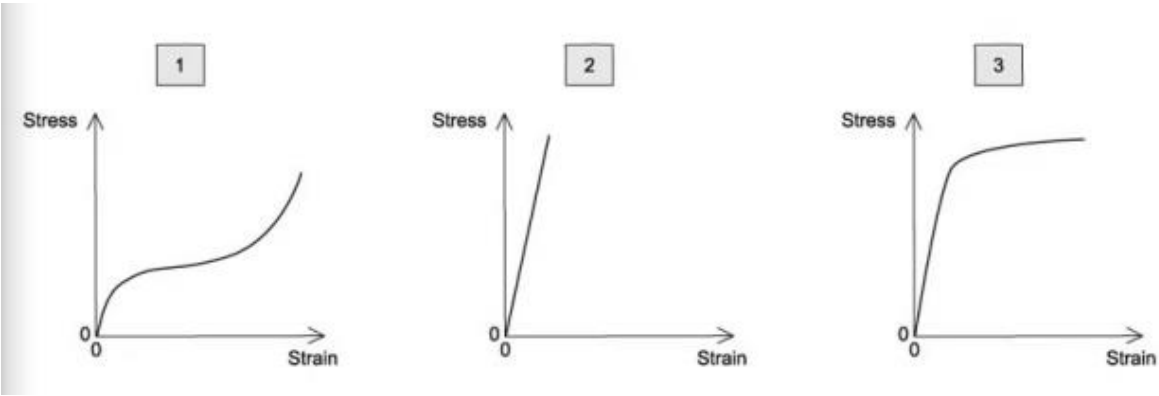
37. Two wires S and T, with the same initial dimensions, were put under stress and strain; the graph shows the results up to their breaking points.



Which statement is not correct?

A) Material S has a larger ultimate tensile stress
B) Material S extends elastically
C) Material S extends more than material T when loaded with the same force
D) Material S is brittle

38. The graphs below show the stress-strain graphs of three materials. The graphs do not have the same scales.



The three materials are copper, rubber and glass.

Which materials are represented by the graphs?

	1	2	3
A	Rubber	Copper	Glass
B	Rubber	Glass	Copper
C	Glass	Copper	Rubber
D	Copper	Glass	Rubber

Section B – Short answer questions (30 marks)

Question 1 (12 marks)

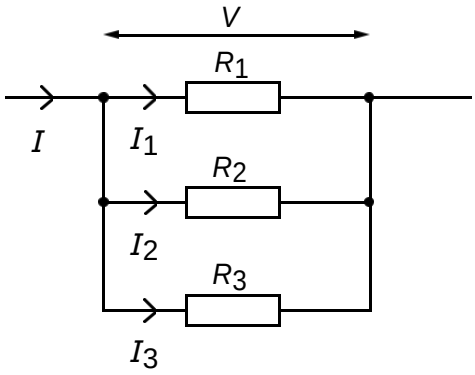


Figure 1.

The currents in the resistors are I_1, I_2 and I_3. The total current in the combination of resistors is I and the potential difference across the combination is V.

Show that the total resistance R of the combination is given by the equation

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

1. **Step 1: Expression for Total Current (1 Mark)**

   - According to Kirchhoff's current law, the total current I entering the parallel combination splits into I_1, I_2, and I_3: [2]

   $$I = I_1 + I_2 + I_3$$

   - Using Ohm's Law for each branch:

   $$I_1 = \frac{V}{R_1}, \quad I_2 = \frac{V}{R_2}, \quad I_3 = \frac{V}{R_3}$$

   - Substituting these into the total current equation:

   $$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}.$$

2. **Step 2: Deriving the Formula for Total Resistance (1 Mark)**

   - By definition, the total current for the equivalent resistance R is:

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

   - Substituting $\frac{V}{R}$ for I into the total current equation:

   $$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}.$$

   - Canceling V (as $V \neq 0$):

   $$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

(b) A battery of electromotive force (e.m.f.) 6.0 V and internal resistance *r* is connected to an external resistor of resistance 12 Ω and a thermistor X, as shown in Figure 2.

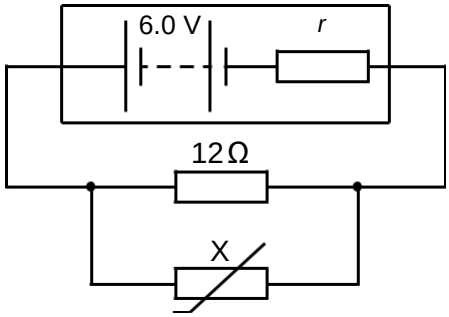


Figure 2.

(i) By considering energy, explain why the potential difference across the terminals of the battery is less than the e.m.f.

.....

..... [1]

1. **Key Concept (1 mark):**
   - Energy is lost within the battery due to its internal resistance r. The current flowing through the circuit causes a voltage drop across r, reducing the terminal potential difference (V):

$$V = \text{e.m.f.} - Ir$$

   - This loss is observed as heat energy dissipated in the battery's internal resistance.

Final Answer:

The potential difference across the terminals is less than the e.m.f. because some energy is dissipated as heat in the internal resistance of the battery.

(ii) A charge of 2.5 kC passes through the battery. Calculate:

- the total energy transferred by the battery

energy = ... J

1. **Calculate the total energy transferred by the battery:**

- The energy transferred by a battery is calculated using:

$$\text{Energy} = Q \cdot \text{e.m.f.}$$

Substituting:

$$Q = 2.5\,\text{kC} = 2.5 \times 10^3\,\text{C}, \quad \text{e.m.f.} = 6.0\,\text{V}$$

$$\text{Energy} = 2.5 \times 10^3 \cdot 6.0 = 1.5 \times 10^4\,\text{J}$$

Award 2 marks for correct substitution and calculation:

- 1 mark for correct formula and substitution.
- 1 mark for the correct final value $1.5 \times 10^4\,\text{J}$.

- the number of electrons that pass through the battery.

number = ...
[3]

2. **Calculate the number of electrons passing through the battery:**

- The total charge passing through the battery is related to the number of electrons by:

$$Q = n \cdot e$$

Rearranging for n:

$$n = \frac{Q}{e}$$

Substituting:

$$Q = 2.5 \times 10^3\,\text{C}, \quad e = 1.6 \times 10^{-19}\,\text{C}$$

$$n = \frac{2.5 \times 10^3}{1.6 \times 10^{-19}} = 1.56 \times 10^{22}\,\text{electrons}$$

Award 1 mark for correct substitution and calculation.

(iii) The combined resistance of the external resistor and thermistor X connected in parallel is 4.8 Ω.

Calculate the resistance of X.

resistance = ... Ω [1]

(b)(iii) Calculate the resistance of X: [1 mark]

- Combined resistance of the external resistor ($R_1 = 12\,\Omega$) and thermistor X in parallel:

$$\frac{1}{R_{\text{combined}}} = \frac{1}{R_1} + \frac{1}{R_X}$$

Rearrange for R_X:

$$R_X = \frac{1}{\frac{1}{R_{\text{combined}}} - \frac{1}{R_1}}$$

Substituting values:

$$R_{\text{combined}} = 4.8\,\Omega, \quad R_1 = 12\,\Omega$$

$$R_X = \frac{1}{\frac{1}{4.8} - \frac{1}{12}} = \frac{1}{0.2083 - 0.0833} = \frac{1}{0.125} = 8.0\,\Omega$$

Award 1 mark for the correct answer $R_X = 8.0\,\Omega$.

(iv) Use your answer in (b)(iii) to determine the ratio

$$\frac{\text{power dissipated in thermistor X}}{\text{power dissipated in 12X resistor}}.$$

ratio = ...

1. **Formula for power:**

$$P = \frac{V^2}{R}$$

The potential difference across the thermistor and resistor is the same because they are in parallel. The ratio of power is therefore inversely proportional to their resistances:

$$\frac{P_X}{P_{12}} = \frac{R_{12}}{R_X}$$

Substituting values:

$$\frac{P_X}{P_{12}} = \frac{12}{8} = 1.5$$

2. **Mark Allocation:**
   - 1 mark for recognizing the ratio is inversely proportional to the resistances.
   - 1 mark for correct final answer $\frac{P_X}{P_{12}} = 1.5$.

(v) The temperature of thermistor X is now decreased.

State and explain the effect, if any, of this temperature change on the total power produced by the battery.

(b)(v) Effect of decreasing temperature on the total power produced by the battery: [2 marks]

1. **Key Concept:**
   - The resistance of a thermistor decreases with a decrease in temperature. This lowers the combined resistance of the circuit.
   - With lower total resistance, the current increases, causing the total power produced by the battery ($P = I \cdot \text{e.m.f.}$) to increase.
2. **Mark Allocation:**
   - 1 mark for stating that total resistance decreases, increasing current.
   - 1 mark for concluding that the total p er produced by the battery increases.

.....

.....

.....

..... [3]

[Total: 12]

Question 2 (14 marks)

(a) (i) Define the term 'force'.

.....

..... [1]

Marking Scheme

(a) (i) Define the term 'force'. [1]

- A force is a push or pull acting on an object that can cause a change in the object's motion or shape.

  Marking Point:

  1 mark for mentioning that force causes a change in motion, shape, or state of rest of an object.

  (e.g., "Force is a push or pull that changes an object's state of motion or shape.")

(ii) State what is meant by work done.

.....

..... [1]

(a) (ii) State what is meant by work done. [1]

- Work is done when a force is applied to an object, and the object moves in the direction of the force.

  Marking Point:

  1 mark for mentioning the product of force and displacement in the direction of the force.

  (e.g., "Work done is the product of force and the displacement of an object in the direction of the force.")

(b) A block of mass 0.40 kg slides in a straight line with a constant speed of 0.30 m s^{-1} along a horizontal surface, as shown in Figure 3.

Figure 3

Assume that there are no resistive forces opposing the motion of the block.

The block hits a spring and decelerates. The speed of the block becomes zero when the compression of the spring is 8.0 cm.

(i) Calculate the initial kinetic energy of the block.

(b) (i) Calculate the initial kinetic energy of the block. [3]

1. **Formula:**
   Kinetic Energy (KE) = $\frac{1}{2}mv^2$
   Marking Point: 1 mark for correctly recalling the formula.
2. **Substitute values:**
   $KE = \frac{1}{2} \times 0.40\,\text{kg} \times (0.30\,\text{m/s})^2$
   Marking Point: 1 mark for correct substitution.
3. **Calculation:**
   $KE = \frac{1}{2} \times 0.40 \times 0.09 = 0.018\,\text{J}$
   Marking Point: 1 mark for correct final answer with unit (0.018 J).

kinetic energy = ... J [2]

(ii) The variation of the compression *x* of the spring with the force *F* applied to the spring is shown in Figure 4.

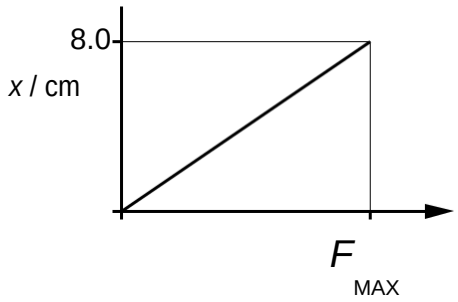


Figure 4

Assume that the elastic potential energy of the spring when its compression is 8.0 cm is equal to the initial kinetic energy of the block.

Use your answer in (b)(i) to calculate the maximum force F_{MAX} exerted on the spring by the block.

(b) (ii) Use your answer in (b)(i) to calculate the maximum force F_{MAX} exerted on the spring by the block. [2]

1. Formula and relationship between energy and force:
   Elastic potential energy = $\frac{1}{2}F_{MAX}x$
   Set elastic potential energy equal to the kinetic energy of the block:
   $0.018 = \frac{1}{2}F_{MAX} \times 0.08\,\text{m}$.
   Marking Point: 1 mark for correctly substituting into the formula.
2. Calculation of F_{MAX}:
   Rearranging: $F_{MAX} = \frac{2\times 0.018}{0.08} = 0.45\,\text{N}$.
   Marking Point: 1 mark for correct calculation and final answer with the unit (N).

F_{MAX} = ... N [2]

(iii) Calculate the maximum deceleration of the block.

(b) (iii) Calculate the maximum deceleration of the block. [2]

1. Formula for force and acceleration:
   $F = ma$, where $a = \frac{F}{m}$.
   Substitution: $a = \frac{0.45}{0.40}$.
   Marking Point: 1 mark for correctly substituting values into the formula.
2. Calculation of a:
   $a = 1.125\,\text{m/s}^2$.
   Marking Point: 1 mark for correct final answer with the unit (m/s^2).

Deceleration = ... m s^{-2} [2]

(iv) State and explain whether the block is in equilibrium:

- before it hits the spring

…….

…….

[2]

- when its speed becomes zero.

…….

…….

[2]

(b) (iv) State and explain whether the block is in equilibrium:

Before it hits the spring. [1]

- **Answer:**
  The block is in equilibrium because the forces acting on it (its weight and the normal reaction force) are balanced.
  Marking Point: 1 mark for stating and explaining the balance of forces.

When its speed becomes zero. [1]

- **Answer:**
  The block is in equilibrium because the spring force is equal and opposite to the force exerted by the block.
  Marking Point: 1 mark for stating and explaining that the spring is fully compressed, and the forces are balanced.

(v) The block is now replaced by another block of the same mass. Frictional forces affect the motion of this block so that it has a speed of $0.25\,\text{m s}^{-1}$ when it makes contact with the spring.

A short time later, the block has a speed of $0.15\,\text{m s}^{-1}$ as it loses contact with the spring and moves back along its original path.

Calculate the magnitude of the change in momentum of the block.

Change in momentum = ... N s [2]

(b) (v) Calculate the magnitude of the change in momentum of the block.

[2]

1. **Formula for momentum:**
   Momentum (p) = mv.
   Change in momentum = $m(v_{\text{initial}} - v_{\text{final}})$.
   Substitution:
   $\Delta p = 0.40 \times (0.25 - (-0.15))$.
   Marking Point: 1 mark for correctly identifying and substituting $v_{\text{initial}} = 0.25\,\text{m/s}$ and $v_{\text{final}} = -0.15\,\text{m/s}$ (negative indicates opposite direction).
2. **Calculation of Δp:**
   $\Delta p = 0.40 \times 0.40 = 0.16\,\text{Ns}$.
   Marking Point: 1 mark for correct calculation and final answer with the unit (Ns).

[Total: 14]

Question 3 (4 marks)

(a) State what is meant by a *scalar* quantity and by a *vector* quantity.

scalar:

.....

.....

vector:

.....

.....

[2]

(a) State what is meant by a scalar quantity and a vector quantity. [2]

1. **Scalar:**
   A quantity that has only magnitude (size) and no direction.
   Marking Point: 1 mark for mentioning only magnitude and no direction.
2. **Vector:**
   A quantity that has both magnitude and direction.
   Marking Point: 1 mark for mentioning both magnitude and direction.

(a) Complete Table 1 below to indicate whether each of the quantities is a vector or a scalar.

Table 1

quantity	vector or scalar
power	
temperature	
momentum	

[2]

(b) Complete Table 1 below to indicate whether each of the quantities is a vector or a scalar. [2]

Quantity	Vector or Scalar
Power	Scalar
Temperature	Scalar
Momentum	Vector

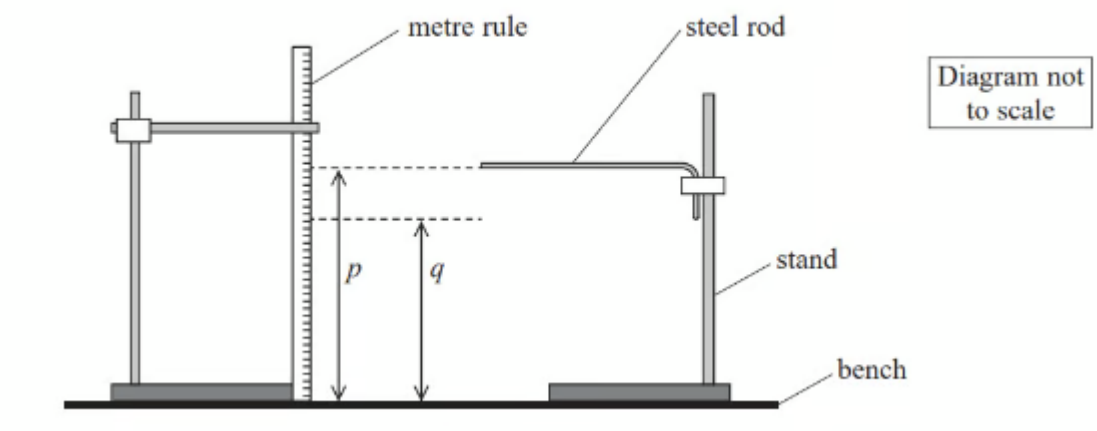
Marking Points:

- 1 mark for correctly identifying **power** and **temperature** as scalars.
- 1 mark for correctly identifying **momentum** as a vector.

Section C: Practical-based skills (15 marks)

Question 1 (15 marks)

An L-shaped steel rod was held horizontally in a stand clamped by its shorter end as shown.



The end of the steel rod was at a height p above the bench.

A student attached a mass m to the end of the steel rod causing it to bend towards the bench. The end of the steel rod was then at a height q above the bench.

a) i) Describe two techniques she should use when measuring p and q.

……

……

……

……

[2 marks]

(a)(i) Describe two techniques she should use when measuring p and q. [2]

1. **Use a ruler positioned perpendicularly:**
   Ensure the ruler is perpendicular to the steel rod and parallel to the bench to minimize parallax error.
   Marking Point: 1 mark for ensuring the ruler is correctly positioned.
2. **Take measurements at eye level:**
   Align the eye with the ruler's markings to reduce parallax error when reading values for p and q.
   Marking Point: 1 mark for reducing parallax error during reading.

ii) The difference between p and q was recorded as 26 mm ± 1 mm. Explain why the uncertainty in this value was given as 1 mm.

[2 marks]

(a)(ii) The difference between p and q was recorded as 26 mm ± 1 mm. Explain why the uncertainty in this value was given as 1 mm. [2]

1. Explanation of uncertainty:
   - The uncertainty is due to the precision of the measuring instrument (e.g., a ruler), which has a smallest division of 1 mm.
     Marking Point: 1 mark for mentioning the precision of the measuring tool.
2. Propagation of uncertainty:
   - Since the difference between two measurements is calculated, the uncertainties of both p and q (each ± 0.5 mm) combine, leading to a total uncertainty of ± 1 mm.
     Marking Point: 1 mark for explaining how the uncertainty is propagated when subtracting measurements.

b) The steel rod had a circular cross-section with a diameter d of approximately 2 mm.

i) Explain the most appropriate instrument the student should use to measure d.

(b)(i) Explain the most appropriate instrument the student should use to measure d. [2]

1. Instrument selection:
   - The student should use a micrometer screw gauge to measure d, as it provides high precision for small diameters.
     Marking Point: 1 mark for correctly identifying the micrometer screw gauge.
2. Reason:
   - A micrometer has an accuracy of ± 0.01 mm, which is suitable for measuring a diameter of approximately 2 mm.
     Marking Point: 1 mark for explaining the precision of the micrometer.

[2 marks]

ii) Explain one technique that she should use to measure d.

(b)(ii) Explain one technique she should use to measure d. [2]

1. Measurement technique:
   - Place the steel rod between the micrometer's jaws and ensure the rod is perpendicular to the measuring surfaces.
     Marking Point: 1 mark for describing correct positioning of the micrometer.
2. Repeat measurements:
   - Take multiple readings at different points along the steel rod and average them to account for irregularities in the diameter.
     Marking Point: 1 mark for mentioning repeated measurements and averaging.

[2 marks]

iii) She recorded the following measurements.

d / mm				
2.35	2.37	2.34	2.35	2.33

Calculate the mean value of *d* in mm and its uncertainty.

Mean value of d = ……..……..…..mm

± ……mm

(b)(iii) Calculate the mean value of d and its uncertainty. [2]

1. Mean value:
   $d_{\text{mean}} = \frac{\text{Sum of values}}{\text{Number of values}} = \frac{2.35+2.37+2.34+2.35+2.33}{5} = 2.348\,\text{mm}.$
   Rounding to 3 significant figures: $d_{\text{mean}} = 2.35\,\text{mm}.$
   Marking Point: 1 mark for correct calculation of mean.
2. Uncertainty:
   Uncertainty is the range of measurements divided by 2:
   $\text{Uncertainty} = \frac{2.37-2.33}{2} = 0.02\,\text{mm}.$
   Final result: $d = 2.35 \pm 0.02\,\text{mm}.$
   Marking Point: 1 mark for correct calculation of uncertainty.

[2 marks]

The shear modulus is a measure of a material's resistance to bending, and is given by:

$$G = \frac{32mglx^2}{\pi y d^4}$$

Where m is the mass attached to the end of the rod and y is the vertical deflection.

L and x are the lengths as shown below.

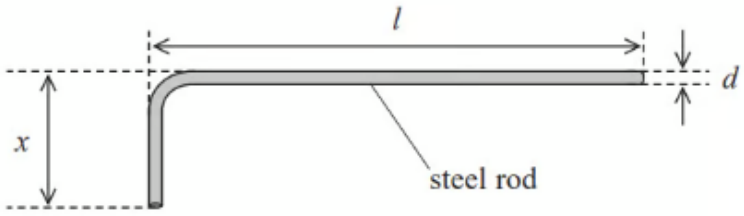


Diagram not to scale

Determine a value of G for steel in N m^{-2}.

m = 100 g with negligible uncertainty
l = 58.9 cm ± 0.1 cm
x = 10.3 cm ± 0.1 cm
y = 26 mm ± 1 mm

Determine a value of G for steel in $\mathrm{N/m^2}$. [4]

Formula and Substitution (2 marks)

1. Recall the formula for shear modulus:
   $G = \frac{32mglx^2}{\pi d^4 y}$
   Marking Point: 1 mark for recalling the correct formula.
2. Substitute values into the formula:
   - Convert units to SI:
     $m = 0.100\,\mathrm{kg},\ l = 0.589\,\mathrm{m},\ x = 0.103\,\mathrm{m},\ y = 0.026\,\mathrm{m},\ d = 0.00235\,\mathrm{m}$
   - Substitution:
     $G = \frac{32\times0.100\times9.81\times0.589\times(0.103)^2}{\pi\times(0.00235)^4\times0.026}$
     Marking Point: 1 mark for correctly substituting all values into the formula.

Simplification and Calculation (2 marks)

1. Simplify the numerator and denominator:
   - Numerator:
     $32 \times 0.100 \times 9.81 \times 0.589 \times (0.103)^2 = 2.003 \times 10^{-1}\,\mathrm{N \cdot m^2}$
   - Denominator:
     $\pi \times (0.00235)^4 \times 0.026 = 1.020 \times 10^{-10}\,\mathrm{m^4}$
2. Calculate G:
   $G = \frac{2.003\times10^{-1}}{1.020\times10^{-10}} = 1.96 \times 10^9\,\mathrm{N/m^2}$.
   Marking Points:
   - 1 mark for correct simplification of numerator and denominator.
   - 1 mark for correct final value with the unit ($\mathrm{N/m^2}$).

G = …….. N m^{-2}.

(2 marks)

(d) The table shows values of G for different types of steel.

Type of Steel	Structural Steel	Carbon Steel
G / 10^9 Nm^{-2}	79.3	77.0

Deduce whether the data provided in part (c) would allow the student to determine the type of steel the rod was made from.

As the data provided does not correspond to the above values. The student can't determine the type of steel the rod was made from.

(3 marks)