

PHYSICS



EXAM QUESTION PACK

MEASUREMENT TECHNIQUES

SCORE

/

PERCENTAGE

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Chapter 2

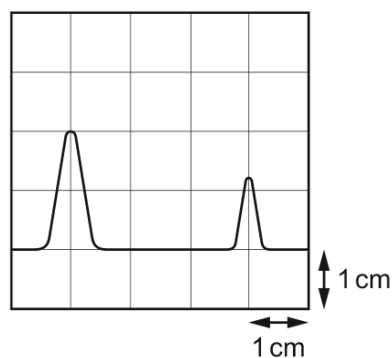
Measurement techniques

2.1 Measurements

104. 9702_m20_qp_12 Q: 4

A transmitter emits a pulse of electromagnetic waves towards a reflector. The pulse is reflected and returns to the transmitter.

A detector is located at the transmitter. The emitted pulse and the reflected pulse are displayed on a cathode-ray oscilloscope (CRO) as shown.



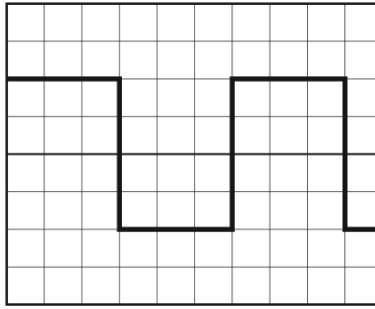
The pulse takes $6.3\ \mu\text{s}$ to travel from the transmitter to the reflector.

What is the time-base setting of the CRO?

- A** $2.1\ \mu\text{s cm}^{-1}$ **B** $3.2\ \mu\text{s cm}^{-1}$ **C** $4.2\ \mu\text{s cm}^{-1}$ **D** $6.3\ \mu\text{s cm}^{-1}$

105. 9702_s20_qp_11 Q: 4

A cathode-ray oscilloscope displays a square wave, as shown.



The time-base setting is 0.20 ms per division.

What is the frequency of the square wave?

- A** 0.83 Hz **B** 830 Hz **C** 1300 Hz **D** 1700 Hz

106. 9702_s20_qp_12 Q: 3

A galvanometer of resistance $5\ \Omega$ is to be used in a null method.

In order to protect the galvanometer from damage due to an excessive initial current, resistors of resistance $0.5\ \Omega$ and $1\ \text{k}\Omega$ are available.

Which arrangement would provide this protection?

- A** the $0.5\ \Omega$ resistor in series with the galvanometer
B the $0.5\ \Omega$ resistor in parallel with the galvanometer and this combination placed in series with the $1\ \text{k}\Omega$ resistor
C the $1\ \text{k}\Omega$ resistor in parallel with the galvanometer
D the $1\ \text{k}\Omega$ resistor in parallel with the galvanometer and this combination placed in series with the $0.5\ \Omega$ resistor
-

107. 9702_s20_qp_13 Q: 4

A circuit is set up in order to determine the resistance of a 12 V, 1.2 W lamp when operating normally. An analogue ammeter and an analogue voltmeter are used.

Which ranges for the meters would be most suitable?

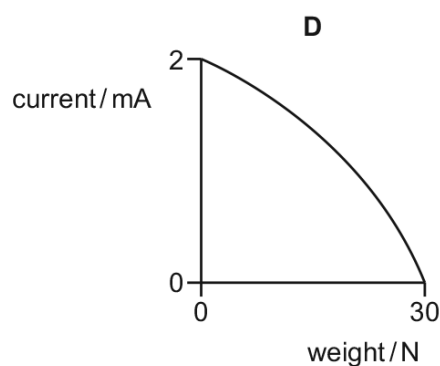
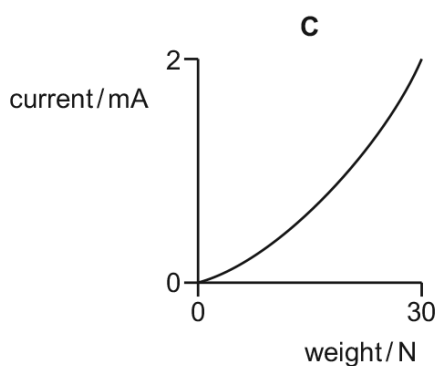
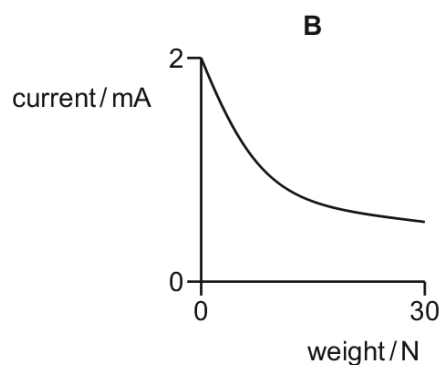
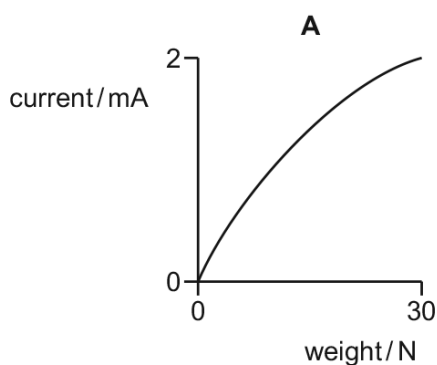
	ammeter range /A	voltmeter range /V
A	0–0.5	0–20
B	0–0.5	0–100
C	0–10	0–20
D	0–10	0–100

108. 9702_m19_qp_12 Q: 4

A digital balance is used to weigh ingredients in a laboratory. When a weight is applied to the digital balance, an electronic circuit generates a current which is then converted into a digital readout on the display.

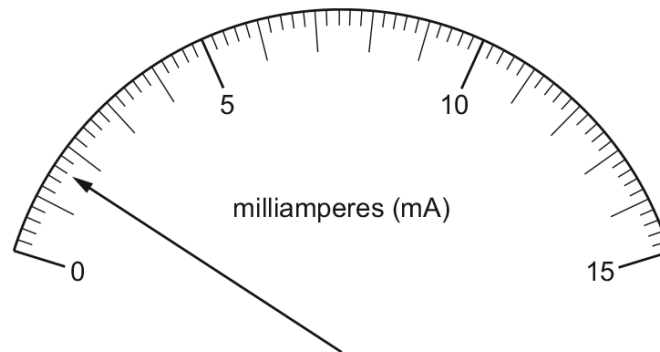
The electronic circuit gives a current of 2.0 mA when a weight of 30 N is applied, and a current of 0.5 mA when a weight of 5 N is applied.

Which calibration curve could represent this circuit?



109. 9702_s19_qp_13 Q: 5

The diagram shows the reading on an analogue ammeter.



Which digital ammeter reading is the same as the reading on the analogue ammeter?

	display units	display reading
A	μA	1600
B	μA	160
C	mA	16.0
D	A	1.60

110. 9702_w19_qp_11 Q: 4

A student intends to measure accurately the diameter of a wire (known to be approximately 1 mm) and the internal diameter of a pipe (known to be approximately 2 cm).

What are the most appropriate instruments for the student to use to make these measurements?

	wire	pipe
A	calipers	calipers
B	calipers	micrometer
C	micrometer	calipers
D	micrometer	micrometer

111. 9702_w19_qp_12 Q: 4

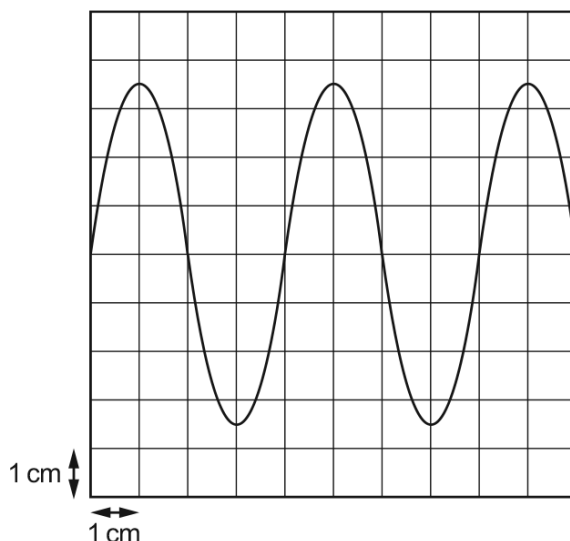
A micrometer is used to measure the 28.50 mm width of a plastic ruler. The micrometer reads to the nearest 0.01 mm.

What is the correct way to record this reading?

- A $0.02850 \pm 0.01 \text{ m}$
- B $0.0285 \pm 0.001 \text{ m}$
- C $(2.850 \pm 0.001) \times 10^{-2} \text{ m}$
- D $(2.850 \pm 0.001) \times 10^{-3} \text{ m}$

112. 9702_m18_qp_12 Q: 6

A cathode-ray oscilloscope (c.r.o.) is connected to an alternating voltage. The following trace is produced on the screen.



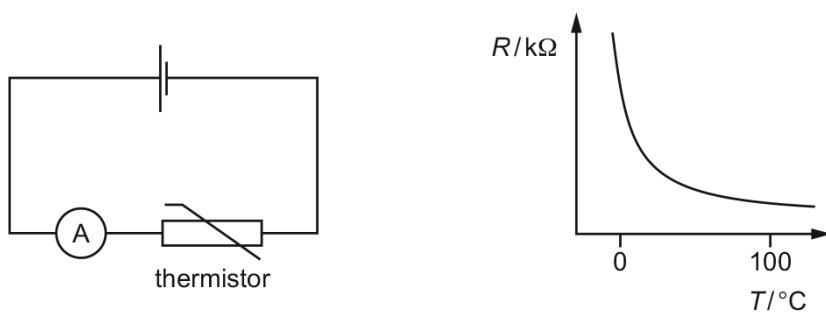
The oscilloscope time-base setting is 0.5 ms cm^{-1} and the Y-plate sensitivity is 2 V cm^{-1} .

Which statement about the alternating voltage is correct?

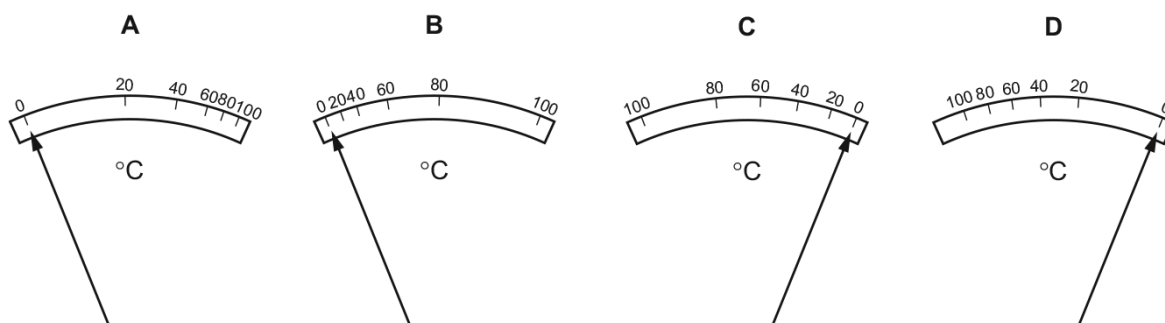
- A The amplitude is 3.5 cm.
- B The frequency is 0.5 kHz.
- C The period is 1 ms.
- D The wavelength is 4 cm.

113. 9702_s18_qp_11 Q: 4

In the circuit shown, an analogue ammeter is to be recalibrated as a thermometer. The ammeter is connected in series with a thermistor. The thermistor is a component with a resistance that varies with temperature. The graph shows how the resistance R of the thermistor changes with temperature T .



Which diagram could represent the temperature scale on the ammeter?



114. 9702_w18_qp_11 Q: 4

A micrometer screw gauge is used to measure the diameter of a copper wire.

The reading with the wire in position is shown in diagram 1. The wire is removed and the jaws of the micrometer are closed. The new reading is shown in diagram 2.

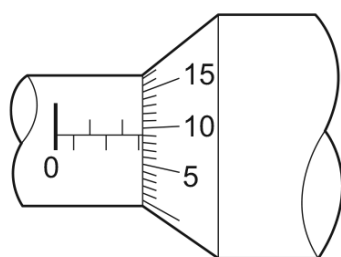


diagram 1

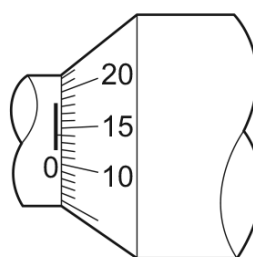


diagram 2

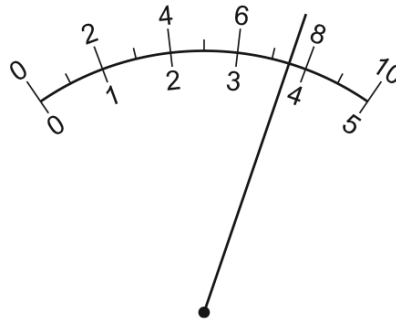
What is the diameter of the wire?

- A** 1.90 mm **B** 2.45 mm **C** 2.59 mm **D** 2.73 mm

115. 9702_w18_qp_13 Q: 4

An ammeter is calibrated so that it shows a full-scale deflection when it measures a current of 2.0 A.

The diagram shows the display of this ammeter when it is measuring a current.



Which current is the ammeter measuring?

- A** 0.75 A **B** 1.5 A **C** 3.8 A **D** 7.5 A

116. 9702_m17_qp_12 Q: 4

A student is investigating an electrical signal using a cathode-ray oscilloscope (c.r.o).

The frequency of the signal is 50 kHz.

Which time-base setting on the oscilloscope should be used?

- A** 50 ms cm⁻¹ **B** 1 ms cm⁻¹ **C** 10 μs cm⁻¹ **D** 0.5 μs cm⁻¹

117. 9702_m17_qp_12 Q: 5

A student wishes to measure a distance of about 10 cm to a precision of 0.01 cm.

Which measuring instrument should be used?

- A** metre rule
B micrometer
C tape measure
D vernier calipers

118. 9702_s17_qp_11 Q: 3

The speed v of a liquid leaving a tube depends on the change in pressure ΔP and the density ρ of the liquid. The speed is given by the equation

$$v = k \left(\frac{\Delta P}{\rho} \right)^n$$

where k is a constant that has no units.

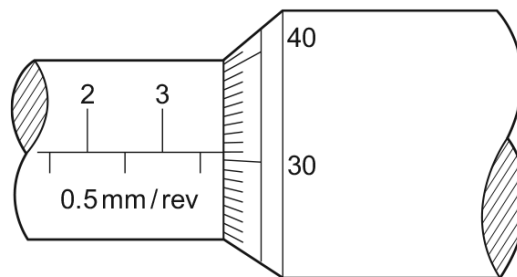
What is the value of n ?

- A** $\frac{1}{2}$ **B** 1 **C** $\frac{3}{2}$ **D** 2

119. 9702_s17_qp_12 Q: 5

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.



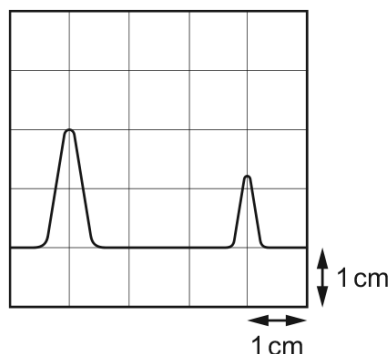
What is the cross-sectional area of the rod?

- A** 3.81 mm^2 **B** 11.4 mm^2 **C** 22.8 mm^2 **D** 45.6 mm^2

120. 9702_w17_qp_12 Q: 5

A transmitter emits a pulse of electromagnetic waves towards a reflector. The pulse is reflected and returns to the transmitter.

A detector is located at the transmitter. The emitted pulse and the reflected pulse are displayed on a cathode-ray oscilloscope (c.r.o.) as shown.



The pulse takes $6.3\ \mu\text{s}$ to travel from the transmitter to the reflector.

What is the time-base setting of the c.r.o.?

- A $2.1\ \mu\text{s cm}^{-1}$ B $3.2\ \mu\text{s cm}^{-1}$ C $4.2\ \mu\text{s cm}^{-1}$ D $6.3\ \mu\text{s cm}^{-1}$

121. 9702_w17_qp_13 Q: 4

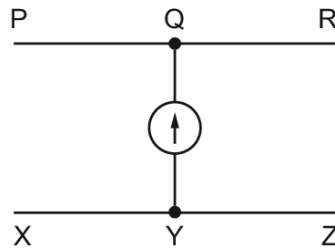
A school has a piece of aluminium that it uses for radioactivity experiments. Its thickness is marked as 3.2 mm. A student decides to check this value. He has vernier calipers which give measurements to 0.1 mm and a micrometer which gives measurements to 0.01 mm.

Which statement **must** be correct?

- A The micrometer gives a more accurate measurement.
B The micrometer gives a more precise measurement.
C The vernier calipers give a more accurate measurement.
D The vernier calipers give a more precise measurement.

122. 9702_m16_qp_12 Q: 5

PQR and XYZ are wires in a circuit. A galvanometer connects Q and Y as a null indicator.

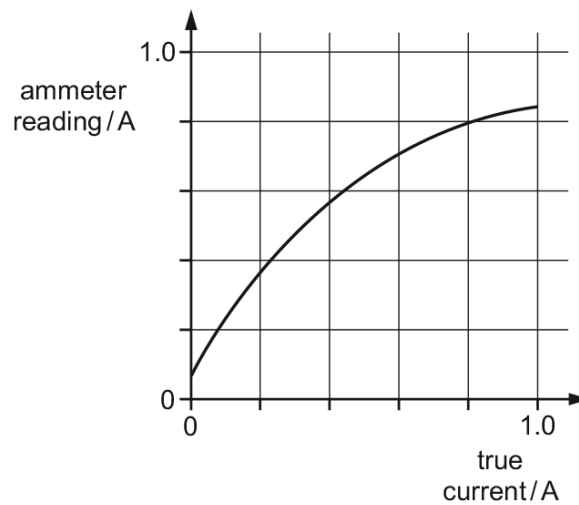


When the galvanometer reads zero, which statement is correct?

- A** The potential difference between Q and Y is infinite.
- B** The potential difference between Q and Y is zero.
- C** The resistance between Q and Y is infinite.
- D** The resistance between Q and Y is zero.

123. 9702_s16_qp_11 Q: 5

A calibration graph is produced for a faulty ammeter.

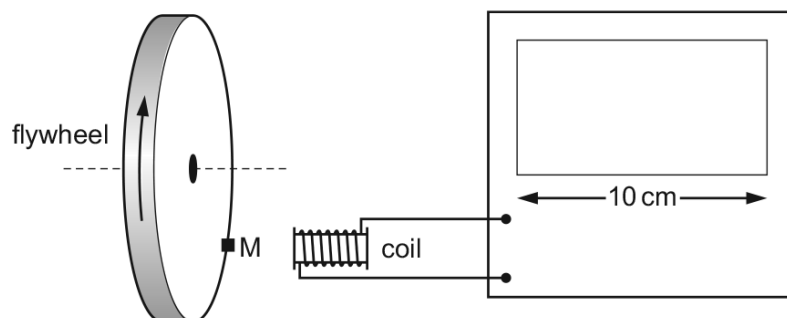


Which ammeter reading will be nearest to the true current?

- A** 0.2 A
- B** 0.4 A
- C** 0.6 A
- D** 0.8 A

124. 9702_s16_qp_12 Q: 4

The diagram shows a cathode-ray oscilloscope (c.r.o.) being used to measure the rate of rotation of a flywheel.



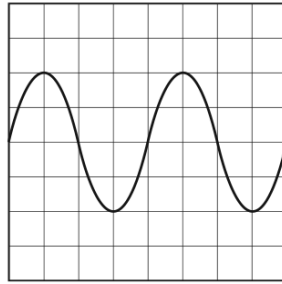
The flywheel has a small magnet M mounted on it. Each time the magnet passes the coil, a voltage pulse is generated, which is passed to the c.r.o. The display of the c.r.o. is 10 cm wide. The flywheel is rotating at 3000 revolutions per minute.

Which time-base setting will display clearly separate pulses on the screen?

- A** 1 s cm^{-1} **B** 10 ms cm^{-1} **C** $100 \text{ } \mu\text{s cm}^{-1}$ **D** $1 \text{ } \mu\text{s cm}^{-1}$

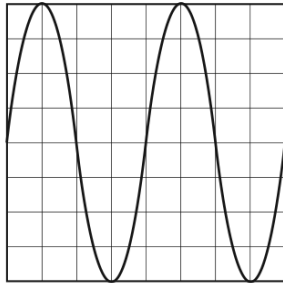
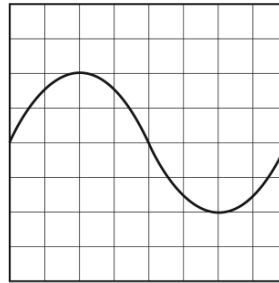
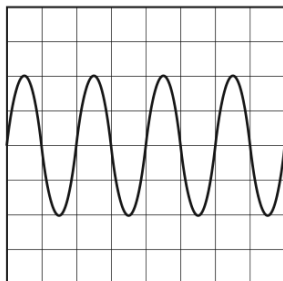
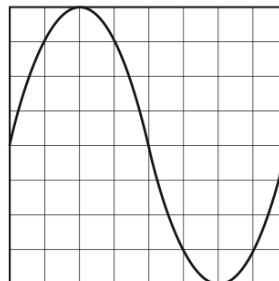
125. 9702_s16_qp_13 Q: 5

The following trace is seen on the screen of a cathode-ray oscilloscope.



The setting of the time-base is then changed from 10mscm^{-1} to 20mscm^{-1} and the Y-plate sensitivity remains constant.

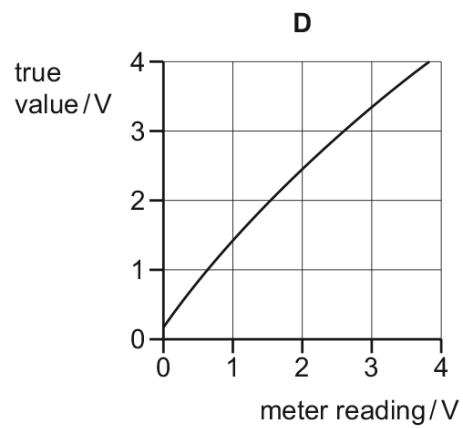
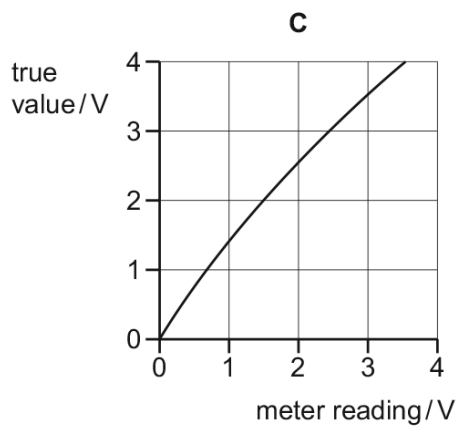
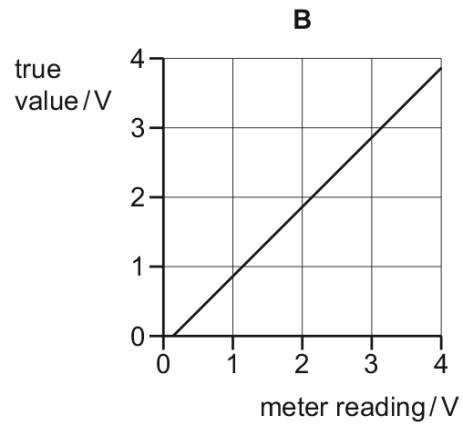
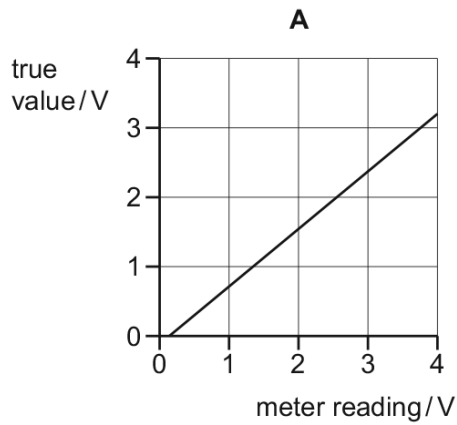
Which trace is now seen on the screen?

A**B****C****D**

126. 9702_w16_qp_11 Q: 4

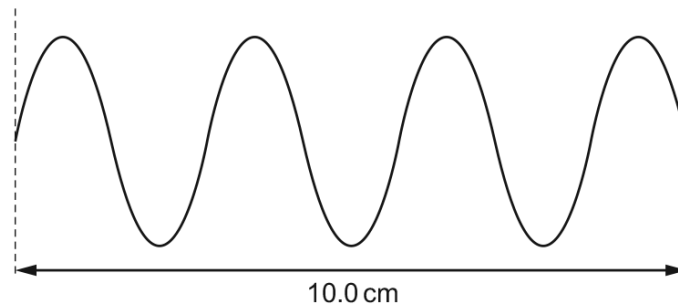
A voltmeter gives readings that are larger than the true values and has a systematic error that varies with voltage.

Which graph shows the calibration curve for the voltmeter?



127. 9702_w16_qp_11 Q: 5

A student uses a cathode-ray oscilloscope (c.r.o.) to measure the period of a signal. She sets the time-base of the c.r.o. to 5 ms cm^{-1} and observes the trace illustrated below. The trace has a length of 10.0 cm.

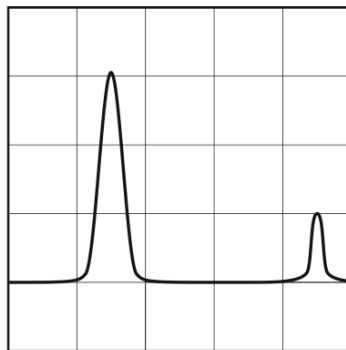


What is the period of the signal?

- A** $7.1 \times 10^{-6} \text{ s}$ **B** $1.4 \times 10^{-5} \text{ s}$ **C** $7.1 \times 10^{-3} \text{ s}$ **D** $1.4 \times 10^{-2} \text{ s}$

128. 9702_w16_qp_12 Q: 4

A cathode-ray oscilloscope (c.r.o.) displays a waveform as shown.



The time interval between two adjacent peaks of the waveform is 0.006 s.

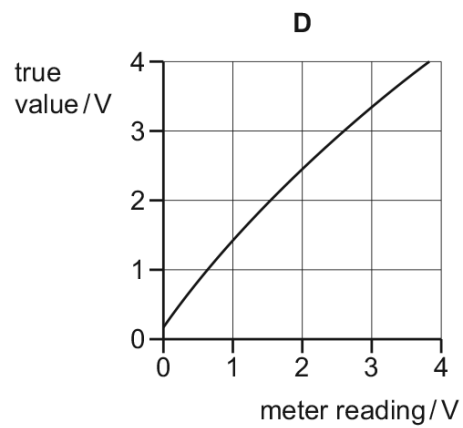
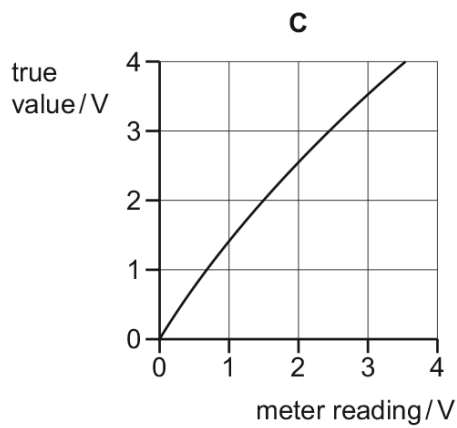
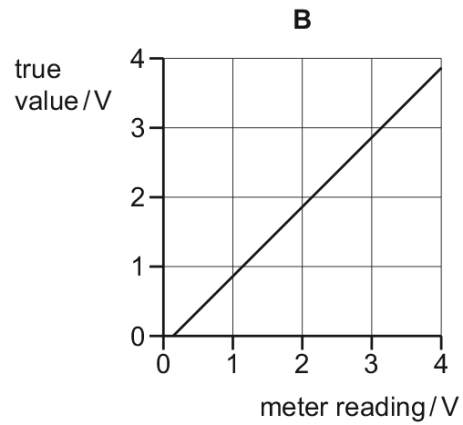
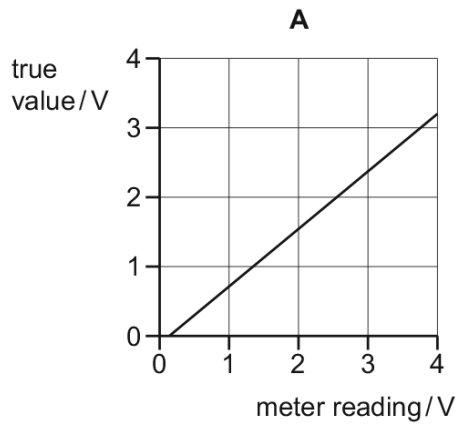
What is the time-base setting of the c.r.o.?

- A** $2 \mu\text{s/division}$
B $20 \mu\text{s/division}$
C 2 ms/division
D 3 ms/division

129. 9702_w16_qp_13 Q: 4

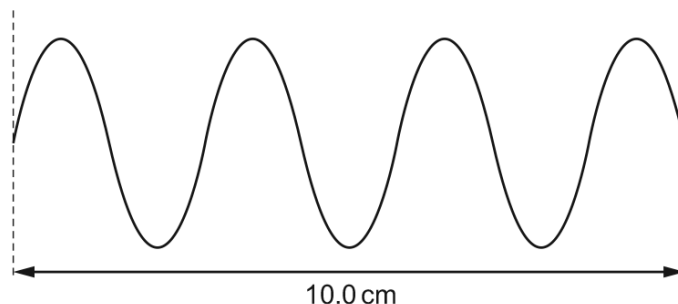
A voltmeter gives readings that are larger than the true values and has a systematic error that varies with voltage.

Which graph shows the calibration curve for the voltmeter?



130. 9702_w16_qp_13 Q: 5

A student uses a cathode-ray oscilloscope (c.r.o.) to measure the period of a signal. She sets the time-base of the c.r.o. to 5 ms cm^{-1} and observes the trace illustrated below. The trace has a length of 10.0 cm.

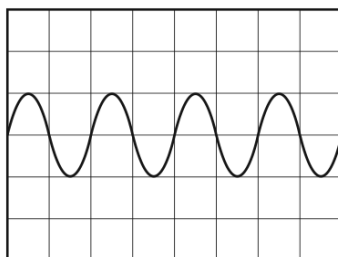


What is the period of the signal?

- A** $7.1 \times 10^{-6}\text{ s}$ **B** $1.4 \times 10^{-5}\text{ s}$ **C** $7.1 \times 10^{-3}\text{ s}$ **D** $1.4 \times 10^{-2}\text{ s}$

131. 9702_s15_qp_11 Q: 4

A whale produces sound waves of frequency 5 Hz. The waves are detected by a microphone and displayed on an oscilloscope.



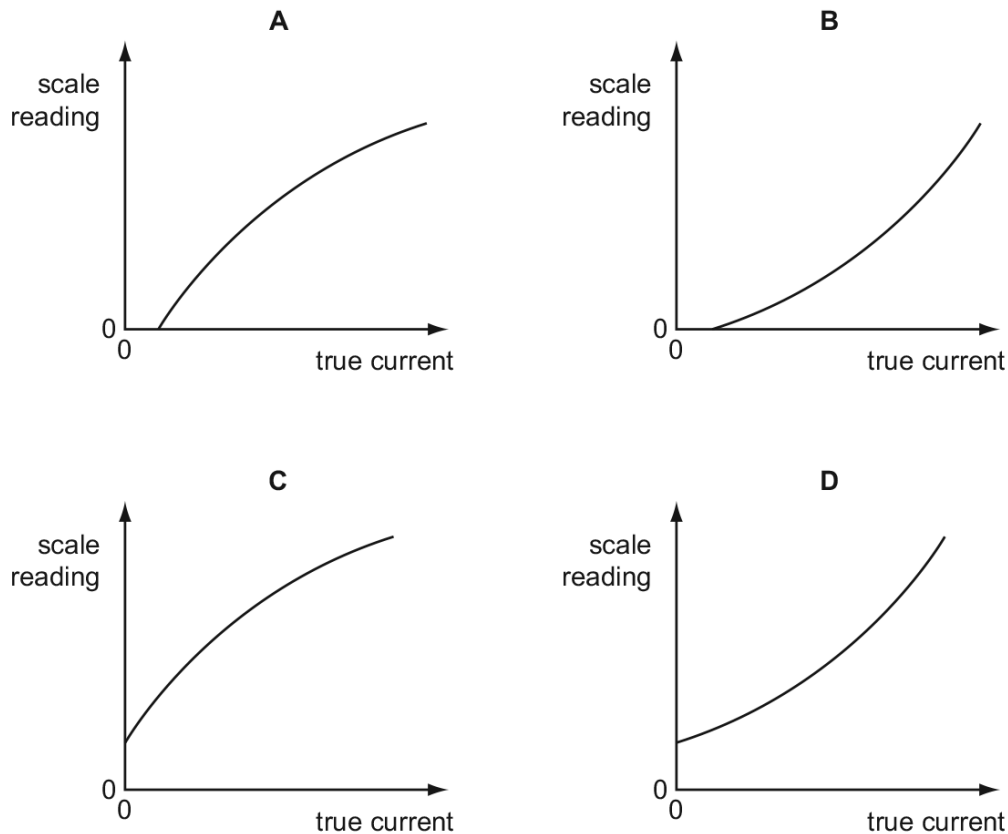
What is the time-base setting on the oscilloscope?

- A** 0.1 ms div^{-1} **B** 1 ms div^{-1} **C** 10 ms div^{-1} **D** 100 ms div^{-1}

132. 9702_s15_qp_12 Q: 3

An analogue ammeter has a pointer which moves over a scale. Following prolonged use, the pointer does not return fully to zero when the current is turned off and the meter has become less sensitive at higher currents than it is at lower currents.

Which diagram best represents the calibration graph needed to obtain an accurate current reading?



133. 9702_s15_qp_13 Q: 4

A student is given a reel of wire of diameter less than 0.2 mm and is asked to find the density of the metal.

Which pair of instruments would be most suitable for finding the **volume** of the wire?

- A balance and micrometer
- B metre rule and micrometer
- C metre rule and vernier calipers
- D micrometer and vernier calipers

2.2 Errors and uncertainties

134. 9702_m20_qp_12 Q: 5

A micrometer is used to measure the diameters of two cylinders.

diameter of first cylinder = (12.78 ± 0.02) mm

diameter of second cylinder = (16.24 ± 0.03) mm

The difference in the diameters is calculated.

What is the uncertainty in this difference?

- A** 0.01 mm **B** 0.02 mm **C** 0.03 mm **D** 0.05 mm
-

135. 9702_s20_qp_11 Q: 5

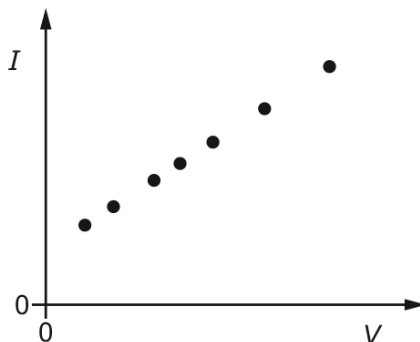
A measurement is taken correctly but with a ruler at a significantly higher temperature than that at which the ruler was calibrated. The higher temperature causes the ruler to expand.

What describes the effect on the measurement caused by the higher temperature and how the measurement may be improved?

- A** The measurement will be subject to a random error. The measurement can be made more accurate by taking the average of several repeated measurements.
- B** The measurement will be subject to a random error. The measurement can be made more precise by taking the average of several repeated measurements.
- C** The measurement will be subject to a systematic error. The measurement can be made more accurate by taking the average of several repeated measurements.
- D** The measurement will be subject to a systematic error. The measurement can be made more precise by taking the average of several repeated measurements.
-

136. 9702_s20_qp_12 Q: 4

Readings are made of the current I for different voltages V across a fixed resistor. The results are plotted on a graph to show the variation of I with V .



What is the best description of the errors in the readings?

- A both systematic and random
- B neither systematic nor random
- C random only
- D systematic only

137. 9702_s20_qp_13 Q: 5

Two liquid-in-glass thermometers in a well-mixed liquid are individually observed by 10 different students. All agree that one thermometer reads 21°C and the other thermometer reads 23°C .

What is a possible explanation for the difference?

- A The liquid is not all at the same temperature.
- B The readings are not precise.
- C There is a random error affecting the readings.
- D There is a systematic error affecting the readings.

138. 9702_m19_qp_12 Q: 5

Four students measure a time interval that is known to be 1.734 s .

The measurement recorded by each student is shown.

Which measurement is the most accurate?

- A 1 s
- B 1.7 s
- C 1.83 s
- D 1.604 s

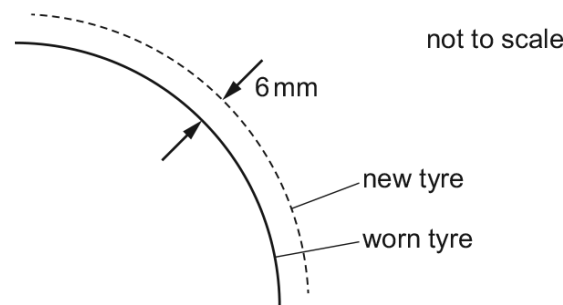
139. 9702_s19_qp_11 Q: 5

The speed shown on a car's speedometer is proportional to the rate of rotation of the tyres.

The variation of the diameter of a tyre as it wears introduces an error in the speed shown on the speedometer.

A car has new tyres of diameter 600 mm. The speedometer is accurately calibrated for this diameter.

The tyres wear as shown, with 6 mm of material being removed from the outer surface.



What is the error in the speed shown on the speedometer after this wear has taken place?

- A The speed shown is too high by 1%.
- B The speed shown is too high by 2%.
- C The speed shown is too low by 1%.
- D The speed shown is too low by 2%.

140. 9702_s19_qp_12 Q: 5

A student wishes to determine the density ρ of lead. She measures the mass and diameter of a small sphere of lead:

$$\text{mass} = (0.506 \pm 0.005) \text{ g}$$

$$\text{diameter} = (2.20 \pm 0.02) \text{ mm}.$$

What is the best estimate of the percentage uncertainty in her calculated value of ρ ?

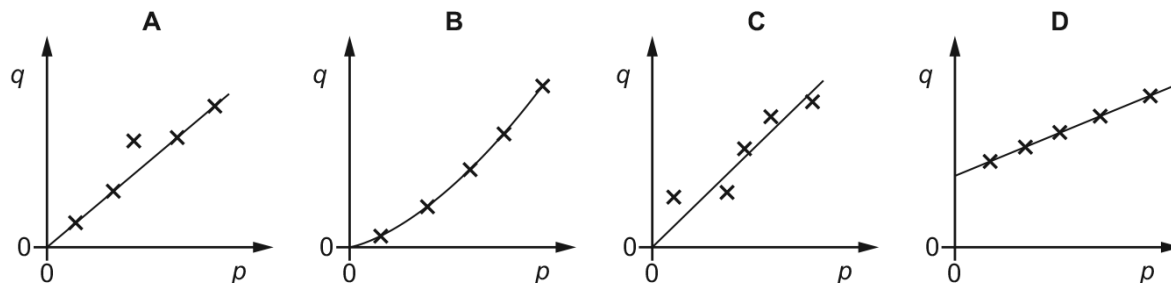
- A 1.7%
- B 1.9%
- C 2.8%
- D 3.7%

141. 9702_s19_qp_12 Q: 6

Two quantities p and q are directly proportional to each other.

Experimental results are taken and plotted in a graph of q against p .

Which graph shows there were random errors in the measurements of p and q ?



142. 9702_s19_qp_12 Q: 7

A man of mass 75.2 kg uses a set of weighing scales to measure his mass three times. He obtains the following readings.

	mass / kg
reading 1	80.2
reading 2	80.1
reading 3	80.2

Which statement best describes the precision and accuracy of the weighing scales?

- A** not precise to ± 0.1 kg and accurate to ± 0.1 kg
- B** not precise to ± 0.1 kg and not accurate to ± 0.1 kg
- C** precise to ± 0.1 kg and accurate to ± 0.1 kg
- D** precise to ± 0.1 kg and not accurate to ± 0.1 kg

143. 9702_s19_qp_13 Q: 6

A micrometer screw gauge is used to measure the diameter of a small uniform steel sphere. The micrometer reading is $5.00 \text{ mm} \pm 0.01 \text{ mm}$.

What will be the percentage uncertainty in a calculation of the volume of the sphere, using these values?

- A** 0.2%
- B** 0.4%
- C** 0.6%
- D** 1.2%

144. 9702_w19_qp_11 Q: 5

The power P dissipated in a resistor of resistance R is calculated using the expression

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

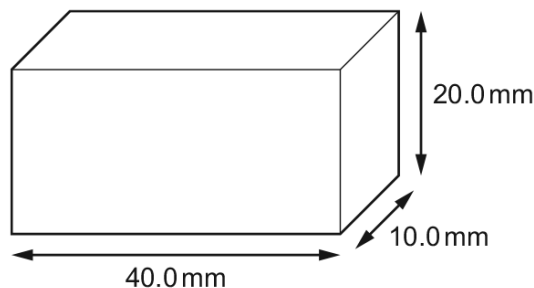
where V is the potential difference (p.d.) across the resistor. The percentage uncertainty in V is 5% and in R is 2%.

What is the percentage uncertainty in P ?

- A** 3% **B** 7% **C** 8% **D** 12%
-

145. 9702_w19_qp_12 Q: 5

The sides of a wooden block are measured with calipers. The lengths of the sides are measured as 20.0 mm, 40.0 mm and 10.0 mm.



The calipers can measure with an absolute uncertainty of ± 0.1 mm.

What is the percentage uncertainty in the calculated volume of the block?

- A** 0.3% **B** 1.8% **C** 3.8% **D** 30%
-

146. 9702_w19_qp_13 Q: 4

What could reduce systematic errors?

- A** averaging a large number of measurements
 - B** careful calibration of measuring instruments
 - C** reducing the sample size
 - D** repeating measurements
-

147. 9702_w19_qp_13 Q: 5

The power loss P in a resistor is calculated using the formula $P = \frac{V^2}{R}$.

The percentage uncertainty in the potential difference V is 3% and the percentage uncertainty in the resistance R is 2%.

What is the percentage uncertainty in P ?

- A** 4% **B** 7% **C** 8% **D** 11%
-

148. 9702_s18_qp_11 Q: 5

The sides of a cube are measured with calipers.

The measured length of each side is (30.0 ± 0.1) mm.

The measurements are used to calculate the volume of the cube.

What is the percentage uncertainty in the calculated value of the volume?

- A** 0.01% **B** 0.3% **C** 1% **D** 3%
-

149. 9702_s18_qp_12 Q: 3

A student measures the current through a resistor and the potential difference (p.d.) across it. There is a 4% uncertainty in the current reading and a 1% uncertainty in the p.d. reading. The student calculates the resistance of the resistor.

What is the percentage uncertainty in the calculated resistance?

- A** 0.25% **B** 3% **C** 4% **D** 5%
-

150. 9702_s18_qp_12 Q: 4

A student applies a potential difference V of (4.0 ± 0.1) V across a resistor of resistance R of $(10.0 \pm 0.3) \Omega$ for a time t of (50 ± 1) s.

The student calculates the energy E dissipated using the equation below.

$$E = \frac{V^2 t}{R} = \frac{4.0^2 \times 50}{10.0} = 80 \text{ J}$$

What is the absolute uncertainty in the calculated energy value?

- A** 1.5 J **B** 3 J **C** 6 J **D** 8 J
-

151. 9702_s18_qp_13 Q: 4

What will reduce the systematic errors when taking a measurement?

- A** adjusting the needle on a voltmeter so that it reads zero when there is no potential difference across it
 - B** measuring the diameter of a wire at different points and taking the average
 - C** reducing the parallax effects by using a marker and a mirror when measuring the amplitude of oscillation of a pendulum
 - D** timing 20 oscillations, rather than a single oscillation, when finding the period of a pendulum
-

152. 9702_s18_qp_13 Q: 5

In an experiment to determine the Young modulus E of the material of a wire, the measurements taken are shown.

mass hung on end of wire	$m = 2.300 \pm 0.002 \text{ kg}$
original length of wire	$l = 2.864 \pm 0.005 \text{ m}$
diameter of wire	$d = 0.82 \pm 0.01 \text{ mm}$
extension of wire	$e = 7.6 \pm 0.2 \text{ mm}$

The Young modulus is calculated using

$$E = \frac{4mgl}{\pi d^2 e}$$

where g is the acceleration of free fall.

The calculated value of E is $1.61 \times 10^{10} \text{ N m}^{-2}$.

How should the calculated value of E and its uncertainty be expressed?

- A** $(1.61 \pm 0.04) \times 10^{10} \text{ N m}^{-2}$
 - B** $(1.61 \pm 0.05) \times 10^{10} \text{ N m}^{-2}$
 - C** $(1.61 \pm 0.07) \times 10^{10} \text{ N m}^{-2}$
 - D** $(1.61 \pm 0.09) \times 10^{10} \text{ N m}^{-2}$
-

153. 9702_w18_qp_11 Q: 5

A digital meter has an accuracy of $\pm 1\%$.

The meter is used to measure the current in an electrical circuit.

The reading on the meter varies between 3.04 A and 3.08 A.

What is the value of the current, with its uncertainty?

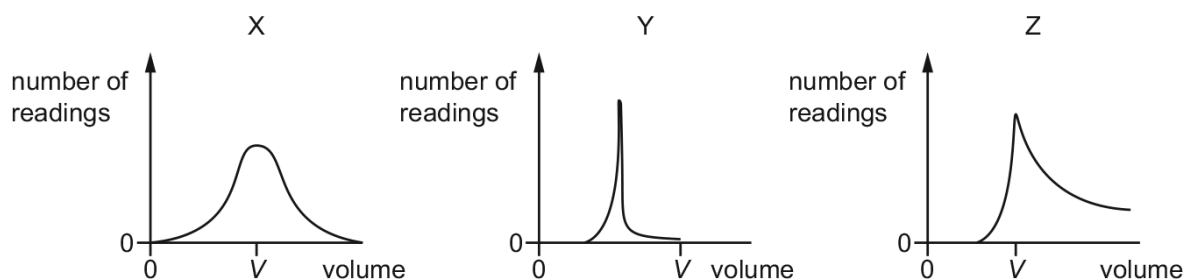
- A** $(3.06 \pm 0.02) \text{ A}$
- B** $(3.06 \pm 0.04) \text{ A}$
- C** $(3.06 \pm 0.05) \text{ A}$
- D** $(3.06 \pm 0.07) \text{ A}$

154. 9702_w18_qp_12 Q: 5

Students take readings of the volume of a liquid using three different pieces of measuring equipment X, Y and Z.

The true value of the volume of the liquid is V .

The students' results are shown.



How many pieces of equipment are precise and how many are accurate?

	number of precise pieces of equipment	number of accurate pieces of equipment
A	1	1
B	1	2
C	2	1
D	2	2

155. 9702_w18_qp_13 Q: 5

The width of a table is measured as (50.3 ± 0.1) cm. Its length is measured as (1.40 ± 0.01) m.

What is the area of the table and its absolute uncertainty?

- A $(0.7 \pm 0.1)\text{m}^2$
 - B $(0.704 \pm 0.006)\text{m}^2$
 - C $(0.704 \pm 0.011)\text{m}^2$
 - D $(70.4 \pm 0.6)\text{m}^2$
-

156. 9702_s17_qp_11 Q: 9

A student attempts to find the density ρ of aluminium by taking measurements of a rectangular sheet.

$$\text{mass } m = 51.6 \pm 0.1 \text{ g}$$

$$\text{length } l = 100.0 \pm 0.1 \text{ cm}$$

$$\text{width } w = 10.0 \pm 0.1 \text{ cm}$$

$$\text{thickness } t = 0.20 \pm 0.01 \text{ mm}$$

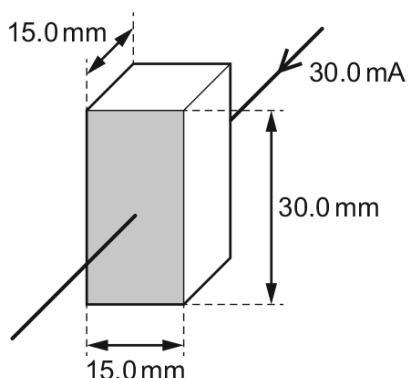
He uses the equation $\rho = \frac{m}{wlt}$ to calculate the density.

What is the calculated value of density with its uncertainty?

- A $0.26 \pm 0.01 \text{ g cm}^{-3}$
 - B $0.26 \pm 0.02 \text{ g cm}^{-3}$
 - C $2.6 \pm 0.1 \text{ g cm}^{-3}$
 - D $2.6 \pm 0.2 \text{ g cm}^{-3}$
-

157. 9702_s17_qp_12 Q: 4

The current in a block of semiconductor is 30.0 mA when there is a potential difference (p.d.) of 10.0 V across it. The dimensions of the block and the direction of the current in it are as shown.



The electrical meters used are accurate to ± 0.1 mA and ± 0.1 V. The dimensions of the block are accurate to ± 0.2 mm.

What is the resistivity of the semiconductor?

- A $10.0 \pm 0.2 \Omega \text{ m}$
- B $10.0 \pm 0.3 \Omega \text{ m}$
- C $10.0 \pm 0.5 \Omega \text{ m}$
- D $10.0 \pm 0.8 \Omega \text{ m}$

158. 9702_s17_qp_13 Q: 4

A voltage is carefully measured with a high-quality instrument and found to be 2.321 V.

Two students, using two different methods, conclude that the voltage is 2.33 V and 2.344 V respectively.

Which statement is correct?

- A 2.33 V is less accurate and less precise than 2.344 V.
- B 2.33 V is less accurate and more precise than 2.344 V.
- C 2.33 V is more accurate and less precise than 2.344 V.
- D 2.33 V is more accurate and more precise than 2.344 V.

159. 9702_w17_qp_12 Q: 4

A quantity y is to be determined from the equation shown.

$$y = \frac{px}{q^2}$$

The percentage uncertainties in p , x and q are shown.

	percentage uncertainty
p	6%
x	2%
q	4%

What is the percentage uncertainty in y ?

- A** 0.5% **B** 0.75% **C** 12% **D** 16%

160. 9702_w17_qp_13 Q: 5

Four possible sources of error in a series of measurements are listed.

- 1 an analogue meter whose scale is read from different angles
- 2 a meter which always measures 5% too high
- 3 a meter with a needle that is not frictionless, so the needle sometimes sticks slightly
- 4 a meter with a zero error

Which errors are random and which are systematic?

	random error	systematic error
A	1 and 2	3 and 4
B	1 and 3	2 and 4
C	2 and 4	1 and 3
D	3 and 4	1 and 2

161. 9702_m16_qp_12 Q: 4

Quantity X has a fractional uncertainty of x . Quantity Y has a fractional uncertainty of y .

What is the fractional uncertainty in $\frac{X}{Y^2}$?

- A** $x + y$ **B** $x - y$ **C** $x + 2y$ **D** $x - 2y$
-

162. 9702_s16_qp_11 Q: 4

When performing an experiment, a student should minimise the uncertainty of any measurement.

In which case is the student reducing the systematic error in a measurement?

- A** adjusting a voltmeter needle pointer to the zero position before using it to measure a potential difference
B measuring the diameter of a wire at several points and orientations
C measuring the mass of 100 paperclips to determine the mass of one paperclip
D timing 20 oscillations of a mass on a spring to determine the period of one oscillation
-

163. 9702_s16_qp_12 Q: 5

A student determines the density ρ of steel by taking measurements from a steel wire.

$$\text{mass } m = 6.2 \pm 0.1 \text{ g}$$

$$\text{length } l = 25.0 \pm 0.1 \text{ cm}$$

$$\text{diameter } d = 2.00 \pm 0.01 \text{ mm}$$

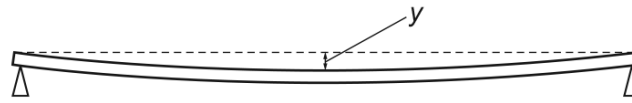
He uses the equation $\rho = \frac{4m}{\pi d^2 l}$.

What is the percentage uncertainty in his calculated value of density?

- A** 1.1% **B** 1.8% **C** 2.5% **D** 3.0%
-

164. 9702_s16_qp_13 Q: 4

A metre rule is supported horizontally by two pivots as shown.



The vertical displacement y at the centre of the rule is given by the equation

$$y = \frac{kML^3}{wt^3}$$

where

k is a constant,

L is the distance between the pivots,

M is the mass of the rule,

t is the thickness of the rule and

w is the width of the rule.

In an experiment, the following results are obtained:

$$L = (80.0 \pm 0.2) \text{ cm}$$

$$M = (60 \pm 1) \text{ g}$$

$$t = (6.0 \pm 0.1) \text{ mm}$$

$$w = (23.0 \pm 0.5) \text{ mm}.$$

Which measurement contributes most to the uncertainty in the calculated value of y ?

- A** L **B** M **C** t **D** w

165. 9702_w16_qp_12 Q: 5

A value for the acceleration of free fall on Earth is given as $(10 \pm 2) \text{ m s}^{-2}$.

Which statement is correct?

- A** The value is accurate but not precise.
B The value is both precise and accurate.
C The value is neither precise nor accurate.
D The value is precise but not accurate.

166. 9702_w16_qp_12 Q: 6

An experiment to determine atmospheric pressure P uses the equation $P = \rho gh$ where

$$\rho = (13600 \pm 100) \text{ kg m}^{-3},$$

$$g = (9.81 \pm 0.02) \text{ m s}^{-2},$$

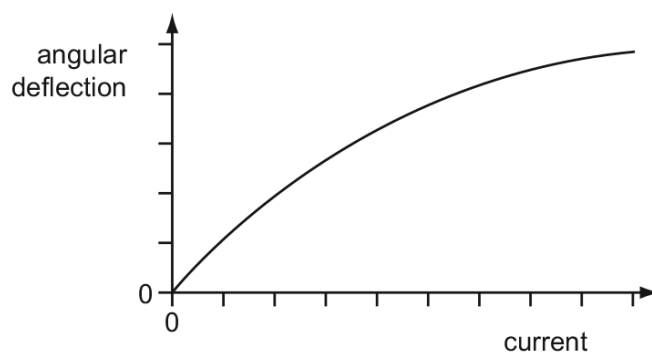
$$h = (0.762 \pm 0.005) \text{ m}.$$

What is the value of P , with its uncertainty, when stated to an appropriate number of significant figures?

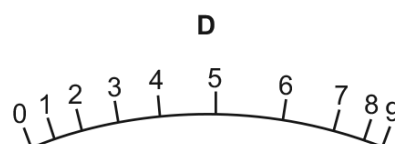
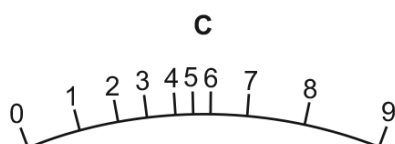
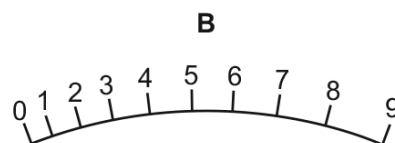
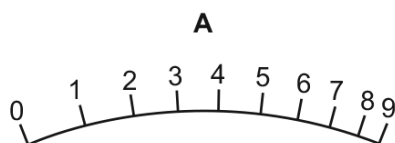
- A $(1.0166 \pm 0.0162) \times 10^5 \text{ Pa}$
- B $(1.017 \pm 0.016) \times 10^5 \text{ Pa}$
- C $(1.017 \pm 1.6\%) \times 10^5 \text{ Pa}$
- D $(1.02 \pm 0.02) \times 10^5 \text{ Pa}$

167. 9702_s15_qp_11 Q: 5

The angular deflection of the needle of an ammeter varies with the current in the ammeter as shown in the graph.



Which diagram could represent the appearance of the scale on this meter?



168. 9702_s15_qp_11 Q: 6

The strain energy W of a spring is determined from its spring constant k and extension x . The spring obeys Hooke's law and the value of W is calculated using the equation shown.

$$W = \frac{1}{2} kx^2$$

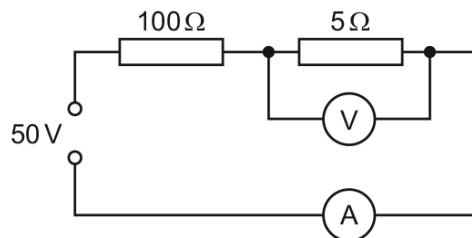
The spring constant is $100 \pm 2 \text{ N m}^{-1}$ and the extension is $0.050 \pm 0.002 \text{ m}$.

What is the percentage uncertainty in the calculated value of W ?

- A** 6% **B** 10% **C** 16% **D** 32%

169. 9702_s15_qp_12 Q: 5

A power supply of electromotive force (e.m.f.) 50 V and negligible internal resistance is connected in series with resistors of resistance 100Ω and 5Ω , as shown.



A voltmeter measures the potential difference (p.d.) across the 5Ω resistor and an ammeter measures the current in the circuit.

What are suitable ranges for the ammeter and for the voltmeter?

	ammeter range / A	voltmeter range / V
A	0–0.1	0–1
B	0–0.1	0–3
C	0–1.0	0–1
D	0–1.0	0–3

170. 9702_s15_qp_12 Q: 6

A single sheet of aluminium foil is folded twice to produce a stack of four sheets. The total thickness of the stack of sheets is measured to be $(0.80 \pm 0.02) \text{ mm}$. This measurement is made using a digital caliper with a zero error of $(-0.20 \pm 0.02) \text{ mm}$.

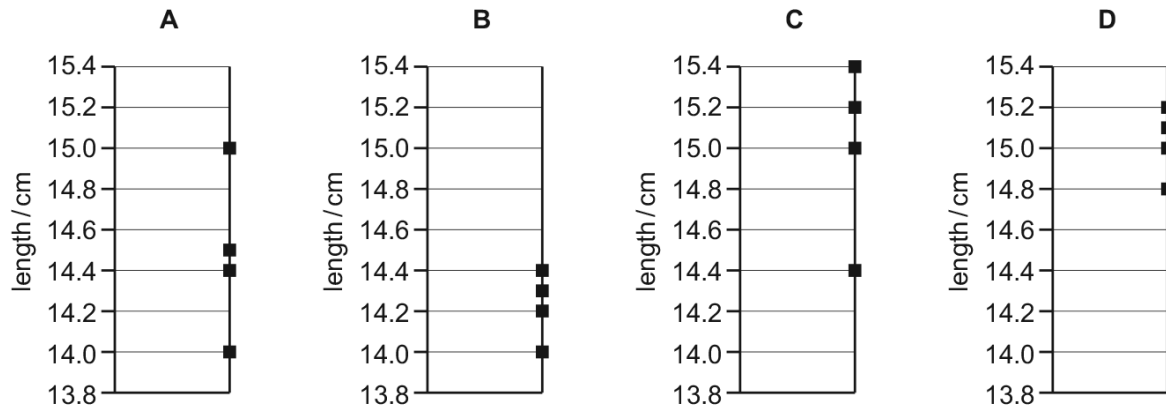
What is the percentage uncertainty in the calculated thickness of a single sheet?

- A** 1.0% **B** 2.0% **C** 4.0% **D** 6.7%

171. 9702_s15_qp_13 Q: 5

Four different students use a ruler to measure the length of a 15.0 cm pencil. Their measurements are recorded on four different charts.

Which chart shows measurements that are precise but **not** accurate?



172. 9702_s15_qp_13 Q: 6

In a simple electrical circuit, the current in a resistor is measured as (2.50 ± 0.05) mA. The resistor is marked as having a value of $4.7 \Omega \pm 2\%$.

If these values were used to calculate the power dissipated in the resistor, what would be the percentage uncertainty in the value obtained?

- A** 2% **B** 4% **C** 6% **D** 8%

Paper 1 Multiple Choice Answers: Measurement Techniques

Question	Paper	Q. No.	Answer
104	9702_m20_qp_12	4	C
105	9702_s20_qp_11	4	B
106	9702_s20_qp_12	3	B
107	9702_s20_qp_13	4	A
108	9702_m19_qp_12	4	A
109	9702_sl9_qp_13	5	A
110	9702_w19_qp_11	4	C
111	9702_w19_qp_12	4	C
112	9702_m18_qp_12	6	B
113	9702_sl8_qp_11	4	A
114	9702_w18_qp_11	4	B
115	9702_w18_qp_13	4	B
116	9702_m17_qp_12	4	C
117	9702_m17_qp_12	5	D
118	9702_sl7_qp_11	3	A
119	9702_sl7_qp_12	5	B
120	9702_w17_qp_12	5	C
121	9702_w17_qp_13	4	B
122	9702_m16_qp_12	5	B
123	9702_sl6_qp_11	5	D
124	9702_sl6_qp_12	4	B
125	9702_sl6_qp_13	5	C
126	9702_w16_qp_11	4	A
127	9702_w16_qp_11	5	D
128	9702_w16_qp_12	4	C
129	9702_w16_qp_13	4	A
130	9702_w16_qp_13	5	D
131	9702_sl5_qp_11	4	D
132	9702_sl5_qp_12	3	C
133	9702_sl5_qp_13	4	B
134	9702_m20_qp_12	5	D
135	9702_s20_qp_11	5	D
136	9702_s20_qp_12	4	D
137	9702_s20_qp_13	5	D
138	9702_m19_qp_12	5	B
139	9702_sl9_qp_11	5	B
140	9702_sl9_qp_12	5	D
141	9702_sl9_qp_12	6	C
142	9702_sl9_qp_12	7	D
143	9702_sl9_qp_13	6	C
144	9702_w19_qp_11	5	D
145	9702_w19_qp_12	5	B
146	9702_w19_qp_13	4	B
147	9702_w19_qp_13	5	C
148	9702_sl8_qp_11	5	C
149	9702_sl8_qp_12	3	D

Paper 1 Multiple Choice Answers: Measurement Techniques (continue

Question	Paper	Q. No.	Answer
150	9702_sl8_qp_12	4	D
151	9702_sl8_qp_13	4	A
152	9702_sl8_qp_13	5	D
153	9702_w18_qp_11	5	C
154	9702_w18_qp_12	5	A
155	9702_w18_qp_13	5	B
156	9702_sl7_qp_11	9	D
157	9702_sl7_qp_12	4	C
158	9702_sl7_qp_13	4	C
159	9702_w17_qp_12	4	D
160	9702_w17_qp_13	5	B
161	9702_m16_qp_12	4	C
162	9702_sl6_qp_11	4	A
163	9702_sl6_qp_12	5	D
164	9702_sl6_qp_13	4	C
165	9702_w16_qp_12	5	A
166	9702_w16_qp_12	6	D
167	9702_sl5_qp_11	5	A
168	9702_sl5_qp_11	6	B
169	9702_sl5_qp_12	5	D
170	9702_sl5_qp_12	6	C
171	9702_sl5_qp_13	5	B
172	9702_sl5_qp_13	6	C

Chapter 2

Measurement techniques

2.1 Errors and uncertainties

11. 9702_m20_qp_22 Q: 1

- (a) Length, mass and temperature are all SI base quantities.

State **two** other SI base quantities.

1.

2.

[2]

- (b) The acceleration of free fall g may be determined from an oscillating pendulum using the equation

$$g = \frac{4\pi^2 l}{T^2}$$

where l is the length of the pendulum and T is the period of oscillation.

In an experiment, the measured values for an oscillating pendulum are

$$l = 1.50 \text{ m} \pm 2\%$$

and $T = 2.48 \text{ s} \pm 3\%$.

- (i) Calculate the acceleration of free fall g .

$$g = \dots \text{ ms}^{-2} \quad [1]$$

- (ii) Determine the percentage uncertainty in g .

$$\text{percentage uncertainty} = \dots \% \quad [2]$$

- (iii) Use your answers in (b)(i) and (b)(ii) to determine the absolute uncertainty of the calculated value of g .

$$\text{absolute uncertainty} = \dots \text{ ms}^{-2} \quad [1]$$

[Total: 6]

12. 9702_s20_qp_21 Q: 1

- (a) Use an expression for work done, in terms of force, to show that the SI base units of energy are $\text{kg m}^2 \text{s}^{-2}$.

[2]

- (b) (i) The energy E stored in an electrical component is given by

$$E = \frac{Q^2}{2C}$$

where Q is charge and C is a constant.

Use this equation and the information in (a) to determine the SI base units of C .

SI base units [2]

- (ii) Measurements of a constant current in a wire are taken using an analogue ammeter.

For these measurements, describe one possible cause of:

1. a random error

.....

2. a systematic error.

.....

[2]

[Total: 6]

13. 9702_s19_qp_22 Q: 1

- (a) The diameter d of a cylinder is measured as $0.0125\text{ m} \pm 1.6\%$.

Calculate the absolute uncertainty in this measurement.

absolute uncertainty = ... m [1]

- (b) The cylinder in (a) stands on a horizontal surface. The pressure p exerted on the surface by the cylinder is given by

$$p = \frac{4W}{\pi d^2}.$$

The measured weight W of the cylinder is $0.38\text{ N} \pm 2.8\%$.

- (i) Calculate the pressure p .

$p =$ Nm^{-2} [1]

- (ii) Determine the absolute uncertainty in the value of p .

absolute uncertainty = ... Nm^{-2} [2]

[Total: 4]

14. 9702_w19_qp_21 Q: 1

(a) Make estimates of:**(i)** the mass, in g, of a new pencil

mass = ... g [1]

(ii) the wavelength of ultraviolet radiation.

wavelength = ... m [1]

(b) The period T of the oscillations of a mass m suspended from a spring is given by

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where k is the spring constant of the spring.

The manufacturer of a spring states that it has a spring constant of $25 \text{ Nm}^{-1} \pm 8\%$. A mass of $200 \times 10^{-3} \text{ kg} \pm 4 \times 10^{-3} \text{ kg}$ is suspended from the end of the spring and then made to oscillate.

(i) Calculate the period T of the oscillations. $T =$ s [1]**(ii)** Determine the value of T , with its absolute uncertainty, to an appropriate number of significant figures. $T =$ $\pm$ s [3]

[Total: 6]

15. 9702_s18_qp_23 Q: 1

- (a) An analogue voltmeter is used to take measurements of a constant potential difference across a resistor.

For these measurements, describe **one** example of

- (i) a systematic error,

.....
[1]

- (ii) a random error.

.....
[1]

- (b) The potential difference across a resistor is measured as $5.0\text{ V} \pm 0.1\text{ V}$. The resistor is labelled as having a resistance of $125\ \Omega \pm 3\%$.

- (i) Calculate the power dissipated by the resistor.

power = ... W [2]

- (ii) Calculate the percentage uncertainty in the calculated power.

percentage uncertainty = ... % [2]

- (iii) Determine the value of the power, with its absolute uncertainty, to an appropriate number of significant figures.

power = ... $\pm$ W [2]

[Total: 8]

16. 9702_s17_qp_21 Q: 1

- (a) Determine the SI base units of stress.
Show your working.

base units[2]

- (b) A beam PQ is clamped so that the beam is horizontal. A mass M of 500 g is hung from end Q and the beam bends slightly, as illustrated in Fig. 1.1.

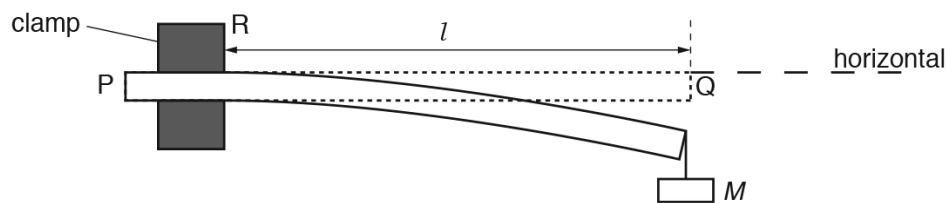


Fig. 1.1

The length l of the beam from the edge of the clamp R to end Q is 60.0 cm. The width b of the beam is 30.0 mm and the thickness d of the beam is 5.00 mm. The material of the beam has Young modulus E .

The mass M is made to oscillate vertically. The time period T of the oscillations is 0.58 s.

The period T is given by the expression

$$T = 2\pi \sqrt{\frac{4Ml^3}{Ebd^3}}.$$

- (i) Determine E in GPa.

$E =$ GPa [3]

(ii) The quantities used to determine E should be measured with accuracy and with precision.

1. Explain the difference between accuracy and precision.

accuracy:

.....

precision:

.....

[2]

2. In a particular experiment, the quantities l and T are measured with the same percentage uncertainty. State and explain which of these two quantities contributes more to the uncertainty in the value of E .

.....

.....

.....[1]

[Total: 8]

17. 9702_s17_qp_22 Q: 1

(a) State two SI base units other than kilogram, metre and second.

1.

2.

[1]

(b) Determine the SI base units of resistivity.

base units[3]

- (c) (i) A wire of cross-sectional area 1.5 mm^2 and length 2.5 m has a resistance of 0.030Ω . Calculate the resistivity of the material of the wire in $\text{n}\Omega\text{m}$.

resistivity = ... $\text{n}\Omega\text{m}$ [3]

- (ii) 1. State what is meant by *precision*.

.....
.....

2. Explain why the precision in the value of the resistivity is improved by using a micrometer screw gauge rather than a metre rule to measure the diameter of the wire.

.....
.....
.....

[2]

[Total: 9]

18. 9702_w17_qp_22 Q: 1

One end of a wire is connected to a fixed point. A load is attached to the other end so that the wire hangs vertically.

The diameter d of the wire and the load F are measured as

$$d = 0.40 \pm 0.02 \text{ mm},$$

$$F = 25.0 \pm 0.5 \text{ N}.$$

(a) For the measurement of the diameter of the wire, state

(i) the name of a suitable measuring instrument,

.....[1]

(ii) how random errors may be reduced when using the instrument in (i).

.....

[2]

(b) The stress σ in the wire is calculated by using the expression

$$\sigma = \frac{4F}{\pi d^2}.$$

(i) Show that the value of σ is $1.99 \times 10^8 \text{ N m}^{-2}$.

[1]

(ii) Determine the percentage uncertainty in σ .

percentage uncertainty = ...% [2]

- (iii) Use the information in **(b)(i)** and your answer in **(b)(ii)** to determine the value of σ , with its absolute uncertainty, to an appropriate number of significant figures.

$$\sigma = \dots\dots\dots \pm \dots\dots\dots \text{Nm}^{-2} [2]$$

[Total: 8]

19. 9702_m16_qp_22 Q: 1

The speed v of a transverse wave on a uniform string is given by the expression

$$v = \sqrt{\frac{Tl}{m}}$$

where T is the tension in the string, l is its length and m is its mass.

An experiment is performed to determine the speed v of the wave. The measurements are shown in Fig. 1.1.

quantity	measurement	uncertainty
T	1.8N	$\pm 5\%$
l	126cm	$\pm 1\%$
m	5.1g	$\pm 2\%$

Fig. 1.1

- (a)** State an appropriate instrument to measure the length l .

..... [1]

- (b) (i)** Use the data in Fig. 1.1 to calculate the speed v .

$v =$ ms^{-1} [2]

- (ii)** Use your answer in **(b)(i)** and the data in Fig. 1.1 to determine the value of v , with its absolute uncertainty, to an appropriate number of significant figures.

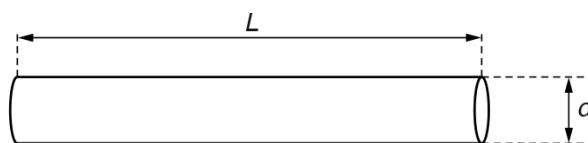
$v =$ $\pm$ ms^{-1} [3]

[Total: 6]

20. 9702_s16_qp_21 Q: 1

(a) Make estimates of**(i)** the mass, in kg, of a wooden metre rule,

mass = ... kg [1]

(ii) the volume, in cm³, of a cricket ball or a tennis ball.volume = ... cm³ [1]**(b)** A metal wire of length L has a circular cross-section of diameter d , as shown in Fig. 1.1.**Fig. 1.1**The volume V of the wire is given by the expression

$$V = \frac{\pi d^2 L}{4}.$$

The diameter, length and mass M are measured to determine the density of the metal of the wire. The measured values are:

$$d = 0.38 \pm 0.01 \text{ mm},$$

$$L = 25.0 \pm 0.1 \text{ cm},$$

$$M = 0.225 \pm 0.001 \text{ g}.$$

Calculate the density of the metal, with its absolute uncertainty. Give your answer to an appropriate number of significant figures.

density = ... $\pm$ kg m⁻³ [5]

[Total: 7]

21. 9702_s16_qp_23 Q: 2

- (a) Describe the effects, one in each case, of systematic errors and random errors when using a micrometer screw gauge to take readings for the diameter of a wire.

systematic errors:

.....

random errors:

.....

[2]

- (b) Distinguish between precision and accuracy when measuring the diameter of a wire.

precision:

.....

accuracy:

.....

[2]

[Total: 4]

22. 9702_s15_qp_23 Q: 4

Fig. 4.1 shows the values obtained in an experiment to determine the Young modulus E of a metal in the form of a wire.

quantity	value	instrument
diameter d	0.48 mm	
length l	1.768 m	
load F	5.0 N to 30.0 N in 5.0 N steps	
extension e	0.25 mm to 1.50 mm	

Fig. 4.1

- (a) (i) Complete Fig. 4.1 with the name of an instrument that could be used to measure each of the quantities. [3]

- (ii) Explain why a series of values of F , each with corresponding extension e , are measured.

.....
[1]

- (b) Explain how a series of readings of the quantities given in Fig. 4.1 is used to determine the Young modulus of the metal. A numerical answer for E is not required.

.....

[2]

23. 9702_w15_qp_21 Q: 1

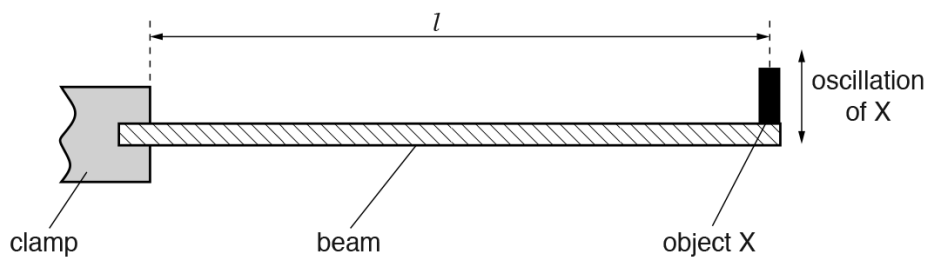
(a) State two SI base quantities other than mass, length and time.

1.

2.

[2]

(b) A beam is clamped at one end and an object X is attached to the other end of the beam, as shown in Fig. 1.1.

**Fig. 1.1**

The object X is made to oscillate vertically.

The time period T of the oscillations is given by

$$T = K \sqrt{\frac{Ml^3}{E}}$$

where M is the mass of X, l is the length between the clamp and X, E is the Young modulus of the material of the beamand K is a constant.(i) 1. Show that the SI base units of the Young modulus are $\text{kg m}^{-1} \text{s}^{-2}$.

2. Determine the SI base units of K .

SI base units of K [2]

- (ii) Data in SI units for the oscillations of X are shown in Fig. 1.2.

quantity	value	uncertainty
T	0.45	$\pm 2.0\%$
l	0.892	$\pm 0.2\%$
M	0.2068	$\pm 0.1\%$
K	1.48×10^5	$\pm 1.5\%$

Fig. 1.2

Calculate E and its actual uncertainty.

$E = \dots \pm \dots \text{ kg m}^{-1} \text{ s}^{-2}$ [4]

11. 9702_m20_qp_22 Q: 1

	Answer	Mark
(a)	time (electric) current <i>allow</i> amount of substance <i>allow</i> luminous intensity <i>any two of the above quantities, 1 mark each</i>	B2
(b)(i)	$g = (4\pi^2 \times 1.50) / (2.48^2)$ $= 9.63 \text{ m s}^{-2}$	A1
(b)(ii)	percentage uncertainty = $2 + (3 \times 2)$ or fraction uncertainty = $0.02 + (0.03 \times 2)$	C1
	percentage uncertainty = 8%	A1
(b)(iii)	absolute uncertainty = 0.08×9.6 $= 0.8 \text{ m s}^{-2}$	A1

12. 9702_s20_qp_21 Q: 1

	Answer	Mark
(a)	(work =) force $\times$ displacement	C1
	units: $\text{kg m s}^{-2} \times \text{m} = \text{kg m}^2 \text{ s}^{-2}$	A1
(b)(i)	units of Q: As	C1
	units of C: $\text{kg}^{-1} \text{ m}^{-2} \text{ A}^2 \text{ s}^4$	A1
(b)(ii)	1. e.g. reading scale from different angles (wrongly) interpolating between scale readings/divisions	B1
	2. e.g. zero error wrongly calibrated scale	B1

13. 9702_s19_qp_22 Q: 1

	Answer	Mark
(a)	absolute uncertainty = $(1.6 / 100) \times 0.0125$ $= 2 \times 10^{-4} \text{ m}$	A1
(b)(i)	$p = (4 \times 0.38) / (\pi \times 0.0125^2)$ $= 3100 \text{ N m}^{-2}$	A1
(b)(ii)	percentage uncertainty = $2.8 + (2 \times 1.6)$ (= 6%) or fractional uncertainty = $0.028 + (2 \times 0.016)$ (= 0.06)	C1
	absolute uncertainty = 0.06×3100 $= 190 \text{ N m}^{-2}$ (<i>allow to 1 significant figure</i>)	A1

14. 9702_w19_qp_21 Q: 1

	Answer	Mark
(a)(i)	mass in range 1–20 g	A1
(a)(ii)	wavelength in range 1×10^{-8} m to 4×10^{-7} m	A1
(b)(i)	$T = 2\pi \times (200 \times 10^{-3} / 25)^{0.5}$ $= 0.56$ s	A1
(b)(ii)	percentage uncertainty = $(2\% + 8\%) / 2$ (= 5%) or fractional uncertainty = $(0.02+0.08) / 2$ (= 0.05)	C1
	$\Delta T = 0.56 \times 0.05$ $= 0.028$ (s)	C1
	$T = (0.56 \pm 0.03)$ s	A1

15. 9702_s18_qp_23 Q: 1

	Answer	Mark
(a)(i)	zero error or wrongly calibrated scale	B1
(a)(ii)	reading scale from different angles or wrongly interpolating between scale readings/divisions	B1
(b)(i)	$P = V^2 / R$ or $P = VI$ and $V = IR$	C1
	$P = 5.0^2 / 125$ or 5.0×0.04 or $(0.04)^2 \times 125$ $= 0.20$ W	A1
(b)(ii)	%V = 2% or $\Delta V / V = 0.02$	C1
	%P = $(2 \times 2\%) + 3\%$ or %P = $(2 \times 0.02 + 0.03) \times 100$ $= 7\%$	A1
(b)(iii)	absolute uncertainty in $P = (7 / 100) \times 0.20$ $= 0.014$	C1
	power = 0.20 ± 0.01 W or $(2.0 \pm 0.1) \times 10^{-1}$ W	A1

16. 9702_s17_qp_21 Q: 1

	Answer	Mark
(a)	(stress =) force / area or $\text{kg m s}^{-2} / \text{m}^2$	B1
	$= \text{kg m}^{-1} \text{s}^{-2}$	A1
(b)(i)	$0.58 = 2\pi \times [(4 \times 0.500 \times 0.600^3) / (E \times 0.0300 \times 0.00500^3)]^{0.5}$	C1
	$E = [4\pi^2 \times 4 \times 0.500 \times (0.600)^3] / [(0.58)^2 \times 0.0300 \times (0.00500)^3]$ $= 1.35 \times 10^{10}$ (Pa)	C1
	$= 14$ (13.5) GPa	A1
(b)(ii)1.	(accuracy determined by) the closeness of the value(s)/measurement(s) to the true value	B1
	(precision determined by) the range of the values/measurements	B1
(b)(ii)2.	l is (cubed so) $3 \times$ (percentage/fractional) uncertainty and T is (squared so) $2 \times$ (percentage / fractional) uncertainty and (so) l contributes more	B1

17. 9702_s17_qp_22 Q: 1

	Answer	Mark
(a)	kelvin, mole, ampere, candela <i>any two</i>	B1
(b)	use of resistivity = RA/l and $V = IR$ (to give $\rho = VA/Il$)	C1
	units of V : (work done / charge) $\text{kg m}^2 \text{s}^{-2} (\text{A s})^{-1}$	C1
	units of resistivity: $(\text{kg m}^2 \text{s}^{-3} \text{A}^{-1} \text{A}^{-1} \text{m})$ $= \text{kg m}^3 \text{s}^{-3} \text{A}^{-2}$	A1
	or	
	use of $R = \rho L/A$ and $P = I^2 R$ (gives $\rho = PA/I^2 L$)	(C1)
	units of P : $\text{kg m}^2 \text{s}^{-3}$	(C1)
	units of resistivity: $(\text{kg m}^2 \text{s}^{-3} \times \text{m}^2) / (\text{A}^2 \times \text{m})$ $= \text{kg m}^3 \text{s}^{-3} \text{A}^{-2}$	(A1)
(c)(i)	$\rho = (RA/l)$	C1
	$= (0.03 \times 1.5 \times 10^{-6}) / 2.5 (= 1.8 \times 10^{-8})$	C1
	$= 18 \text{ n}\Omega \text{ m}$	A1
(c)(ii)	1. precision is determined by the range in the measurements/values/readings/data/results	B1
	2. metre rule measures to $\pm 1 \text{ mm}$ and micrometer to $\pm 0.01 \text{ mm}$ (so there is less (percentage) uncertainty/random error)	B1

18. 9702_w17_qp_22 Q: 1

	Answer	Mark
(a)(i)	micrometer (screw gauge)/digital calipers	B1
(a)(ii)	take several readings (and average)	M1
	along the wire or around the circumference	A1
(b)(i)	$\sigma = 4 \times 25 / [\pi \times (0.40 \times 10^{-3})^2] = 1.99 \times 10^8 \text{ N m}^{-2}$ or $\sigma = 25 / [\pi \times (0.20 \times 10^{-3})^2] = 1.99 \times 10^8 \text{ N m}^{-2}$	A1
(b)(ii)	$\%F = 2\%$ and $\%d = 5\%$	C1
	or $\Delta F/F = \frac{0.5}{25}$ and $\Delta d/d = \frac{0.02}{0.4}$	
	$\%\sigma = 2\% + (2 \times 5\%)$ or $\%\sigma = [0.02 + (2 \times 0.05)] \times 100$	A1
	$\%\sigma = 12\%$	
(b)(iii)	absolute uncertainty $= (12/100) \times 1.99 \times 10^8$ $= 2.4 \times 10^7$	C1
	$\sigma = 2.0 \times 10^8 \pm 0.2 \times 10^8 \text{ N m}^{-2}$ or $2.0 \pm 0.2 \times 10^8 \text{ N m}^{-2}$	A1

19. 9702_m16_qp_22 Q: 1

- (a) metre rule/tape measure B1
- (b) (i) $v = [(1.8 \times 126 \times 10^{-2}) / 5.1 \times 10^{-3}]^{1/2}$ C1
 $= 21.1 (\text{ms}^{-1})$ A1
- (ii) percentage uncertainty = 4% or fractional uncertainty = 0.04 C1
 $\Delta v = 0.04 \times 21.1$
 $= 0.84$ C1
 $v = 21.1 \pm 0.8 (\text{ms}^{-1})$ A1

20. 9702_s16_qp_21 Q: 1

- (a) (i) $(50 \text{ to } 200) \times 10^{-3} \text{ kg}$ or $(0.05 \text{ to } 0.2) \text{ kg}$ B1 [1]
- (ii) $(50 \text{ to } 300) \text{ cm}^3$ B1 [1]
- (b) density = mass/volume or $\rho = M/V$ C1
- $V = [\pi(0.38 \times 10^{-3})^2 \times 25.0 \times 10^{-2}] / 4 (= 2.835 \times 10^{-8} \text{ m}^3)$ C1
- $\rho = (0.225 \times 10^{-3}) / 2.835 \times 10^{-8}$
 $= 7940 (\text{kg m}^{-3})$ A1
- $\Delta\rho/\rho = 2(0.01/0.38) + (0.1/25.0) + (0.001/0.225) [= 0.061]$
or
 $\%\rho = 5.3\% + 0.40\% + 0.44\% (= 6.1\%)$ C1
- $\Delta\rho = 0.061 \times 7940 = 480 (\text{kg m}^{-3})$
- density = $(7.9 \pm 0.5) \times 10^3 \text{ kg m}^{-3}$ or $(7900 \pm 500) \text{ kg m}^{-3}$ A1 [5]

21. 9702_s16_qp_23 Q: 2

- (a) systematic: the reading is larger or smaller than (or varying from) the true reading by a constant amount B1
- random: scatter in readings about the true reading B1 [2]
- (b) precision: the size of the smallest division (on the measuring instrument)
or
0.01 mm for the micrometer B1
- accuracy: how close (diameter) value is to the true (diameter) value B1 [2]

22. 9702_s15_qp_23 Q: 4

- (a) (i) diameter and extension: micrometer (screw gauge) or digital calipers B1
length: tape measure or metre rule B1
load: spring balance or Newton meter B1 [3]
- (ii) to reduce the effect of random errors **or** to plot a graph to check for zero error in measurement of extension **or** to see if limit of proportionality is exceeded B1 [1]
- (b) plot a graph of F against e and determine the gradient B1
 $E = (\text{gradient} \times l) / [\pi d^2 / 4]$ B1 [2]

23. 9702_w15_qp_21 Q: 1

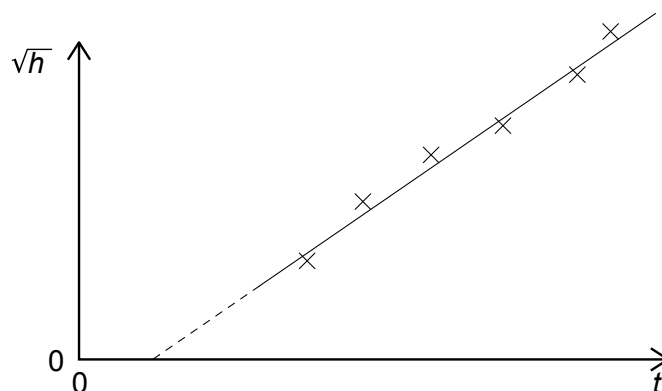
- (a) temperature B1
current B1 [2]
(allow amount of substance, luminous intensity)
- (b) (i) 1. $E = (\text{stress} / \text{strain}) = [\text{force} / \text{area}] / [\text{extension} / \text{original length}]$
units of stress: $\text{kg m s}^{-2} / \text{m}^2$ and no units for strain B1
units of E : $\text{kg m}^{-1} \text{s}^{-2}$ A0 [1]
2. units for T : s, l : m and M : kg
 $K^2 = T^2 E / M l^3$ hence units: $\text{s}^2 \text{kg m}^{-1} \text{s}^{-2} / \text{kg}^3 (= \text{m}^{-4})$ C1
units of K : m^{-2} A1 [2]
- (ii) % uncertainty in $E = 4\%$ (for T^2) + 0.6% (for l^3) + 0.1% (for M) + 3% (for K^2)
= 7.7% B1
- $E = [(1.48 \times 10^5)^2 \times 0.2068 \times (0.892)^3] / (0.45)^2$
= 1.588×10^{10} C1
- 7.7% of $E = 1.22 \times 10^9$ C1
- $E = (1.6 \pm 0.1) \times 10^{10} \text{ kg m}^{-1} \text{s}^{-2}$ A1 [4]

24. 9702_s20_qp_23 Q: 1

	Answer	Mark
(a)	similarity: both have magnitude	B1
	difference: distance is a scalar/does not have direction or displacement is a vector/has direction	B1
(b)(i)	the measurements have a small range	B1
(b)(ii)	the (average of the) measurements is not close to the true value	B1

- 4 A student measures the time t for a ball to fall from rest through a vertical distance h . Knowing that the equation $h = \frac{1}{2}gt^2$ applies, the student plots the graph shown.

9702/1/M/J/02



Which of the following is an explanation for the intercept on the t axis?

- A Air resistance has not been taken into account for larger values of h .
 - B There is a constant delay between starting the timer and releasing the ball.
 - C There is an error in the timer that consistently makes it run fast.
 - D The student should have plotted h against t^2 .
- 5 A student carries out a series of determinations of the acceleration of free fall g . The table shows the results.

9702/1/O/N/02

g/ms^{-2}
4.91
4.89
4.88
4.90
4.93
4.92

What can be said about this experiment?

- A It is accurate and precise.
- B It is accurate but not precise.
- C It is not accurate and not precise.
- D It is not accurate but is precise.

- 5 The power loss P in a resistor is calculated using the formula $P = V^2/R$. 9702/1/M/J/02

The uncertainty in the potential difference V is 3% and the uncertainty in the resistance R is 2%.

What is the uncertainty in P ?

- A** 4% **B** 7% **C** 8% **D** 11%

- 4 Which experimental technique reduces the systematic error of the quantity being investigated? 9702/01/M/J/03

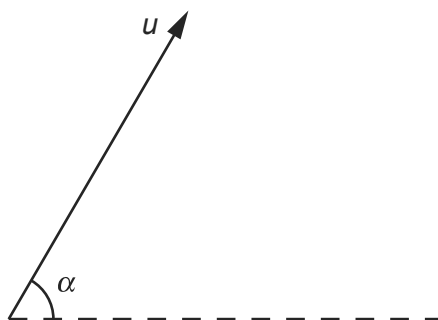
- A** adjusting an ammeter to remove its zero error before measuring a current
B measuring several internodal distances on a standing wave to find the mean internodal distance
C measuring the diameter of a wire repeatedly and calculating the average
D timing a large number of oscillations to find a period

- 5 A student makes measurements from which she calculates the speed of sound as 327.66 m s^{-1} . She estimates that her result is accurate to $\pm 3\%$. 9702/01/M/J/03

Which of the following gives her result expressed to the appropriate number of significant figures?

- A** 327.7 m s^{-1} **B** 328 m s^{-1} **C** 330 m s^{-1} **D** 300 m s^{-1}

- 7 A projectile is fired at an angle α to the horizontal at a speed u , as shown. 9702/01/M/J/03



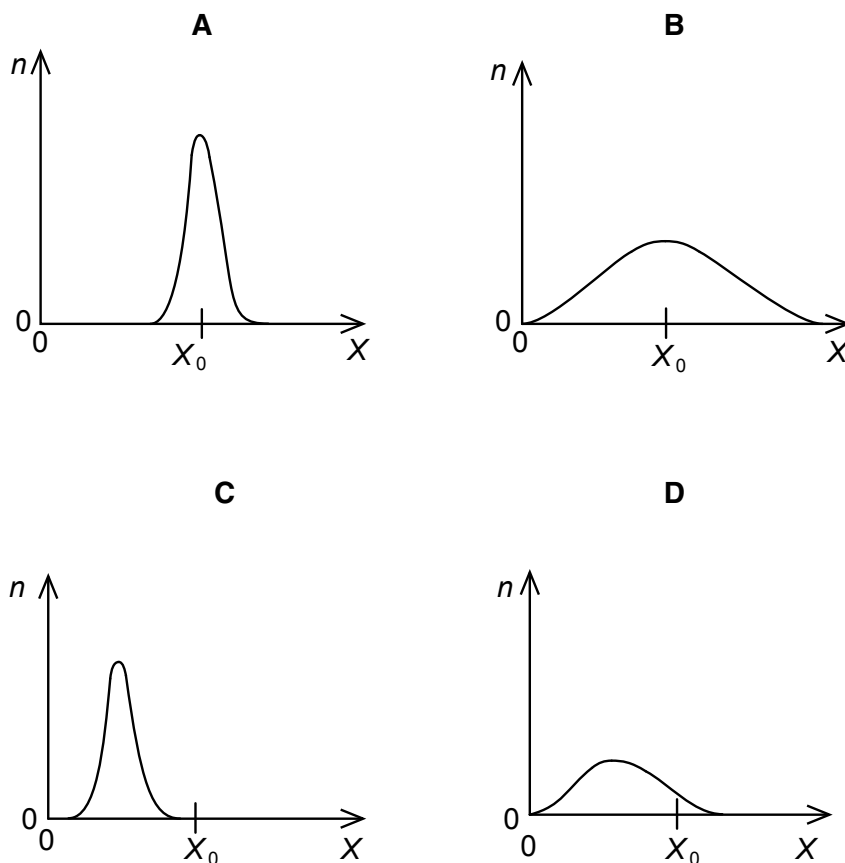
What will be the vertical and horizontal components of its velocity after a time t ? Assume that air resistance is negligible. The acceleration of free fall is g .

	vertical component	horizontal component
A	$u \sin \alpha$	$u \cos \alpha$
B	$u \sin \alpha - gt$	$u \cos \alpha - gt$
C	$u \sin \alpha - gt$	$u \cos \alpha$
D	$u \cos \alpha$	$u \sin \alpha - gt$

- 6 A quantity X is measured many times. A graph is plotted showing the number n of times a particular value of X is obtained. X has a true value X_0 .

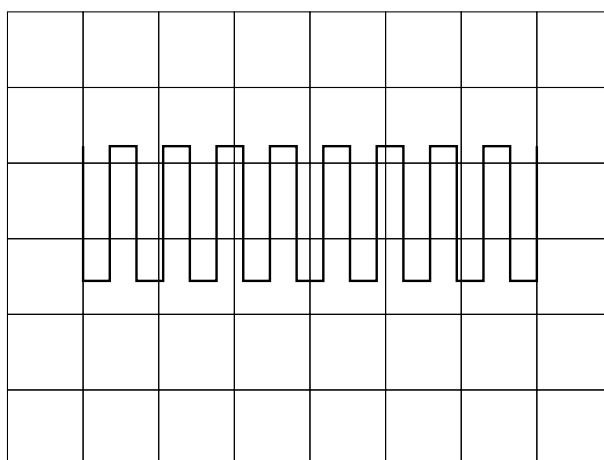
9702/1/O/N/02

Which graph could be obtained if the measurement of X has a large systematic error but a small random error?



- 7 The diagram shows a square-wave trace on the screen of a cathode-ray oscilloscope. A grid of 1 cm squares covers the screen. The time-base setting is 10 ms cm^{-1} .

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What is the approximate frequency of the square-wave?

- A** 70 Hz **B** 140 Hz **C** 280 Hz **D** 1400 Hz

- 6 A steel rule can be read to the nearest millimetre. It is used to measure the length of a bar whose true length is 895 mm. Repeated measurements give the following readings.

9702/01/M/J/03

length / mm	892, 891, 892, 891, 891, 892
-------------	------------------------------

Are the readings accurate and precise to within 1 mm?

	results are accurate to within 1 mm	results are precise to within 1 mm
A	no	no
B	no	yes
C	yes	no
D	yes	yes

- 4 A thermometer can be read to an accuracy of $\pm 0.5^\circ\text{C}$. This thermometer is used to measure a temperature rise from 40°C to 100°C .

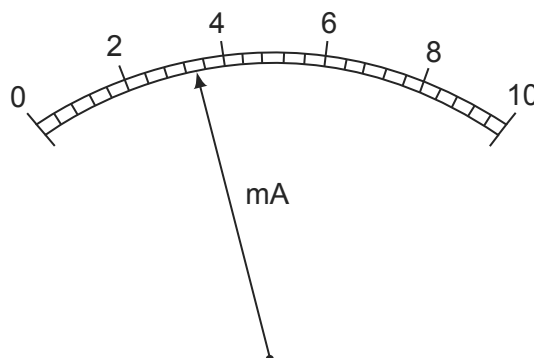
9702/01/O/N/03

What is the percentage uncertainty in the measurement of the temperature rise?

- A** 0.5 % **B** 0.8 % **C** 1.3 % **D** 1.7 %

- 4 What is the reading shown on this milliammeter?

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- A** 2.35 mA **B** 2.7 mA **C** 3.4 mA **D** 3.7 mA

- 4 In an experiment, a radio-controlled car takes $2.50 \pm 0.05\text{ s}$ to travel $40.0 \pm 0.1\text{ m}$.

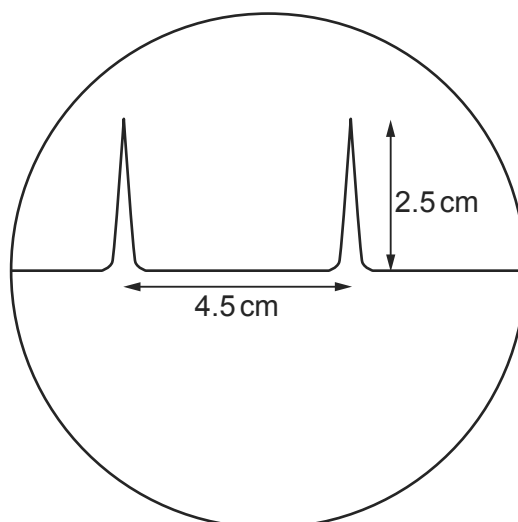
9702/01/M/J/05

What is the car's average speed and the uncertainty in this value?

- A** $16 \pm 1\text{ m s}^{-1}$
B $16.0 \pm 0.2\text{ m s}^{-1}$
C $16.0 \pm 0.4\text{ m s}^{-1}$
D $16.00 \pm 0.36\text{ m s}^{-1}$

- 5 The time-base on a cathode-ray oscilloscope is set at 6 ms / cm.

A trace consisting of two pulses is recorded as shown in the diagram.



What is the time interval between the two pulses?

- A** 0.42 ms **B** 0.75 ms **C** 1.33 ms **D** 27 ms
- 6 A micrometer screw gauge is used to measure the diameter of a copper wire.

9702/01/O/N/03

The reading with the wire in position is shown in diagram 1. The wire is removed and the jaws of the micrometer are closed. The new reading is shown in diagram 2.

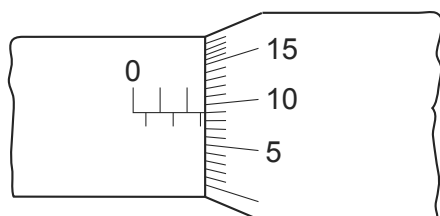


diagram 1

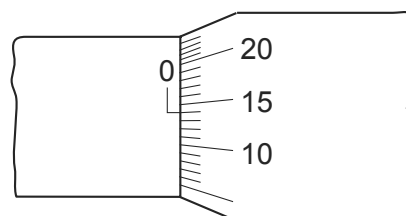


diagram 2

What is the diameter of the wire?

- A** 1.90 mm **B** 2.45 mm **C** 2.59 mm **D** 2.73 mm
- 6 The resistance R of an unknown resistor is found by measuring the potential difference V across the resistor and the current I through it and using the equation $R = \frac{V}{I}$. The voltmeter reading has a 3 % uncertainty and the ammeter reading has a 2 % uncertainty.

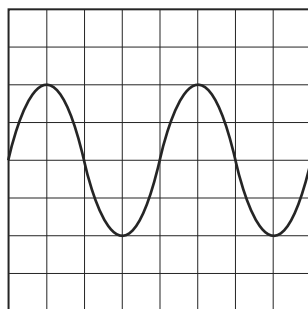
9702/01/M/J/06

What is the uncertainty in the calculated resistance?

- A** 1.5 % **B** 3 % **C** 5 % **D** 6 %

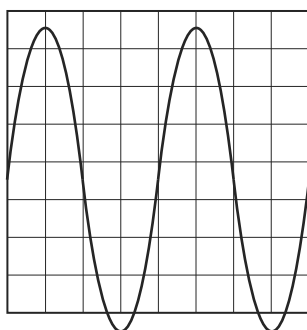
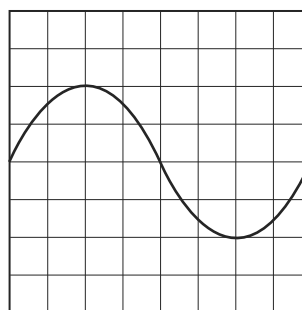
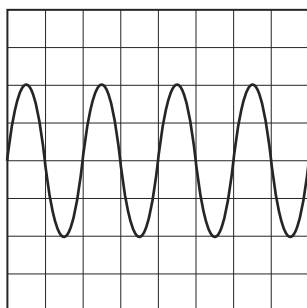
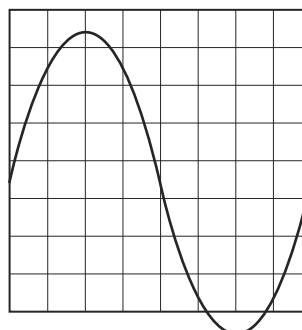
- 5 The following trace is seen on the screen of a cathode-ray oscilloscope.

9702/01/M/J/04



The setting of the time base is then changed from 10 ms cm^{-1} to 20 ms cm^{-1} and the Y-sensitivity is unaltered.

Which trace is now seen on the screen?

A**B****C****D**

- 6 Four students each made a series of measurements of the acceleration of free fall g . The table shows the results obtained.

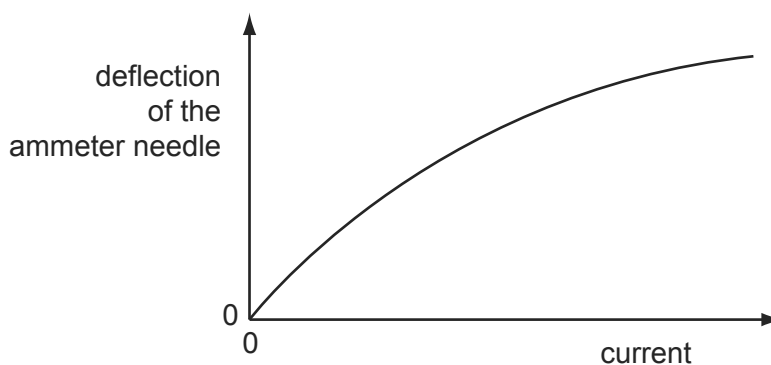
9702/01/O/N/04

Which student obtained a set of results that could be described as precise but not accurate?

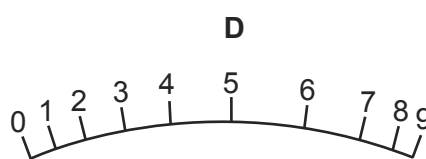
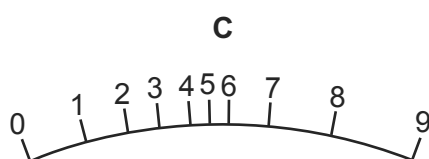
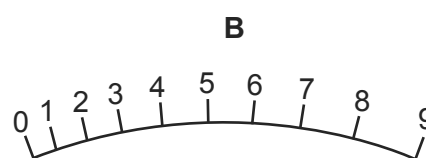
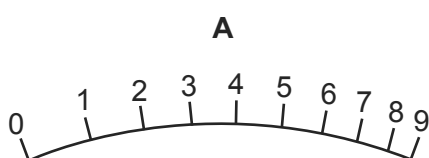
student	results, $g / \text{m s}^{-2}$			
A	9.81	9.79	9.84	9.83
B	9.81	10.12	9.89	8.94
C	9.45	9.21	8.99	8.76
D	8.45	8.46	8.50	8.41

- 4 The deflection of the needle of an ammeter varies with the current passing through the ammeter as shown in the graph.

9702/01/O/N/04

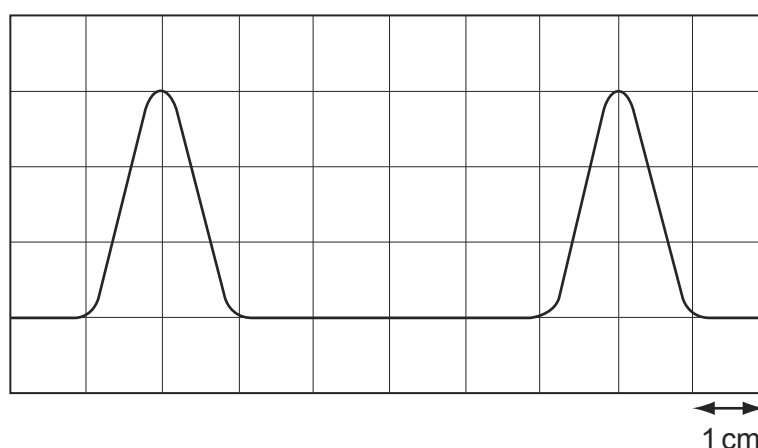


Which diagram could represent the appearance of the scale of this meter?



- 5 The diagram shows two pulses on the screen of a cathode ray oscilloscope. A grid of 1 cm squares covers the screen. The time base setting is $1 \mu\text{s cm}^{-1}$.

9702/01/M/J/05

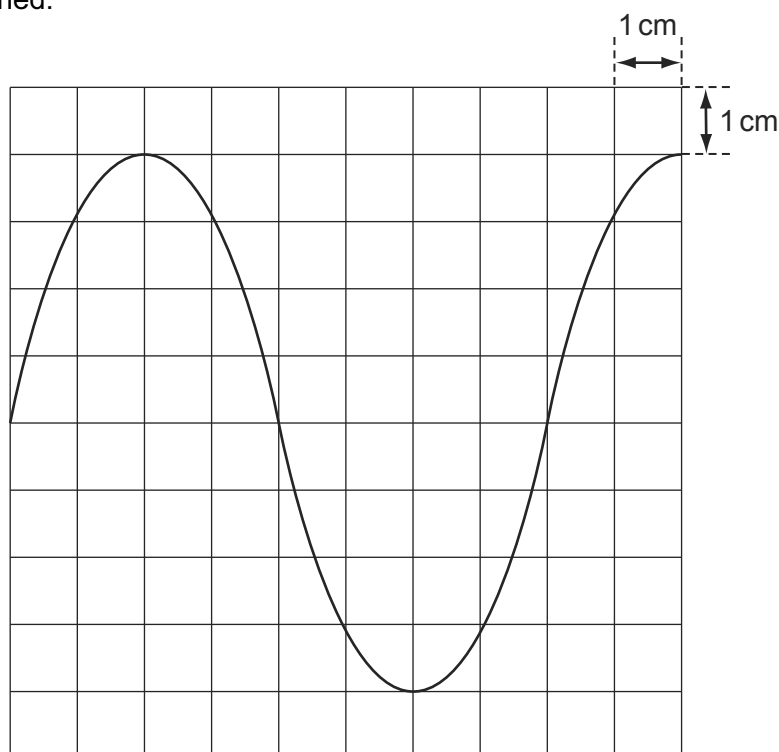


How long does each pulse last?

- A** $2 \mu\text{s}$ **B** $3 \mu\text{s}$ **C** $4 \mu\text{s}$ **D** $6 \mu\text{s}$

- 5 When a 12 V 50 Hz supply is connected to the Y-terminals of an oscilloscope, the trace in the diagram is obtained.

9702/01/O/N/04



What is the setting of the time-base control?

- A** 2.0 ms cm^{-1} **B** 2.5 ms cm^{-1} **C** 5 ms cm^{-1} **D** 20 ms cm^{-1}
- 4 A steel rule can be read to the nearest millimetre. It is used to measure the length of a bar whose true length is 895 mm. Repeated measurements give the following readings.

9702/01/O/N/05

length/mm 892, 891, 892, 891, 891, 892

Are the readings accurate and precise to within 1 mm?

	results are accurate to within 1 mm	results are precise to within 1 mm
A	no	no
B	no	yes
C	yes	no
D	yes	yes

- 6 In a simple electrical circuit, the current in a resistor is measured as $(2.50 \pm 0.05) \text{ mA}$. The resistor is marked as having a value of $4.7 \Omega \pm 2\%$.

9702/01/M/J/04

If these values were used to calculate the power dissipated in the resistor, what would be the percentage uncertainty in the value obtained?

- A** 2% **B** 4% **C** 6% **D** 8%

- 5 The density of the material of a rectangular block is determined by measuring the mass and linear dimensions of the block. The table shows the results obtained, together with their uncertainties.

9702/01/O/N/05

mass	=	$(25.0 \pm 0.1)\text{g}$
length	=	$(5.00 \pm 0.01)\text{cm}$
breadth	=	$(2.00 \pm 0.01)\text{cm}$
height	=	$(1.00 \pm 0.01)\text{cm}$

The density is calculated to be 2.50g cm^{-3} .

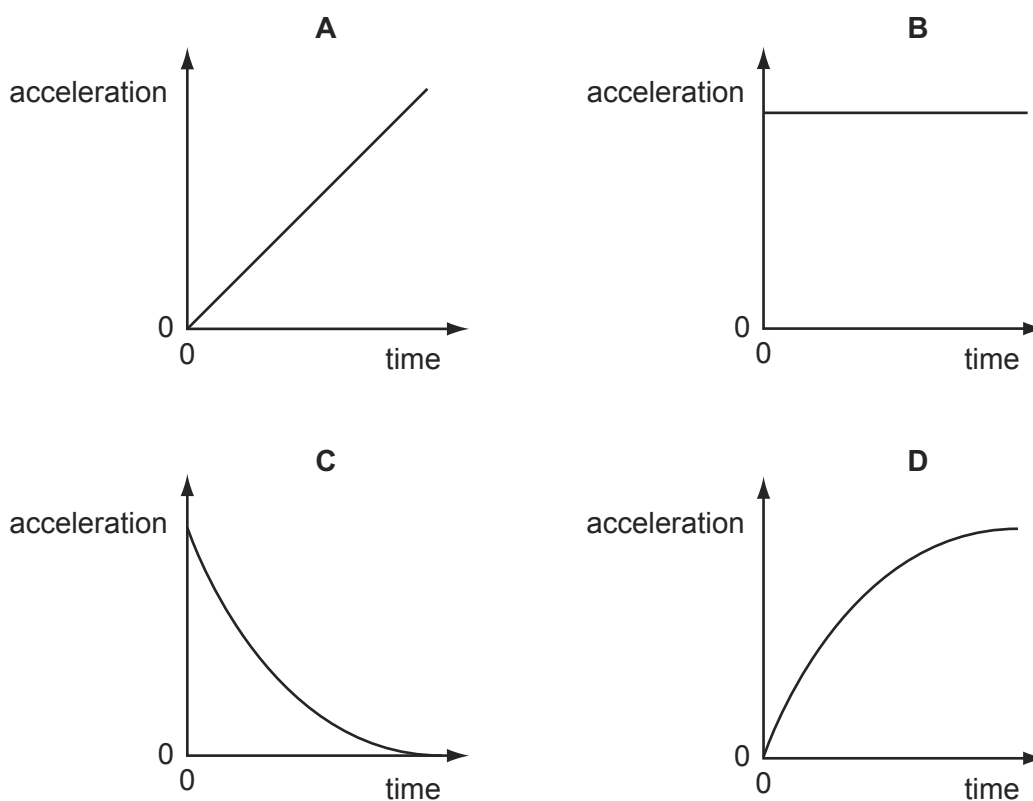
What is the uncertainty in this result?

- A** $\pm 0.01\text{g cm}^{-3}$ **B** $\pm 0.02\text{g cm}^{-3}$ **C** $\pm 0.05\text{g cm}^{-3}$ **D** $\pm 0.13\text{g cm}^{-3}$

- 6 A football is dropped from the top of a tall building.

9702/01/O/N/05

Which acceleration-time graph best represents the motion of the football through the air?



- 4 A metre rule is used to measure the length of a piece of wire. It is found to be 70 cm long to the nearest millimetre.

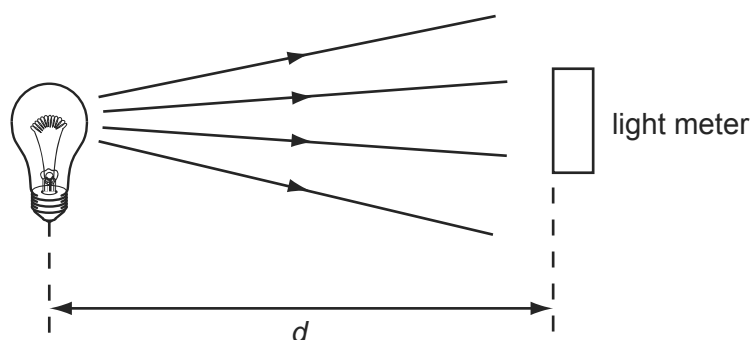
9702/12/O/N/10

How should this result be recorded in a table of results?

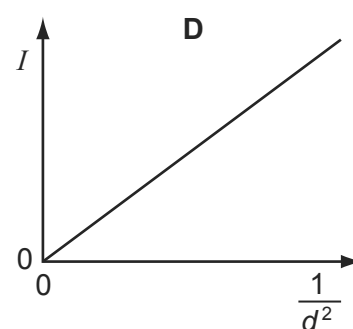
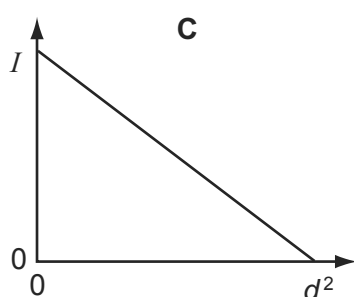
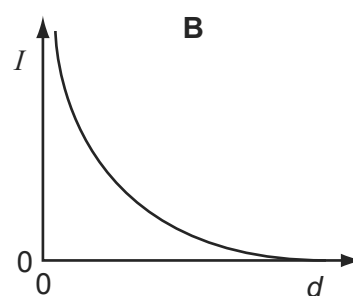
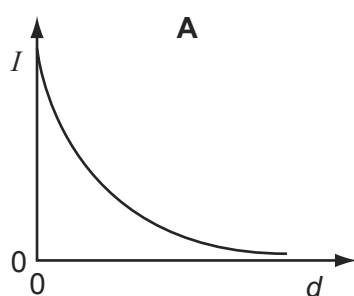
- A** 0.7 m **B** 0.70 m **C** 0.700 m **D** 0.7000 m

- 4 A light meter measures the intensity I of the light falling on it. Theory suggests that this varies as the inverse square of the distance d .

9702/01/M/J/06

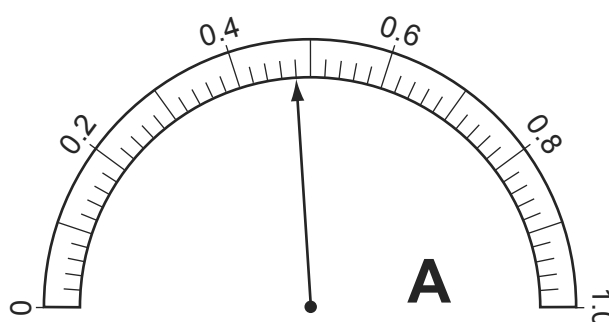


Which graph of the results supports this theory?



- 5 The resistance of an electrical component is measured. The following meter readings are obtained.

9702/01/M/J/07

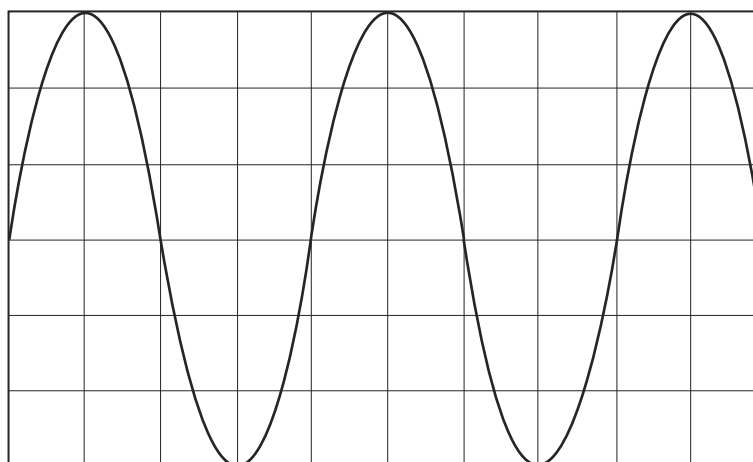


What is the resistance?

- A** 2.5Ω **B** 2.7Ω **C** 2500Ω **D** 2700Ω

- 5 The cathode-ray oscilloscope (c.r.o.) display shows the waveform produced by an electronic circuit. The c.r.o. time-base is set at 10 ms per division.

9702/01/M/J/06



What is the period of the signal shown?

- A** 20 ms **B** 30 ms **C** 40 ms **D** 80 ms

- 4 A series of measurements of the acceleration of free fall g is shown in the table.

9702/01/O/N/07

Which set of results is precise but not accurate?

	g/ms^{-2}				
A	9.81	9.79	9.84	9.83	9.79
B	9.81	10.12	9.89	8.94	9.42
C	9.45	9.21	8.99	8.76	8.51
D	8.45	8.46	8.50	8.41	8.47

- 5 A mass m has acceleration a . It moves through a distance s in time t . The power used in accelerating the mass is equal to the product of force and velocity. The percentage uncertainties are

9702/01/O/N/07

0.1 % in m ,

1 % in a ,

1.5 % in s ,

0.5 % in t .

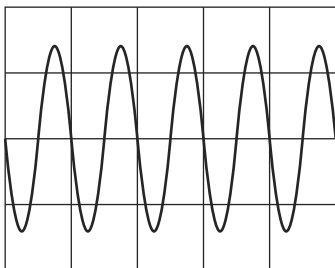
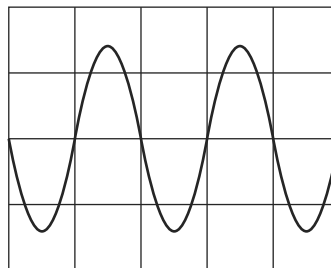
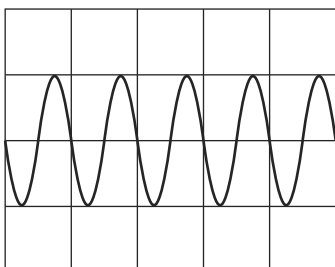
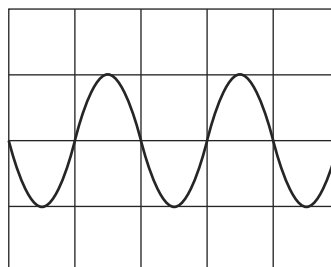
What is the percentage uncertainty in the average power?

- A** 2.1 % **B** 2.6 % **C** 3.1 % **D** 4.1 %

- 4 The Y-input terminals of a cathode-ray oscilloscope (c.r.o.) are connected to a supply of peak value 5.0 V and of frequency 50 Hz. The time-base is set at 10 ms per division and the Y-gain at 5.0 V per division.

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Which trace is obtained?

A**B****C****D**

- 5 The measurement of a physical quantity may be subject to random errors and to systematic errors.

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Which statement is correct?

- A** Random errors can be reduced by taking the average of several measurements.
- B** Random errors are always caused by the person taking the measurement.
- C** A systematic error cannot be reduced.
- D** A systematic error results in a different reading each time the measurement is taken.

- 6 An experiment is done to measure the resistance of a wire.

9702/01/O/N/06

The current in the wire is 1.0 ± 0.2 A and the potential difference across the wire is 8.0 ± 0.4 V.

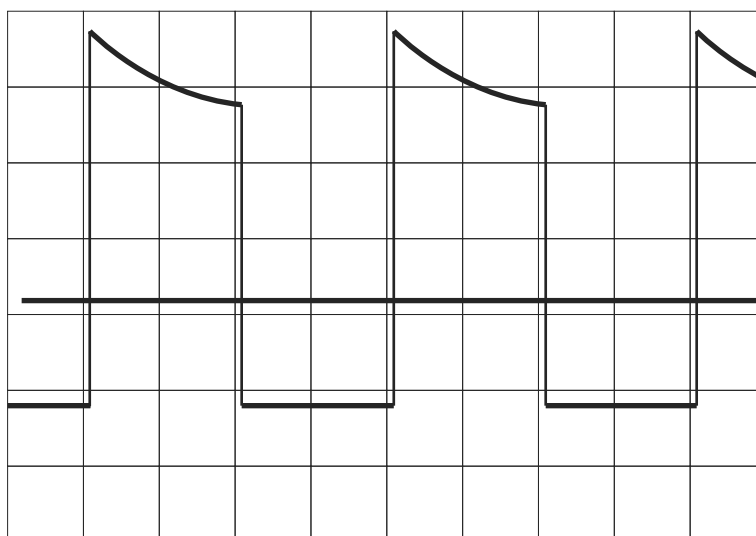
What is the resistance of the wire and its uncertainty?

- A** $(8.0 \pm 0.2) \Omega$
- B** $(8.0 \pm 0.6) \Omega$
- C** $(8 \pm 1) \Omega$
- D** $(8 \pm 2) \Omega$

- 4 An oscilloscope display consists of two separate traces, a waveform and a long horizontal line. The horizontal line may be taken as the zero level.

9702/01/M/J/07

The grid on the screen is calibrated in cm squares, the timebase setting is 2.5 ms cm^{-1} , and the Y-sensitivity is 5 mV cm^{-1} .



What are the period and the peak positive voltage of the waveform in the diagram?

	period / ms	peak positive voltage / mV
A	5	17
B	5	25
C	10	17
D	10	25

- 4 The resistance R of a resistor is determined by measuring the potential difference V across it and the current I in it. The value of R is then calculated using the equation

9702/01/M/J/08

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

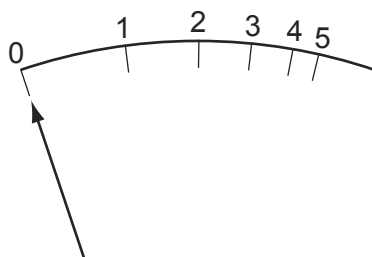
The values measured are $V = 1.00 \pm 0.05 \text{ V}$ and $I = 0.50 \pm 0.01 \text{ A}$.

What is the percentage uncertainty in the value of R ?

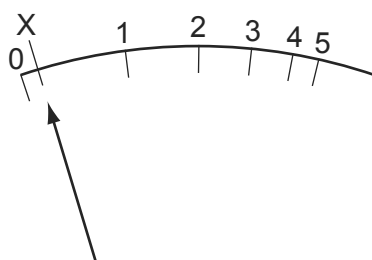
- A** 2.5% **B** 3.0% **C** 7.0% **D** 10.0%

- 6 The diagram shows the graduations of a correctly calibrated ammeter. When the current is zero, the pointer is at 0.

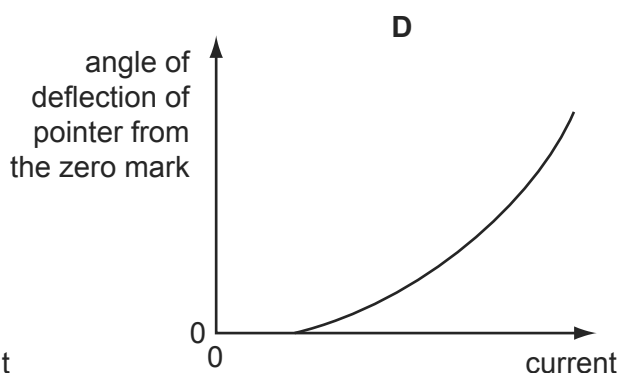
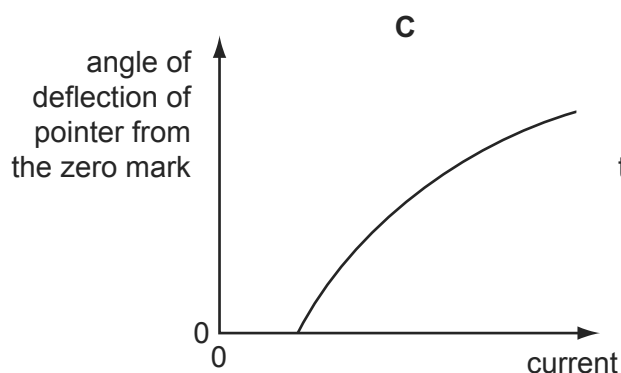
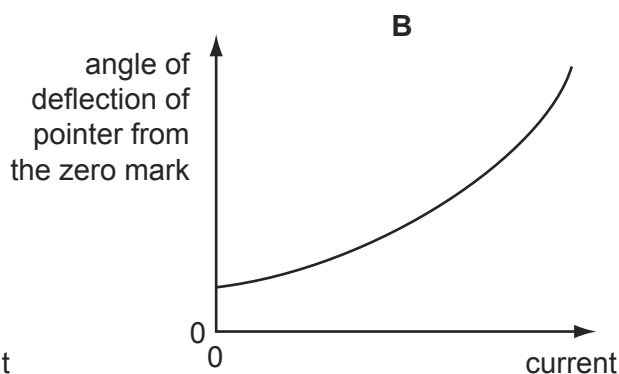
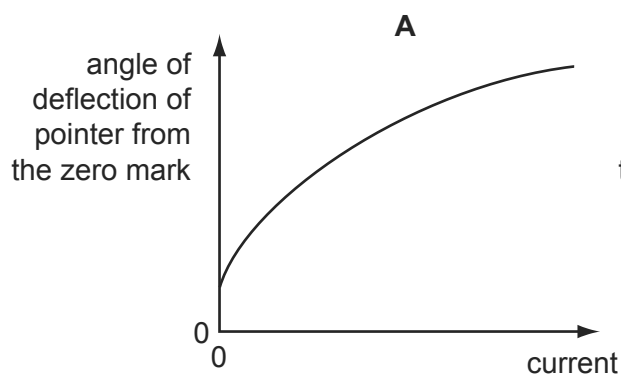
9702/01/O/N/07



The ammeter is accidentally readjusted so that when the current is zero, the pointer is at X.



Which calibration graph best represents the response of the readjusted ammeter?



- 5 Four students each made a series of measurements of the acceleration of free fall g . The table shows the results obtained.

9702/01/M/J/08

Which set of results could be described as precise but **not** accurate?

	g/ms^{-2}			
A	9.81	9.79	9.84	9.83
B	9.81	10.12	9.89	8.94
C	9.45	9.21	8.99	8.76
D	8.45	8.46	8.50	8.41

- 4 A student uses a digital ammeter to measure a current. The reading of the ammeter is found to fluctuate between 1.98 A and 2.02 A.

9702/01/O/N/08

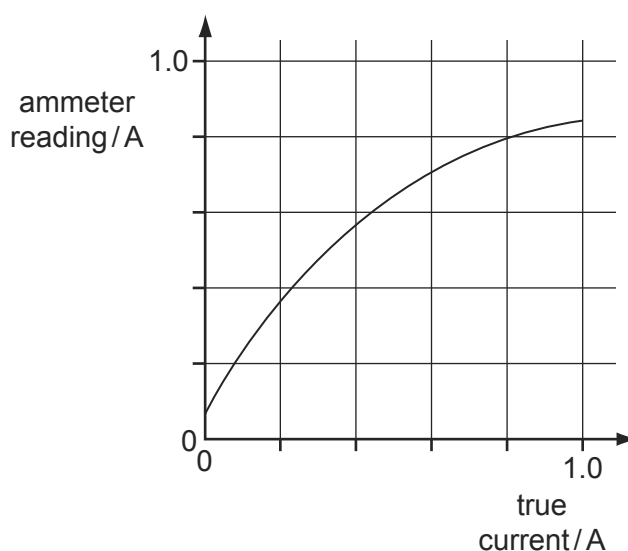
The manufacturer of the ammeter states that any reading has a systematic uncertainty of $\pm 1\%$.

Which value of current should be quoted by the student?

- A** $(2.00 \pm 0.01)\text{A}$
B $(2.00 \pm 0.02)\text{A}$
C $(2.00 \pm 0.03)\text{A}$
D $(2.00 \pm 0.04)\text{A}$

- 5 A calibration graph is produced for a faulty ammeter.

9702/01/O/N/08

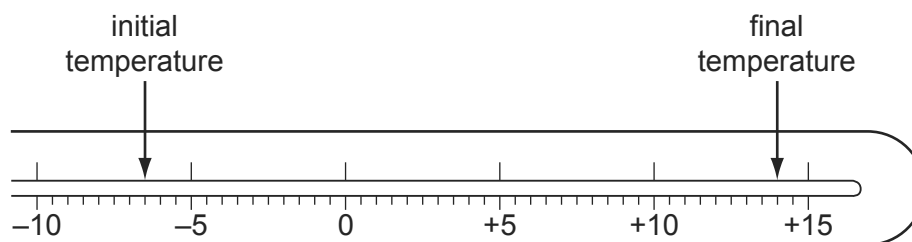


Which ammeter reading will be nearest to the correct value?

- A** 0.2 A **B** 0.4 A **C** 0.6 A **D** 0.8 A

- 3 The diagram shows the stem of a Celsius thermometer marked to show initial and final temperature values.

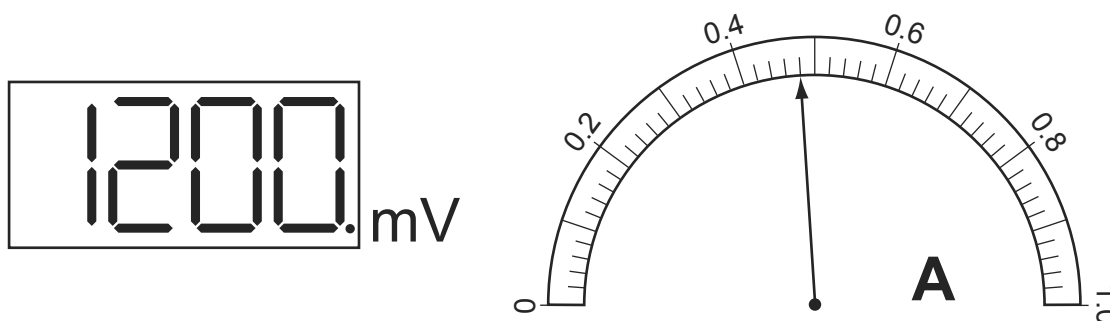
9702/01/M/J/09



What is the temperature change expressed to an appropriate number of significant figures?

- A 14 °C B 20.5 °C C 21 °C D 22.0 °C
- 4 The diagrams show digital voltmeter and analogue ammeter readings from a circuit in which electrical heating is occurring.

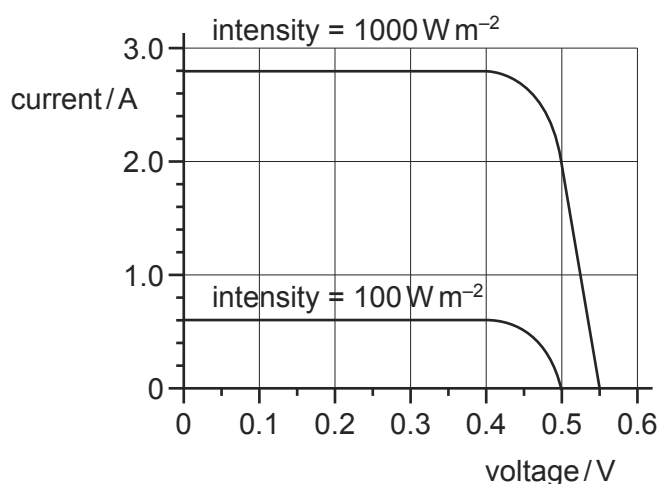
9702/01/M/J/09



What is the electrical power of the heater?

- A 0.53 W B 0.58 W C 530 W D 580 W
- 3 The graph shows two current-voltage calibration curves for a solar cell exposed to different light intensities.

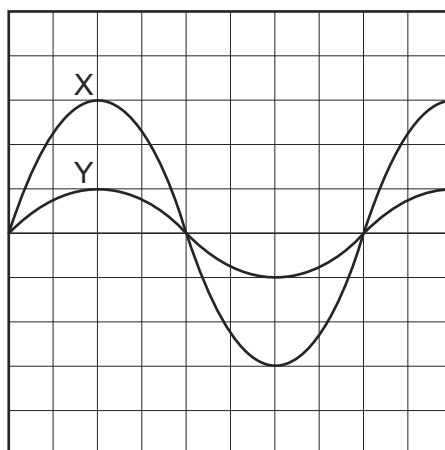
9702/11/O/N/09



At zero voltage, what is the ratio $\frac{\text{current at } 1000 \text{ W m}^{-2}}{\text{current at } 100 \text{ W m}^{-2}}$?

- A 1.1 B 4.7 C 8.0 D 10

- 4 The diagram shows an oscilloscope screen displaying two signals.



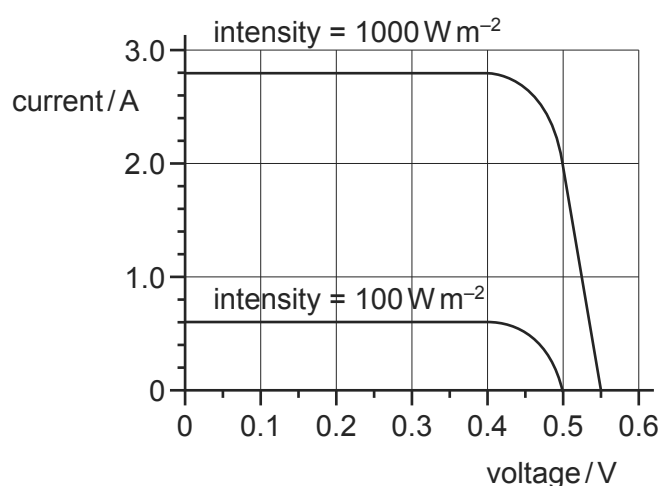
Signal X has a frequency of 50 Hz and peak voltage of 12 V.

What is the period and peak voltage of signal Y?

	period / ms	peak voltage / V
A	20	4
B	20	12
C	50	4
D	50	12

- 2 The graph shows two current-voltage calibration curves for a solar cell exposed to different light intensities.

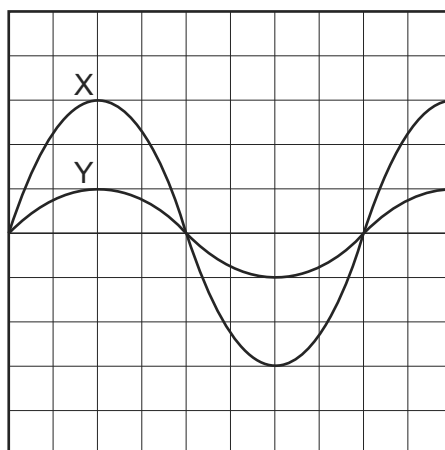
9702/12/O/N/09



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- A** 1.1 **B** 4.7 **C** 8.0 **D** 10

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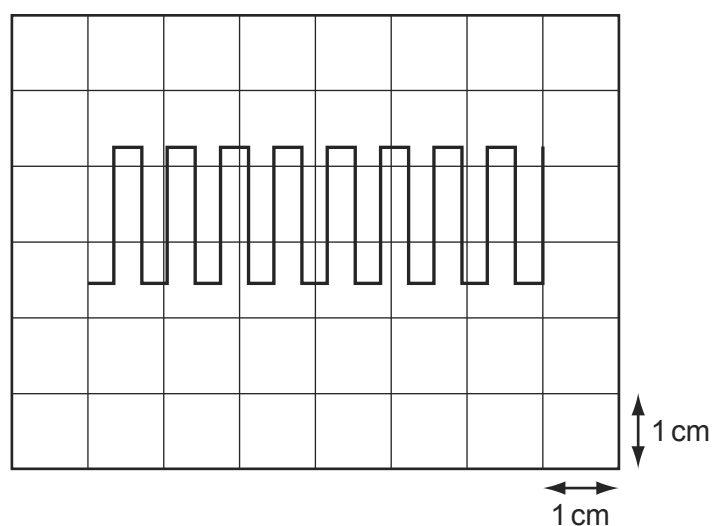
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	period / ms	peak voltage / V
A	20	4
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C	50	4
D	50	12

- 4 The diagram shows a square-wave trace on the screen of a cathode-ray oscilloscope. A grid of 1 cm squares covers the screen. The time-base setting is 10 ms cm^{-1} .

9702/11/M/J/10



What is the approximate frequency of the square wave?

- A** 70 Hz **B** 140 Hz **C** 280 Hz **D** 1400 Hz

- 6 A student finds the density of a liquid by measuring its mass and its volume. The following is a summary of his measurements.

9702/11/M/J/10

$$\text{mass of empty beaker} = (20 \pm 1)\text{g}$$

$$\text{mass of beaker + liquid} = (70 \pm 1)\text{g}$$

$$\text{volume of liquid} = (10.0 \pm 0.6)\text{cm}^3$$

He correctly calculates the density of the liquid as 5.0g cm^{-3} .

What is the uncertainty in this value?

- A 0.3g cm^{-3} B 0.5g cm^{-3} C 0.6g cm^{-3} D 2.6g cm^{-3}
- 7 A micrometer screw gauge is used to measure the diameter of a copper wire.

The reading with the wire in position is shown in diagram 1. The wire is removed and the jaws of the micrometer are closed. The new reading is shown in diagram 2.

9702/11/M/J/10

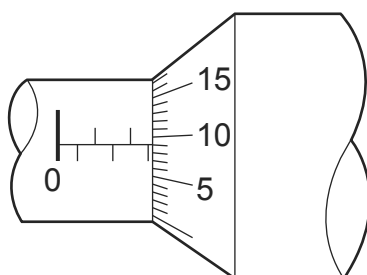


diagram 1

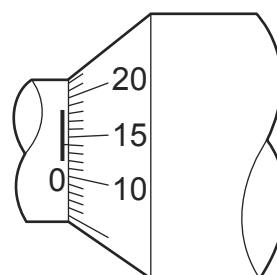


diagram 2

What is the diameter of the wire?

- A 1.90 mm B 2.45 mm C 2.59 mm D 2.73 mm
- 1 A micrometer screw gauge is used to measure the diameter of a copper wire.

9702/12/M/J/10

The reading with the wire in position is shown in diagram 1. The wire is removed and the jaws of the micrometer are closed. The new reading is shown in diagram 2.

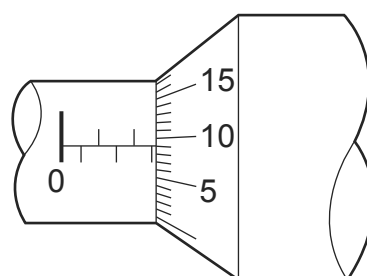


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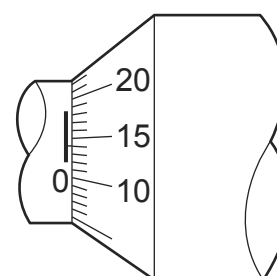


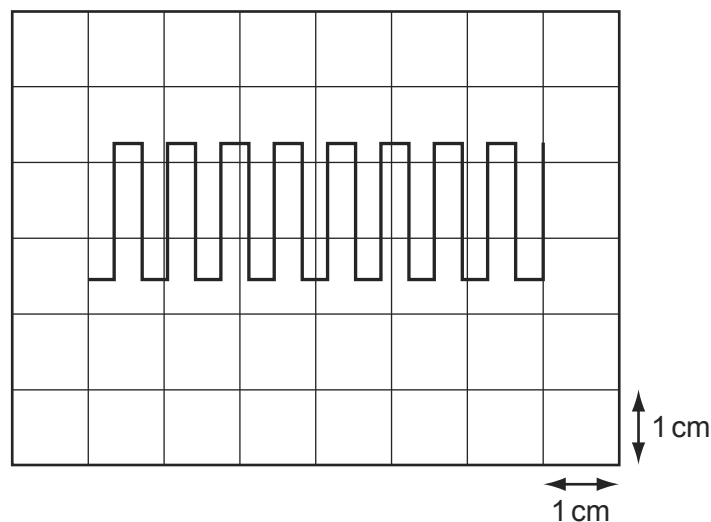
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9702/12/M/J/10



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- A** 70 Hz **B** 140 Hz **C** 280 Hz **D** 1400 Hz
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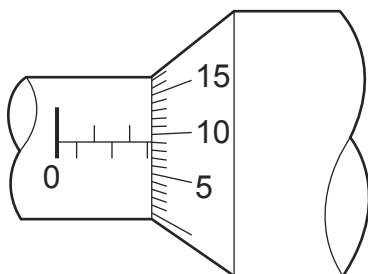


diagram 1

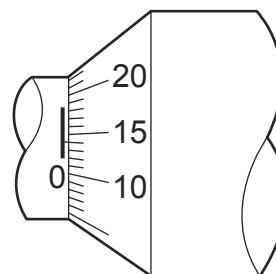


diagram 2

What is the diameter of the wire?

- A** 1.90 mm **B** 2.45 mm **C** 2.59 mm **D** 2.73 mm
- 5 A quantity x is to be determined from the equation 9702/12/O/N/10

$$x = P - Q.$$

P is measured as $1.27 \pm 0.02 \text{ m}$.

Q is measured as $0.83 \pm 0.01 \text{ m}$.

What is the percentage uncertainty in x to one significant figure?

- A** 0.4 % **B** 2 % **C** 3 % **D** 7 %

- 3 A student finds the density of a liquid by measuring its mass and its volume. The following is a summary of his measurements.

9702/12/M/J/10

$$\text{mass of empty beaker} = (20 \pm 1) \text{ g}$$

$$\text{mass of beaker + liquid} = (70 \pm 1) \text{ g}$$

$$\text{volume of liquid} = (10.0 \pm 0.6) \text{ cm}^3$$

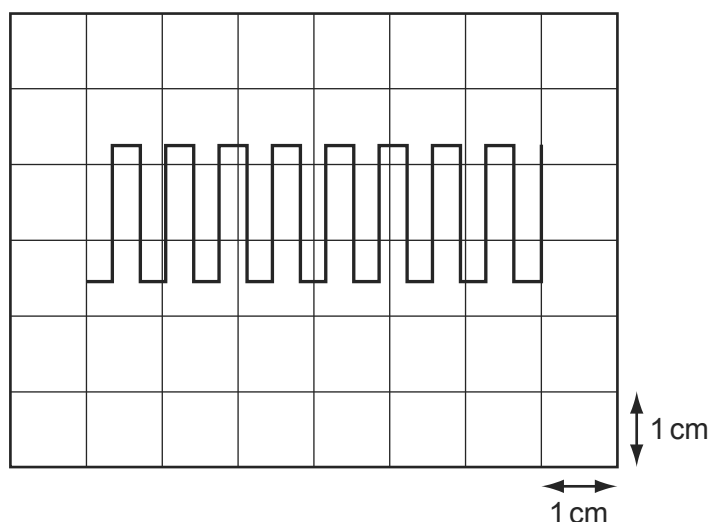
He correctly calculates the density of the liquid as 5.0 g cm^{-3} .

What is the uncertainty in this value?

- A** 0.3 g cm^{-3} **B** 0.5 g cm^{-3} **C** 0.6 g cm^{-3} **D** 2.6 g cm^{-3}

- 3 The diagram shows a square-wave trace on the screen of a cathode-ray oscilloscope. A grid of 1 cm squares covers the screen. The time-base setting is 10 ms cm^{-1} .

9702/13/M/J/10



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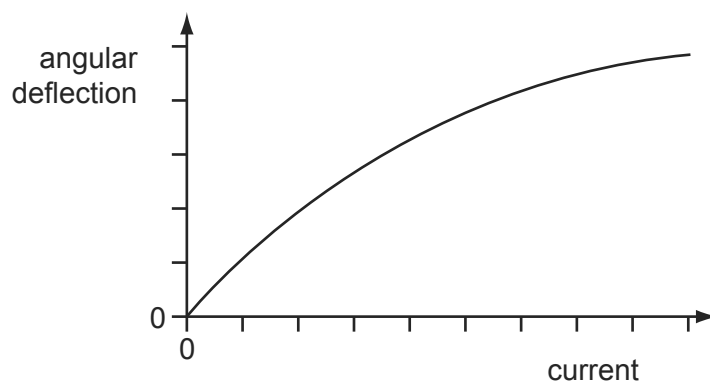
He correctly calculates the density of the liquid as 5.0 g cm^{-3} .

What is the uncertainty in this value?

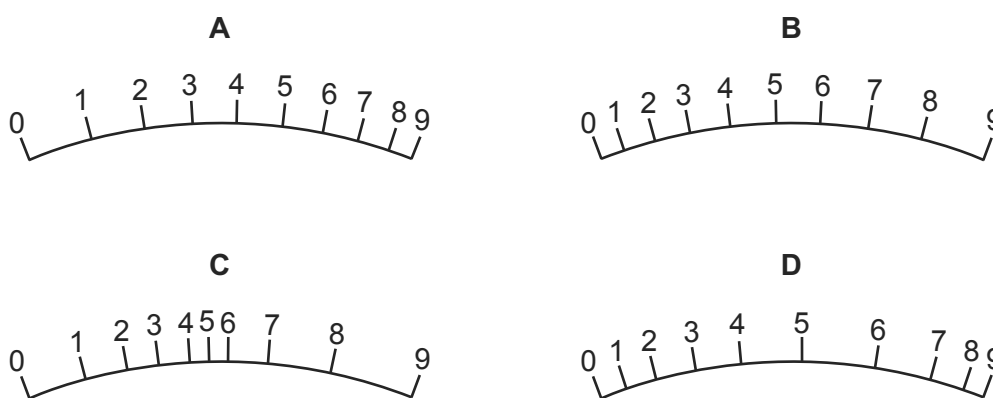
- A** 0.3 g cm^{-3} **B** 0.5 g cm^{-3} **C** 0.6 g cm^{-3} **D** 2.6 g cm^{-3}

- 4 The angular deflection of the needle of an ammeter varies with the current passing through the ammeter as shown in the graph.

9702/11/O/N/10

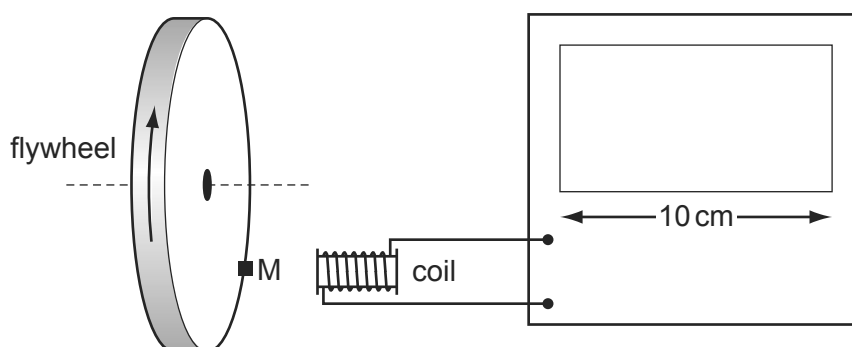


Which diagram could represent the appearance of the scale on this meter?



- 5 The diagram shows a cathode-ray oscilloscope (c.r.o.) being used to measure the rate of rotation of a flywheel.

9702/11/O/N/10



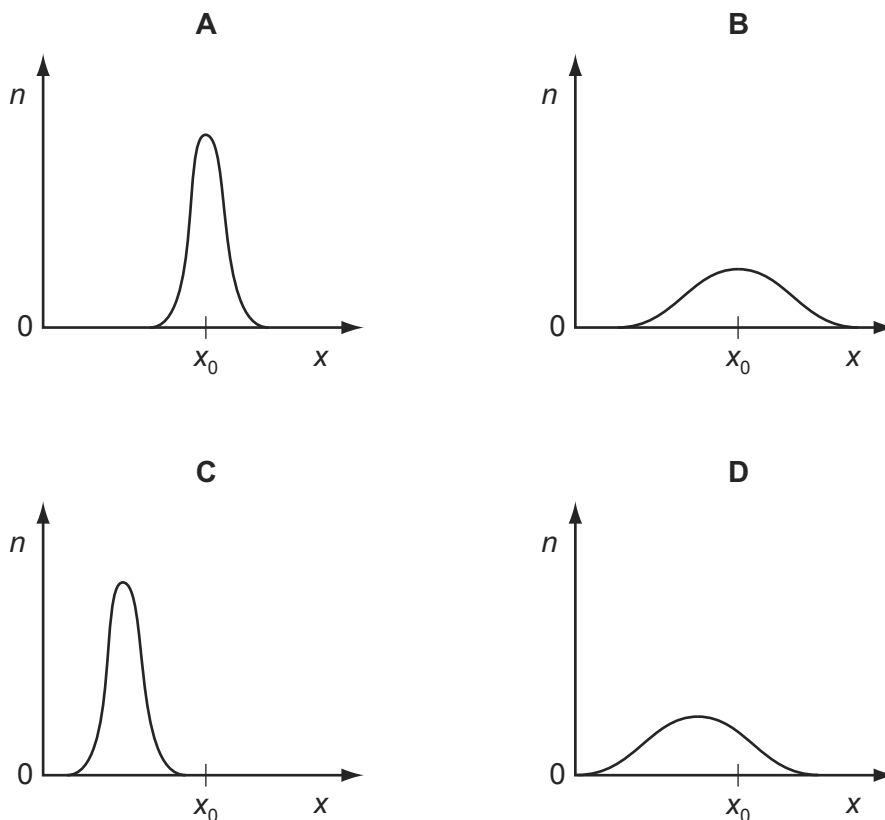
The flywheel has a small magnet M mounted on it. Each time the magnet passes the coil, a voltage pulse is generated, which is passed to the c.r.o. The display of the c.r.o. is 10 cm wide. The flywheel is rotating at a rate of about 3000 revolutions per minute.

Which time-base setting will display clearly separate pulses on the screen?

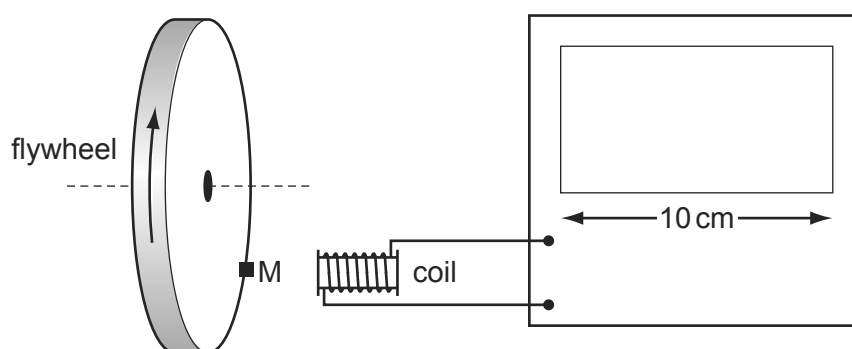
- A 1 s cm^{-1} B 10 ms cm^{-1} C $100 \mu\text{s cm}^{-1}$ D $1 \mu\text{s cm}^{-1}$

- 6 A fixed quantity x_0 is measured many times in an experiment that has experimental uncertainty. A graph is plotted to show the number n of times that a particular value x is obtained. 9702/11/O/N/10

Which graph could be obtained if the measurement of x_0 has a large systematic error but a small random error?



- 2 The diagram shows a cathode-ray oscilloscope (c.r.o.) being used to measure the rate of rotation of a flywheel. 9702/13/O/N/10



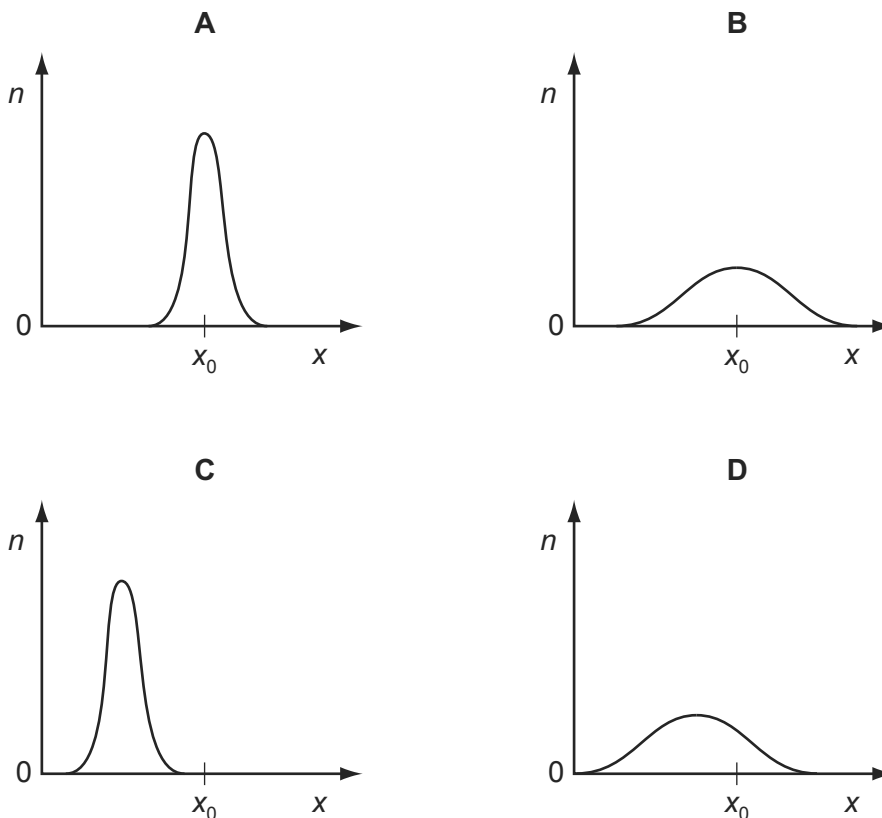
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Which time-base setting will display clearly separate pulses on the screen?

- A** 1 s cm^{-1} **B** 10 ms cm^{-1} **C** $100 \mu\text{s cm}^{-1}$ **D** $1 \mu\text{s cm}^{-1}$

- 3 A fixed quantity x_0 is measured many times in an experiment that has experimental uncertainty. A graph is plotted to show the number n of times that a particular value x is obtained. 9702/13/O/N/10

Which graph could be obtained if the measurement of x_0 has a large systematic error but a small random error?



- 4 The uncertainty in the value of the momentum of a trolley passing between two points X and Y varies with the choice of measuring devices. 9702/12/M/J/11

Measurements for the same trolley made by different instruments were recorded.

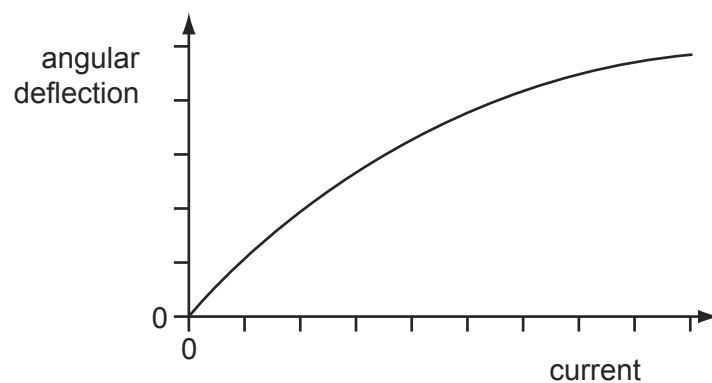
- 1 distance between X and Y using a metre rule with cm divisions = 0.55 m
- 2 distance between X and Y using a metre rule with mm divisions = 0.547 m
- 3 timings using a wristwatch measuring to the nearest 0.5 s at X = 0.0 s and at Y = 4.5 s
- 4 timings using light gates measuring to the nearest 0.1 s at X = 0.0 s and at Y = 4.3 s
- 5 mass of trolley using a balance measuring to the nearest g = 6.4×10^{-2} kg
- 6 mass of trolley using a balance measuring to the nearest 10 g = 6×10^{-2} kg

Which measurements, one for each quantity measured, lead to the least uncertainty in the value of the momentum of the trolley?

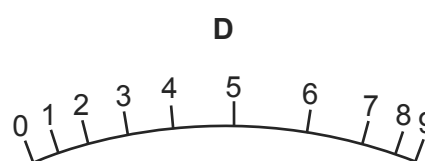
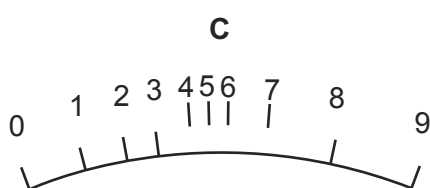
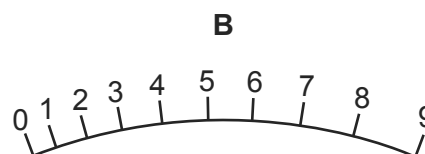
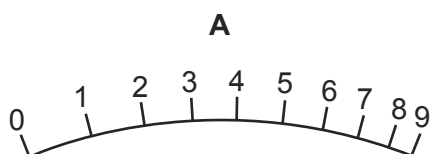
- A** 1, 3 and 6 **B** 1, 4 and 6 **C** 2, 3 and 6 **D** 2, 4 and 5

- 5 The angular deflection of the needle of an ammeter varies with the current passing through the ammeter as shown in the graph.

9702/13/O/N/10



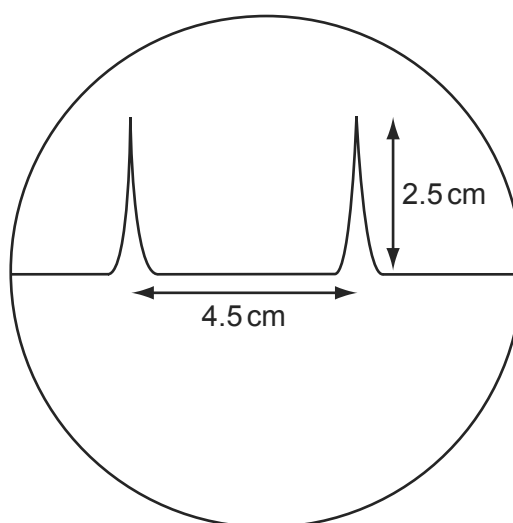
Which diagram could represent the appearance of the scale on this meter?



- 5 The time-base on a cathode-ray oscilloscope is set at 6 ms/cm .

9702/12/M/J/11

A trace consisting of two pulses is recorded as shown in the diagram.



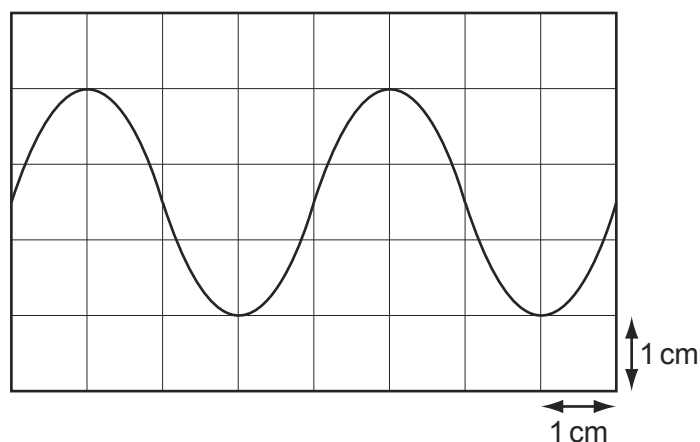
What is the time interval between the two pulses?

- A** 0.42 ms **B** 0.75 ms **C** 1.33 ms **D** 27 ms

- 4 The diagram shows a trace of a wave on a cathode-ray oscilloscope.

9702/11/M/J/11

The vertical and horizontal gridlines have a spacing of 1.0 cm. The voltage scaling is 4 V cm^{-1} and the time scaling is 5 ms cm^{-1} .



What are the amplitude and period of the wave?

	amplitude/V	period/ms
A	1.5	4
B	5.0	10
C	6.0	20
D	12.0	20

- 4 A cylindrical tube rolling down a slope of inclination θ moves a distance L in time T . The equation relating these quantities is

9702/11/O/N/11

$$L \left(3 + \frac{a^2}{P} \right) = QT^2 \sin \theta$$

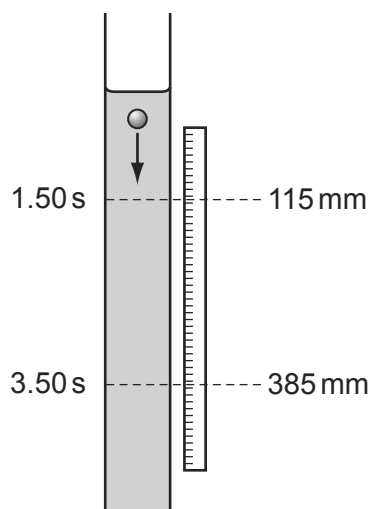
Where a is the internal radius of the tube and P and Q are constants.

Which line gives the correct units for P and Q ?

	P	Q
A	m^2	$\text{m}^2 \text{s}^{-2}$
B	m^2	m s^{-2}
C	m^2	$\text{m}^3 \text{s}^{-2}$
D	m^3	m s^{-2}

- 5 The diagram shows an experiment to measure the speed of a small ball falling at constant speed through a clear liquid in a glass tube.

9702/11/M/J/11



There are two marks on the tube. The top mark is positioned at 115 ± 1 mm on the adjacent rule and the lower mark at 385 ± 1 mm. The ball passes the top mark at 1.50 ± 0.02 s and passes the lower mark at 3.50 ± 0.02 s.

The constant speed of the ball is calculated by $\frac{385 - 115}{3.50 - 1.50} = \frac{270}{2.00} = 135 \text{ mm s}^{-1}$.

Which expression calculates the fractional uncertainty in the value of this speed?

- A $\frac{2}{270} + \frac{0.04}{2.00}$
- B $\frac{2}{270} - \frac{0.04}{2.00}$
- C $\frac{1}{270} \times \frac{0.02}{2.00}$
- D $\frac{1}{270} \div \frac{0.02}{2.00}$

- 5 The speedometer in a car consists of a pointer which rotates. The pointer is situated several millimetres from a calibrated scale.

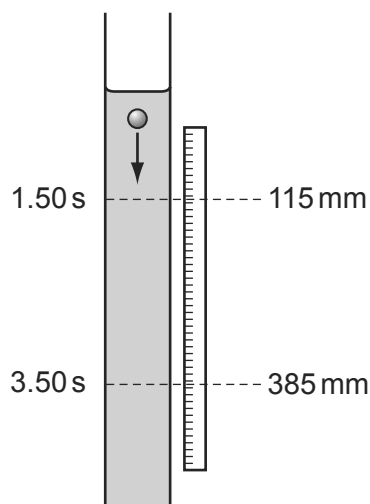
9702/12/O/N/11

What could cause a random error in the driver's measurement of the car's speed?

- A The car's speed is affected by the wind direction.
- B The driver's eye is not always in the same position in relation to the pointer.
- C The speedometer does not read zero when the car is at rest.
- D The speedometer reads 10 % higher than the car's actual speed.

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9702/13/M/J/11



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- B $\frac{2}{270} - \frac{0.04}{2.00}$
- C $\frac{1}{270} \times \frac{0.02}{2.00}$
- D $\frac{1}{270} \div \frac{0.02}{2.00}$

- 4 A micrometer is used to measure the diameters of two cylinders.

9702/12/O/N/11

diameter of first cylinder = 12.78 ± 0.02 mm

diameter of second cylinder = 16.24 ± 0.03 mm

The difference in the diameters is calculated.

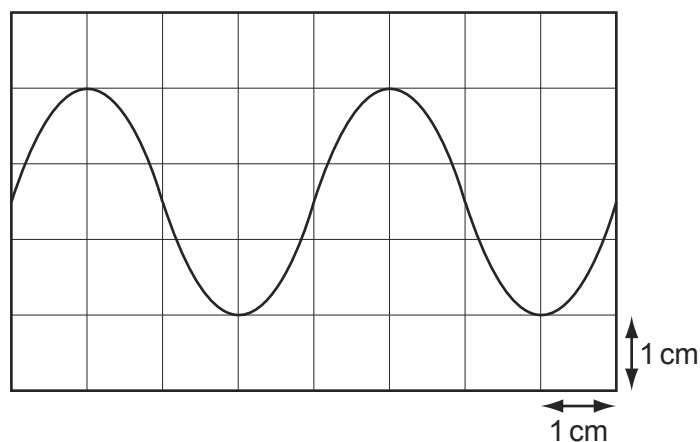
What is the uncertainty in this difference?

- A ± 0.01 mm B ± 0.02 mm C ± 0.03 mm D ± 0.05 mm

- 5 The diagram shows a trace of a wave on a cathode-ray oscilloscope.

9702/13/M/J/11

The vertical and horizontal gridlines have a spacing of 1.0 cm. The voltage scaling is 4 V cm^{-1} and the time scaling is 5 ms cm^{-1} .



What are the amplitude and period of the wave?

	amplitude / V	period / ms
A	1.5	4
B	5.0	10
C	6.0	20
D	12.0	20

- 5 The Young modulus of the material of a wire is to be found. The Young modulus E is given by the equation below.

9702/11/O/N/11

$$E = \frac{4Fl}{\pi d^2 x}$$

The wire is extended by a known force and the following measurements are made.

Which measurement has the largest effect on the uncertainty in the value of the calculated Young modulus?

	measurement	symbol	value
A	length of wire before force applied	l	$2.043 \pm 0.002 \text{ m}$
B	diameter of wire	d	$0.54 \pm 0.02 \text{ mm}$
C	force applied	F	$19.62 \pm 0.01 \text{ N}$
D	extension of wire with force applied	x	$5.2 \pm 0.2 \text{ mm}$

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$$L \left(3 + \frac{a^2}{P} \right) = QT^2 \sin \theta$$

Where a is the internal radius of the tube and P and Q are constants.

Which line gives the correct units for P and Q ?

	P	Q
A	m^2	$\text{m}^2 \text{s}^{-2}$
B	m^2	m s^{-2}
C	m^2	$\text{m}^3 \text{s}^{-2}$
D	m^3	m s^{-2}

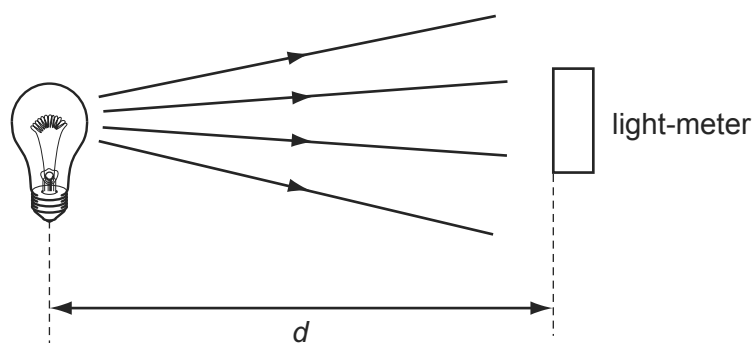
- 5 In an experiment, a radio-controlled car takes 2.50 ± 0.05 s to travel 40.0 ± 0.1 m. 9702/11/M/J/12

What is the car's average speed and the uncertainty in this value?

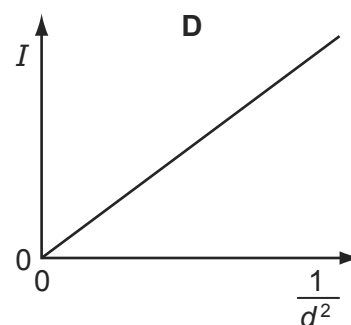
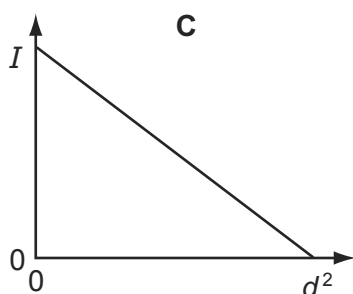
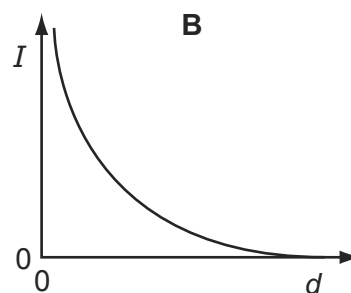
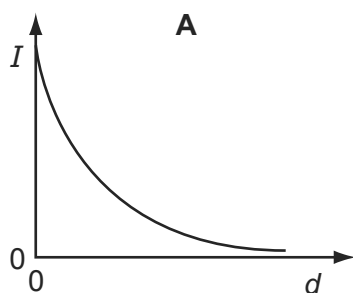
- A** $16 \pm 1 \text{ m s}^{-1}$
B $16.0 \pm 0.2 \text{ m s}^{-1}$
C $16.0 \pm 0.4 \text{ m s}^{-1}$
D $16.00 \pm 0.36 \text{ m s}^{-1}$

- 4 A light-meter measures the intensity I of the light falling on it. Theory suggests that I varies inversely as the square of the distance d .

9702/11/M/J/12

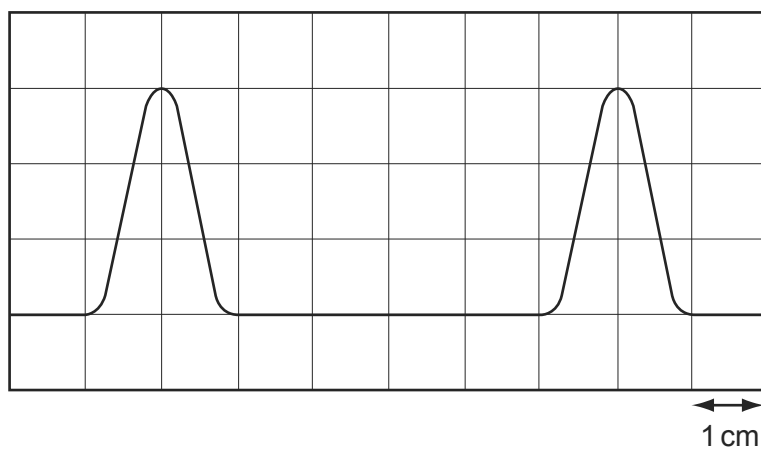


Which graph of the results supports this theory?



- 6 The diagram shows two complete pulses on the screen of a cathode-ray oscilloscope. A grid of 1 cm squares covers the screen. The time-base setting is $1 \mu\text{s cm}^{-1}$.

9702/12/M/J/12

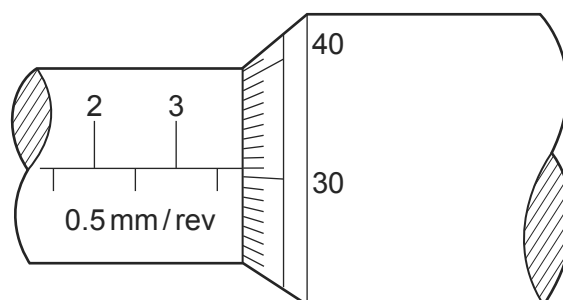


How long does each pulse last?

- A** $2 \mu\text{s}$ **B** $3 \mu\text{s}$ **C** $4 \mu\text{s}$ **D** $6 \mu\text{s}$

- 4 The diameter of a cylindrical metal rod is measured using a micrometer screw gauge. 9702/12/M/J/12

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 mm² B 11.4 mm² C 22.8 mm² D 45.6 mm²
- 5 A mass is dropped from rest, and falls through a distance of 2.0 m in a vacuum. An observer records the time taken for the mass to fall through this distance using a manually operated stopwatch and repeats the measurements a further two times. The average result of these measured times, displayed in the table below, was used to determine a value for the acceleration of free fall. This was calculated to be 9.8 ms⁻². 9702/12/M/J/12

	first measurement	second measurement	third measurement	average
time/s	0.6	0.73	0.59	0.64

Which statement best relates to the experiment?

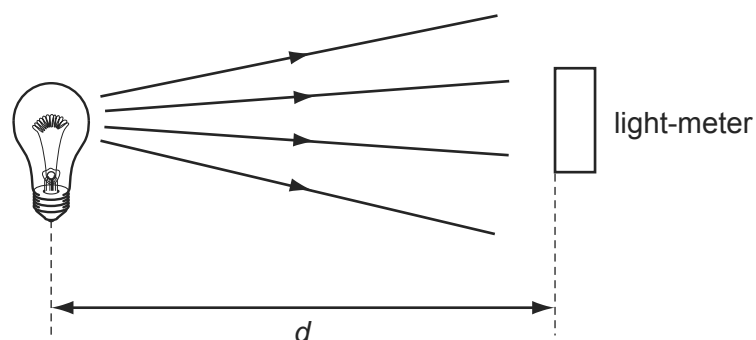
- A The measurements are precise and accurate with no evidence of random errors.
- B The measurements are not accurate and not always recorded to the degree of precision of the measuring device but the calculated experimental result is accurate.
- C The measurements are not always recorded to the degree of precision of the measuring device but are accurate. Systematic errors may be present.
- D The range of results shows that there were random errors made but the calculated value is correct so the experiment was successful.
- 4 In an experiment, a radio-controlled car takes 2.50 ± 0.05 s to travel 40.0 ± 0.1 m. 9702/13/M/J/12

What is the car's average speed and the uncertainty in this value?

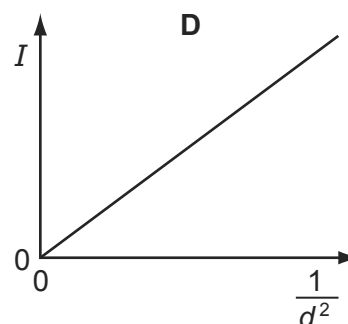
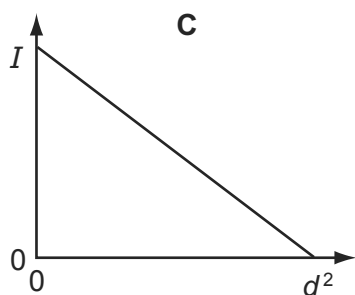
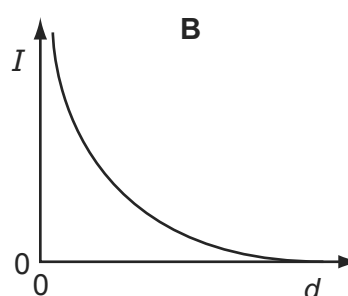
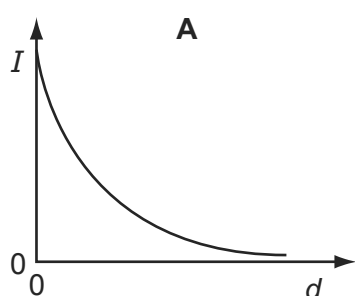
- A 16 ± 1 ms⁻¹
- B 16.0 ± 0.2 ms⁻¹
- C 16.0 ± 0.4 ms⁻¹
- D 16.00 ± 0.36 ms⁻¹

- 5 A light-meter measures the intensity I of the light falling on it. Theory suggests that I varies inversely as the square of the distance d .

9702/13/M/J/12



Which graph of the results supports this theory?



- 5 A student is given a reel of wire of diameter less than 0.2 mm and is asked to find the density of the metal.

9702/12/O/N/12

Which pair of instruments would be most suitable for finding the **volume** of the wire?

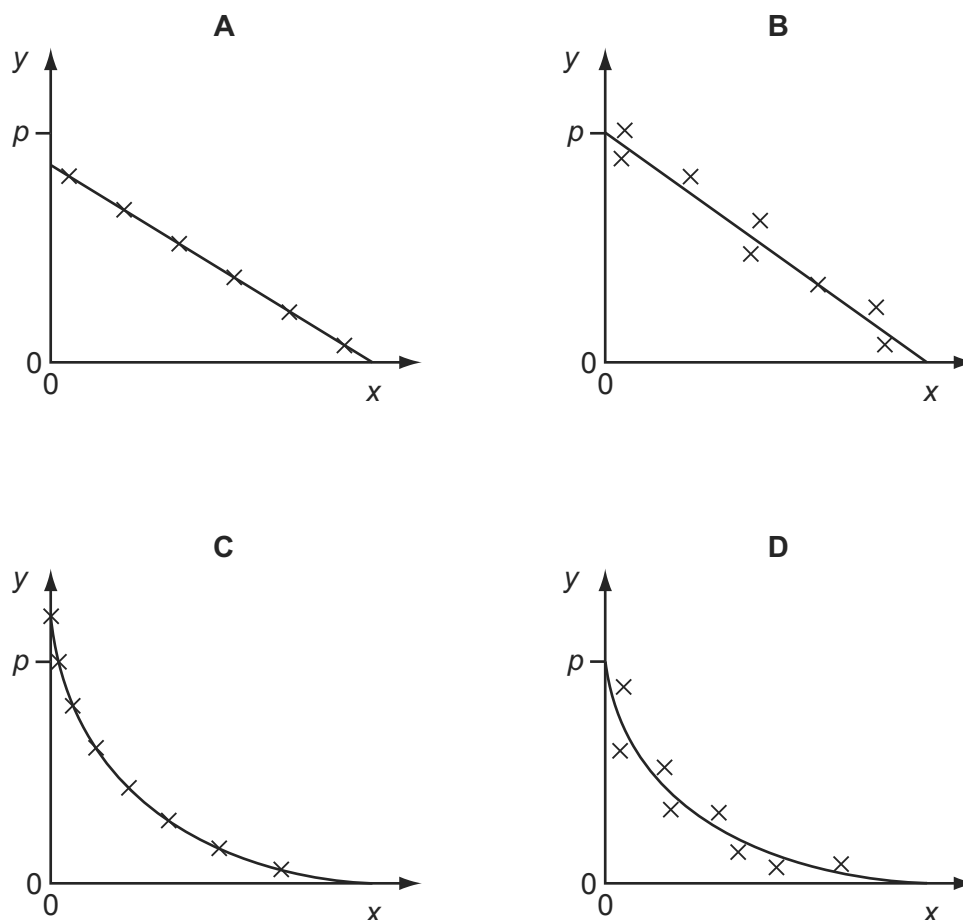
- A** balance and micrometer
- B** metre rule and micrometer
- C** metre rule and vernier calipers
- D** micrometer and vernier calipers

- 6 Variables x and y are related by the equation $y = p - qx$ where p and q are constants.

Values of x and y are measured experimentally. The results contain a systematic error.

9702/12/O/N/12

Which graph best represents these results?



- 7 The speed of a car is calculated from measurements of the distance travelled and the time taken.

9702/12/O/N/12

The distance is measured as 200 m, with an uncertainty of ± 2 m.

The time is measured as 10.0 s, with an uncertainty of ± 0.2 s.

What is the percentage uncertainty in the calculated speed?

- A** $\pm 0.5\%$ **B** $\pm 1\%$ **C** $\pm 2\%$ **D** $\pm 3\%$
- 8 A science museum designs an experiment to show the fall of a feather in a vertical glass vacuum tube.

9702/12/O/N/12

The time of fall from rest is to be close to 0.5 s.

What length of tube is required?

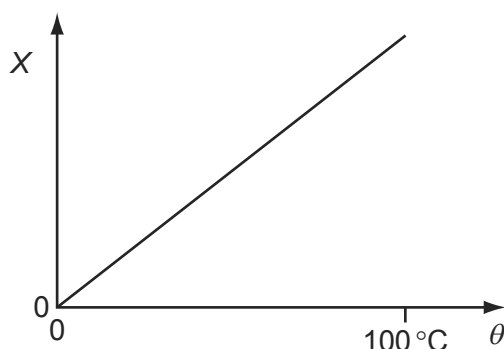
- A** 1.3 m **B** 2.5 m **C** 5.0 m **D** 10.0 m

- 5 The density of the material of a coil of thin wire is to be found.

Which set of instruments could be used to do this most accurately?

- A metre rule, protractor, spring balance
- B micrometer, metre rule, top-pan balance
- C stopwatch, newton-meter, vernier calipers
- D tape measure, vernier calipers, lever balance

- 6 A quantity X varies with temperature θ as shown.



θ is determined from the corresponding values of X by using this graph.
 X is measured with a percentage uncertainty of $\pm 1\%$ of its value at all temperatures.

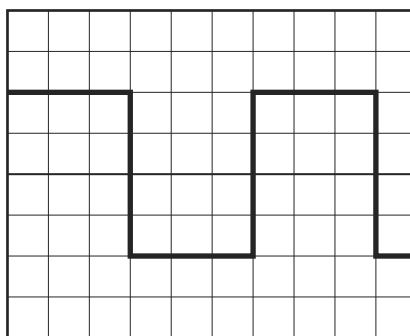
Which statement about the uncertainty in θ is correct?

- A The percentage uncertainty in θ is least near 0°C .
 - B The percentage uncertainty in θ is least near 100°C .
 - C The actual uncertainty in θ is least near 0°C .
 - D The actual uncertainty in θ is least near 100°C .
- 7 The measurement of a physical quantity may be subject to random errors and to systematic errors.

Which statement is correct?

- A Random errors can be reduced by taking the average of several measurements.
- B Random errors are always caused by the person taking the measurement.
- C A systematic error cannot be reduced by adjusting the apparatus.
- D A systematic error results in a different reading each time the measurement is taken.

- 5 A cathode-ray oscilloscope displays a square wave, as shown in the diagram.



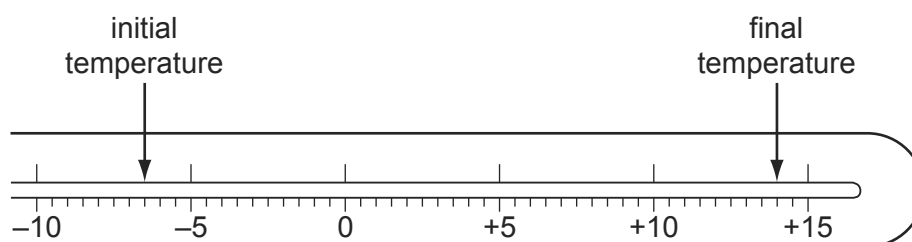
The time-base setting is 0.20 ms per division.

What is the frequency of the square wave?

- A** 8.3 Hz **B** 830 Hz **C** 1300 Hz **D** 1700 Hz

- 6 The diagram shows the stem of a Celsius thermometer, marked to show initial and final temperature values.

9702/13/M/J/13



What is the temperature change expressed to an appropriate number of significant figures?

- A** 14 °C **B** 20.5 °C **C** 21 °C **D** 22.0 °C

- 5 A student takes measurements of the current in a resistor of constant resistance and the potential difference (p.d.) across it. The readings are then used to plot a graph of current against p.d.

9702/13/M/J/13

There is a systematic error in the current readings.

How could this be identified from the graph?

- A** At least one anomalous data point can be identified.
B The data points are scattered about the straight line of best fit.
C The graph is a curve, not a straight line.
D The straight line graph does not pass through the origin.

- 5 In an experiment to determine the acceleration of free fall g , the period of oscillation T and length l of a simple pendulum were measured. The uncertainty in the measurement of l is estimated to be 4%, and the uncertainty in the measurement of T is estimated to be 1%.

9702/11/M/J/13

The value of g is determined using the formula

$$g = \frac{4\pi^2 l}{T^2}.$$

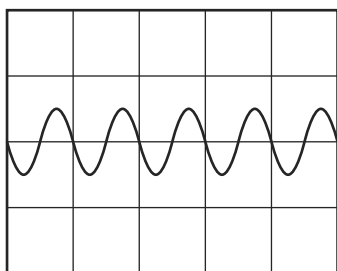
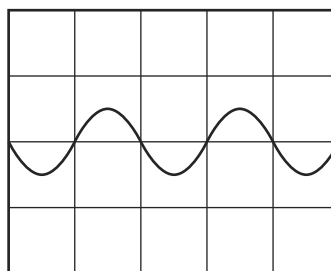
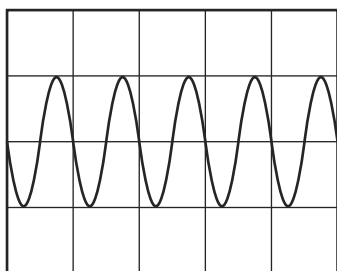
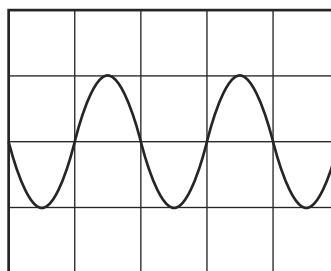
What is the uncertainty in the calculated value for g ?

- A** 2% **B** 3% **C** 5% **D** 6%

- 6 The Y-input terminals of a cathode-ray oscilloscope (c.r.o.) are connected to a supply of amplitude 5.0 V and frequency 50 Hz. The time-base is set at 10 ms per division and the Y-gain at 5.0 V per division.

9702/11/M/J/13

Which trace is obtained?

A**B****C****D**

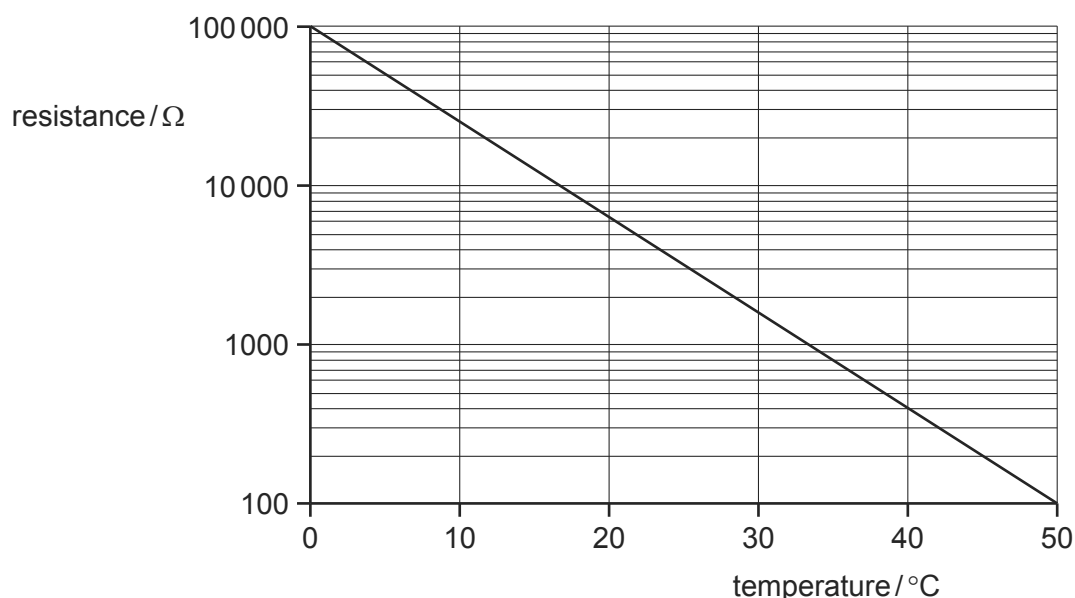
- 4 A student carried out an experiment in which an electric current was known to decrease with time. The readings he found, from first to last, were 3.62 mA, 2.81 mA, 1.13 mA, 1.76 mA and 0.90 mA.

9702/12/M/J/13

Which statement could **not** explain the anomalous 1.13 mA reading?

- A He has reversed the third and fourth readings in the results table.
 B He read the ammeter incorrectly; the reading should have been 2.13 mA.
 C He took the current reading at the wrong time.
 D There was a systematic error in the readings from the ammeter.
- 5 The diagram shows a calibration curve for a thermistor, drawn with an unusual scale on the vertical axis.

9702/12/M/J/13



What is the thermistor resistance corresponding to a temperature of 40 °C?

- A 130 Ω B 150 Ω C 400 Ω D 940 Ω
- 6 What will reduce the systematic errors when taking a measurement?
- A adjusting the needle on a voltmeter so that it reads zero when there is no potential difference across it
 B measuring the diameter of a wire at different points and taking the average
 C reducing the parallax effects by using a marker and a mirror when measuring the amplitude of oscillation of a pendulum
 D timing 20 oscillations, rather than a single oscillation, when finding the period of a pendulum

9702/13/O/N/12

- 7 In an experiment to determine the acceleration of free fall g , the time t taken for a ball to fall through distance s was measured. The uncertainty in the measurement of s is estimated to be 2%. The uncertainty in the measurement of t is estimated to be 3%.

9702/13/O/N/12

The value of g is determined using the equation

$$g = \frac{2s}{t^2}.$$

What is the uncertainty in the calculated value of g ?

- A** 1% **B** 5% **C** 8% **D** 11%

- 4 A signal that repeats periodically is displayed on the screen of a cathode-ray oscilloscope.

9702/11/O/N/13



The screen has 1 cm squares and the time base is set at 2.00 ms cm^{-1} .

What is the frequency of this periodic signal?

- A** 50 Hz **B** 100 Hz **C** 125 Hz **D** 200 Hz

- 5 A micrometer screw gauge is used to measure the diameter of a small uniform steel sphere. The micrometer reading is $5.00 \text{ mm} \pm 0.01 \text{ mm}$.

9702/11/O/N/13

What will be the percentage uncertainty in a calculation of the volume of the sphere, using these values?

- A** 0.2% **B** 0.4% **C** 0.6% **D** 1.2%

- 6 A student wishes to determine the density ρ of lead. She measures the mass and diameter of a small sphere of lead:

9702/13/O/N/13

$$\text{mass} = (0.506 \pm 0.005) \text{ g}$$

$$\text{diameter} = (2.20 \pm 0.02) \text{ mm}.$$

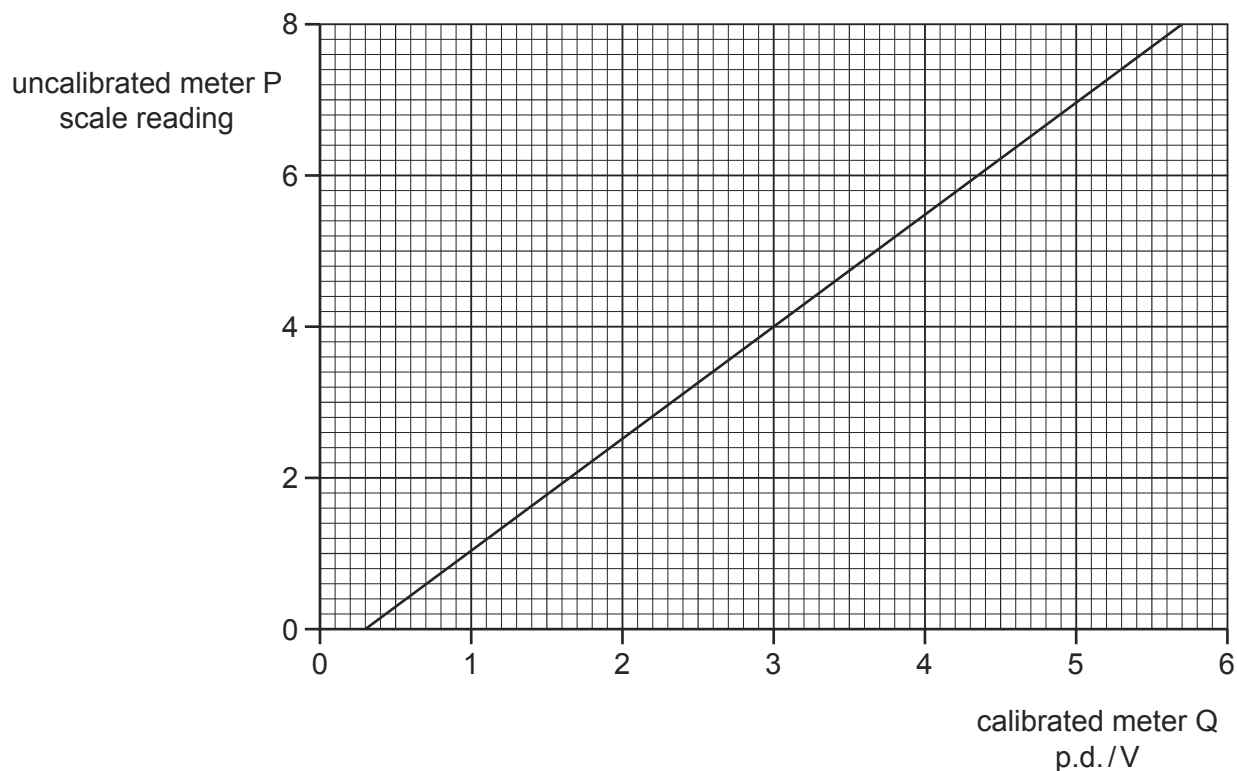
What is the best estimate of the percentage uncertainty in her value of ρ ?

- A** 1.9% **B** 2.0% **C** 2.8% **D** 3.7%

- 5 An uncalibrated analogue voltmeter P is connected in parallel with another voltmeter Q which is known to be accurately calibrated. For a range of values of potential difference (p.d.), readings are taken from the two meters.

9702/13/O/N/13

The diagram shows the calibration graph obtained.



The graph shows that meter P has a zero error. This meter is now adjusted to remove this zero error. When the meter is recalibrated, the gradient of the calibration graph is found to be unchanged.

What is the new scale reading on meter P when it is used to measure a p.d. of 5.0 V?

- A** 6.6 **B** 6.7 **C** 7.2 **D** 7.4

- 4 An experiment is carried out to measure the resistance of a wire.

9702/11/M/J/14

The current in the wire is $(1.0 \pm 0.2)\text{A}$ and the potential difference across the wire is $(8.0 \pm 0.4)\text{V}$.

What is the resistance of the wire and its uncertainty?

- A** $(8.0 \pm 0.2)\Omega$
B $(8.0 \pm 0.6)\Omega$
C $(8 \pm 1)\Omega$
D $(8 \pm 2)\Omega$

- 5 The Young modulus of the material of a wire is to be found. The Young modulus E is given by the equation below.

9702/11/M/J/14

$$E = \frac{4Fl}{\pi d^2 x}$$

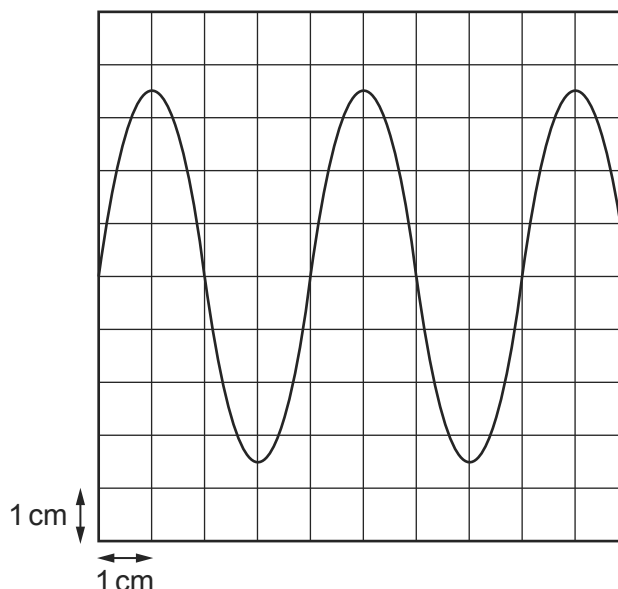
The wire is extended by a known force and the following measurements are made.

Which measurement has the largest effect on the uncertainty in the value of the calculated Young modulus?

	measurement	symbol	value
A	length of wire before force applied	l	2.043 ± 0.002 m
B	diameter of wire	d	0.54 ± 0.02 mm
C	force applied	F	19.62 ± 0.01 N
D	extension of wire with force applied	x	5.2 ± 0.2 mm

- 3 A cathode-ray oscilloscope (c.r.o.) is connected to an alternating voltage. The following trace is produced on the screen.

9702/12/M/J/14



The oscilloscope time-base setting is 0.5 ms cm^{-1} and the Y-plate sensitivity is 2 V cm^{-1} .

Which statement about the alternating voltage is correct?

- A** The amplitude is 3.5 cm.
- B** The frequency is 0.5 kHz.
- C** The period is 1 ms.
- D** The wavelength is 4 cm.

- 4 A quantity y is to be determined from the equation shown.

9702/12/M/J/14

$$y = \frac{px}{q^2}$$

The percentage uncertainties in p , x and q are shown.

	percentage uncertainty
p	6%
x	2%
q	4%

What is the percentage uncertainty in y ?

- A** 0.5% **B** 1% **C** 16% **D** 192%
- 5 A thermometer can be read to an accuracy of $\pm 0.5^\circ\text{C}$. This thermometer is used to measure a temperature rise from 40°C to 100°C .

9702/12/M/J/14

What is the percentage uncertainty in the measurement of the temperature rise?

- A** 0.5% **B** 0.8% **C** 1.3% **D** 1.7%
- 4 The resistance of a lamp is calculated from the value of the potential difference (p.d.) across it and the value of the current passing through it.

9702/13/M/J/14

Which statement correctly describes how to combine the uncertainties in the p.d. and in the current?

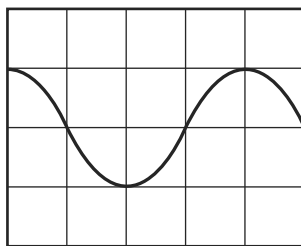
- A** Add together the actual uncertainty in the p.d. and the actual uncertainty in the current.
- B** Add together the percentage uncertainty in the p.d. and the percentage uncertainty in the current.
- C** Subtract the actual uncertainty in the current from the actual uncertainty in the p.d.
- D** Subtract the percentage uncertainty in the current from the percentage uncertainty in the p.d.
- 6 A digital caliper is used to measure the 28.50 mm width of a plastic ruler. The digital caliper reads to the nearest 0.01 mm.

9702/13/M/J/14

What is the correct way to record this reading?

- A** $0.02850 \pm 0.01 \text{ m}$
- B** $0.0285 \pm 0.001 \text{ m}$
- C** $(2.850 \pm 0.001) \times 10^{-2} \text{ m}$
- D** $(2.850 \pm 0.001) \times 10^{-3} \text{ m}$

- 5 The display on a cathode-ray oscilloscope shows the signal produced by an electronic circuit. The time-base is set at 5.0 ns per division and the Y-gain at 10 V per division. 9702/13/M/J/14



What is the frequency of the signal?

- A $2.0 \times 10^{-8} \text{ Hz}$
 B $2.5 \times 10^{-2} \text{ Hz}$
 C $5.0 \times 10^7 \text{ Hz}$
 D $3.1 \times 10^8 \text{ Hz}$
- 1 A 0.10 kg mass is taken to Mars and then weighed on a spring balance and on a lever balance. The acceleration due to gravity on Mars is 38% of its value on Earth. 9702/11/O/N/14

What are the readings on the two balances on Mars? (Assume that on Earth $g = 10 \text{ m s}^{-2}$.)

	spring balance / N	lever balance / kg
A	0.38	0.038
B	0.38	0.10
C	1.0	0.038
D	1.0	0.10

- 4 A steel wire is stretched in an experiment to determine the Young modulus for steel. 9702/11/O/N/14

The uncertainties in the measurements are given below.

measurement	uncertainty
load on wire	$\pm 2\%$
length of wire	$\pm 0.2\%$
diameter of wire	$\pm 1.5\%$
extension	$\pm 1\%$

What is the percentage uncertainty in the Young modulus?

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

- 5 The acceleration of free fall on the Moon is one-sixth of that on Earth.

9702/11/O/N/14

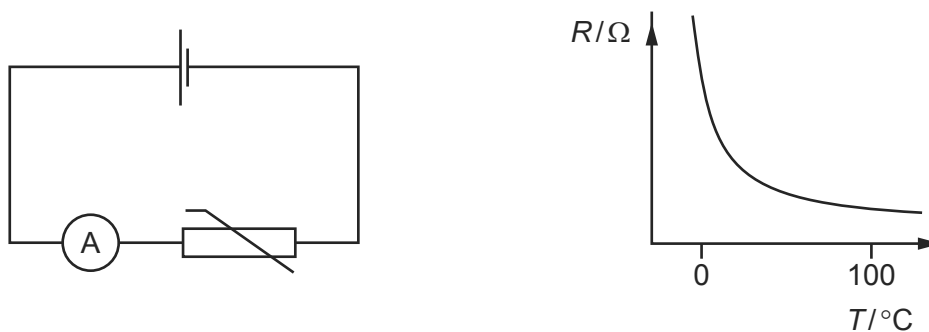
On Earth it takes time t for a stone to fall from rest a distance of 2 m.

What is the time taken for a stone to fall from rest a distance of 2 m on the Moon?

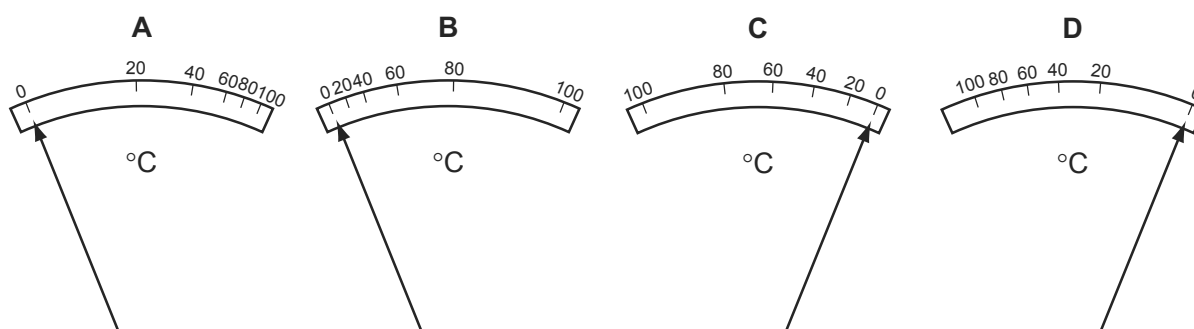
- A $6t$ B $\frac{t}{6}$ C $t\sqrt{6}$ D $\frac{t}{\sqrt{6}}$

- 3 In the circuit shown, an analogue ammeter is to be recalibrated as a thermometer. The graph shows how the resistance R of the thermistor changes with temperature T .

9702/13/O/N/14

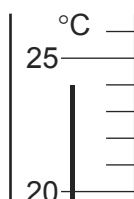


Which diagram could represent the temperature scale on the ammeter?



- 4 The diagram shows part of a thermometer.

9702/13/O/N/14



What is the correct reading on the thermometer and the uncertainty in this reading?

	reading / °C	uncertainty in reading / °C
A	24	± 1
B	24	± 0.5
C	24	± 0.2
D	24.0	± 0.5

- 5 The resistance R of a resistor is to be determined. The current I in the resistor and the potential difference V across it are measured.

9702/13/O/N/14

The results, with their uncertainties, are

$$I = (2.0 \pm 0.2) \text{ A} \qquad V = (15.0 \pm 0.5) \text{ V}.$$

The value of R is calculated to be 7.5Ω .

What is the uncertainty in this value for R ?

- A $\pm 0.3 \Omega$ B $\pm 0.5 \Omega$ C $\pm 0.7 \Omega$ D $\pm 1 \Omega$

- 3 The speed of an aeroplane in still air is 200 km h^{-1} . The wind blows from the west at a speed of 85.0 km h^{-1} .

9702/13/M/J/15

In which direction must the pilot steer the aeroplane in order to fly due north?

- A 23.0° east of north
B 23.0° west of north
C 25.2° east of north
D 25.2° west of north

- 4 A student is given a reel of wire of diameter less than 0.2 mm and is asked to find the density of the metal.

9702/13/M/J/15

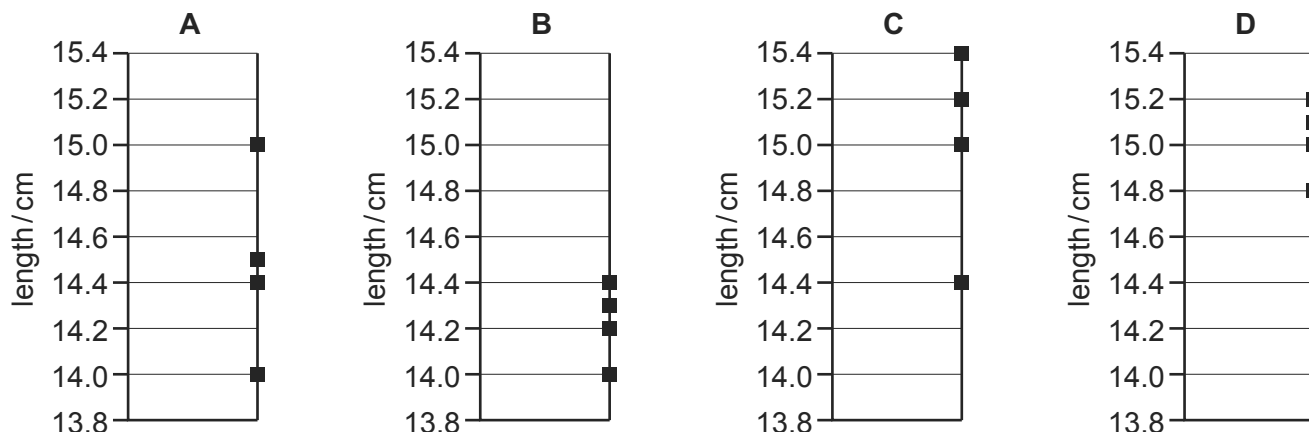
Which pair of instruments would be most suitable for finding the **volume** of the wire?

- A balance and micrometer
B metre rule and micrometer
C metre rule and vernier calipers
D micrometer and vernier calipers

- 5 Four different students use a ruler to measure the length of a 15.0 cm pencil. Their measurements are recorded on four different charts.

9702/13/M/J/15

Which chart shows measurements that are precise but **not** accurate?



- 6 In a simple electrical circuit, the current in a resistor is measured as (2.50 ± 0.05) mA. The resistor is marked as having a value of $4.7 \Omega \pm 2\%$.

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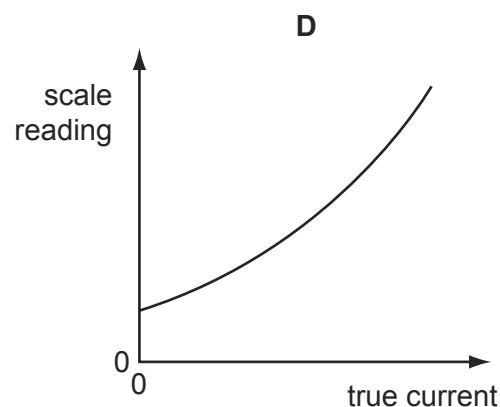
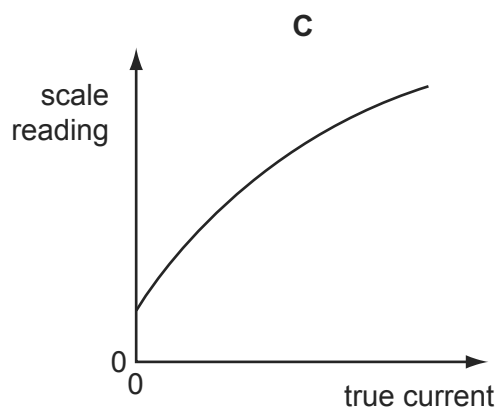
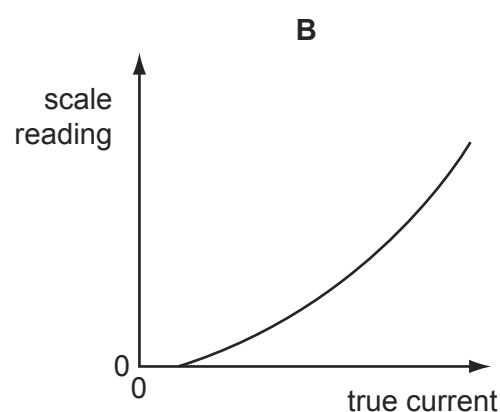
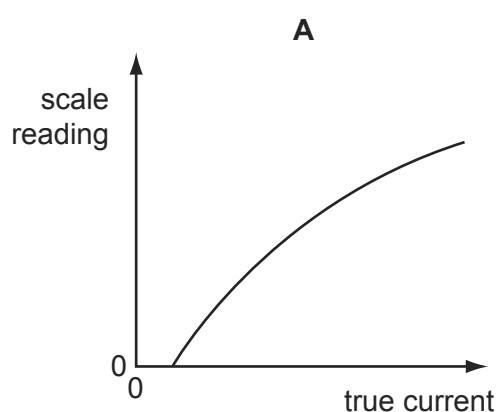
If these values were used to calculate the power dissipated in the resistor, what would be the percentage uncertainty in the value obtained?

- A 2% B 4% C 6% D 8%

- 3 An analogue ammeter has a pointer which moves over a scale. Following prolonged use, the pointer does not return fully to zero when the current is turned off and the meter has become less sensitive at higher currents than it is at lower currents.

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Which diagram best represents the calibration graph needed to obtain an accurate current reading?



- 6 A single sheet of aluminium foil is folded twice to produce a stack of four sheets. The total thickness of the stack of sheets is measured to be (0.80 ± 0.02) mm. This measurement is made using a digital caliper with a zero error of (-0.20 ± 0.02) mm.

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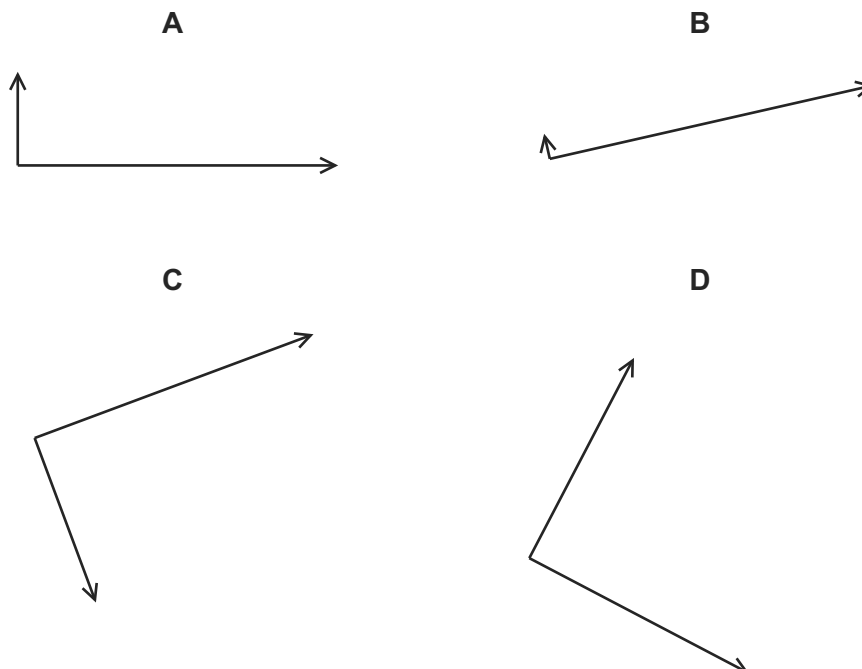
What is the percentage uncertainty in the calculated thickness of a single sheet?

- A 1.0% B 2.0% C 4.0% D 6.7%

- 4 The arrow represents the vector R .

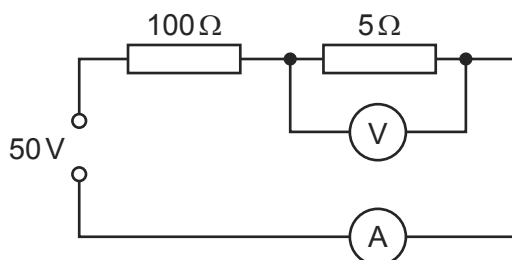


Which diagram does **not** represent R as two perpendicular components?



- 5 A power supply of electromotive force (e.m.f.) 50 V and negligible internal resistance is connected in series with resistors of resistance $100\ \Omega$ and $5\ \Omega$, as shown.

9702/12/M/J/15



A voltmeter measures the potential difference (p.d.) across the $5\ \Omega$ resistor and an ammeter measures the current in the circuit.

What are suitable ranges for the ammeter and for the voltmeter?

	ammeter range / A	voltmeter range / V
A	0–0.1	0–1
B	0–0.1	0–3
C	0–1.0	0–1
D	0–1.0	0–3

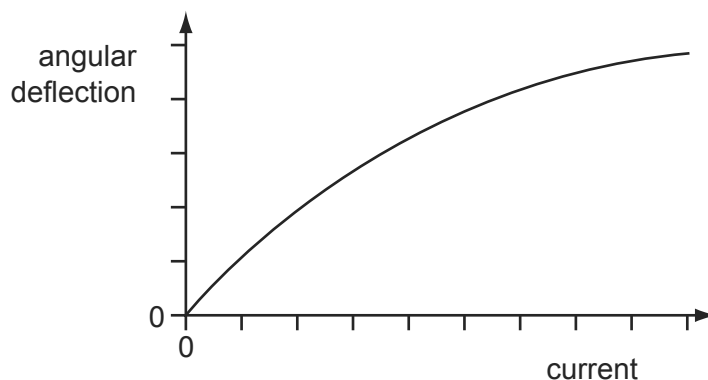
- 7 In an experiment to determine the acceleration of free fall g , a ball bearing is held by an electromagnet. When the current to the electromagnet is switched off, a clock starts and the ball bearing falls. After falling a distance h , the ball bearing strikes a switch to stop the clock which measures the time t of the fall.

9702/12/M/J/15

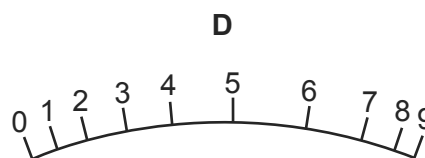
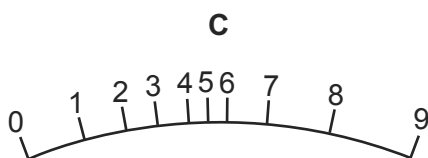
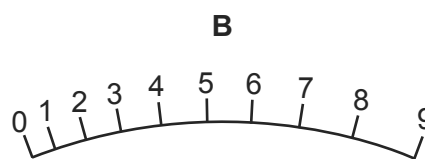
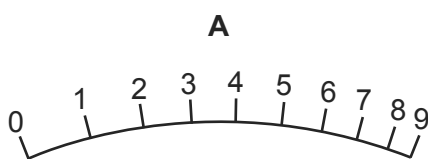
If systematic errors cause t and h to be measured incorrectly, which error **must** cause g to appear greater than 9.81 m s^{-2} ?

- A h measured as being **smaller** than it actually is and t is measured correctly
- B h measured as being **smaller** than it actually is and t measured as being **larger** than it actually is
- C h measured as being **larger** than it actually is and t measured as being **larger** than it actually is
- D h is measured correctly and t measured as being **smaller** than it actually is
- 5 The angular deflection of the needle of an ammeter varies with the current in the ammeter as shown in the graph.

9702/11/M/J/15



Which diagram could represent the appearance of the scale on this meter?



- 6 The strain energy W of a spring is determined from its spring constant k and extension x . The spring obeys Hooke's law and the value of W is calculated using the equation shown. 9702/11/M/J/15

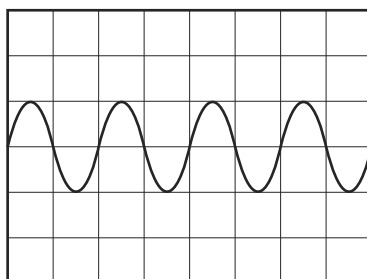
$$W = \frac{1}{2} kx^2$$

The spring constant is $100 \pm 2 \text{ N m}^{-1}$ and the extension is $0.050 \pm 0.002 \text{ m}$.

What is the percentage uncertainty in the calculated value of W ?

- A** 6% **B** 10% **C** 16% **D** 32%

- 4 A whale produces sound waves of frequency 5 Hz. The waves are detected by a microphone and displayed on an oscilloscope. 9702/11/M/J/15



What is the time-base setting on the oscilloscope?

- A** 0.1 ms div^{-1} **B** 1 ms div^{-1} **C** 10 ms div^{-1} **D** 100 ms div^{-1}

Measurement and its techniques

Q.No	Answers
1	B
2	D
3	C
4	A
5	C
6	C
7	C
8	B
9	B
10	D
11	C
12	C
13	D
14	B
15	C
16	C
17	D
18	A
19	A
20	B
21	B
22	C
23	C
24	C
25	C
26	D
27	A
28	C
29	D
30	C
31	D

32	A
33	D
34	C
35	C
36	A
37	D
38	D
39	D
40	B
41	B
42	B
43	A
44	B
45	A
46	B
47	B
48	B
49	B
50	B
51	B
52	D
53	B
54	B
55	B
56	A
57	B
58	C
59	B
60	C
61	D
62	A
63	D

64	C
65	B
66	A
67	B
68	A
69	D
70	C
71	B
72	B
73	B
74	C
75	D
76	A
77	B
78	B
79	C
80	D
81	B
82	A
83	D
84	A
85	B
86	C
87	A
88	B
89	B
90	D
91	D
92	D
93	D
94	C
95	A

96	C
97	B
98	C
99	D
100	D
101	D
102	B
103	B
104	C
105	D
106	B
107	C
108	C
109	B
110	D
111	C
112	A
113	D
114	D
115	D
116	B
117	B
118	C
119	C
120	C
121	C
122	D
123	D
124	A
125	B
126	D

Q1.

- 1 Complete Fig. 1.1 to show each quantity and its unit.

[4]

<i>quantity</i>	<i>unit</i>
speed	m s^{-1}
density	
.....	s^{-1}
electric field strength	
.....	kg m s^{-1}

Fig. 1.1

Q2.

- 1 (a) State the difference between a scalar quantity and a vector quantity.

scalar:

.....

vector:

..... [2]

- (b) Two forces of magnitude 6.0 N and 8.0 N act at a point P. Both forces act away from point P and the angle between them is 40° .
Fig. 1.1 shows two lines at an angle of 40° to one another.

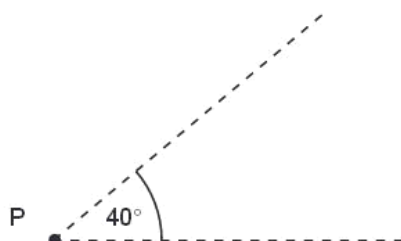


Fig. 1.1

On Fig. 1.1, draw a vector diagram to determine the magnitude of the resultant of the two forces.

magnitude of resultant = ... N [4]

Q3.

- 3 A student has been asked to determine the linear acceleration of a toy car as it moves down a slope. He sets up the apparatus as shown in Fig. 3.1.

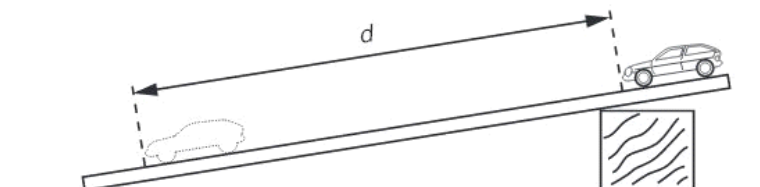
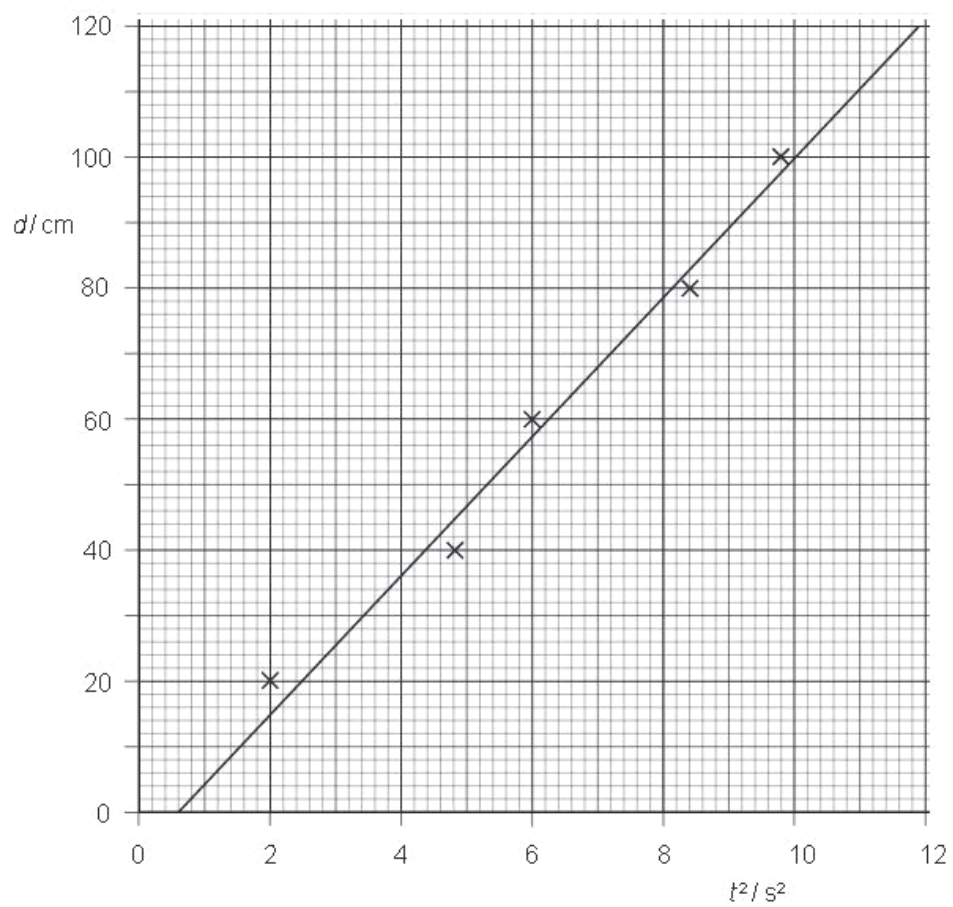


Fig. 3.1

The time t to move from rest through a distance d is found for different values of d . A graph of d (y-axis) is plotted against t^2 (x-axis) as shown in Fig. 3.2.



- (a) Theory suggests that the graph is a straight line through the origin.
Name the feature on Fig. 3.2 that indicates the presence of

(i) random error,

.....

(ii) systematic error.

.....

[2]

- (b) (i) Determine the gradient of the line of the graph in Fig. 3.2.

gradient = ... [2]

- (ii) Use your answer to (i) to calculate the acceleration of the toy down the slope.
Explain your working.

acceleration = ... m s^{-2} [3]

Q4.

1 Make estimates of the following quantities.

(a) the speed of sound in air

speed = ... [1]

(b) the density of air at room temperature and pressure

density = ... [1]

(c) the mass of a protractor

mass = ... [1]

(d) the volume, in cm^3 , of the head of an adult person

volume = ... cm^3 [1]

Q5.

1 (a) Derive the SI base unit of force.

SI base unit of force = ... [1]

- (b) A spherical ball of radius r experiences a resistive force F due to the air as it moves through the air at speed v . The resistive force F is given by the expression

$$F = crv,$$

where c is a constant.

Derive the SI base unit of the constant c .

SI base unit of c = ... [1]

✓

Exam
6

- (c) The ball is dropped from rest through a height of 4.5 m.
- (i) Assuming air resistance to be negligible, calculate the final speed of the ball.

speed = ... m s^{-1} [2]

- (ii) The ball has mass 15 g and radius 1.2 cm.

The numerical value of the constant c in the equation in (b) is equal to 3.2×10^{-4} when measured using the SI system of units.

Show quantitatively whether the assumption made in (i) is justified.

[3]

Q6.

- 1 The uncalibrated scale and the pointer of a meter are shown in Fig. 1.1.

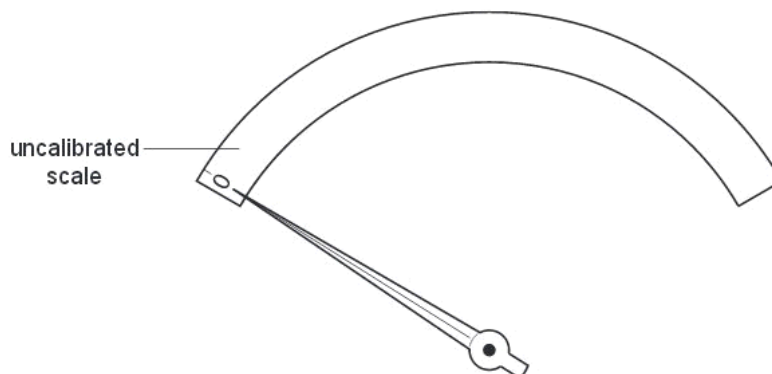


Fig. 1.1

The pointer is shown in the zero position.

The meter is to be used to indicate the volume of fuel in the tank of a car.

A known volume V of fuel is poured into the tank and the deflection θ of the pointer is noted.

Fig. 1.2 shows the variation with θ of V .

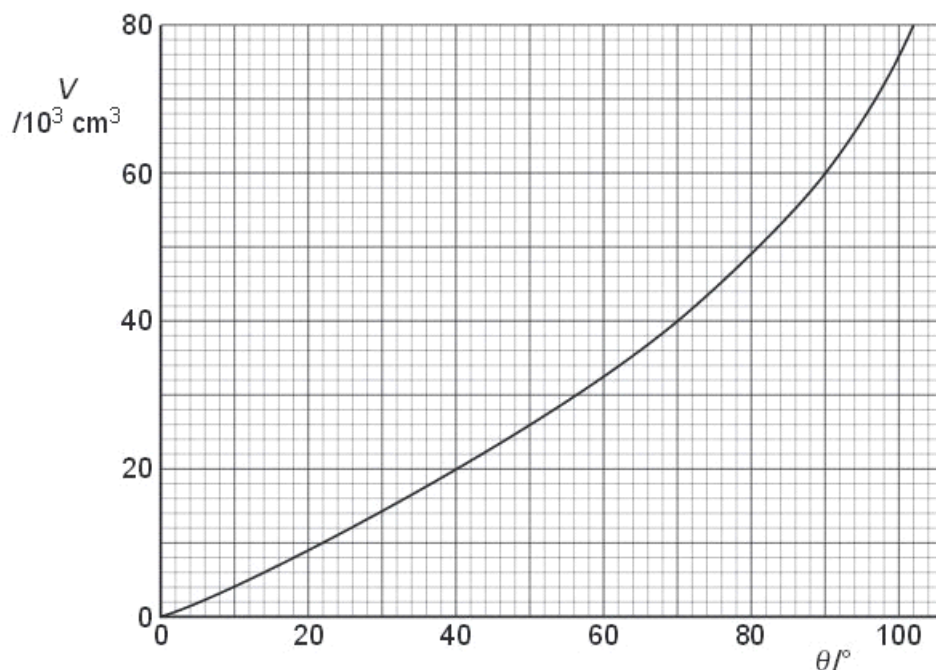


Fig. 1.2

(a) On Fig. 1.1,

(i) calibrate the scale at $20 \times 10^3 \text{ cm}^3$ intervals,

[2]

(ii) mark a possible position for a volume of $1.0 \times 10^5 \text{ cm}^3$.

[1]

(b) Suggest one advantage of this scale, as compared with a uniform scale, for measuring fuel volumes in the tank of the car.

.....
[1]

Use

Q7.

1 Make reasonable estimates of the following quantities.

(a) the frequency of an audible sound wave

frequency = ... Hz [1]

(b) the wavelength, in nm, of ultraviolet radiation

wavelength = ... nm [1]

(c) the mass of a plastic 30 cm ruler

mass = ... g [1]

(d) the density of air at atmospheric pressure

density = ... kg m^{-3} [1]

Q8.

1 (a) State the most appropriate instrument, or instruments, for the measurement of the following.

(i) the diameter of a wire of diameter about 1 mm

..... [1]

(ii) the resistance of a filament lamp

..... [1]

(iii) the peak value of an alternating voltage

..... [1]

(b) The mass of a cube of aluminium is found to be 580 g with an uncertainty in the measurement of 10 g. Each side of the cube has a length of (6.0 ± 0.1) cm.

Calculate the density of aluminium with its uncertainty. Express your answer to an appropriate number of significant figures.

density = ... $\pm$ g cm^{-3} [5]

Q9.

- 1 (a) Two of the SI base quantities and their units are mass (kg) and length (m).

Name three other SI base quantities and their units.

1. quantity unit
2. quantity unit
3. quantity unit

[3]

- (b) The pressure p due to a liquid of density ρ is related to the depth h by the expression

$$p = \rho gh,$$

where g is the acceleration of free fall.

Use this expression to determine the derived units of pressure. Explain your working.

[5]

Q10.

- 1 A unit is often expressed with a prefix. For example, the gram may be written with the prefix 'kilo' as the kilogram. The prefix represents a power-of-ten. In this case, the power-of-ten is 10^3 .

Complete Fig. 1.1 to show each prefix with its symbol and power-of-ten.

prefix	symbol	power-of-ten
kilo	k	10^3
nano	n	
centi		10^{-2}
.....	M	10^6
.....	T	10^{12}

Fig. 1.1

[4]

Q11.

- 2 (a) Complete Fig. 2.1 to show whether each of the quantities listed is a vector or a scalar.

	vector / scalar
distance moved	
speed	
acceleration	

Fig. 2.1

[3]

Q12.

1 A metal wire has a cross-section of diameter approximately 0.8 mm.

(a) State what instrument should be used to measure the diameter of the wire.

.....[1]

(b) State how the instrument in **(a)** is

(i) checked so as to avoid a systematic error in the measurements,

.....

.....[1]

(ii) used so as to reduce random errors.

.....

.....

.....[2]

Q13.

1 A digital voltmeter with a three-digit display is used to measure the potential difference across a resistor. The manufacturers of the meter state that its accuracy is $\pm 1\%$ and ± 1 digit. The reading on the voltmeter is 2.05V.

(a) For this reading, calculate, to the nearest digit,

(i) a change of 1% in the voltmeter reading,

change = ...V [1]

- (ii) the maximum possible value of the potential difference across the resistor.

maximum value = ...V [1]

- (b) The reading on the voltmeter has high precision. State and explain why the reading may not be accurate.

.....

[2]

Q14.

- 1 Measurements made for a sample of metal wire are shown in Fig. 1.1.

quantity	measurement	uncertainty
length	1750 mm	± 3 mm
diameter	0.38 mm	± 0.01 mm
resistance	7.5Ω	$\pm 0.2 \Omega$

Fig. 1.1

- (a) State the appropriate instruments used to make each of these measurements.

- (i) length

..... [1]

- (ii) diameter

..... [1]

- (iii) resistance

..... [1]

(b) (i) Show that the resistivity of the metal is calculated to be $4.86 \times 10^{-7} \Omega \text{m}$.

[2]

(ii) Calculate the uncertainty in the resistivity.

uncertainty = $\pm$ Ωm [4]

(c) Use the answers in (b) to express the resistivity with its uncertainty to the appropriate number of significant figures.

resistivity = ... $\pm$ Ωm [1]

Q15.

- 2 (a) A sphere of radius R is moving through a fluid with constant speed v . There is a frictional force F acting on the sphere, which is given by the expression

$$F = 6\pi DRv$$

where D depends on the fluid.

- (i) Show that the SI base units of the quantity D are $\text{kg m}^{-1} \text{s}^{-1}$.

[3]

- (ii) A raindrop of radius 1.5 mm falls vertically in air at a velocity of 3.7 m s^{-1} . The value of D for air is $6.6 \times 10^{-4} \text{ kg m}^{-1} \text{s}^{-1}$. The density of water is 1000 kg m^{-3} .

Calculate

1. the magnitude of the frictional force F ,

$$F = \dots\dots\dots \text{ N [1]}$$

2. the acceleration of the raindrop.

$$\text{acceleration} = \dots\dots\dots \text{ m s}^{-2} [3]$$

Q16.

- 1 (a) For each of the following, tick [✓] one box to indicate whether the experimental technique would reduce random error, systematic error or neither. The first row has been completed as an example.

Exa
1

	random error	systematic error	neither
keeping your eye in line with the scale and the liquid level for a single reading of a thermometer		✓	
averaging many readings of the time taken for a ball to roll down a slope			
using a linear scale on an ammeter			
correcting for a non-zero reading when a micrometer screw gauge is closed			

[2]

- (b) The measurement of a particular time interval is repeated many times. The readings are found to vary. The results are shown in Fig. 1.1.

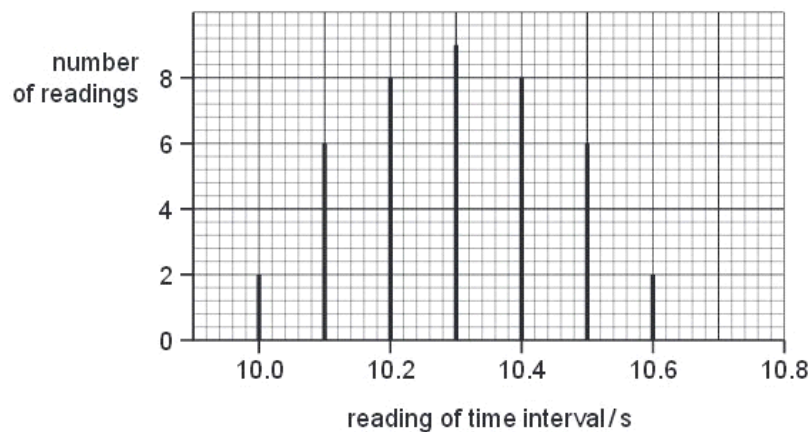


Fig. 1.1

The true value of the time interval is 10.1 s.

(i) State how the readings on Fig. 1.1 show the presence of

1. a systematic error,

.....
[1]

2. a random error.

.....
[1]

(ii) State the expected changes to Fig. 1.1 for experimental measurements that are

1. more accurate,

.....
[1]

2. more precise.

.....
[1]

Q17.

1 (a) (i) State the SI base units of volume.

base units of volume [1]

(ii) Show that the SI base units of pressure are $\text{kg m}^{-1} \text{s}^{-2}$.

[1]

- (b) The volume V of liquid that flows through a pipe in time t is given by the equation

$$\frac{V}{t} = \frac{\pi P r^4}{8 C l}$$

where P is the pressure difference between the ends of the pipe of radius r and length l . The constant C depends on the frictional effects of the liquid.

Determine the base units of C .

base units of C [3]

Q18.

- 1 The volume V of liquid flowing in time t through a pipe of radius r is given by the equation

$$\frac{V}{t} = \frac{\pi P r^4}{8 C l}$$

where P is the pressure difference between the ends of the pipe of length l , and C depends on the frictional effects of the liquid.

An experiment is performed to determine C . The measurements made are shown in Fig. 1.1.

$\frac{V}{t} / 10^{-6} \text{ m}^3 \text{ s}^{-1}$	$P / 10^3 \text{ N m}^{-2}$	r / mm	l / m
1.20 ± 0.01	2.50 ± 0.05	0.75 ± 0.01	0.250 ± 0.001

Fig. 1.1

(a) Calculate the value of C .

$$C = \dots\dots\dots \text{Nsm}^{-2} \text{ [2]}$$

(b) Calculate the uncertainty in C .

$$\text{uncertainty} = \dots\dots\dots \text{Nsm}^{-2} \text{ [3]}$$

(c) State the value of C and its uncertainty to the appropriate number of significant figures.

$$C = \dots\dots\dots \pm \dots\dots\dots \text{Nsm}^{-2} \text{ [1]}$$

Q19.

(b) Show that the SI units of energy per unit volume are $\text{kgm}^{-1}\text{s}^{-2}$.

[2]

(c) For a wire extended elastically, the elastic energy per unit volume X is given by

$$X = C\varepsilon^2 E$$

where C is a constant,

ε is the strain of the wire,

and E is the Young modulus of the wire.

Show that C has no units.

[3]

Q20.

- 1 (a) Determine the SI base units of power.

SI base units of power [3]

(b) Fig. 1.1 shows a turbine that is used to generate electrical power from the wind.

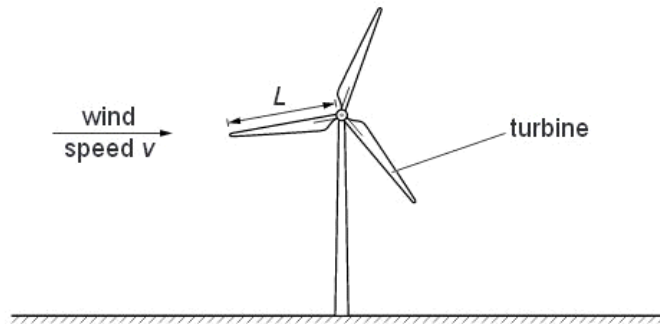


Fig. 1.1

The power P available from the wind is given by

$$P = CL^2\rho v^3$$

where L is the length of each blade of the turbine,
 ρ is the density of air,
 v is the wind speed,
 C is a constant.

(i) Show that C has no units.

[3]

- (ii) The length L of each blade of the turbine is 25.0 m and the density ρ of air is 1.30 in SI units. The constant C is 0.931.
The efficiency of the turbine is 55% and the electric power output P is $3.50 \times 10^5 \text{ W}$.

Calculate the wind speed.

wind speed = ... m s^{-1} [3]

- (iii) Suggest two reasons why the electrical power output of the turbine is less than the power available from the wind.

1.

.....

2.

.....

[2]

Q21.

- 1 (a) State the SI base units of force.

.....[1]

- (b) Two wires each of length l are placed parallel to each other a distance x apart, as shown in Fig. 1.1.

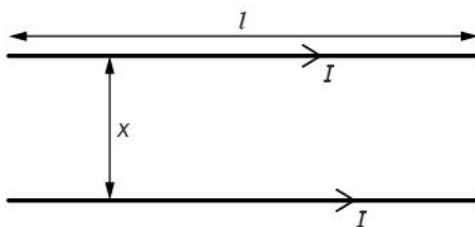


Fig. 1.1

Each wire carries a current I . The currents give rise to a force F on each wire given by

$$F = \frac{KI^2l}{x}$$

where K is a constant.

- (i) Determine the SI base units of K .

units of K [2]

- (ii) On Fig. 1.2, sketch the variation with x of F . The quantities I and l remain constant.



Fig. 1.2

[2]

- (iii) The current I in both of the wires is varied.

On Fig. 1.3, sketch the variation with I of F . The quantities x and l remain constant.



Fig. 1.3

[1]

Q22.

- 1 (a) (i) Define *density*.

.....

- (ii) State the base units in which density is measured.

.....

[2]

- (b) The speed v of sound in a gas is given by the expression

$$v = \sqrt{\left(\frac{\gamma p}{\rho}\right)},$$

where p is the pressure of the gas of density ρ . γ is a constant.

Given that p has the base units of $\text{kg m}^{-1} \text{s}^{-2}$, show that the constant γ has no unit.

[3]

Q23.

- 2 A student uses a metre rule to measure the length of an elastic band before and after stretching it.

The lengths are recorded as

length of band before stretching, $L_0 = 50.0 \pm 0.1$ cm

length of band after stretching, $L_S = 51.6 \pm 0.1$ cm.

Determine

- (a) the change in length ($L_S - L_0$), quoting your answer with its uncertainty,

$$(L_S - L_0) = \dots\dots\dots \text{cm} \quad [1]$$

- (b) the fractional change in length, $\frac{(L_S - L_0)}{L_0}$,

$$\text{fractional change} = \dots\dots\dots [1]$$

- (c) the uncertainty in your answer in (b).

$$\text{uncertainty} = \dots\dots\dots [3]$$

Q24.

- 1 A student takes readings to measure the mean diameter of a wire using a micrometer screw gauge.

(a) Make suggestions, one in each case, that the student may adopt in order to

(i) reduce a systematic error in the readings,

.....
.....

(ii) allow for a wire of varying diameter along its length,

.....
.....

(iii) allow for a non-circular cross-section of the wire.

.....
.....

[3]

- (b) The mean diameter of the wire is found to be 0.50 ± 0.02 mm. Calculate the percentage uncertainty in

(i) the diameter,

uncertainty = ... %

(ii) the area of cross-section of the wire.

uncertainty = ... %
[2]

Q25.

- 1 (a) (i) Define *pressure*.

.....
 [1]

- (ii) State the units of pressure in base units.

..... [1]

- (b) The pressure p at a depth h in an incompressible fluid of density ρ is given by

$$p = \rho gh,$$

where g is the acceleration of free fall.

Use base units to check the homogeneity of this equation.

.....

 [3]

Q26.

- 1 (a) Distinguish between systematic errors and random errors.

systematic errors

.....

random errors

..... [2]

- (b) A cylinder of length L has a circular cross-section of radius R , as shown in Fig. 1.1.

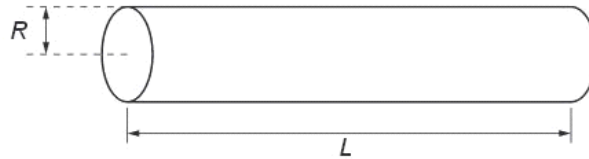


Fig. 1.1

The volume V of the cylinder is given by the expression

$$V = \pi R^2 L.$$

The volume and length of the cylinder are measured as

$$V = 15.0 \pm 0.5 \text{ cm}^3$$

$$L = 20.0 \pm 0.1 \text{ cm}.$$

Calculate the radius of the cylinder, with its uncertainty.

radius = ... $\pm$ cm [5]

Q27.

1 (a) The current in a wire is I . Charge Q passes one point in the wire in time t . State

(i) the relation between I , Q and t .

..... [1]

(ii) which of the quantities I , Q and t are base quantities.

.....
..... [2]

(b) The current in the wire is due to electrons, each with charge q , that move with speed v along the wire. There are n of these electrons per unit volume.
For a wire having a cross-sectional area S , the current I is given by the equation

$$I = nSqv^k,$$

where k is a constant.

(i) State the units of I , n , S , q and v in terms of the base units.

I

n

S

q

v

[3]

(ii) By considering the homogeneity of the equation, determine the value of k .

$k =$ [2]

Q28.

- 1 The volume of fuel in the tank of a car is monitored using a meter as illustrated in Fig. 1.1.

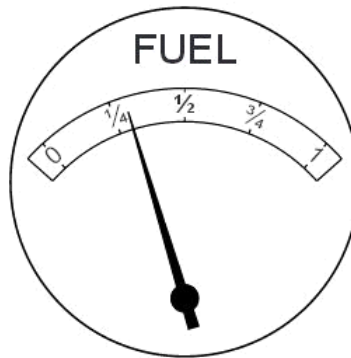


Fig. 1.1

The meter has an analogue scale. The meter reading for different volumes of fuel in the tank is shown in Fig. 1.2.

The meter has an analogue scale. The meter reading for different volumes of fuel in the tank is shown in Fig. 1.2.

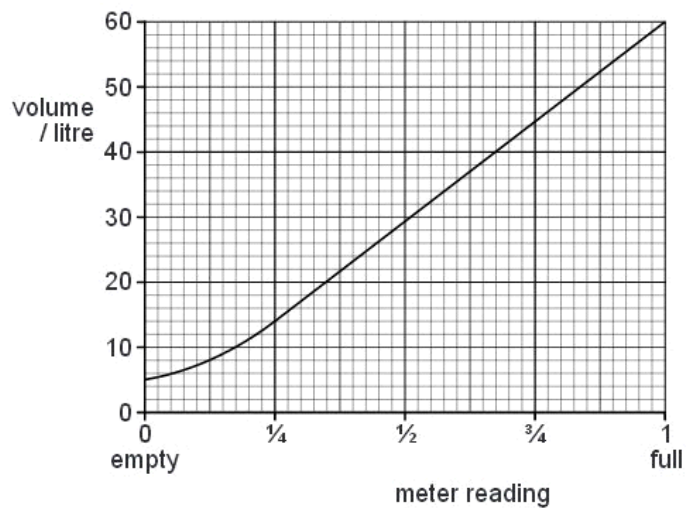


Fig. 1.2

The meter is calibrated in terms of the fraction of the tank that remains filled with fuel.

(a) The car uses 1.0 litre of fuel when travelling 14 km. The car starts a journey with a full tank of fuel.

(i) Calculate the volume of fuel remaining in the tank after a journey of 210 km.

volume = ... litres [2]

(ii) Use your answer to **(i)** and Fig. 1.2 to determine the change in the meter reading during the 210 km journey.

from *full* to [1]

(b) There is a systematic error in the meter.

(i) State the feature of Fig. 1.2 that indicates that there is a systematic error.

.....
 [1]

(ii) Suggest why, for this meter, it is an advantage to have this systematic error.

.....
 [1]

Q29.

- 1 A simple pendulum may be used to determine a value for the acceleration of free fall g . Measurements are made of the length L of the pendulum and the period T of oscillation.

The values obtained, with their uncertainties, are as shown.

$$T = (1.93 \pm 0.03) \text{ s}$$

$$L = (92 \pm 1) \text{ cm}$$

- (a) Calculate the percentage uncertainty in the measurement of

- (i) the period T ,

uncertainty = ... % [1]

- (ii) the length L .

uncertainty = ... % [1]

- (b) The relationship between T , L and g is given by

$$g = \frac{4\pi^2 L}{T^2}.$$

Using your answers in (a), calculate the percentage uncertainty in the value of g .

uncertainty = ... % [1]

- (c) The values of L and T are used to calculate a value of g as 9.751 m s^{-2} .

- (i) By reference to the measurements of L and T , suggest why it would not be correct to quote the value of g as 9.751 m s^{-2} .

.....
 [1]

- (ii) Use your answer in (b) to determine the absolute uncertainty in g .

Hence state the value of g , with its uncertainty, to an appropriate number of significant figures.

$g = \dots \pm \dots \text{ m s}^{-2}$ [2]

Q30.

- 1 (a) Two of the SI base quantities are mass and time. State three other SI base quantities.

1.

2.

3.

[3]

- (b) A sphere of radius r is moving at speed v through air of density ρ . The resistive force F acting on the sphere is given by the expression

$$F = Br^2\rho v^k$$

where B and k are constants without units.

- (i) State the SI base units of F , ρ and v .

F

ρ

v

[3]

- (ii) Use base units to determine the value of k .

$k =$ [2]

Q31.

1 (a) (i) Distinguish between vector quantities and scalar quantities.

.....
.....
.....[2]

(ii) State whether each of the following is a vector quantity or a scalar quantity.

1. temperature

.....[1]

2. acceleration of free fall

.....[1]

3. electrical resistance

.....[1]

(b) A block of wood of weight 25N is held stationary on a slope by means of a string, as shown in Fig. 1.1.

For
Examiner
Use

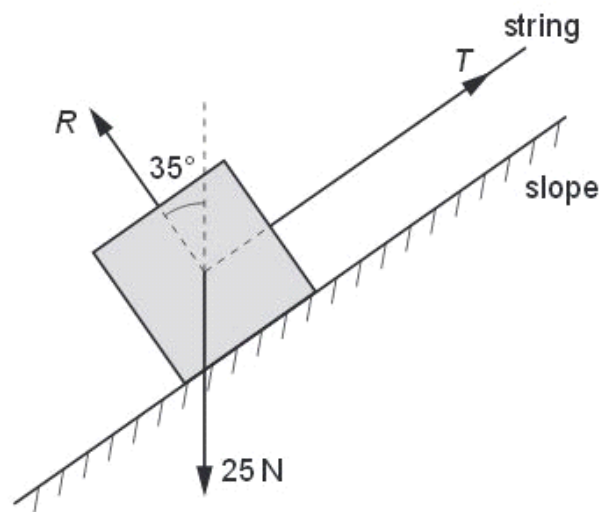


Fig. 1.1

The tension in the string is T and the slope pushes on the block with a force R that is normal to the slope.

Either by scale drawing on Fig. 1.1 or by calculation, determine the tension T in the string.

$T = \dots\dots\dots$ N [3]

Q32.

1 Make estimates of the following quantities.

(a) the thickness of a sheet of paper

thickness = ... mm [1]

(b) the time for sound to travel 100 m in air

time = ... s [1]

(c) the weight of 1000 cm^3 of water

weight = ... N [1]

Q33.

1 (a) The spacing between two atoms in a crystal is $3.8 \times 10^{-10} \text{ m}$. State this distance in pm.

spacing = ... pm [1]

(b) Calculate the time of one day in Ms.

time = ... Ms [1]

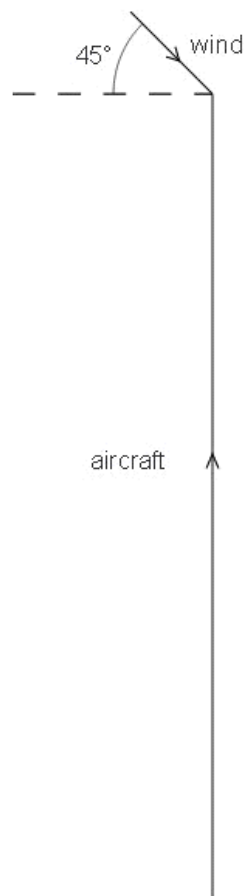
(c) The distance from the Earth to the Sun is 0.15 Tm. Calculate the time in minutes for light to travel from the Sun to the Earth.

time = ... min [2]

(d) Underline all the vector quantities in the list below.

distance energy momentum weight work [1]

(e) The velocity vector diagram for an aircraft heading due north is shown to scale in Fig. 1.1. There is a wind blowing from the north-west.



The speed of the wind is 36 ms^{-1} and the speed of the aircraft is 250 ms^{-1} .

- (i) Draw an arrow on Fig. 1.1 to show the direction of the resultant velocity of the aircraft. [1]
- (ii) Determine the magnitude of the resultant velocity of the aircraft.

resultant velocity = ... ms^{-1} [2]

Q34.

- 1 (a) State two SI base units other than the kilogram, metre and second.

1.

2.

[2]

- (b) A metal wire has original length l_0 . It is then suspended and hangs vertically as shown in Fig. 1.1.

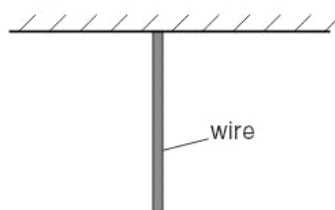


Fig. 1.1

The weight of the wire causes it to stretch. The elastic potential energy stored in the wire is E .

- (i) Show that the SI base units of E are $\text{kg m}^2 \text{s}^{-2}$.

[2]

- (ii) The elastic potential energy E is given by

$$E = C\rho^2 g^2 A l_0^3$$

where ρ is the density of the metal,
 g is the acceleration of free fall,
 A is the cross-sectional area of the wire
 and C is a constant.

Determine the SI base units of C .

SI base units of C [3]

Q35.

- 2 A source of radio waves sends a pulse towards a reflector. The pulse returns from the reflector and is detected at the same point as the source. The emitted and reflected pulses are recorded on a cathode-ray oscilloscope (c.r.o.) as shown in Fig. 2.1.

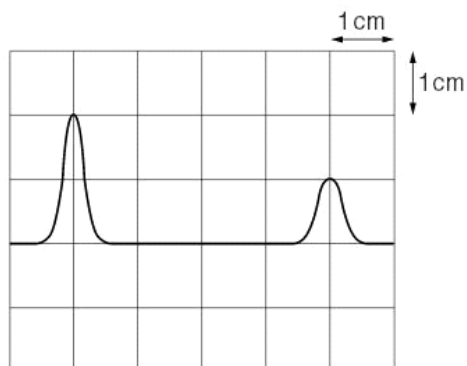


Fig. 2.1

The time-base setting is $0.20 \mu\text{s cm}^{-1}$.

- (a) Using Fig. 2.1, determine the distance between the source and the reflector.

distance = ... m [4]

- (b) Determine the time-base setting required to produce the same separation of pulses on the c.r.o. when sound waves are used instead of radio waves.
The speed of sound is 300 m s^{-1} .

.....
.....
..... [3]

Q36.

- 2 The time T for a satellite to orbit the Earth is given by

$$T = \sqrt{\left(\frac{KR^3}{M}\right)}$$

where R is the distance of the satellite from the centre of the Earth,
 M is the mass of the Earth,
and K is a constant.

- (a) Determine the SI base units of K .

SI base units of K [2]

F_1
Exam
 U_1

(b) Data for a particular satellite are given in Fig. 2.1.

quantity	measurement	uncertainty
T	$8.64 \times 10^4 \text{ s}$	$\pm 0.5\%$
R	$4.23 \times 10^7 \text{ m}$	$\pm 1\%$
M	$6.0 \times 10^{24} \text{ kg}$	$\pm 2\%$

Fig. 2.1

Calculate K and its actual uncertainty in SI units.

$K = \dots\dots\dots \pm \dots\dots\dots$ SI units [4]

Q1.

1	kg m ⁻³	B1	
	frequency or count rate or activity or decay constant	B1	
	NC ⁻¹ or V m ⁻¹ or kg m s ⁻² C ⁻¹ etc.	B1	
	momentum or impulse.....	B1	[4]
	(Allow solidus notation and non SI units)		

Q2.

1	(a)	scalar: magnitude only	B1	
		vector: magnitude and direction (<i>allow scalar with direction</i>)	B1	[2]
		<i>(allow 1 mark for scalar has no direction, vector has direction)</i>		
	(b)	diagram has correct shape	M1	
		with arrows in correct directions	A1	
		resultant = 13.2 ± 0.2 N (<i>allow 2 sig. fig</i>)	A2	[4]
		<i>(for 12.8 → 13.0 and 13.4 → 13.6, allow 1 mark)</i>		
		<i>(calculated answer with a correct sketch, allow max 4 marks)</i>		
		<i>(calculated answer with no sketch – no marks)</i>		
		Total		[6]

Q3.

3	(a)	(i) scatter of points (about the line)	B1	
		(ii) intercept (on t^2 axis)	B1	[2]
		<i>(note that answers must relate to the graph)</i>		
	(b)	(i) gradient = $\Delta y / \Delta x = (100 - 0) / (10.0 - 0.6)$	C1	
		gradient = $10.6 \text{ (cm s}^{-2}\text{)}$ (<i>allow ± 0.2</i>)	A1	[2]
		<i>(Read points to within $\pm \frac{1}{2}$ square. Allow 1 mark for 11 cm s⁻²</i>		
		<i>i.e. 2 sig fig, -1. Answer of 10 scores 0/2 marks)</i>		
		(ii) $s = ut + \frac{1}{2}at^2$	B1	
		so acceleration = 2 x gradient	B1	
		acceleration = 0.212 m s^{-2}	B1	[3]
		Total		[7]

Q4.

1	(a)	allow $100 \text{ m s}^{-1} \rightarrow 900 \text{ m s}^{-1}$	B1	[1]
	(b)	allow $0.5 \text{ kg m}^{-3} \rightarrow 1.5 \text{ kg m}^{-3}$	B1	[1]
	(c)	allow $5 \text{ g} \rightarrow 50 \text{ g}$	B1	[1]
	(d)	allow $2 \times 10^3 \text{ cm}^3 \rightarrow 9 \times 10^3 \text{ cm}^3$	B1	[1]

Q5.

1	(a)	kg m s^{-2}	B1	[1]
	(b)	$\text{kg m}^{-1} \text{s}^{-1}$	B1	[1]
	(c) (i)	$v^2 = 2gs$ $= 2 \times 9.8 \times 4.5$ $v = 9.4 \text{ m s}^{-1}$	C1 A1	[2]
	(ii)	<i>either</i> $F (= 3.2 \times 10^{-4} \times 1.2 \times 10^{-2} \times 9.4) = 3.6 \times 10^{-5} \text{ N}$ weight of sphere $(= mg = 15 \times 10^{-3} \times 9.8) = 0.15 \text{ N}$ $3.6 \times 10^{-5} \ll 0.15$, so justified <i>or</i> $mg = crv_T$ (M1) terminal speed $= 3.8 \times 10^4 \text{ m s}^{-1}$ (M1) $9.4 \ll 3.8 \times 10^4$, so justified (A1)	M1 M1 A1	[3]

Q6.

1	(a) (i)	all positions (accept 20, 40, 60, 80) marked to within $\pm 5^\circ$ positions are 40° , 70° , 90° and 102° (-1 for each error or omission)	B2	
	(ii)	allow $107^\circ \rightarrow 113^\circ$	B1	[3]
	(b)	e.g. more sensitive at <u>low</u> volumes (do not allow reference to 'accuracy')	B1	[1]

Q7.

1	(a)	allow anything in range $20 \text{ Hz} \rightarrow 20 \text{ kHz}$	B1	[1]
	(b)	allow anything in range $10 \text{ nm} \rightarrow 400 \text{ nm}$	B1	[1]
	(c)	allow anything in range $10 \text{ g} \rightarrow 100 \text{ g}$	B1	[1]
	(d)	allow anything in range $0.1 \text{ kg m}^{-3} \rightarrow 10 \text{ kg m}^{-3}$	B1	[1]

Q8.

1	(a) (i)	micrometer (screw gauge) / travelling microscope	B1	[1]
	(ii)	either ohm-meter or voltmeter and ammeter or multimeter/avo on ohm setting	B1	[1]
	(iii)	either (calibrated) c.r.o. or a.c. voltmeter and $\times \sqrt{2}$	B1	[1]
	(b)	density = mass / volume	C1	
		= $580 / 6^3 = 2.685 \text{ g cm}^{-3}$... (allow 2.68, 2.69, 2.7)	A1	
		% uncertainty in mass = $(10 / 580) \times 100 = 1.7\%$	C1	
		% uncertainty in volume = $3 \times (0.1 / 6) \times 100 = 5.0\%$	C1	
		uncertainty in density = 0.18 g cm^{-3}		
		density = $2.7 \pm 0.2 \text{ g cm}^{-3}$	A1	[5]
		(answer $2.69 \pm 0.09 \text{ g cm}^{-3}$ scores 4 marks)		

Q9.

1	(a)	e.g. time (s), current (A), temperature (K), amount of substance (mol), luminous intensity (cdl) 1 each, max 3	B3	[3]
	(b)	density = mass / volume	C1	
		unit of density: kg m^{-3}	C1	
		unit of acceleration: m s^{-2}	C1	
		unit of pressure: $\text{kg m}^{-3} \text{ m s}^{-2} \text{ m}$	B1	
		$\text{kg m}^{-1} \text{ s}^{-2}$	B1	[5]
		(allow 4/5 for solution in terms of only dimensions)		

Q10.

1	10^{-9}	B1	
	c	B1	
	mega	B1	
	tera	B1	[4]

Q11.

2	(a)	scalar	B1	
		scalar	B1	
		vector	B1	[3]

Q12.

1	(a)	micrometer/screw gauge/digital callipers	B1	[1]
	(b) (i)	look/check for zero error	B1	[1]
	(ii)	take several readings	M1	
		around the circumference/along the wire	A1	[2]

Q13.

- 1 (a) (i) 1% of ± 2.05 is ± 0.02 A1 [1]
(ii) max. value is 2.08 V A1 [1]
(b) there may be a zero error/calibration error/systematic error which makes all readings either higher or lower than true value M1 A1 [2]

Q14.

- 1 (a) (i) metre rule / tape (*not 'rule'*) B1 [1]
(ii) micrometer (screw gauge) / digital caliper B1 [1]
(iii) ammeter and voltmeter / ohmmeter / multimeter on 'ohm' setting B1 [1]
(b) (i) resistivity = RA / L C1
 $= [7.5 \times \pi \times (0.38 \times 10^{-3})^2 / 4] / 1.75$ M1
 $= 4.86 \times 10^{-7} \Omega \text{ m}$ A0 [2]
(ii) (uncertainty in R =) $[0.2 / 7.5] \times 100 = 2.7\%$
and (uncertainty in L =) $[3 / 1750] \times 100 = 0.17\%$ C1
(uncertainty in A =) $2 \times (0.01 / 0.38) \times 100 = 5.3\%$ C1
total = 8.13% C1
uncertainty = $0.395 \times 10^{-7} (\Omega \text{ m})$ A1 [4]
(*missing 2 factor in uncertainty in A, then allow max 3/4*)
(c) resistivity = $(4.9 \times 10^{-7} \pm 0.4 \times 10^{-7}) \Omega \text{ m}$ A1 [1]

Q15.

- 2 (a) (i) base units of D :
force: kg m s^{-2} B1
radius: m velocity: m s^{-1} B1
base units of D : $[F / (R \times v)] \text{ kg m s}^{-2} / (\text{m} \times \text{m s}^{-1})$ M1
 $= \text{kg m}^{-1} \text{ s}^{-1}$ A0 [3]
(ii) 1. $F = 6\pi \times D \times R \times v = [6\pi \times 6.6 \times 10^{-4} \times 1.5 \times 10^{-3} \times 3.7]$
 $= 6.9 \times 10^{-5} \text{ N}$ A1 [1]
2. $mq - F = ma$ hence $a = g - [F / m]$ C1
 $m = \rho \times V = \rho \times 4/3 \pi R^3 = (1.4 \times 10^{-5})$ M1
 $a = 9.81 - [6.9 \times 10^{-5}] / \rho \times 4/3 \pi \times (1.5 \times 10^{-3})^3$ (9.81 - 4.88) A1 [3]
 $a = 4.9(3) \text{ ms}^{-2}$

Q16.

1	(a)	2nd row random, 3rd row neither, 4th row systematic all correct two correct scores 1 only	B2	[2]
	(b)	(i)		
		1. systematic error: the average / peak is not the true value / the readings are not centred around the true value	B1	[1]
		2. random error: readings have positive and negative values around the peak value / values are scattered / wide range	B1	[1]
		(ii)		
		1. accurate: peak / average value moves towards the true value	B1	[1]
		2. precise: lines are closer together / sharper peak	B1	[1]

Q17.

1	(a)	(i)	V units: m^3 (allow metres cubed or cubic metres)	A1	[1]
		(ii)	Pressure units: $\text{kg ms}^{-2} / \text{m}^2$ (allow use of $P = \rho gh$) Units: $\text{kgm}^{-1} \text{s}^{-2}$	M1 A0	[1]
	(b)	V / t units: $\text{m}^3 \text{s}^{-1}$ Clear substitution of units for P , r^4 and l			B1 M1
		$C = \frac{\pi P r^4}{8 V t^{-1} l} = \frac{\text{kgm}^{-1} \text{s}^{-2} \text{m}^4}{\text{m}^3 \text{s}^{-1} \text{m}}$			
		Units: $\text{kgm}^{-1} \text{s}^{-1}$ (8 or π in final answer – 1. Use of dimensions max 2/3)			A1 [3]

Q18.

1	(a)	$\frac{V}{t} = \frac{\pi P r^4}{8 C l}$ $C = [\pi \times 2.5 \times 10^3 \times (0.75 \times 10^{-3})^4] / (8 \times 1.2 \times 10^{-6} \times 0.25)$ $= 1.04 \times 10^{-3} \text{ N s m}^{-2}$	C1 A1	[2]
	(b)	$4 \times \%r$ $\%C = \%P + 4 \times \%r + \%V/t + \%l$ $= 2\% + 5.3\% + 0.83\% + 0.4\% (= 8.6\%)$ $\Delta C = \pm 0.089 \times 10^{-3} \text{ N s m}^{-2}$	C1 A1 A1	[3]
	(c)	$C = (1.04 \pm 0.09) \times 10^{-3} \text{ N s m}^{-2}$	A1	[1]

Q19.

- (b) energy: $\text{N m} / \text{kg m}^2 \text{s}^{-2}$ and volume m^3
 energy / volume: $\text{kg m}^2 \text{s}^{-2} / \text{m}^3$
 energy / volume: $\text{kg m}^{-1} \text{s}^{-2}$ C1
 M1
 A0 [2]
- (c) ε has no units B1
 E : $\text{kg m s}^{-2} \text{m}^{-2}$ M1
 units of RHS: $\text{kg m}^{-1} \text{s}^{-2} = \text{LHS units}$ / satisfactory conclusion to show C has no units A1 [3]

Q20.

- 1 (a) power = energy / time C1
 = (force $\times$ distance / time) = $\text{kg m}^2 \text{s}^{-2} / \text{s}$ C1
 = $\text{kg m}^2 \text{s}^{-3}$ A1 [3]
- (b) (i) units of L^2 : m^2 and units of ρ : kg m^{-3} and units of v^3 : $\text{m}^3 \text{s}^{-3}$ C1
 $(C = P / L^2 \rho v^3)$ hence units of C : $\text{kg m}^2 \text{s}^{-3} \text{m}^{-2} \text{kg}^{-1} \text{m}^3 \text{m}^{-3} \text{s}^3$ M1
 or any correct statement of component units A1 [3]
 argument / discussion / cancelling leading to C having no units
- (ii) power available from wind = $3.5 \times 10^5 \times 100 / 55 (= 6.36 \times 10^5)$ C1
 $v^3 = 3.5 \times 10^5 \times 100 / (55 \times 0.931 \times (25)^2 \times 1.3)$ C1
 $v = 9.4 \text{ m s}^{-1}$ A1 [3]
- (iii) not all kinetic energy of wind converted to kinetic energy of blades B1
 generator / conversion to electrical energy not 100% efficient / heat produced in generator / bearings etc B1 [2]
 (there must be cause of loss and where located)

Q21.

- 1 (a) force: kg m s^{-2} A1 [1]
- (b) (i) I^2 : A^2 t : m x : m C1
 K : $\text{kg m s}^{-2} \text{A}^{-2}$ A1 [2]
- (ii) curve of the correct shape (for inverse proportionality) M1
 clearly approaching each axis but never touching the axis A1 [2]
- (iii) curving upwards and through origin A1 [1]

Q22.

- 1 (a) (i) mass / volume ...(ratio must be clear)..... B1
 (ii) kg m^{-3} OR kg / m^3 B1 [2]
- (b) v has unit of m s^{-1} B1
 p / ρ has unit of $\text{kg m}^{-1} \text{s}^{-2} / \text{kg m}^{-3}$ (no e.c.f. from (a)) M1
 $\sqrt{p / \rho}$ has unit of m s^{-1} A1
 LHS = RHS so γ has no unit A0 [3]

Q23.

- 2 (a) $1.6 \pm 0.2 \text{ cm}$ B1 [1]
- (b) $1.6 / 50 = 0.032$...(ignore any uncertainties)..... B1 [1]
- (c) idea of adding fractional uncertainties C1
 $(0.2 / 1.6) + (0.1 / 50)$
 $= 0.127$ OR 12.7% ...(-2 marks if uncertainties not added) A1
 actual uncertainty = $(\pm) 0.004$ A1 [3]
 (do not allow more than 2 sig. fig)

Q24.

- 1 (a) (i) e.g. check for zero error (on micrometer)/zero the micrometer B1
 (ii) take readings along the length of the wire/at different points B1
 (iii) take readings spirally/around the wire B1 [3]
- (b) (i) 4% A1
 (ii) 8% A1 [2]

Q25.

- 1 (a) (i) force per unit area (ratio idea essential) B1
 (ii) $\text{kg m}^{-1} \text{s}^{-2}$ B1 [2]
- (b) ρ has base unit kg m^{-3} B1
 g has base unit m s^{-2} B1
 $h\rho g$ has base unit $\text{m} \times \text{kg m}^{-3} \times \text{m s}^{-2}$ M1
 same as pressure QED A0 [3]

Q26.

- 1 (a) systematic: e.g. constant error (in all readings)
cannot be eliminated by averaging
error in measuring instrument B1
- random: e.g. readings scattered (equally) about true value
error due to observer
can be eliminated by averaging
(only if averaging not included for systematic) B1 [2]
- (b) $15 = \pi \times R^2 \times 20$
 $R = 0.4886 \text{ cm}$ (accept any number of s.f.) C1
 % uncertainty in $V = 3.3 \%$ (or $0.5/15$) C1
 % uncertainty in $L = 0.5 \%$ (or $0.1/20$) C1
 % uncertainty in $R = 1.9 \%$ (i.e. one half of the sum) C1
 $R = 0.489 \pm 0.009 \text{ cm}$ A1 [5]

Q27.

- 1 (a) (i) $Q = It$ (allow any subject for the equation) B1 [1]
- (ii) $\frac{I}{t}$ B1
 (allow 1 mark only if all three quoted) B1 [2]
- (b) (i) base unit of I is A
 base unit of n is m^{-3} (not $/\text{m}^{-3}$)
 base unit of S is m^2
 base unit of q is A s (not C)
 base unit of v is m s^{-1}
 (–1 for each error or omission) B3 [3]
- (ii) $A = \text{m}^{-3} \text{m}^2 \text{A s} (\text{m s}^{-1})^k$ M1
 e.g. for m: $0 = -3 + 2 + k$
 $k = 1$ A1 [2]

Q28.

- 1 (a) (i) car uses $210 / 14 = 15$ litres of fuel C1
 volume reading = 45 litres A1 [2]
- (ii) from 'full' to '3/4' mark B1 [1]
- (b) (i) line/graph does not pass through ('empty, 0') / there is an intercept B1 [1]
 (do not allow 'non-linear')
- (ii) (meter shows zero fuel when there is some left in the tank so)
 acts as a 'reserve' B1 [1]

[Total: 5]

Q29.

- 1 (a) (i) either 1.55% or 1.6% ... (not 1.5 or 2) A1 [1]
 (ii) either 1.09% or 1.1% ... (not 1.0 or 1) A1 [1]
- (b) answer of {(ii) + 2 × (i)} to any number of sig. fig.
 either 4.2% or 4.3% A1 [1]
- (c) (i) either the value has more significant figures than the data
 or uncertainty of ± 0.4 renders more than 2 s.f. meaningless) B1 [1]
- (ii) uncertainty in $g = \pm 0.41 / \pm 0.42$ to any number of s.f. C1
 $g = (9.8 \pm 0.4) \text{ m s}^{-2}$ A1 [2]

[Total: 6]

Q30.

- 1 (a) length, current, temperature, amount of substance, (luminous intensity)
 any three, 1 each B3 [3]
- (b) (i) $F: \text{kg m s}^{-2}$ B1
 $\rho: \text{kg m}^{-3}$ B1
 $v: \text{m s}^{-1}$ B1 [3]
- (ii) some working e.g. $\text{kg m s}^{-2} = \text{m}^2 \text{kg m}^{-3} (\text{m s}^{-1})^k$ M1
 hence $k = 2$ A1 [2]

Q31.

- 1 (a) (i) scalar quantity has magnitude (allow size) B1
 vector quantity has magnitude and direction B1 [2]
- (ii) 1. temperature: scalar B1 [1]
 2. acceleration: vector B1 [1]
 3. resistance: scalar B1 [1]
- (b) either triangle / parallelogram with correct shape C1
 tension = 14.3 N (allow $\pm 0.5 \text{ N}$) A2 [3]
- (if $> \pm 0.5 \text{ N}$ but $\leq \pm 1 \text{ N}$, allow 1 mark)
- or $R = 25 \cos 35^\circ$ (C1)
 $T = R \tan 35^\circ$ (C1)
 $T = 14.3 \text{ N}$ (A1)
- or $T = 25 \sin 35^\circ$ (C2)
 $T = 14.3 \text{ N}$ (A1)
- or R and T resolved vertically and horizontally (C2)
 leading to $T = 14.3 \text{ N}$ (A1)

Q32.

- 1 (a) allow 0.05 mm $\rightarrow$ 0.15 mm B1 [1]
- (b) allow 0.25 s $\rightarrow$ 0.5 s B1 [1]
- (c) allow 8 N $\rightarrow$ 12 N B1 [1]
- ignore number of significant figures

Q33.

- 1 (a) spacing = 380 or 3.8×10^2 pm B1 [1]
- (b) time = 24×3600
time = 0.086 (0.0864) Ms B1 [1]
- (c) time = distance / speed = $\frac{1.5 \times 10^{11}}{3 \times 10^8}$ C1
= 500 (s) = 8.3 min A1 [2]
- (d) momentum and weight B1 [1]
- (e) (i) arrow to the right of plane direction (about 4° to 24°) B1 [1]
- (ii) scale diagram drawn
or use of cosine formula $v^2 = 250^2 + 36^2 - 2 \times 250 \times 36 \times \cos 45^\circ$
or resolving $v = [(36 \cos 45^\circ)^2 + (250 - 36 \sin 45^\circ)^2]^{1/2}$ C1

resultant velocity = 226 (220 – 240 for scale diagram) ms^{-1}
allow one mark for values 210 to 219 or 241 to 250 ms^{-1}
or use of formula ($v^2 = 51068$) $v = 230$ (226) ms^{-1} A1 [2]

Q34.

- 1 (a) kelvin / K B1
ampere / amp / A B1 [2]
[allow mole / mol and candela / Cd]
- (b) (i) energy OR work = force $\times$ distance [allow any energy expression] C1
units: $\text{kg m s}^{-2} \times \text{m}$ OR $\text{kg (ms}^{-1})^2$ for $\frac{1}{2}mv^2$ or mc^2 M1
(ignore any numerical factor)
= $\text{kg m}^2 \text{s}^{-2}$ A0 [2]
- (ii) units: ρ : kg m^{-3} g : m s^{-2} A : m^2 I_0 : m C1
C: $\text{kg m}^2 \text{s}^{-2} / \text{kg}^2 \text{m}^{-6} \text{m}^2 \text{s}^{-4} \text{m}^2 \text{m}^3$ [any subject] C1
= $\text{kg}^{-1} \text{m s}^2$ (allow ms^2 / kg) A1 [3]

Q35.

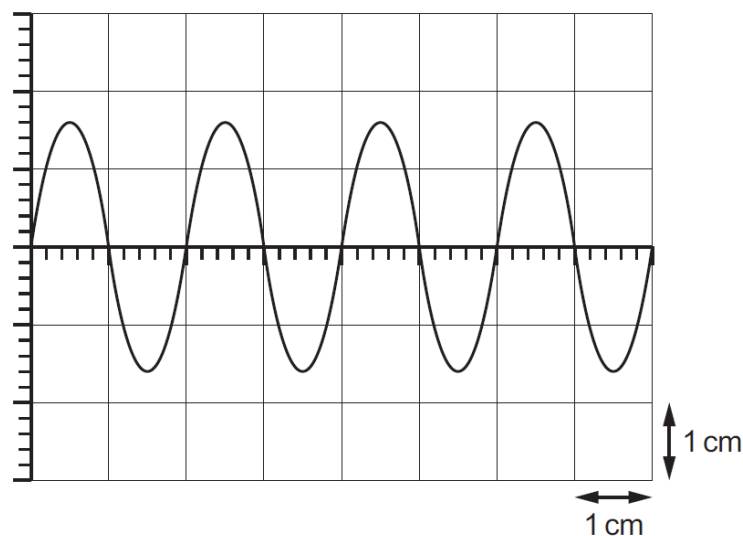
- 2 (a) $d = v \times t$ C1
 $t = 0.2 \times 4$ (allow $t = 0.2 \times 2$) C1
 $d = 3 \times 10^8 \times 0.8 \times 10^{-6}$ OR $3 \times 10^8 \times 0.4 \times 10^{-6}$ C1
 $d = 240$ m hence distance from source to reflector = 120 m A1 [4]
- (b) speed of sound 300 cf speed of light 3×10^8 OR time = $240 / 300$ (= 0.8)
OR time = $120 / 300$ (= 0.4) C1
sound slower by factor of 10^6 OR time for one division $0.8 / 4$
OR time for one division $0.4 / 2$ C1
time base setting 0.2 s cm^{-1} [unit required] A1 [3]

Q36.

- 2 (a) SI units for T : s, R : m and M : kg (or seen clearly in formula) C1
 $K = T^2 M / R^3$ units: $\text{s}^2 \text{ kg m}^{-3}$ (allow $\text{s}^2 \text{ kg} / \text{m}^3$ or $\frac{\text{s}^2 \text{ kg}}{\text{m}^3}$) A1 [2]
- (b) % uncertainty in K : 1% (for T) + 3% (for R) + 2% (for M) OR = 6% C1
 $K = [(86400)^2 \times 6 \times 10^{24}] / (4.23 \times 10^7)^3 = 5.918 \times 10^{11}$ C1
6% of $K = 0.355 \times 10^{11}$ C1
 $K = (5.9 \pm 0.4) \times 10^{11}$ (SI units) correct power of ten required for both A1 [4]
[incorrect % value then max. 1]

1. June/2021/Paper_11/No.4

A signal of frequency 25 Hz is displayed on the screen of a cathode-ray oscilloscope.



What is the time-base setting?

- A** 10 ms cm⁻¹ **B** 20 ms cm⁻¹ **C** 25 ms cm⁻¹ **D** 40 ms cm⁻¹

2. June/2021/Paper_11/No.5

A micrometer screw gauge is used to measure the diameter of a wire.

The reading on the micrometer with the jaws closed is (-0.05 ± 0.02) mm.

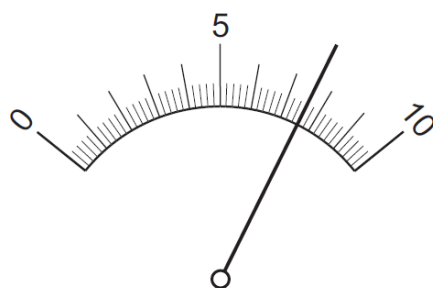
The reading with the wire in position between the two jaws is $(+1.03 \pm 0.02)$ mm.

What is the diameter of the wire?

- A** (0.98 ± 0.02) mm
B (1.08 ± 0.02) mm
C (0.98 ± 0.04) mm
D (1.08 ± 0.04) mm

3. [June/2021/Paper_12/No.4](#)

An analogue ammeter with a range of 0–250 mA is connected into an electrical circuit. The diagram shows the ammeter's display.



What is the reading on the ammeter?

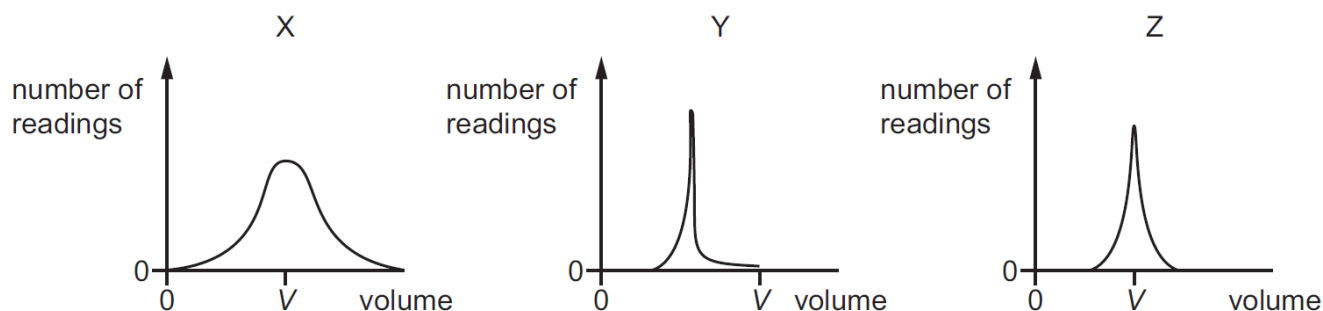
- A** 76 mA **B** 165 mA **C** 183 mA **D** 190 mA

4. [June/2021/Paper_12/No.5](#)

Students take readings of the volume of a liquid using three different pieces of measuring equipment X, Y and Z.

The true value of the volume of the liquid is V .

The students' results are shown.



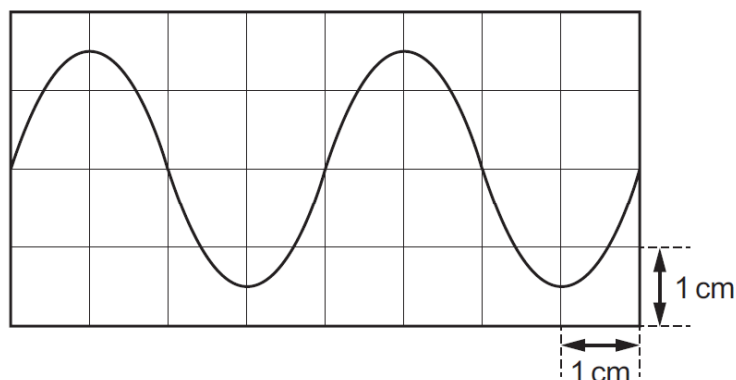
How many pieces of equipment are precise and how many are accurate?

	number of precise pieces of equipment	number of accurate pieces of equipment
A	1	1
B	1	2
C	2	1
D	2	2

5. Nov/2021/Paper_11/No.4

A cathode-ray oscilloscope (CRO) is used to display a sound wave of frequency 2000 Hz.

The display of the CRO is shown.



What is the time-base setting on the CRO?

- A** $125 \mu\text{s cm}^{-1}$ **B** $250 \mu\text{s cm}^{-1}$ **C** $500 \mu\text{s cm}^{-1}$ **D** $1000 \mu\text{s cm}^{-1}$

6. Nov/2021/Paper_11/No.5

Four possible sources of error in a series of measurements are listed.

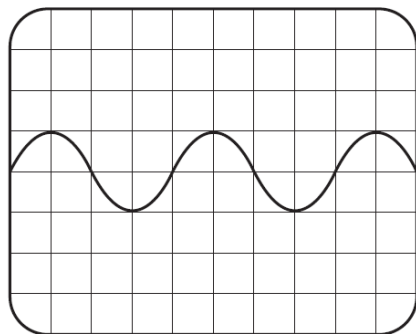
- 1 an analogue meter whose scale is read from different angles
- 2 a meter which always measures 5% too high
- 3 a meter with a needle that is not frictionless, so the needle sometimes sticks slightly
- 4 a meter with a zero error

Which errors are random and which are systematic?

	random error	systematic error
A	1 and 2	3 and 4
B	1 and 3	2 and 4
C	2 and 4	1 and 3
D	3 and 4	1 and 2

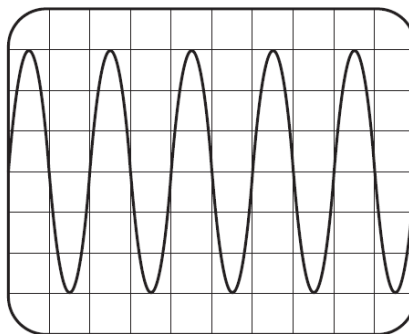
Four cathode-ray oscilloscope (CRO) screens each display a waveform. The screen and the time-base setting of each CRO is shown.

1



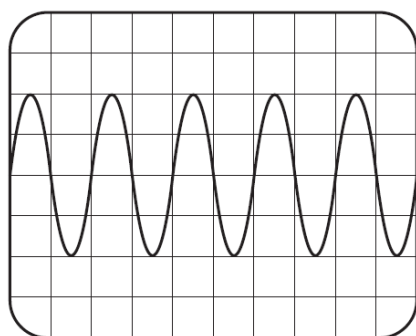
time-base setting: 0.02 s/div

2



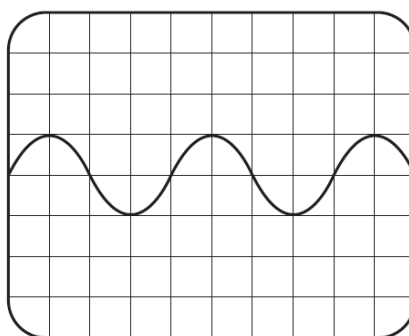
time-base setting: 0.04 s/div

3



time-base setting: 0.01 s/div

4



time-base setting: 0.08 s/div

Which screens show waveforms of the same frequency?

A 1 and 2

B 1 and 3

C 1 and 4

D 2 and 3

8. Nov/2021/Paper_12/No.5

A student measures the time T for one complete oscillation of a pendulum of length l .

Her results are shown in the table.

l/m	T/s
0.420 ± 0.001	1.3 ± 0.1

She uses the formula

$$T = 2\pi \sqrt{\frac{l}{g}}$$

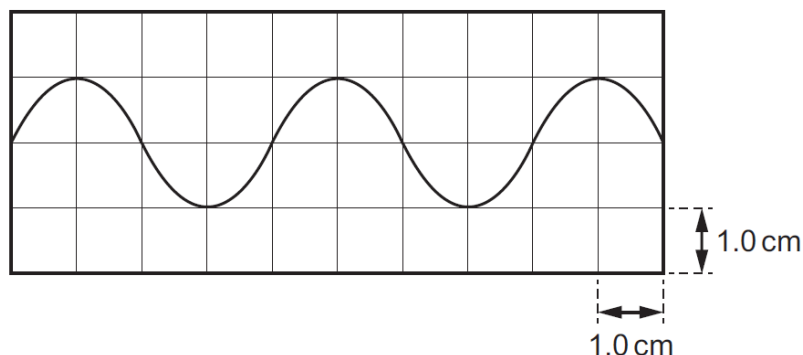
to calculate the acceleration of free fall g .

What is the best estimate of the percentage uncertainty in the value of g ?

- A** 0.02% **B** 4% **C** 8% **D** 16%

9. Nov/2021/Paper_13/No.4

The output of a signal generator is connected to a cathode-ray oscilloscope (CRO). A trace is shown on the screen.



The time-base of the CRO is set at 2.00 ms cm^{-1} .

What is the frequency of the signal?

- A** 50 Hz **B** 125 Hz **C** 250 Hz **D** 500 Hz

10. Nov/2021/Paper_13/No.5

After measuring the width of a shelf to be 305 mm, it is found that the graduations on the ruler used are 1.0% further apart than they should be.

Which type of measurement error is this and what is the true width of the shelf?

	type of error	true width / mm
A	random	302
B	random	308
C	systematic	302
D	systematic	308

1. Nov/2021/Paper_21/No.1

(a) Define *density*.

.....
..... [1]

(b) A smooth pebble, made from uniform rock, has the shape of an elongated sphere as shown in Fig. 1.1.

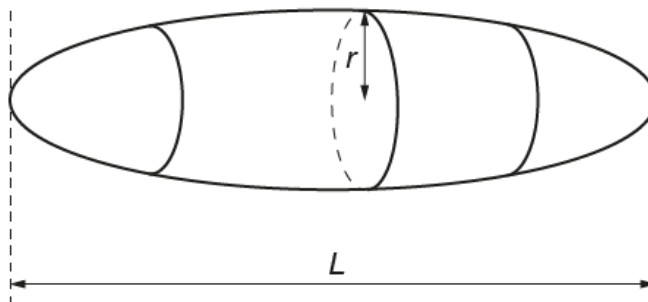


Fig. 1.1

The length of the pebble is L . The cross-section of the pebble, in the plane perpendicular to L , is circular with a maximum radius r .

A student investigating the density of the rock makes measurements to determine the values of L , r and the mass M of the pebble as follows:

$$L = (0.1242 \pm 0.0001) \text{ m}$$

$$r = (0.0420 \pm 0.0004) \text{ m}$$

$$M = (1.072 \pm 0.001) \text{ kg.}$$

(i) State the name of a measuring instrument suitable for making this measurement of L .

..... [1]

(ii) Determine the percentage uncertainty in the measurement of r .

percentage uncertainty = ... % [1]

- (c) The density ρ of the rock from which the pebble in (b) is composed is given by

$$\rho = \frac{Mr^n}{kL}$$

where n is an integer and k is a constant, with no units, that is equal to 2.094.

- (i) Use SI base units to show that n is equal to -2 .

[2]

- (ii) Calculate the percentage uncertainty in ρ .

percentage uncertainty = ... % [3]

- (iii) Determine ρ with its absolute uncertainty. Give your values to the appropriate number of significant figures.

$\rho = (\dots\dots\dots \pm \dots\dots\dots) \text{ kg m}^{-3}$ [3]

[Total: 11]

- (a) A unit may be stated with a prefix that represents a power-of-ten multiple or submultiple.

Complete Table 1.1 to show the name and symbol of each prefix and the corresponding power-of-ten multiple or submultiple.

Table 1.1

prefix	power-of-ten multiple or submultiple
kilo (k)	10^3
tera (T)	
()	10^{-12}

[2]

- (b) In the following list, underline all the units that are SI base units.

ampere

coulomb

metre

newton

[1]

- (c) The potential difference V between the two ends of a uniform metal wire is given by

$$V = \frac{4\rho LI}{\pi d^2}$$

where d is the diameter of the wire,

I is the current in the wire,

L is the length of the wire,

and ρ is the resistivity of the metal.

For a particular wire, the percentage uncertainties in the values of some of the above quantities are listed in Table 1.2.

Table 1.2

quantity	percentage uncertainty
d	$\pm 3.0\%$
I	$\pm 2.0\%$
L	$\pm 2.5\%$
V	$\pm 3.5\%$

The quantities listed in Table 1.2 have values that are used to calculate ρ as $4.1 \times 10^{-7} \Omega \text{ m}$.

For this value of ρ , calculate:

- (i) the percentage uncertainty

percentage uncertainty = ...% [2]

- (ii) the absolute uncertainty.

absolute uncertainty = ... $\Omega \text{ m}$ [1]

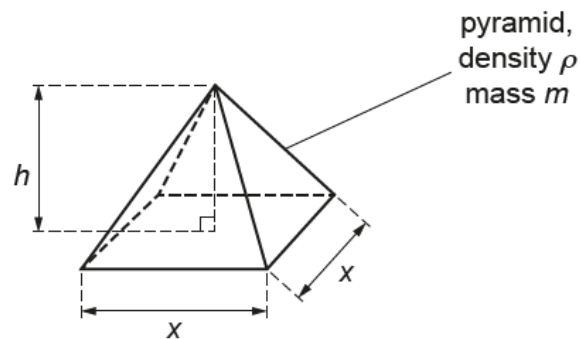
[Total: 6]

(a) Define *density*.

.....

..... [1]

(b) Fig. 1.1 shows a solid pyramid with a square base.

**Fig. 1.1**The mass m of the pyramid is given by

$$m = \frac{1}{3}\rho hx^2$$

where ρ is the density of the material of the pyramid,
 h is the height, and
 x is the length of each side of the base.

Measurements are taken as shown in Table 1.1.

Table 1.1

quantity	measurement	percentage uncertainty
m	19.5g	$\pm 2\%$
x	4.0cm	$\pm 5\%$
h	4.8cm	$\pm 4\%$

(i) Calculate the absolute uncertainty in length x .

absolute uncertainty = ... cm [1]

(ii) The density ρ is calculated from the measurements in Table 1.1.

Determine the percentage uncertainty in the calculated value of ρ .

percentage uncertainty = ... % [2]

(c) The square base of the pyramid in (b) rests on the horizontal surface of a bench.

Use data from Table 1.1 to calculate the average pressure of the pyramid on the surface of the bench. The uncertainty in your answer is not required.

pressure = ... Pa [3]

[Total: 7]

1. June/2023/Paper_9702/11/No.3

A copper pipe has a true diameter of 42.03 mm.

A builder measures the diameter of the pipe five times using digital calipers. The measurements are shown.

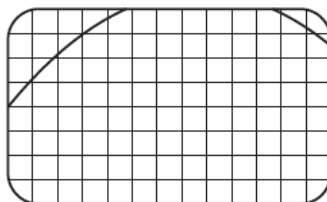
diameter / mm
48.01
47.99
48.01
48.00
47.99

What describes the builder's measurements?

- A** accurate and precise
- B** accurate but not precise
- C** not precise and not accurate
- D** precise but not accurate

2. June/2023/Paper_9702/11/No.20

In an experiment, a student uses a microphone and a cathode-ray oscilloscope (CRO) to analyse a sound wave. The diagram shows the trace on the screen of the CRO.



The student is expecting a sinusoidal waveform to be shown on the screen.

Which changes should the student make to the time-base and the y-gain of the CRO so that the screen shows a continuous trace for one complete cycle of the waveform?

	time-base	y-gain
A	decrease	decrease
B	decrease	increase
C	increase	decrease
D	increase	increase

3. June/2023/Paper_9702/12/No.3

Two measurements for a solid sphere are shown.

$$\text{mass} = (32.5 \pm 0.1)\text{g}$$

$$\text{diameter} = (1.87 \pm 0.04)\text{cm}$$

These values are used to determine the density of the sphere.

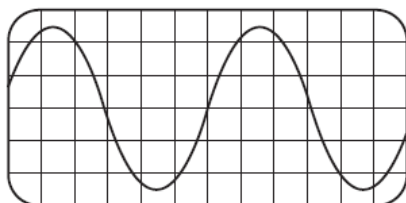
What is the percentage uncertainty in the density?

- A** 2.4% **B** 4.6% **C** 6.1% **D** 6.7%

4. June/2023/Paper_9702/12/No.20

A microphone detects a sound wave. The microphone is connected to a cathode-ray oscilloscope (CRO).

The shape of the trace on the screen of the CRO is shown.



Which property of the sound wave can be determined by using only the measurement of a horizontal distance on the screen and the value of a control setting of the CRO?

- A** amplitude
B frequency
C speed
D wavelength

5. June/2023/Paper_9702/13/No.3

What is the ohm expressed in SI base units?

- A** $\text{kg m}^2 \text{s}^{-3} \text{A}^{-2}$ **B** $\text{kg}^{-1} \text{m}^{-2} \text{s}^3 \text{A}^2$ **C** $\text{J C}^{-1} \text{A}^{-1}$ **D** W A^{-2}

6. June/2023/Paper_9702/22/No.1(c)

- (c) An experiment is performed to determine the value of k by measuring the values of the other quantities in the equation in (b).

The values of L and R each have a percentage uncertainty of 2%.

State and explain, quantitatively, which of these two quantities contributes more to the percentage uncertainty in the calculated value of k .

.....

.....

..... [1]

7. March/2023/Paper_9702/12/No.3

A hollow cylinder, which is open at both ends, has a radius of $(3.0 \pm 0.1)\text{cm}$ and a length of $(15.0 \pm 0.1)\text{cm}$.

What is the value, with its absolute uncertainty, of the surface area of the cylinder?

- A $(280 \pm 10)\text{cm}^2$
- B $(282.7 \pm 0.2)\text{cm}^2$
- C $(420 \pm 30)\text{cm}^2$
- D $(424.1 \pm 0.3)\text{cm}^2$

- (c) An experiment is performed to determine the acceleration of the car in (b). The following measurements are obtained:

$$s = 3.89 \text{ m} \pm 0.5\%$$

$$v = 2.75 \text{ ms}^{-1} \pm 0.8\%$$

- (i) Calculate the acceleration a of the car.

$$a = \dots\dots\dots \text{ ms}^{-2} \quad [1]$$

- (ii) Determine the percentage uncertainty, to two significant figures, in a .

$$\text{percentage uncertainty} = \dots\dots\dots \% \quad [2]$$

- (iii) Use your answers in (c)(i) and (c)(ii) to determine the absolute uncertainty in the calculated value of a .

$$\text{absolute uncertainty} = \dots\dots\dots \text{ ms}^{-2} \quad [1]$$