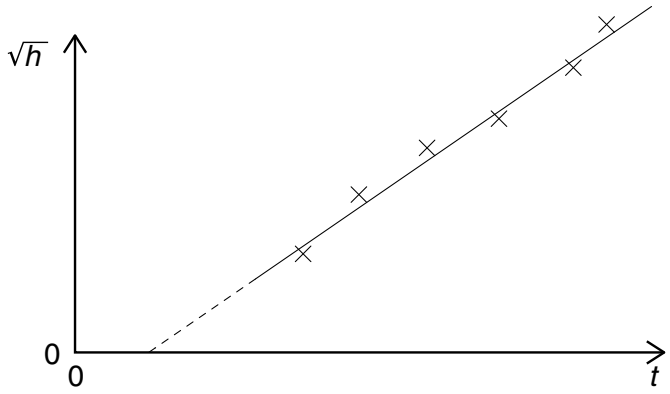
4 A student measures the time t for a ball to fall from rest through a vertical distance h. Knowing that the equation $h = \frac{1}{2} gt^2$ applies, the student plots the graph shown. 9702/1/M/J/02



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/m s^{-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

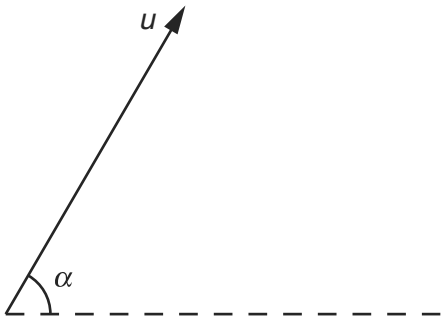
D timing a large number of oscillations to find a period

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 ±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



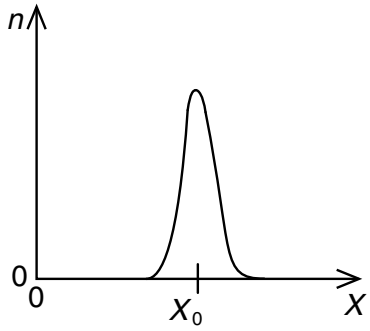
What will be the vertical and horizontal components of its velocity after a time t?
Assume that air resistance is negligible. The acceleration of free fall is g.

	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	$u \cos \alpha$	$u \sin \alpha - gt$

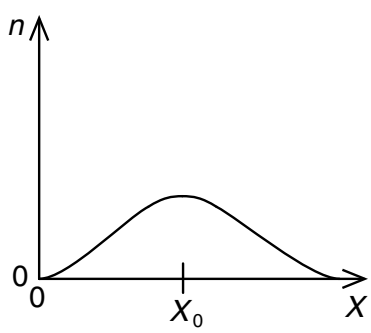
6 A quantity X is measured many times. A graph is plotted showing the number n of times a particular value of X is obtained. X has a true value X_0. 9702/1/O/N/02

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

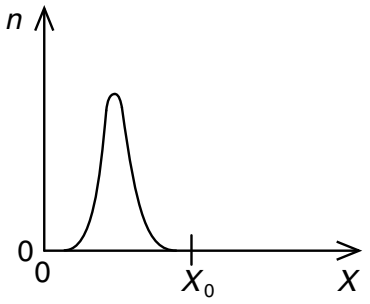
A



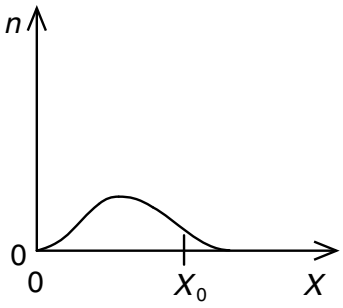
B



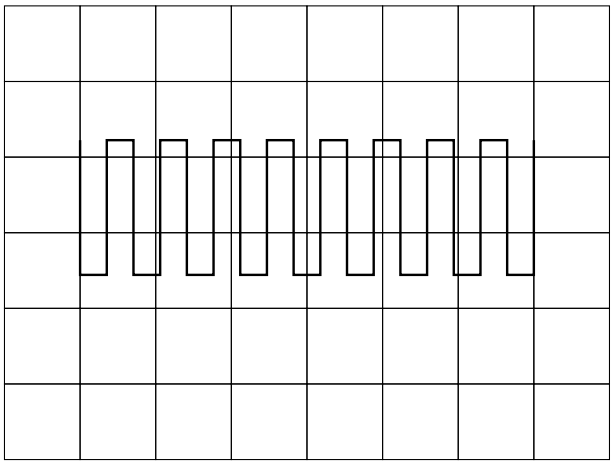
C



D



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}. 9702/1/O/N/02



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?

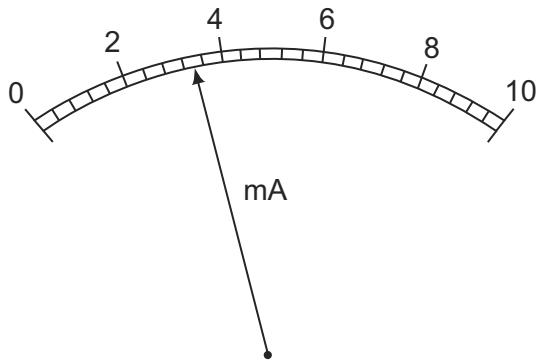
	results are accurate to within 1 mm	results are precise to within 1 mm
A	no	no
B	no	yes
C	yes	no
D	yes	yes

4 A thermometer can be read to an accuracy of ± 0.5 °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? 9702/01/M/J/04



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 ± 0.05 s to travel 40.0 ± 0.1 m. 9702/01/M/J/05

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

A 16 ± 1 m s^{-1}

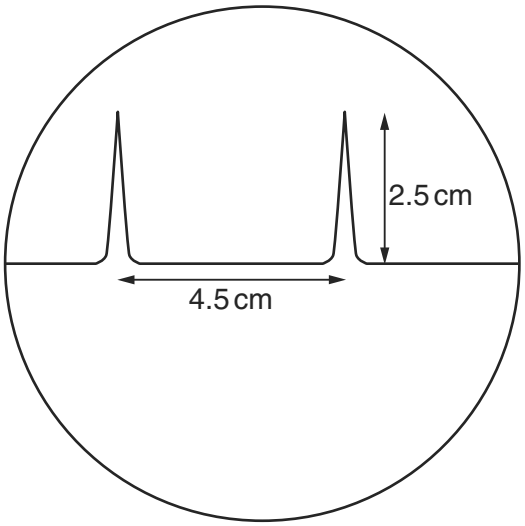
B 16.0 ± 0.2 m s^{-1}

C 16.0 ± 0.4 m s^{-1}

D 16.00 ± 0.36 m s^{-1}

5 The time-base on a cathode-ray oscilloscope is set at 6 ms / cm. 9702/01/O/N/03

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.

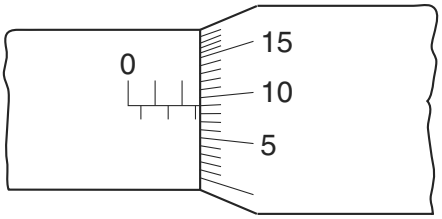


diagram 1

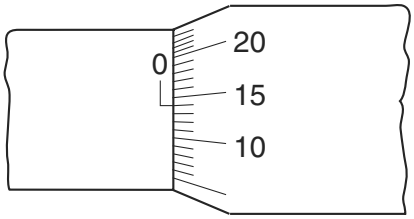


diagram 2

What is the diameter of the wire?

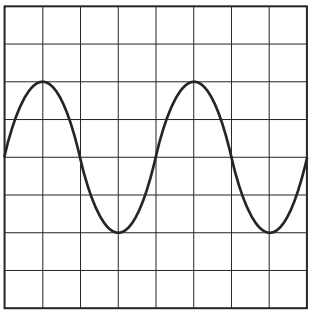
A 1.90 mm **B** 2.45 mm **C** 2.59 mm **D** 2.73 mm

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 %

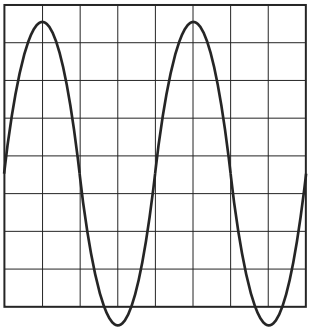
5 The following trace is seen on the screen of a cathode-ray oscilloscope. 9702/01/M/J/04



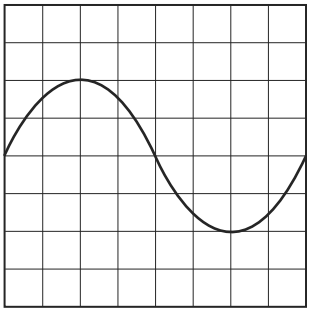
The setting of the time base is then changed from 10 ms cm^{-1} to 20 ms cm^{-1} and the Y-sensitivity is unaltered.

Which trace is now seen on the screen?

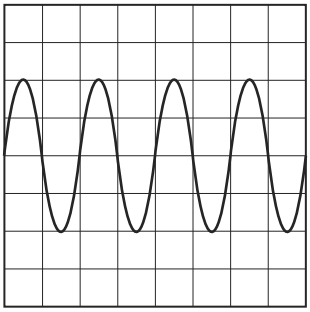
A



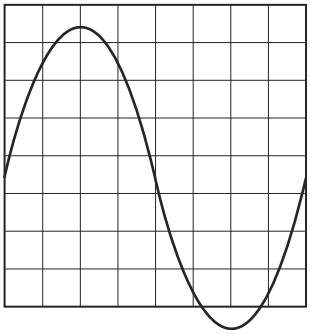
B



C



D

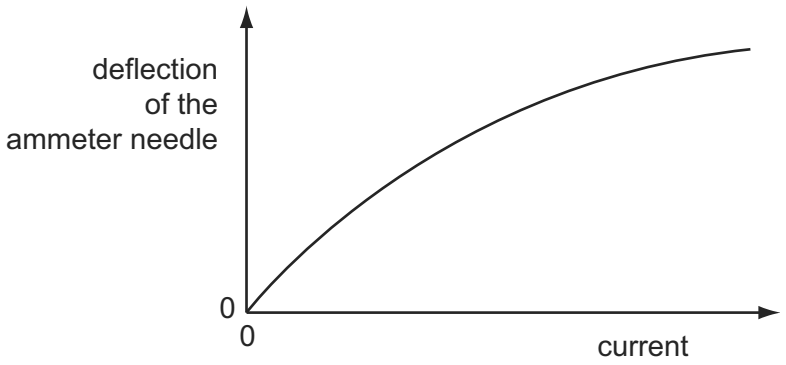


6 Four students each made a series of measurements of the acceleration of free fall *g*. The table shows the results obtained. 9702/01/O/N/04

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

student	results, g / 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?

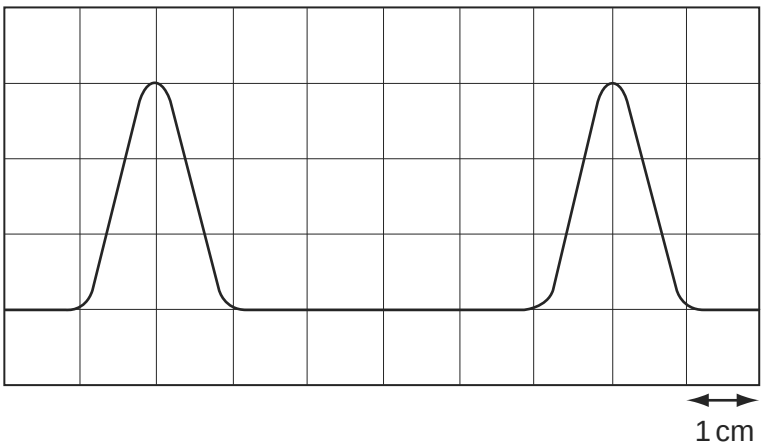
A

B

C

D

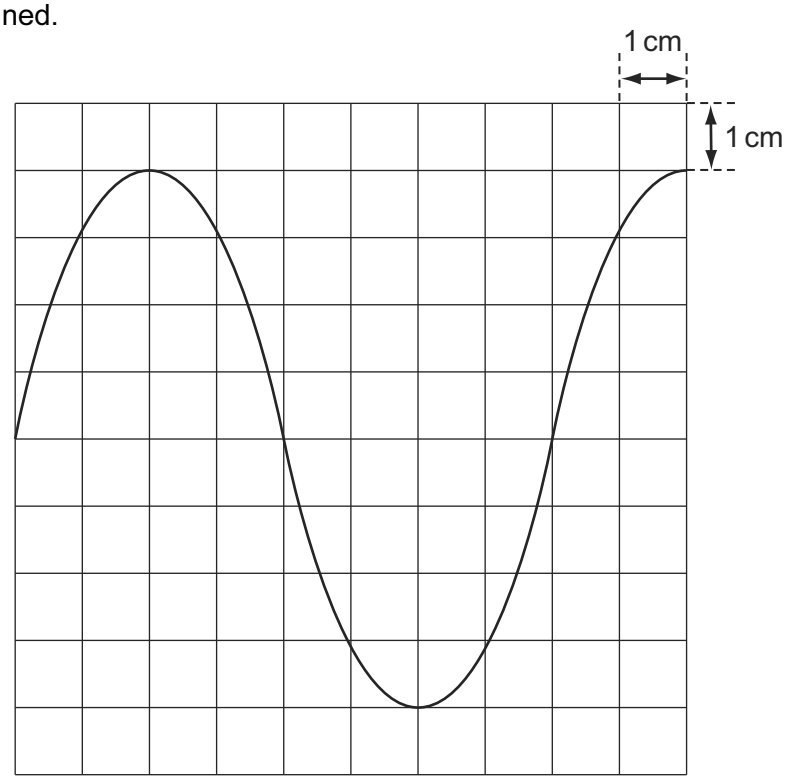
5 The diagram shows two pulses on the screen of a cathode ray oscilloscope. A grid of 1 cm squares covers the screen. The time base setting is 1 μs cm^{-1}. 9702/01/M/J/05



How long does each pulse last?

A 2 μs **B** 3 μs **C** 4 μs **D** 6 μs

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 ± 0.05) mA. The resistor is marked as having a value of 4.7 Ω ± 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 ± 0.1) g
length	=	(5.00 ± 0.01) cm
breadth	=	(2.00 ± 0.01) cm
height	=	(1.00 ± 0.01) cm

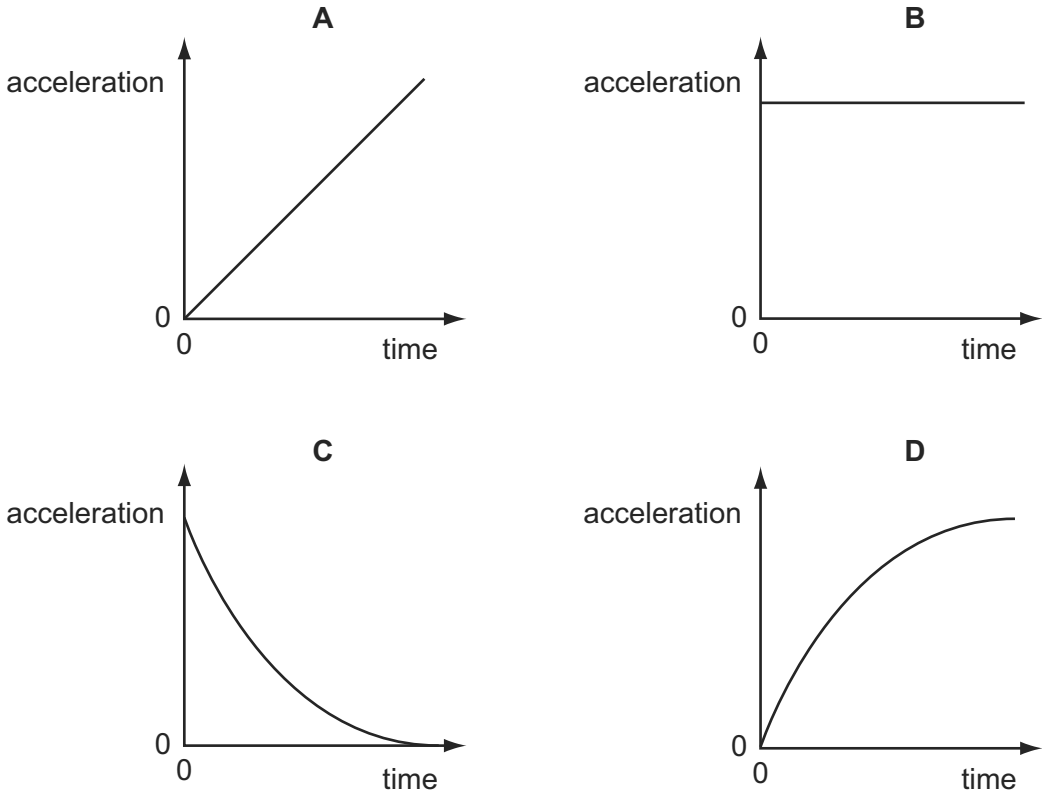
The density is calculated to be 2.50 g cm^{-3}.

What is the uncertainty in this result?

A ± 0.01 g cm^{-3} **B** ± 0.02 g cm^{-3} **C** ± 0.05 g cm^{-3} **D** ± 0.13 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?



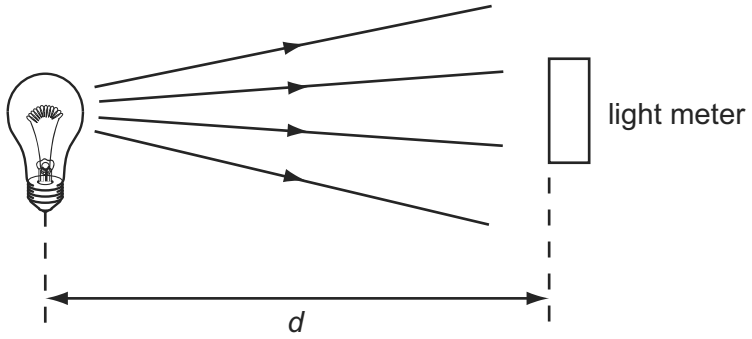
4 A metre rule is used to measure the length of a piece of wire. It is found to be 70 cm long to the nearest millimetre. 9702/12/O/N/10

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

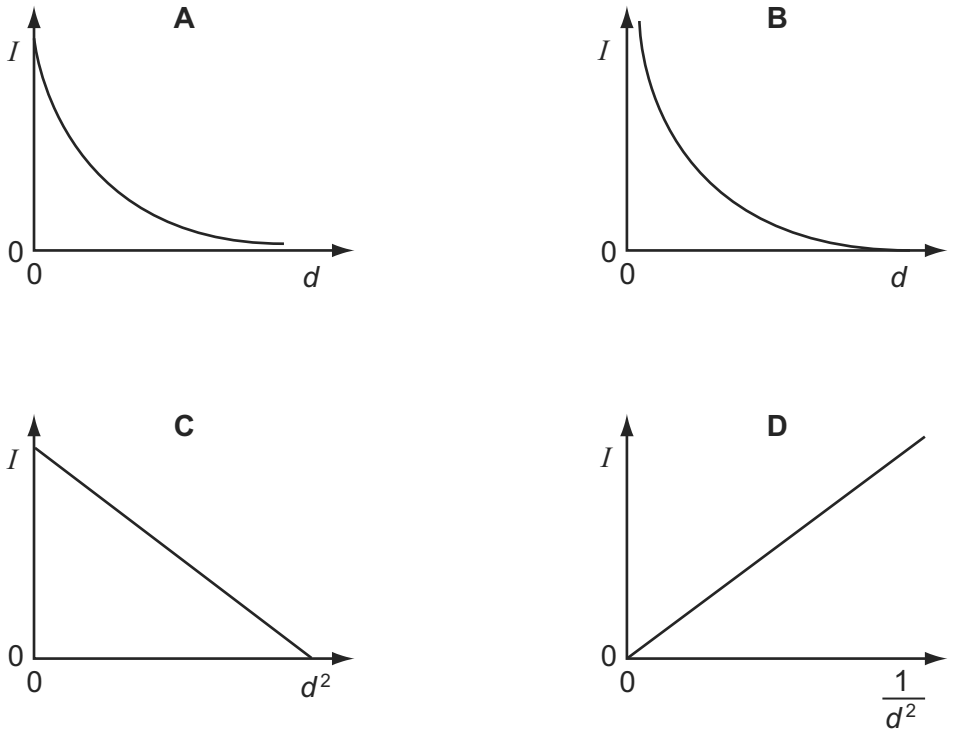
A 0.7 m **B** 0.70 m **C** 0.700 m **D** 0.7000 m

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

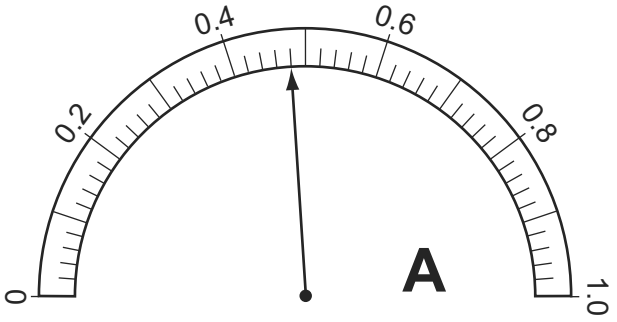


Which graph of the results supports this theory?



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

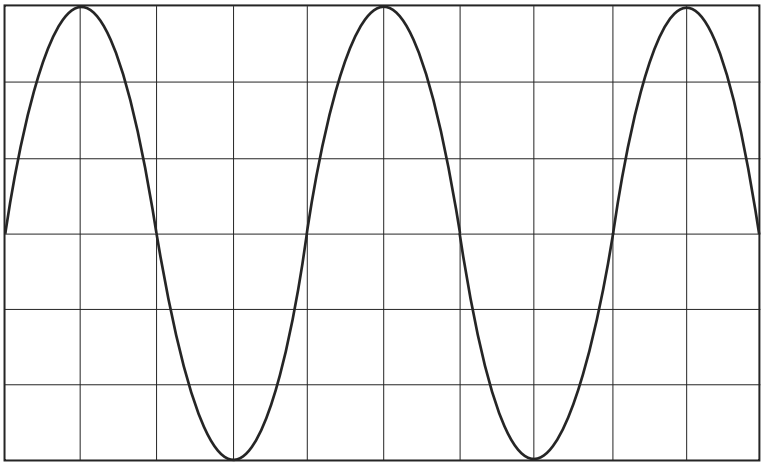
9702/01/M/J/07



What is the resistance?

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

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 / m s^{-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.

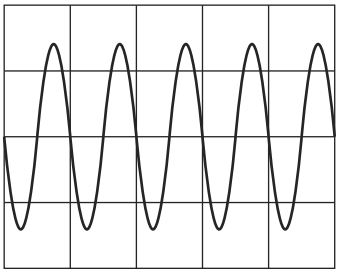
What is the percentage uncertainty in the average power?

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

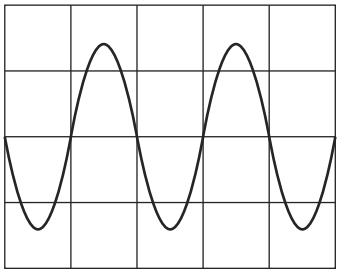
4 The Y-input terminals of a cathode-ray oscilloscope (c.r.o.) are connected to a supply of peak value 5.0 V and of frequency 50 Hz. The time-base is set at 10 ms per division and the Y-gain at 5.0 V per division. 9702/01/O/N/06

Which trace is obtained?

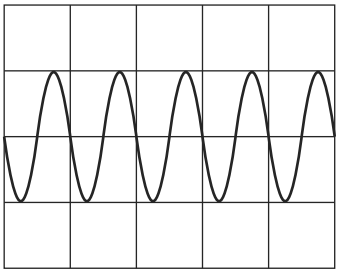
A



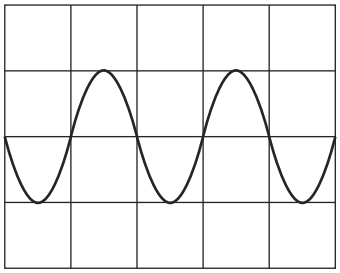
B



C



D



5 The measurement of a physical quantity may be subject to random errors and to systematic errors. 9702/01/O/N/06

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 $(8.0 \pm 0.2)\Omega$

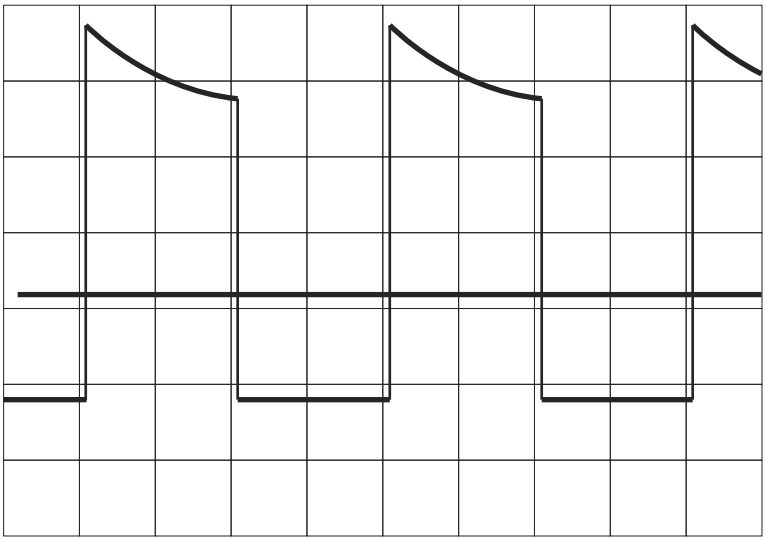
B $(8.0 \pm 0.6)\Omega$

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

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

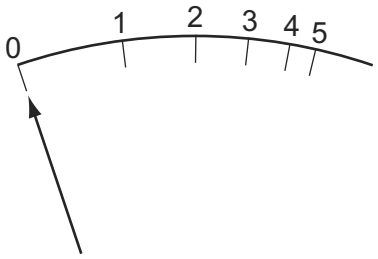
The values measured are $V = 1.00 \pm 0.05$ V and $I = 0.50 \pm 0.01$ A.

What is the percentage uncertainty in the value of R?

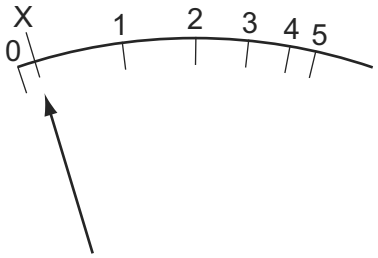
A 2.5 % **B** 3.0 % **C** 7.0 % **D** 10.0 %

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

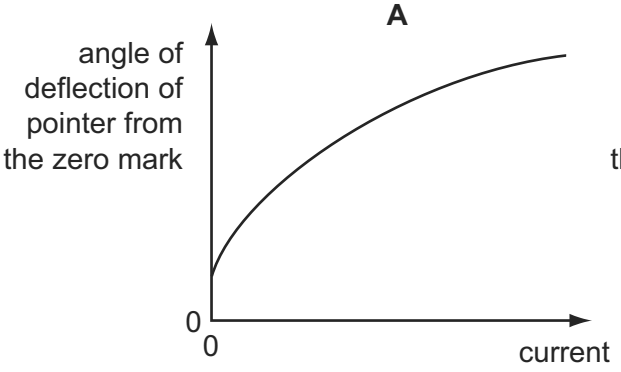


The ammeter is accidentally readjusted so that when the current is zero, the pointer is at X.

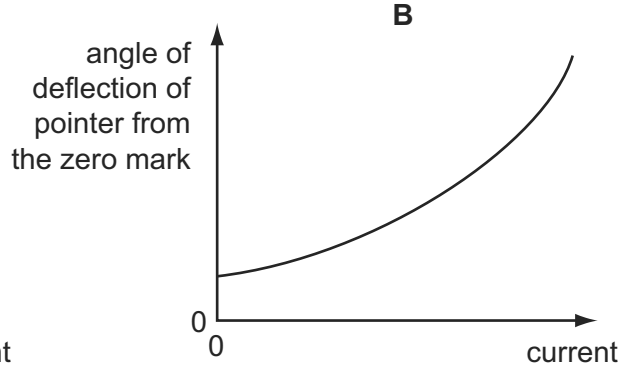


Which calibration graph best represents the response of the readjusted ammeter?

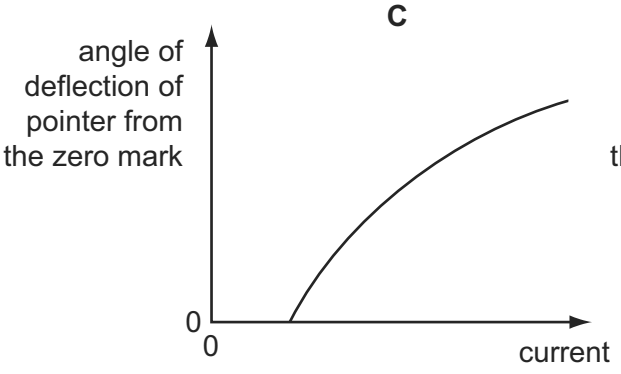
A



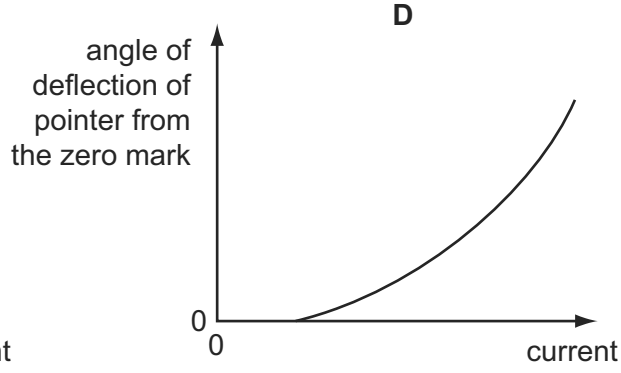
B



C



D



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 / 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 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 ± 1 %.

Which value of current should be quoted by the student?

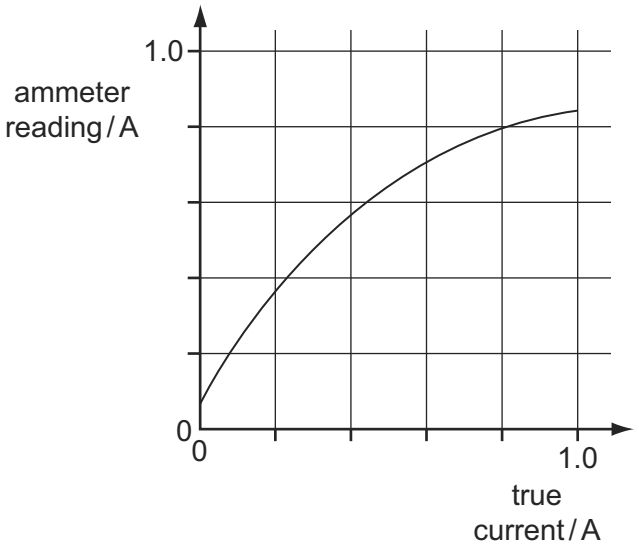
A (2.00 ± 0.01) A

B (2.00 ± 0.02) A

C (2.00 ± 0.03) A

D (2.00 ± 0.04) A

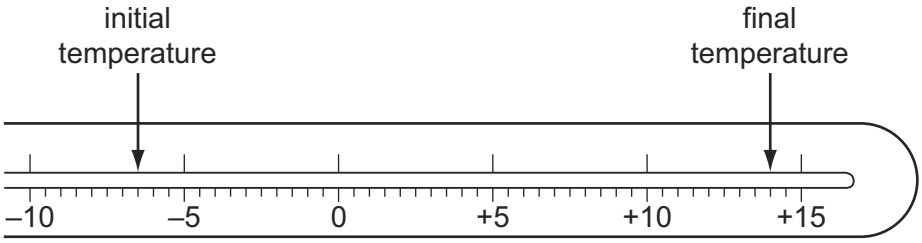
5 A calibration graph is produced for a faulty ammeter. 9702/01/O/N/08



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

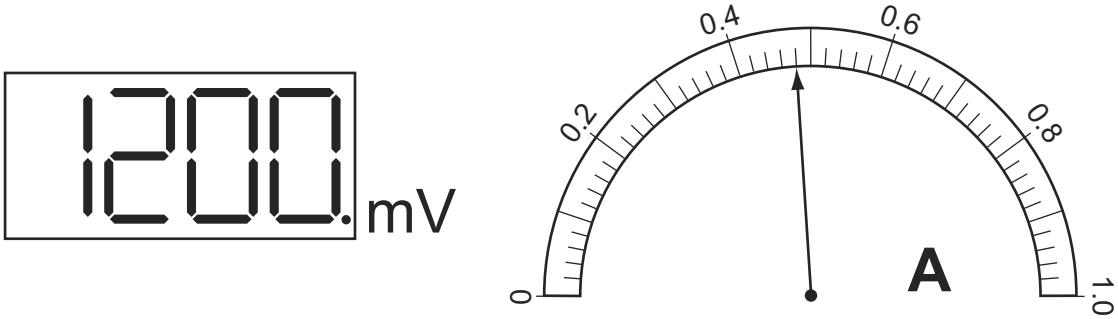
3 The diagram shows the stem of a Celsius thermometer marked to show initial and final temperature values. 9702/01/M/J/09



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

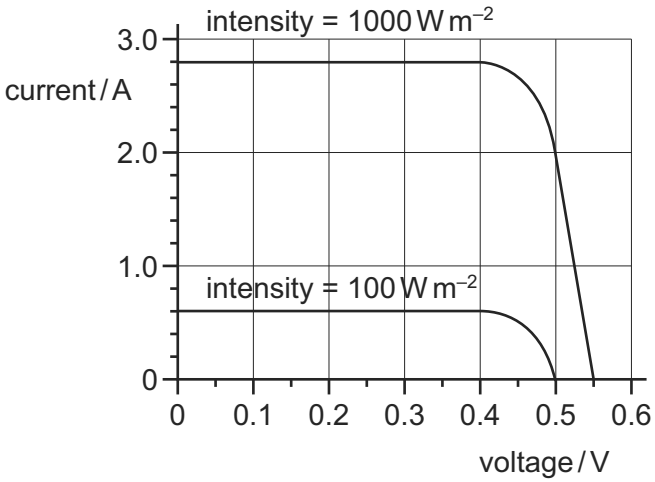
4 The diagrams show digital voltmeter and analogue ammeter readings from a circuit in which electrical heating is occurring. 9702/01/M/J/09



What is the electrical power of the heater?

A 0.53 W **B** 0.58 W **C** 530 W **D** 580 W

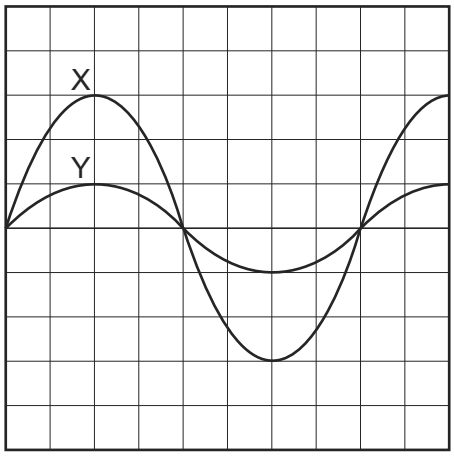
3 The graph shows two current-voltage calibration curves for a solar cell exposed to different light intensities. 9702/11/O/N/09



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. 9702/11/O/N/09

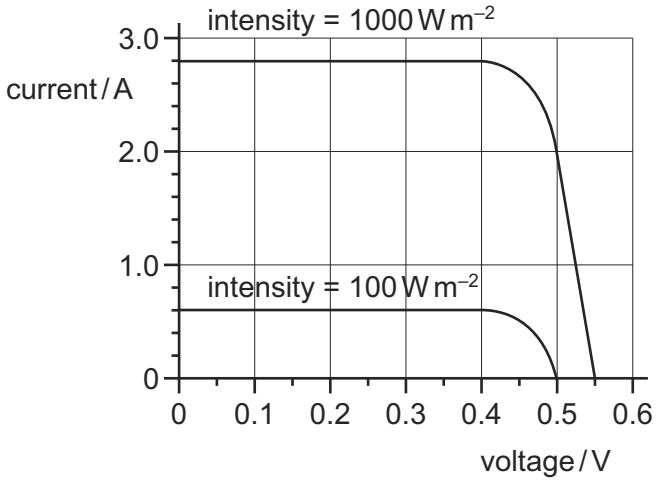


Signal X has a frequency of 50 Hz and peak voltage of 12 V.

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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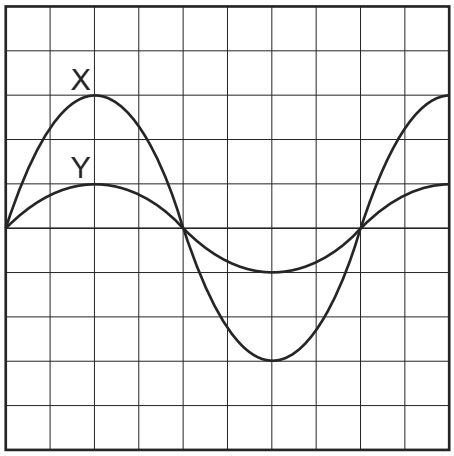
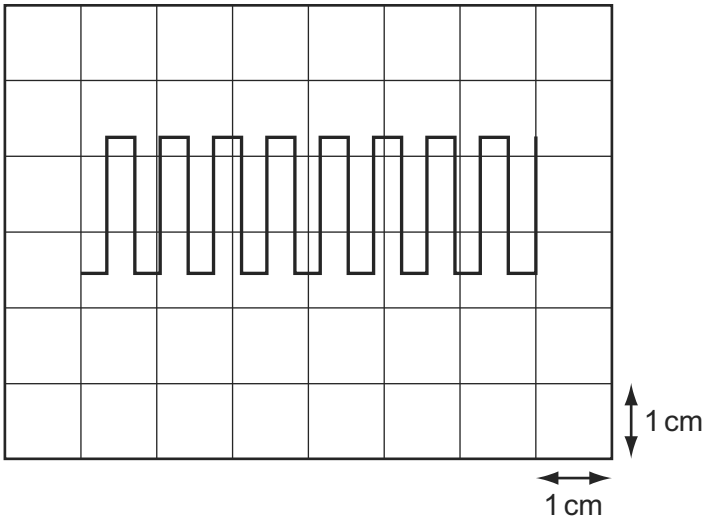


Signal X has a frequency of 50 Hz and peak voltage of 12 V.

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

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

mass of empty beaker = $(20 \pm 1)\,g$

mass of beaker + liquid = $(70 \pm 1)\,g$

volume of liquid = $(10.0 \pm 0.6)\,cm^3$

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** $2.6\,g\,cm^{-3}$

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

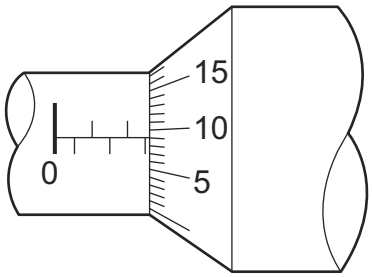


diagram 1

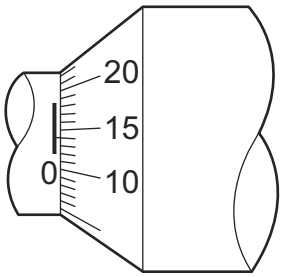


diagram 2

What is the diameter of the wire?

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

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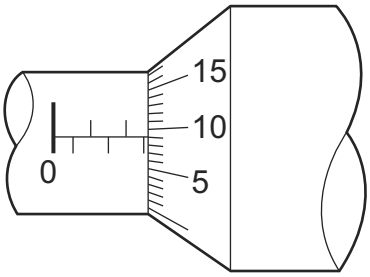
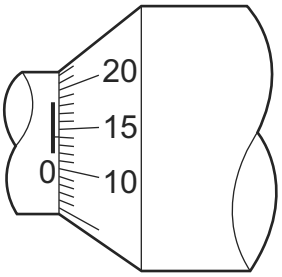


diagram 1



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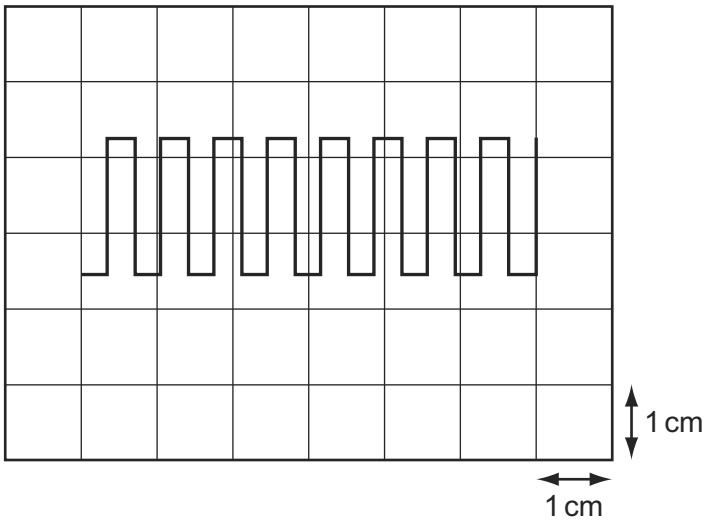

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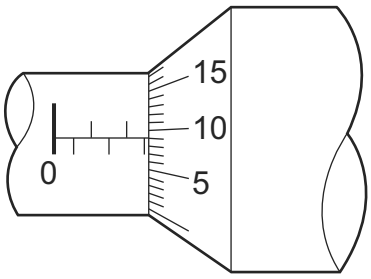

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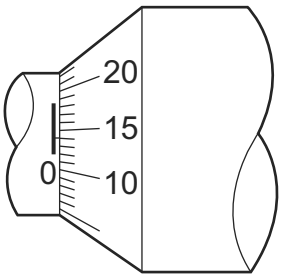

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5 A quantity x is to be determined from the equation 9702/12/O/N/10

$$x = P - Q.$$

P is measured as 1.27 ± 0.02 m.

Q is measured as 0.83 ± 0.01 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

mass of empty beaker = (20 ± 1) g

mass of beaker + liquid = (70 ± 1) g

volume of liquid = (10.0 ± 0.6) 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}

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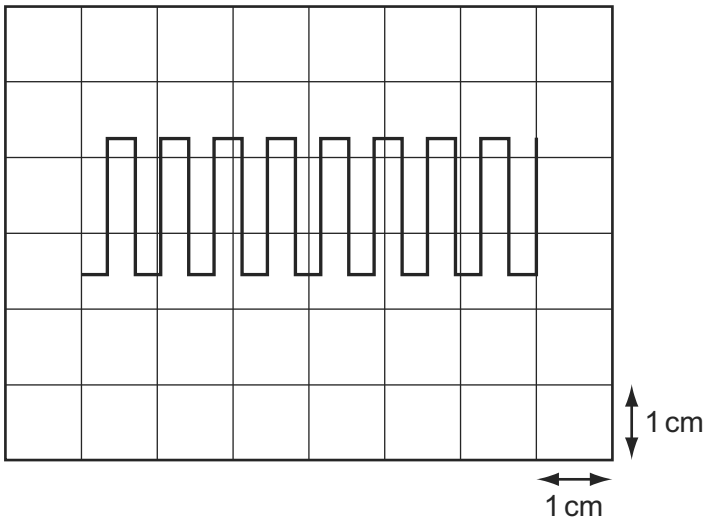

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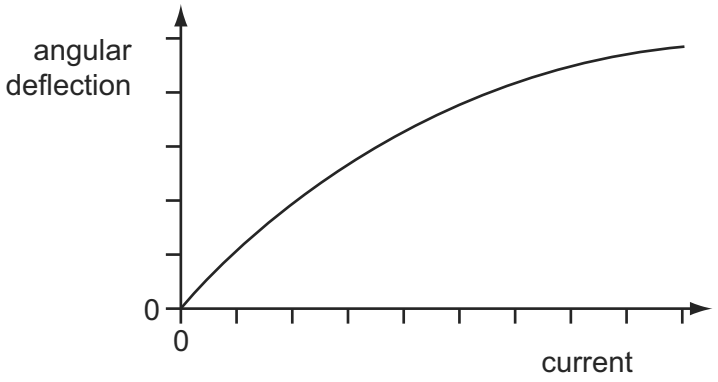
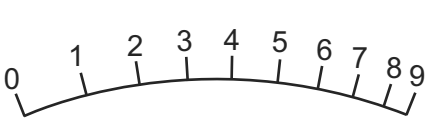
4 The angular deflection of the needle of an ammeter varies with the current passing through the ammeter as shown in the graph. 9702/11/O/N/10



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

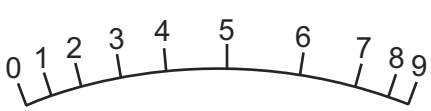
A



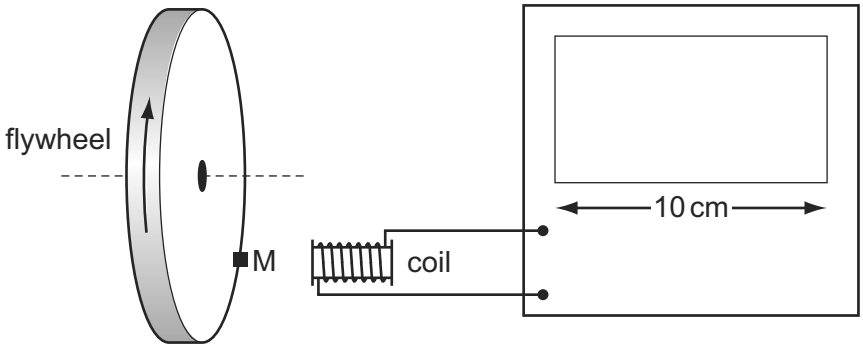
B

C

D



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



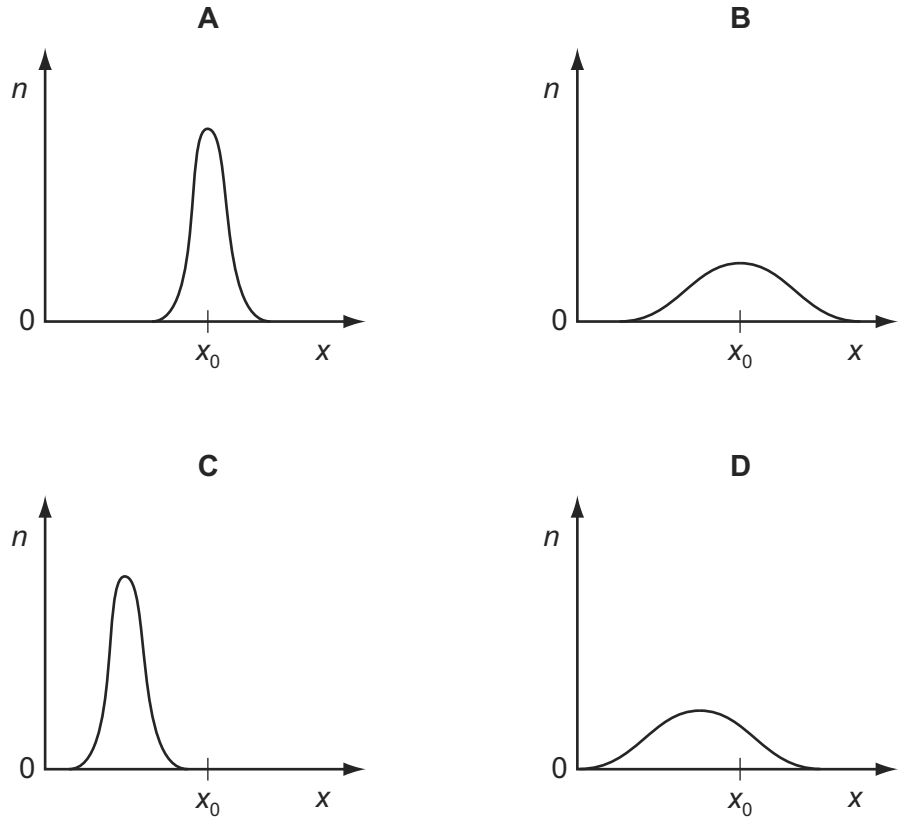
The flywheel has a small magnet M mounted on it. Each time the magnet passes the coil, a voltage pulse is generated, which is passed to the c.r.o. The display of the c.r.o. is 10 cm wide. The flywheel is rotating at a rate of about 3000 revolutions per minute.

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

A $1\,\text{s cm}^{-1}$ **B** $10\,\text{ms cm}^{-1}$ **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?



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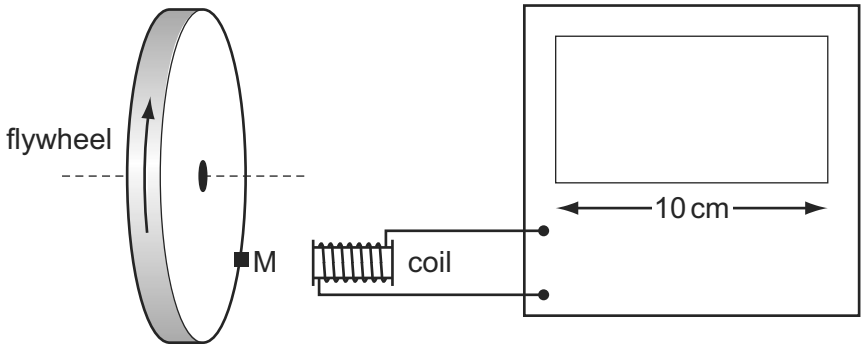

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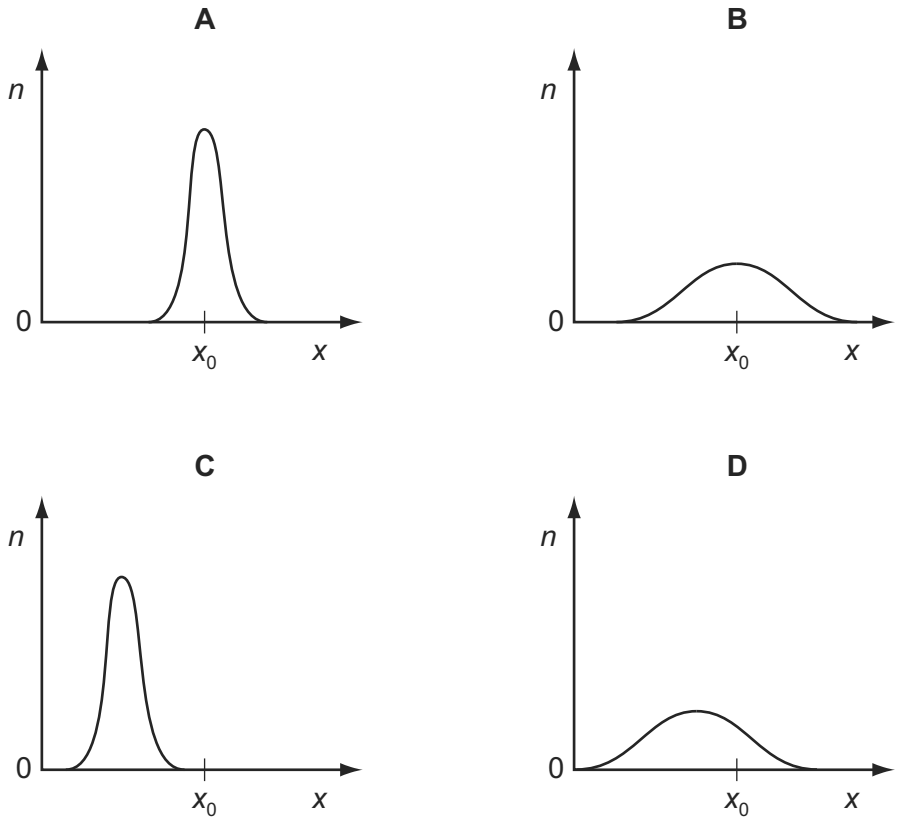


4 The uncertainty in the value of the momentum of a trolley passing between two points X and Y varies with the choice of measuring devices. 9702/12/M/J/11

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

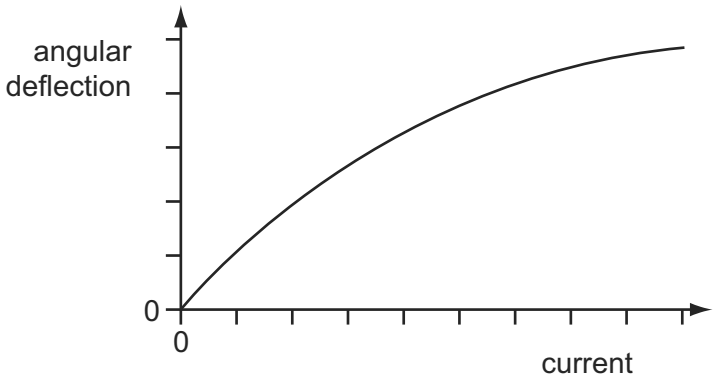
5 mass of trolley using a balance measuring to the nearest g = 6.4×10^{-2} kg

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



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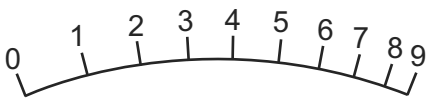
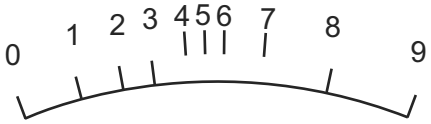


B

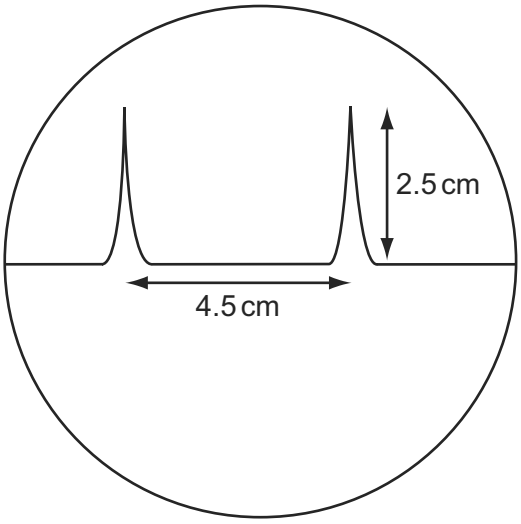
C



D

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.

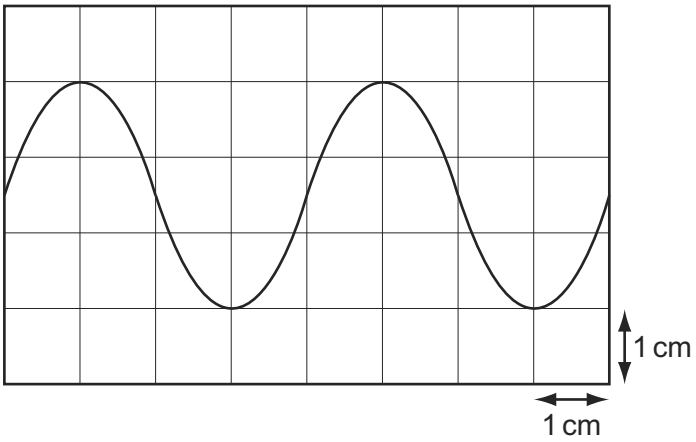


What is the time interval between the two pulses?

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

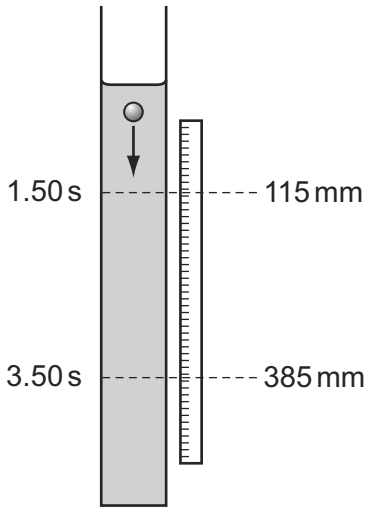
$$L\left(3+\frac{a^2}{P}\right) = QT^2 \sin\theta$$

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	m^2 s^{-2}
B	m^2	m s^{-2}
C	m^2	m^3 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 $\frac{385-115}{3.50-1.50} = \frac{270}{2.00} = 135\,\text{mm}\,\text{s}^{-1}$.

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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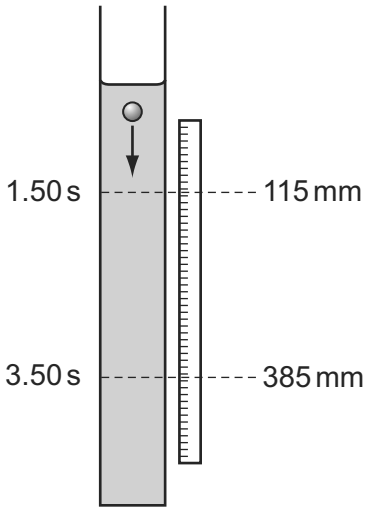

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A $\frac{2}{270} + \frac{0.04}{2.00}$

B $\frac{2}{270} - \frac{0.04}{2.00}$

C $\frac{1}{270} \times \frac{0.02}{2.00}$

D $\frac{1}{270} \div \frac{0.02}{2.00}$

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

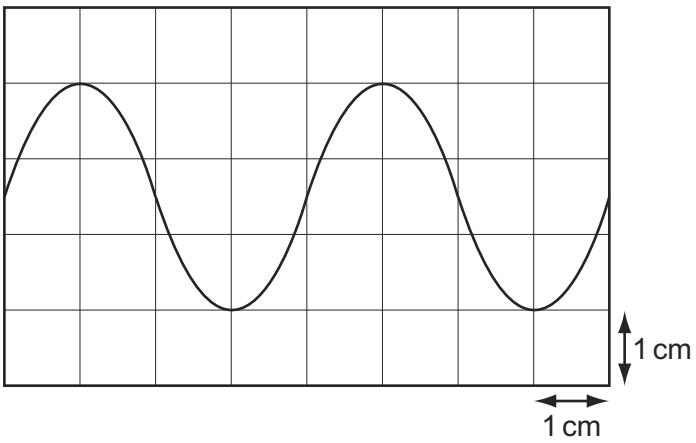
The difference in the diameters is calculated.

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 ± 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

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D	extension of wire with force applied	x	5.2 ± 0.2 mm

5 A cylindrical tube rolling down a slope of inclination θ moves a distance L in time T. The equation relating these quantities is 9702/13/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	$m^2 s^{-2}$
B	m^2	$m s^{-2}$
C	m^2	$m^3 s^{-2}$
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?

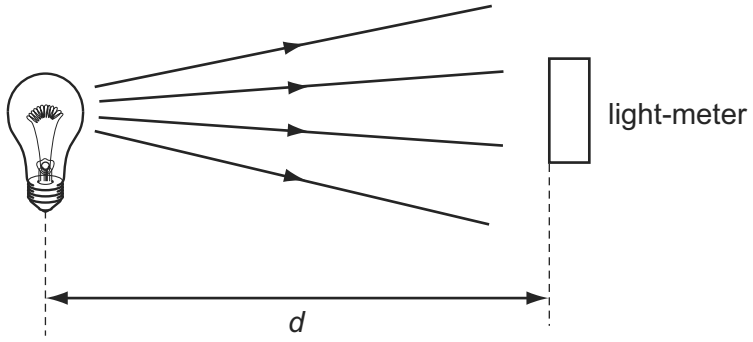
A $16 \pm 1\ m s^{-1}$

B $16.0 \pm 0.2\ m s^{-1}$

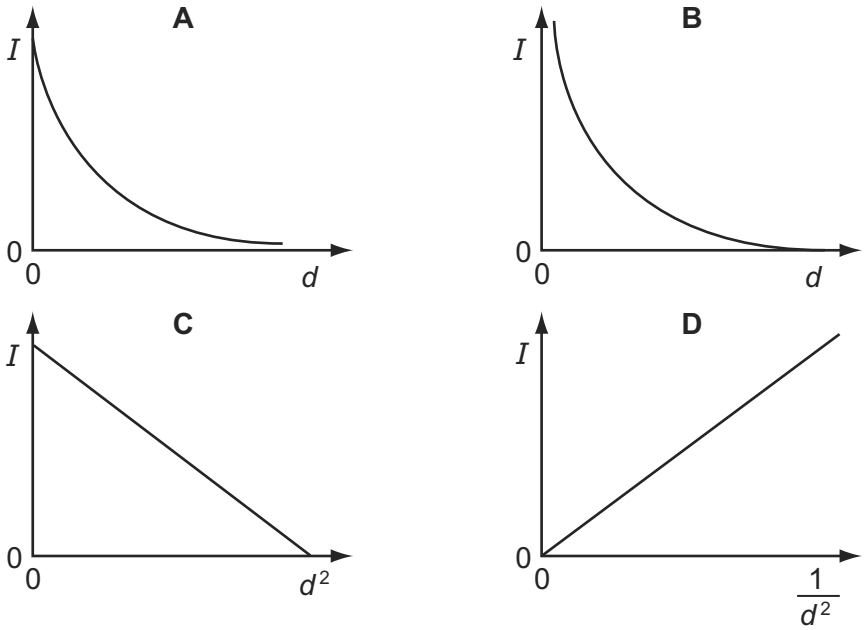
C $16.0 \pm 0.4\ m s^{-1}$

D $16.00 \pm 0.36\ m s^{-1}$

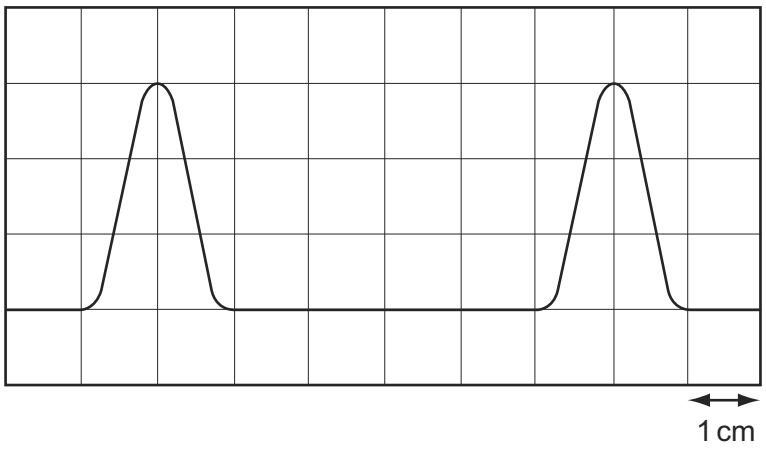
4 A light-meter measures the intensity I of the light falling on it. Theory suggests that I varies inversely as the square of the distance d. 9702/11/M/J/12



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 μs cm^{-1}. 9702/12/M/J/12

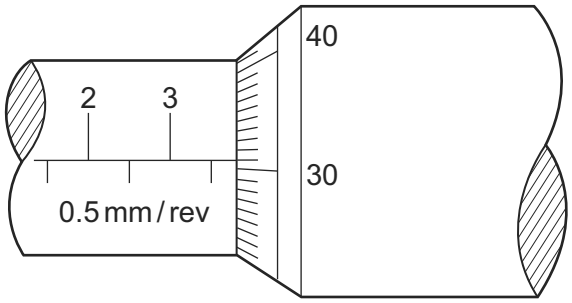


How long does each pulse last?

A 2 μs **B** 3 μs **C** 4 μs **D** 6 μs

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 mm^2 **B** 11.4 mm^2 **C** 22.8 mm^2 **D** 45.6 mm^2

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 m s^{-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?

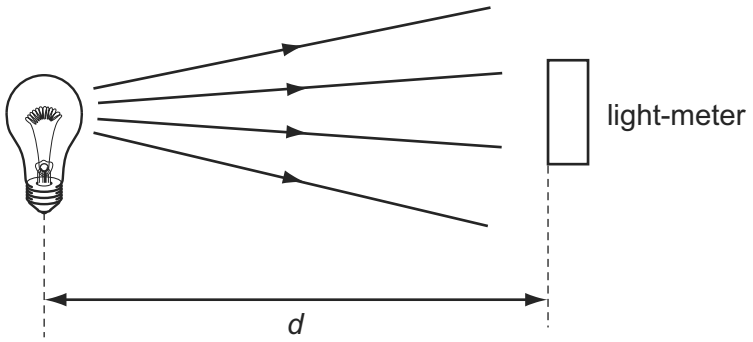
A 16 ± 1 m s^{-1}

B 16.0 ± 0.2 m s^{-1}

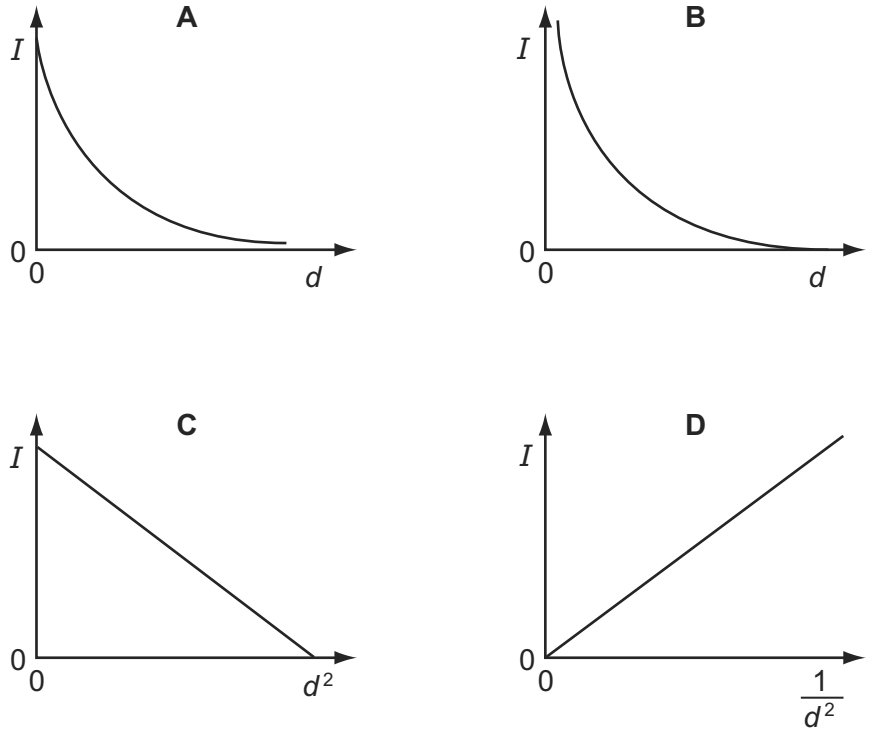
C 16.0 ± 0.4 m s^{-1}

D 16.00 ± 0.36 m s^{-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

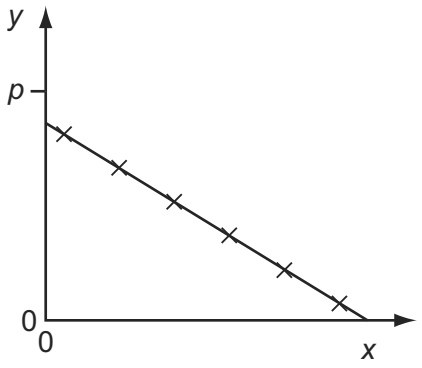
6 Variables x and y are related by the equation $y = p - qx$ where p and q are constants.

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

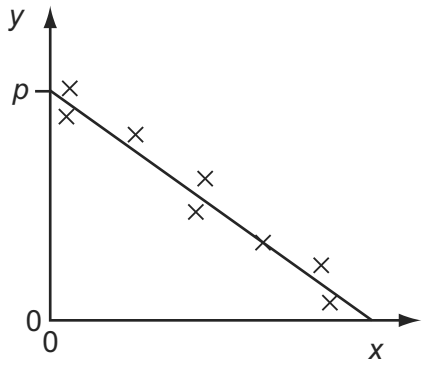
9702/12/O/N/12

Which graph best represents these results?

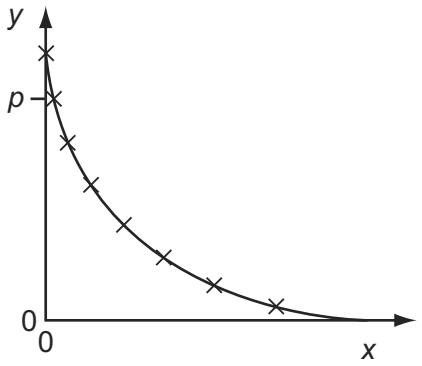
A



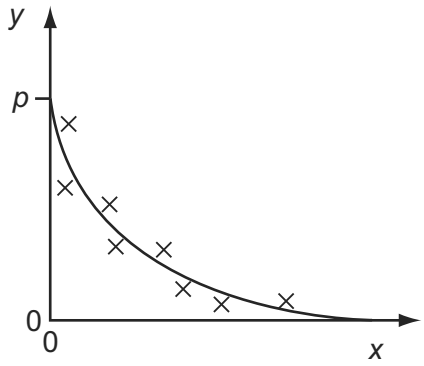
B



C



D



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 ± 0.5 % **B** ± 1 % **C** ± 2 % **D** ± 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. 9702/11/O/N/12

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

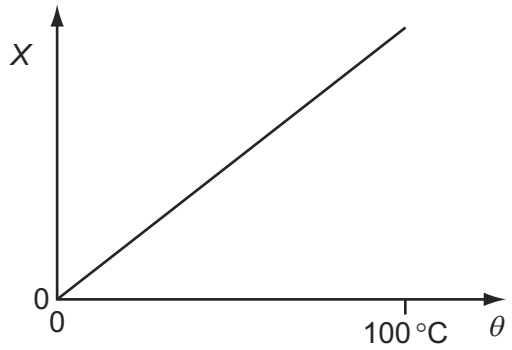
A metre rule, protractor, spring balance

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. 9702/11/O/N/12



θ is determined from the corresponding values of X by using this graph.
X is measured with a percentage uncertainty of ± 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. 9702/11/O/N/12

Which statement is correct?

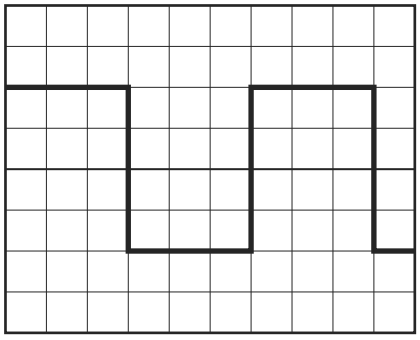
A Random errors can be reduced by taking the average of several measurements.

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. 9702/13/O/N/12



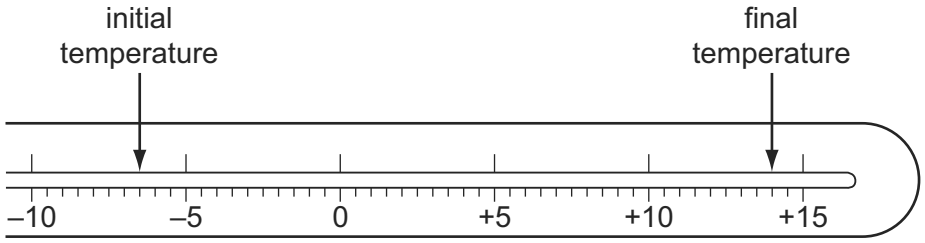
The time-base setting is 0.20 ms per division.

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

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

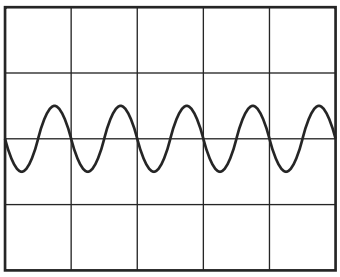
What is the uncertainty in the calculated value for g?

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

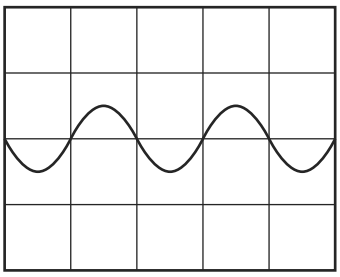
6 The Y-input terminals of a cathode-ray oscilloscope (c.r.o.) are connected to a supply of amplitude 5.0 V and frequency 50 Hz. The time-base is set at 10 ms per division and the Y-gain at 5.0 V per division. 9702/11/M/J/13

Which trace is obtained?

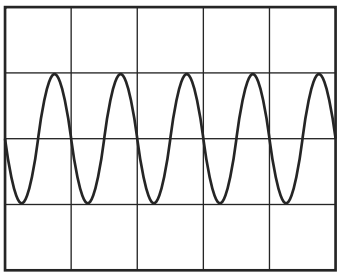
A



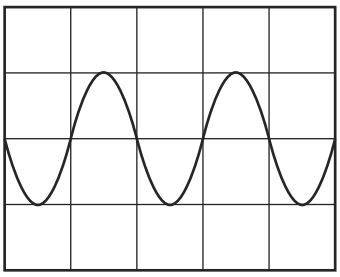
B



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?

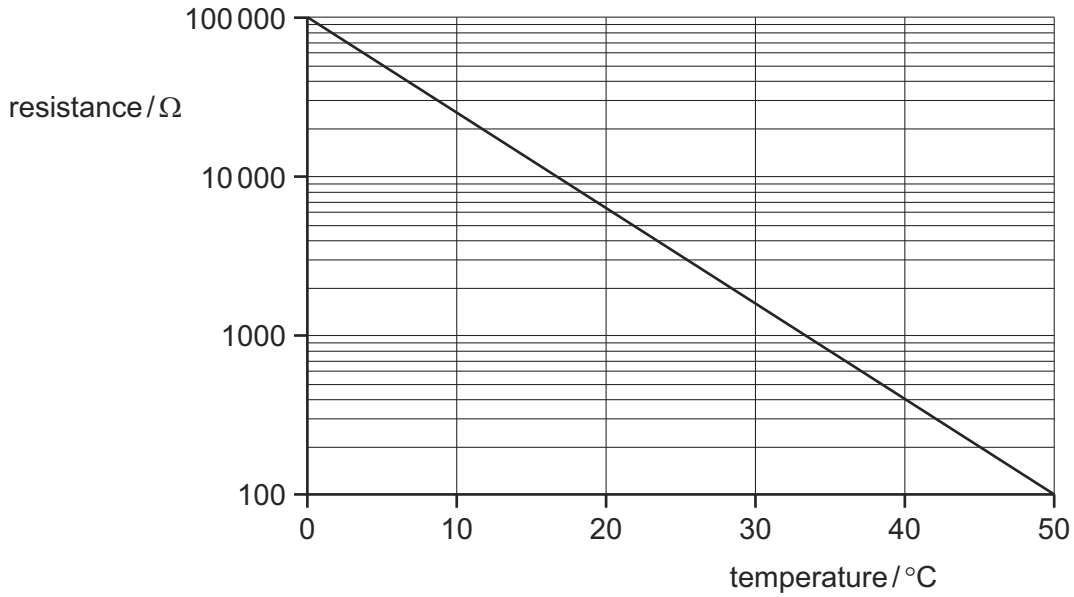
A He has reversed the third and fourth readings in the results table.

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? 9702/13/O/N/12

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

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

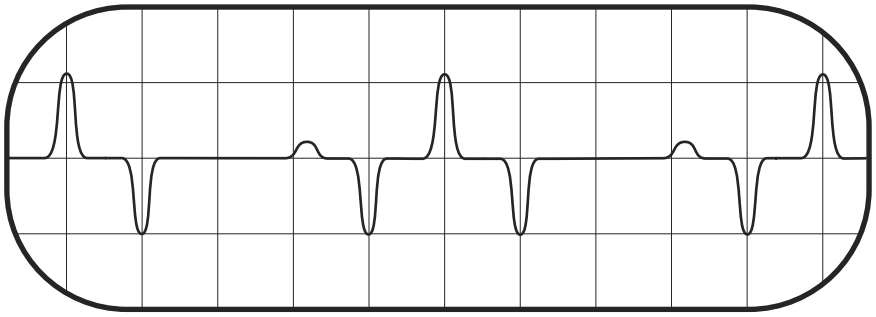
The value of g is determined using the equation

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

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 mm ± 0.01 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

mass = (0.506 ± 0.005) g

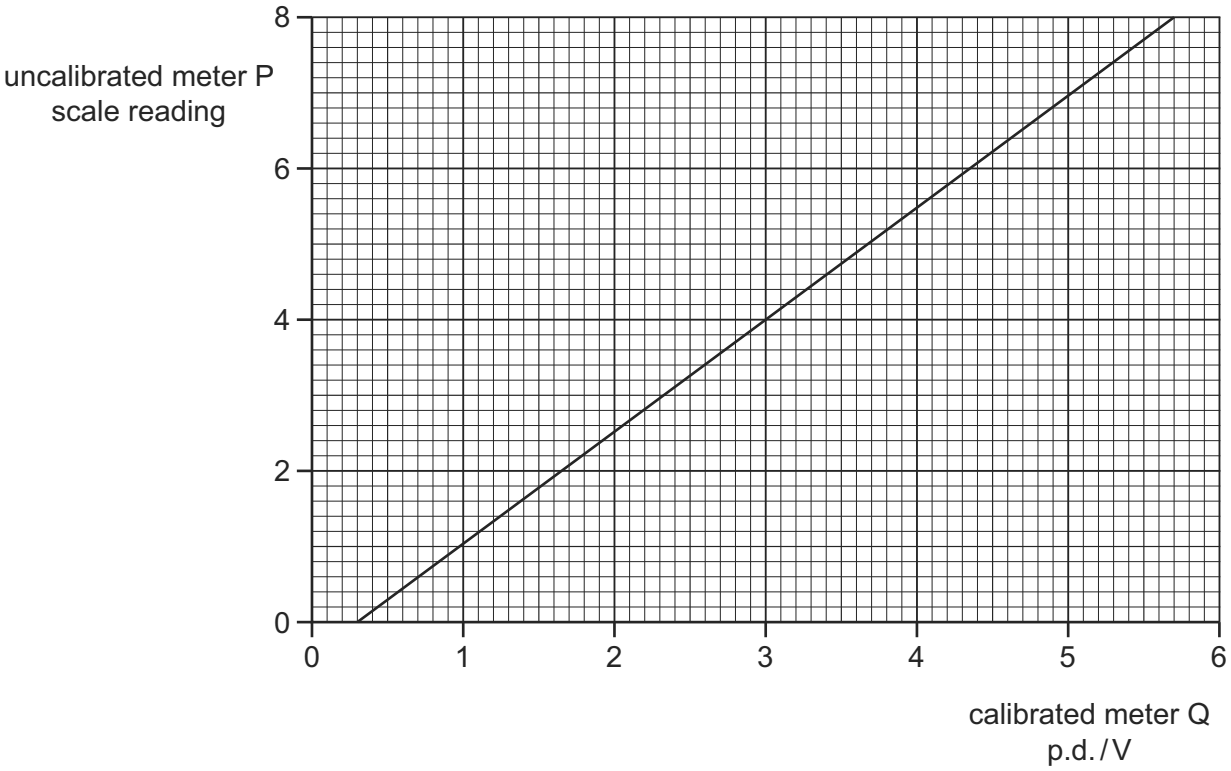
diameter = (2.20 ± 0.02) mm.

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 ± 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 $(8 \pm 2)\,\Omega$

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

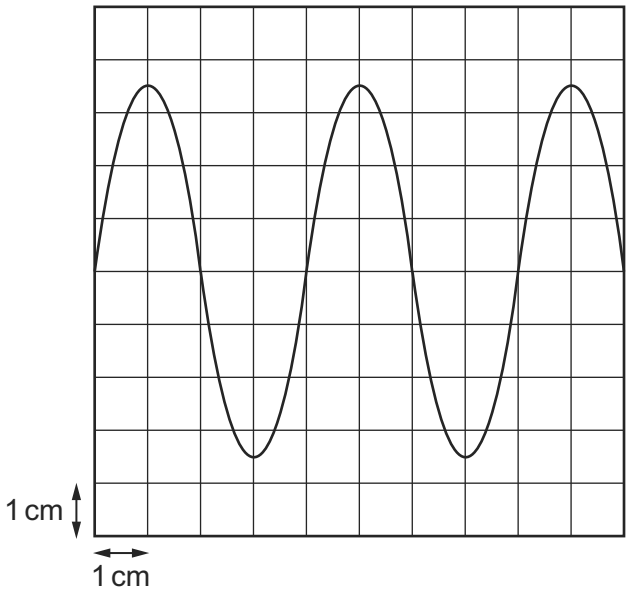
$$E = \frac{4Fl}{\pi d^2 x}$$

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 $0.5\,\text{ms}\,\text{cm}^{-1}$ and the Y-plate sensitivity is $2\,\text{V}\,\text{cm}^{-1}$.

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 ± 0.5 °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?

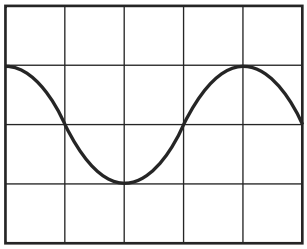
A 0.02850 ± 0.01 m

B 0.0285 ± 0.001 m

C $(2.850 \pm 0.001) \times 10^{-2}$ m

D $(2.850 \pm 0.001) \times 10^{-3}$ 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 2.0×10^{-8} Hz

B 2.5×10^{-2} Hz

C 5.0×10^{7} Hz

D 3.1×10^{8} 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 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	±2%
length of wire	±0.2%
diameter of wire	±1.5%
extension	±1%

What is the percentage uncertainty in the Young modulus?

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

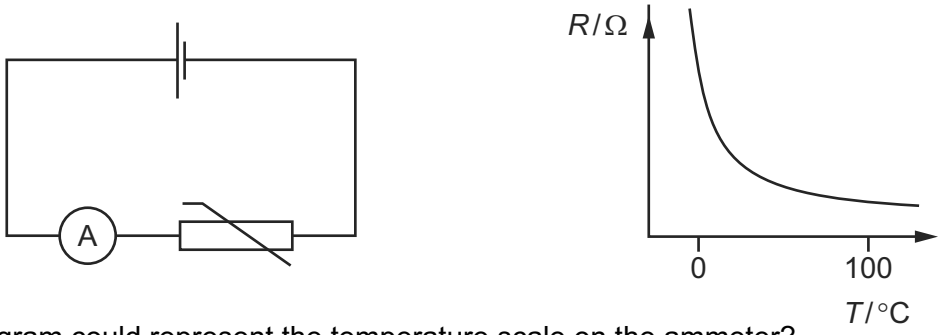
5 The acceleration of free fall on the Moon is one-sixth of that on Earth. 9702/11/O/N/14

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

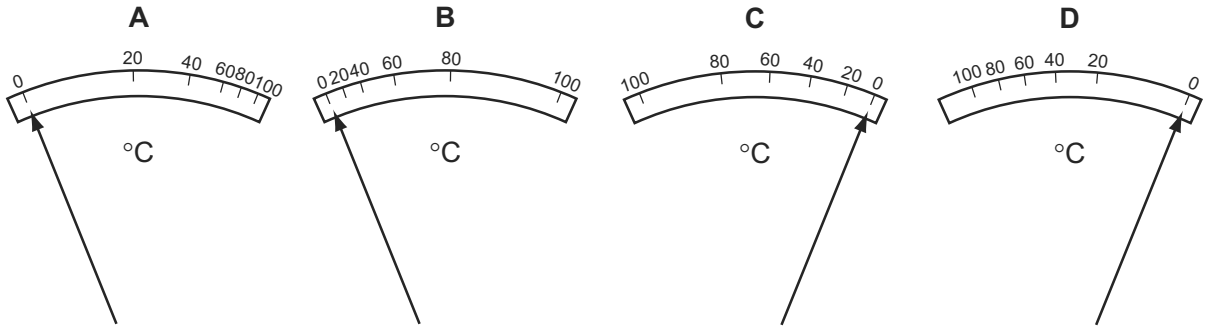
What is the time taken for a stone to fall from rest a distance of 2 m on the Moon?

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

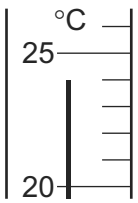
3 In the circuit shown, an analogue ammeter is to be recalibrated as a thermometer. The graph shows how the resistance R of the thermistor changes with temperature T. 9702/13/O/N/14



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 $7.5\,\Omega$.

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 $200\,\text{km h}^{-1}$. The wind blows from the west at a speed of $85.0\,\text{km h}^{-1}$.

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

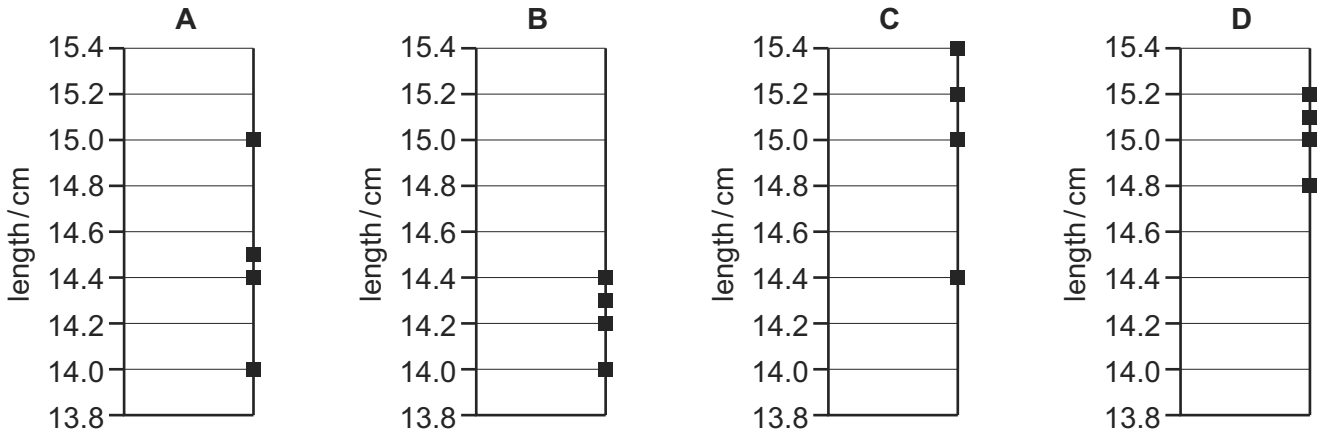
C metre rule and vernier calipers

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 Ω ± 2 %.

9702/13/M/J/15

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

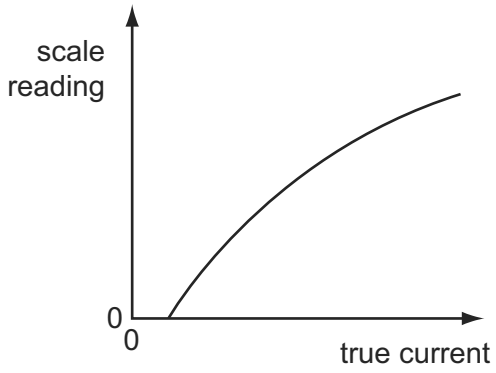
A 2 % **B** 4 % **C** 6 % **D** 8 %

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.

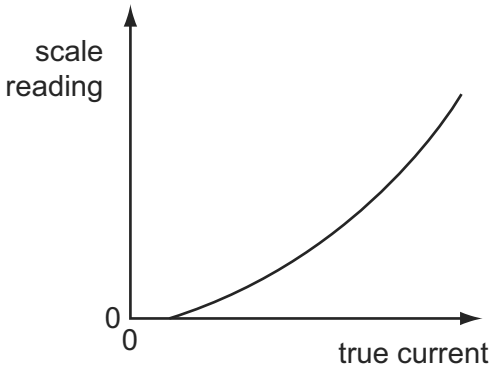
9702/12/M/J/15

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

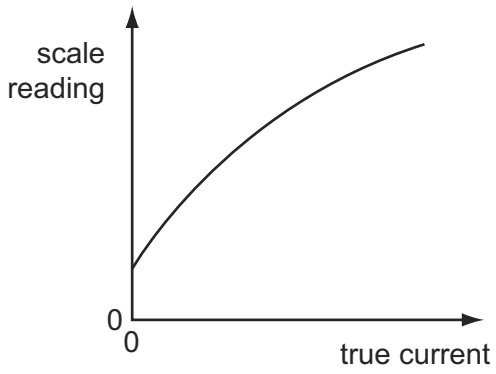
A



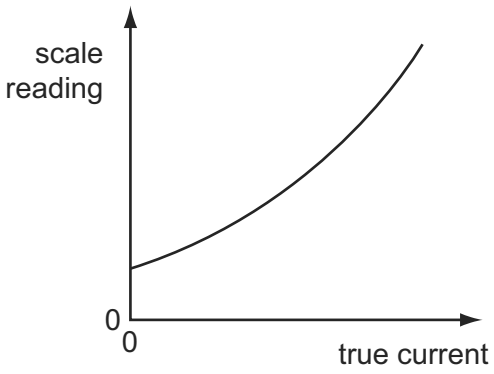
B



C



D



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.

9702/12/M/J/15

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%

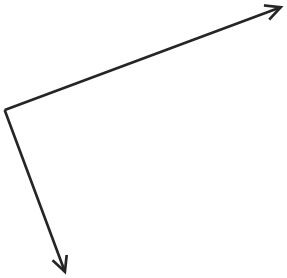
4 The arrow represents the vector R. 9702/12/M/J/15

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

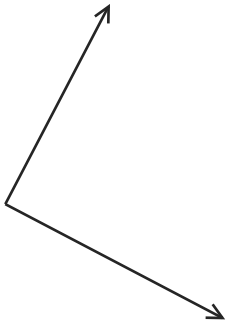
A

B

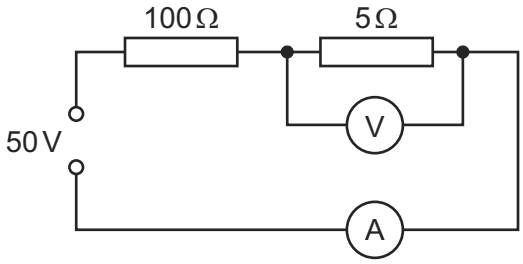
C



D



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 Ω and 5 Ω, as shown. 9702/12/M/J/15



A voltmeter measures the potential difference (p.d.) across the 5 Ω 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

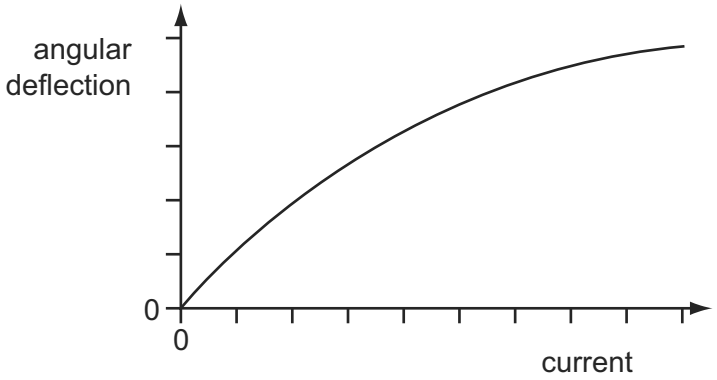
B h measured as being **smaller** than it actually is and t measured as being **larger** than it actually is

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

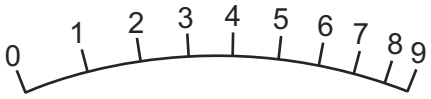
5 The angular deflection of the needle of an ammeter varies with the current in the ammeter as shown in the graph.

9702/11/M/J/15



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

A



B

C

D

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

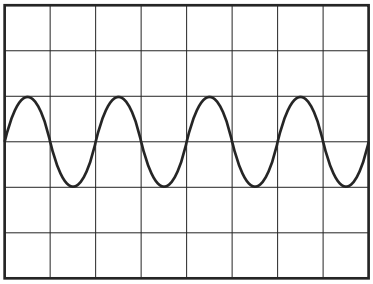
$$W = \tfrac{1}{2}kx^2$$

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 $0.1\,\text{ms div}^{-1}$ **B** $1\,\text{ms div}^{-1}$ **C** $10\,\text{ms div}^{-1}$ **D** $100\,\text{ms div}^{-1}$