

# Uncertainties [49 marks]

1. How many significant figures are there in the number 0.0450?

[1 mark]

- A. 2
- B. 3
- C. 4
- D. 5

## Markscheme

B

2. An object is positioned in a gravitational field. The measurement of gravitational force acting on the object has an uncertainty of 3% [1 mark] and the uncertainty in the mass of the object is 9%. What is the uncertainty in the gravitational field strength of the field?

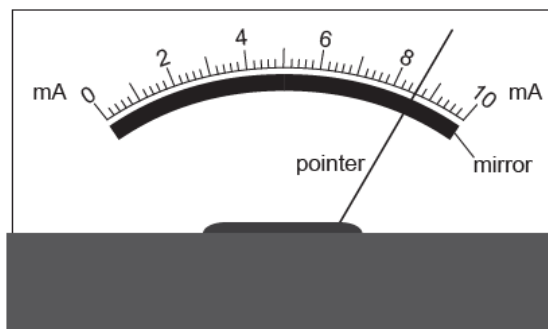
- A. 3%
- B. 6%
- C. 12%
- D. 27%

## Markscheme

C

3. The diagram shows an analogue meter with a mirror behind the pointer.

[1 mark]



What is the main purpose of the mirror?

- A. To provide extra light when reading the scale
- B. To reduce the risk of parallax error when reading the scale
- C. To enable the pointer to be seen from different angles
- D. To magnify the image of the pointer

## Markscheme

B

4. What is a correct value for the charge on an electron?

[1 mark]

- A.  $1.60 \times 10^{-12} \mu\text{C}$
- B.  $1.60 \times 10^{-15} \text{mC}$
- C.  $1.60 \times 10^{-22} \text{kC}$
- D.  $1.60 \times 10^{-24} \text{MC}$

## Markscheme

C

5. What is the unit of electrical energy in fundamental SI units?

[1 mark]

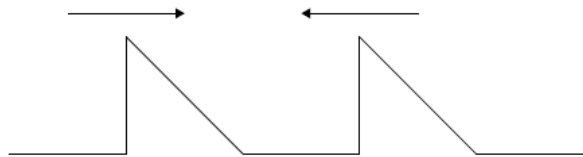
- A.  $\text{kg m}^2 \text{C}^{-1} \text{s}$
- B.  $\text{kg m s}^{-2}$
- C.  $\text{kg m}^2 \text{s}^{-2}$
- D.  $\text{kg m}^2 \text{s}^{-1} \text{A}$

## Markscheme

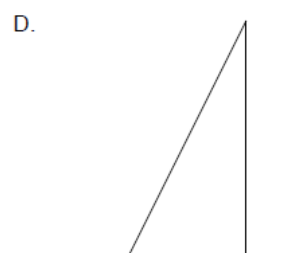
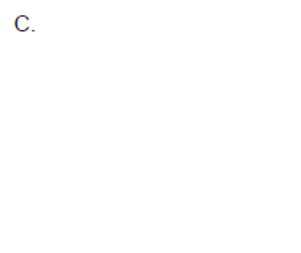
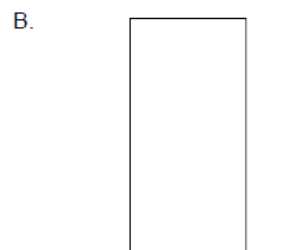
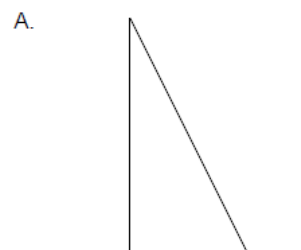
C

6. Two pulses are travelling towards each other.

[1 mark]



What is a possible pulse shape when the pulses overlap?



## Markscheme

A

7. Which of the following is a scalar quantity?

[1 mark]

- A. Velocity
- B. Momentum
- C. Kinetic energy
- D. Acceleration

## Markscheme

C

8. A stone falls from rest to the bottom of a water well of depth  $d$ . The time  $t$  taken to fall is  $2.0 \pm 0.2$  s. The depth of the well is calculated to be 20 m using  $d = \frac{1}{2}at^2$ . The uncertainty in  $a$  is negligible.

[1 mark]

What is the absolute uncertainty in  $d$ ?

- A.  $\pm 0.2$  m
- B.  $\pm 1$  m
- C.  $\pm 2$  m
- D.  $\pm 4$  m

## Markscheme

D

9. Which is a vector quantity?

[1 mark]

- A. Pressure
- B. Electric current
- C. Temperature
- D. Magnetic field

## Markscheme

D

10a. Suggest why it is unlikely that the relation between  $d$  and  $\lambda$  is linear.

[1 mark]

## Markscheme

it is not possible to draw a straight line through all the error bars

**OR**

the line of best-fit is curved/not a straight line

*Treat as neutral any reference to the origin.*

*Allow "linear" for "straight line".*

[1 mark]

10b. fractional uncertainty in  $d$ .

[2 marks]

## Markscheme

$d = 0.35 \pm 0.01$  **AND**  $\Delta d = 0.05 \pm 0.01$  «cm»

$$\left\langle \frac{\Delta d}{d} = \frac{0.5}{0.35} \right\rangle = 0.14$$

**OR**

$$\frac{1}{7} \text{ or } 14\% \text{ or } 0.1$$

Allow final answers in the range of 0.11 to 0.18.

Allow **[1 max]** for 0.03 to 0.04 if

$\lambda = 5 \times 10^6$  m is used.

**[2 marks]**

10c. percentage uncertainty in  $d^2$ .

[1 mark]

## Markscheme

28 to 30%

Allow ECF from (b)(i), but only accept answer as a %

**[1 mark]**

10d. State the fundamental SI unit of the constant  $a$  and of the constant  $b$ .

[2 marks]

$a$ : .....

$b$ : .....

## Markscheme

$a$ :  $\text{m}^2$

$b$ : m

Allow answers in words

**[2 marks]**

10e. Determine the distance travelled inside the conductor by very high frequency electromagnetic waves.

[2 marks]

## Markscheme

**ALTERNATIVE 1** – if graph on page 4 is used

$$d^2 = 0.040 \times 10^{-4} \text{ «m}^2\text{»}$$

$$d = 0.20 \times 10^{-2} \text{ «m»}$$

**ALTERNATIVE 2** – if graph on page 2 is used

any evidence that  $d$  intercept has been determined

$$d = 0.20 \pm 0.05 \text{ «cm»}$$

For MP1 accept answers in range of 0.020 to 0.060 «cm<sup>2</sup>» if they fail to use given value of “a”.

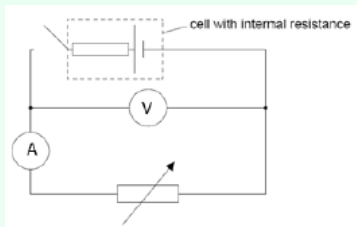
For MP2 accept answers in range 0.14 to 0.25 «cm» .

[2 marks]

- 11a. An ammeter and a voltmeter are connected in the circuit. Label the ammeter with the letter A and the voltmeter with the letter V. [1 mark]

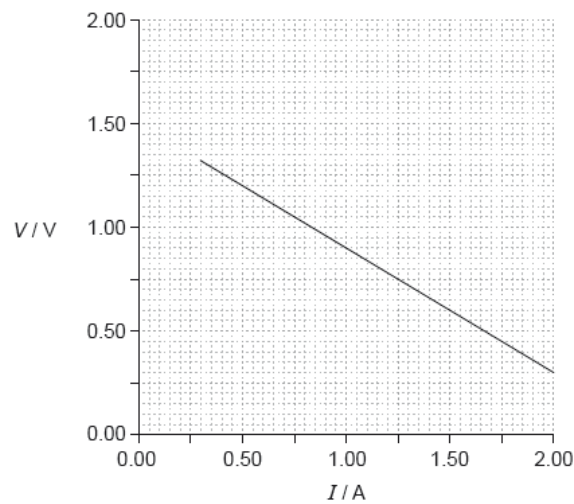
## Markscheme

correct labelling of both instruments



[1 mark]

- 11b. In one experiment a student obtains the following graph showing the variation with current  $I$  of the potential difference  $V$  across the [3 marks] cell.



Using the graph, determine the best estimate of the internal resistance of the cell.

## Markscheme

$$V = E - Ir$$

large triangle to find gradient and correct read-offs from the line

**OR**

use of intercept  $E = 1.5 \text{ V}$  and another correct data point

internal resistance =  $0.60 \Omega$

*For MP1 – do not award if only*

$$R = \frac{V}{I} \text{ is used.}$$

*For MP2 points at least 1A apart must be used.*

*For MP3 accept final answers in the range of  $0.55 \Omega$  to  $0.65 \Omega$ .*

**[3 marks]**

- 11c. State what is meant by a zero error.

[1 mark]

## Markscheme

a non-zero reading when a zero reading is expected/no current is flowing

**OR**

a calibration error

*OWTTE*

*Do not accept just "systematic error".*

**[1 mark]**

- 11d. After taking measurements the student observes that the ammeter has a positive zero error. Explain what effect, if any, this zero error will have on the calculated value of the internal resistance in (b). [2 marks]

## Markscheme

the error causes «all» measurements to be high/different/incorrect

effect on calculations/gradient will cancel out

**OR**

effect is that value for  $r$  is unchanged

*Award [1 max] for statement of "no effect" without valid argument.*

*OWTTE*

**[2 marks]**

12. A boy jumps from a wall 3m high. What is an estimate of the change in momentum of the boy when he lands without rebounding? [1 mark]

A.  $5 \times 10^0 \text{ kg m s}^{-1}$

B.  $5 \times 10^1 \text{ kg m s}^{-1}$

C.  $5 \times 10^2 \text{ kg m s}^{-1}$

D.  $5 \times 10^3 \text{ kg m s}^{-1}$

## Markscheme

C

13. Light of wavelength  $400\text{nm}$  is incident on two slits separated by  $1000\mu\text{m}$ . The interference pattern from the slits is observed from a satellite orbiting  $0.4\text{Mm}$  above the Earth. The distance between interference maxima as detected at the satellite is [1 mark]
- A.  $0.16\text{Mm}$ .  
 B.  $0.16\text{km}$ .  
 C.  $0.16\text{m}$ .  
 D.  $0.16\text{mm}$ .

## Markscheme

B

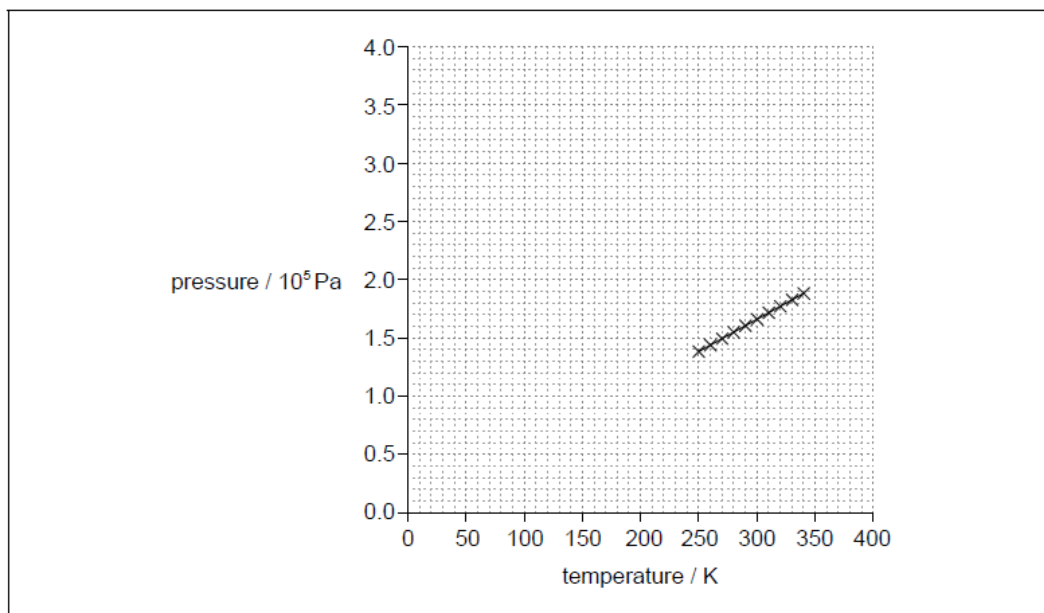
14. A car moves north at a constant speed of  $3\text{m s}^{-1}$  for  $20\text{s}$  and then east at a constant speed of  $4\text{m s}^{-1}$  for  $20\text{s}$ . What is the average speed of the car during this motion? [1 mark]
- A.  $7.0\text{m s}^{-1}$   
 B.  $5.0\text{m s}^{-1}$   
 C.  $3.5\text{m s}^{-1}$   
 D.  $2.5\text{m s}^{-1}$

## Markscheme

C

- 15a. The graph shows the data recorded.

[1 mark]



Identify the fundamental SI unit for the gradient of the pressure–temperature graph.

## Markscheme

$\text{kg m}^{-1} \text{s}^{-2} \text{K}^{-1}$

- 15b. The experiment is repeated using a different gas in the glass jar. The pressure for both experiments is low and both gases can be considered to be ideal. [3 marks]
- (i) Using the axes provided in (a), draw the expected graph for this second experiment.
- (ii) Explain the shape and intercept of the graph you drew in (b)(i).

## Markscheme

i

any straight line that either goes or would go, if extended, through the origin

ii

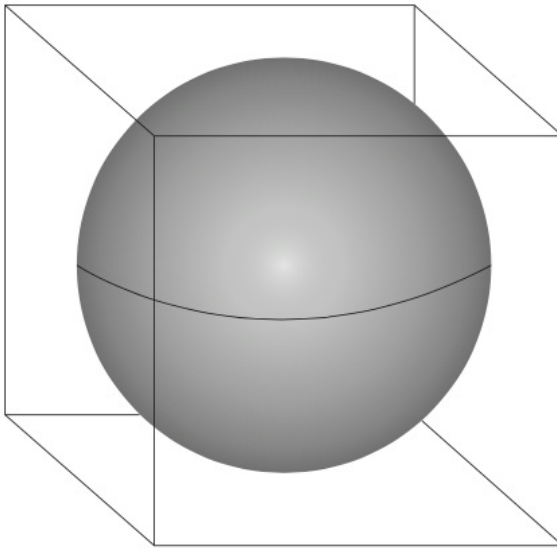
for ideal gas  $p$  is proportional to  $T / P = nRT/V$

gradient is constant / graph is a straight line

line passes through origin / 0,0

16. A sphere fits inside a cube.

[1 mark]



The length of the cube and the diameter of the sphere are  $10.0 \pm 0.2$  cm.

What is the ratio  $\frac{\text{percentage uncertainty of the volume of the sphere}}{\text{percentage uncertainty of the volume of the cube}}$ ?

- A.  $\frac{3}{4\pi}$
- B. 1
- C. 2
- D. 8

## Markscheme

B

17. A swimming pool contains  $18 \times 10^6$  kg of pure water. The molar mass of water is  $18 \text{ g mol}^{-1}$ . What is the correct estimate of the number of water molecules in the swimming pool?

[1 mark]

- A.  $10^4$
- B.  $10^{24}$
- C.  $10^{25}$
- D.  $10^{33}$

## Markscheme

D



18. Which of the following is a derived unit?

[1 mark]

- A. Mole
- B. Kelvin
- C. Coulomb
- D. Ampere

## Markscheme

C

19a. Draw the line of best-fit for the data.

[1 mark]

## Markscheme

smooth curve line through all error bars;

*Do not allow kinked or thick lines or double/multiple lines.*

*Ignore any line beyond the range of plotted points.*

*Assume a broken line is due to scan and allow BOD.*

*Line must go through vertical part of error bar. Do not allow line to clip horizontal endcaps.*

19b. State why the line of best-fit suggests that  $h_{\text{mean}}$  is not proportional to  $T$ .

[1 mark]

## Markscheme

line (of best-fit) not straight/curved/changing gradient;

ratio of  $h$  to  $T \times 10^{-4}$  is not constant;

*Allow "does not pass through origin" **only** if a straight line drawn in (a).*

*Otherwise treat as neutral.*

19c. State the uncertainty in each value of  $T$ .

[1 mark]

## Markscheme

$(\pm)1^\circ \text{ C/K/deg}$ ; *(do not allow 2 or more sig figs in the answer)*

19d. The temperature is measured using a liquid in glass thermometer. State what physical characteristic of the thermometer suggests that the change in the liquid's length is proportional to the change in temperature. [1 mark]

## Markscheme

equal graduations / constant cross-section/capillary diameter / (volume of) liquid expands linearly/proportionally to  $T$  / OWTTE;

*Accept synonym for "capillary", eg: "tube".*

19e. Another hypothesis is that  $h_{\text{mean}} = KT^3$  where  $K$  is a constant. Using the graph on page 2, calculate the absolute uncertainty in  $K$  corresponding to  $T = 50^\circ\text{C}$ . [4 marks]

## Markscheme

$$\frac{\Delta h}{h} = \frac{0.01}{0.72} \text{ or } 0.014 \text{ or } 1.4\% \text{ and } \frac{\Delta T}{T} = \frac{1}{50} \text{ or } 0.02 \text{ or } 2\%; \text{ (allow ECF from (c)(i))}$$

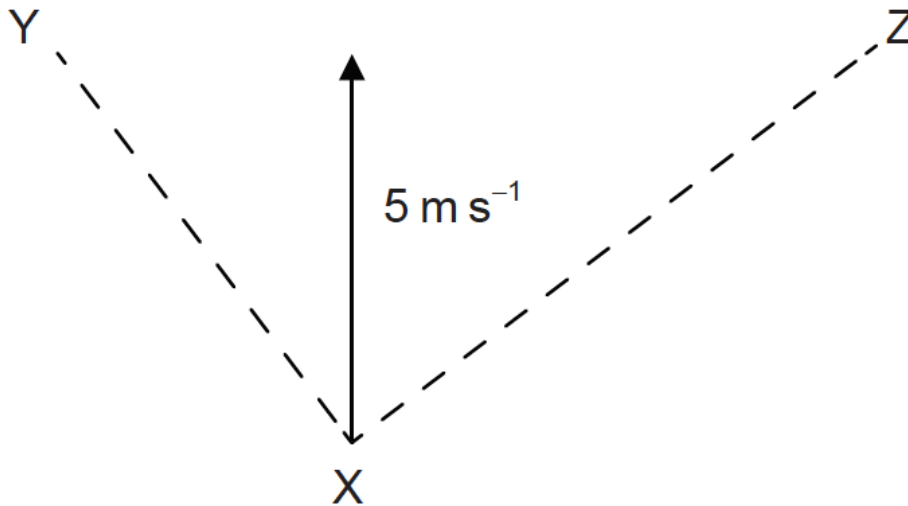
$$\frac{\Delta K}{K} = 3 \times \frac{1}{50} + \frac{0.01}{0.72} \text{ or } 7.4 \times 10^{-2} \text{ or } 7.4\%;$$

$$K = 5.8/5.76/6 \times 10^{-6};$$

$$\Delta K = 4 \times 10^{-7} \text{ mK}^{-3} \text{ or } \text{m}^{\circ}\text{C}^{-3}; \text{ (1 sig fig and correct unit required)}$$

20. A velocity of  $5 \text{ m s}^{-1}$  can be resolved along perpendicular directions XY and XZ.

[1 mark]



The component of the velocity in the direction XY is of magnitude  $4 \text{ m s}^{-1}$ . What is the magnitude of the component in the direction XZ?

- A.  $4 \text{ m s}^{-1}$
- B.  $3 \text{ m s}^{-1}$
- C.  $2 \text{ m s}^{-1}$
- D.  $1 \text{ m s}^{-1}$

## Markscheme

B

21. What is the unit of energy density?

[1 mark]

- A.  $\text{J kg}^{-1}$
- B.  $\text{J kg}^{-1} \text{ m}^3$
- C.  $\text{J mol}^{-1}$
- D.  $\text{J K}^{-1}$

## Markscheme

A

22. Which of the following expresses the watt in terms of fundamental units?

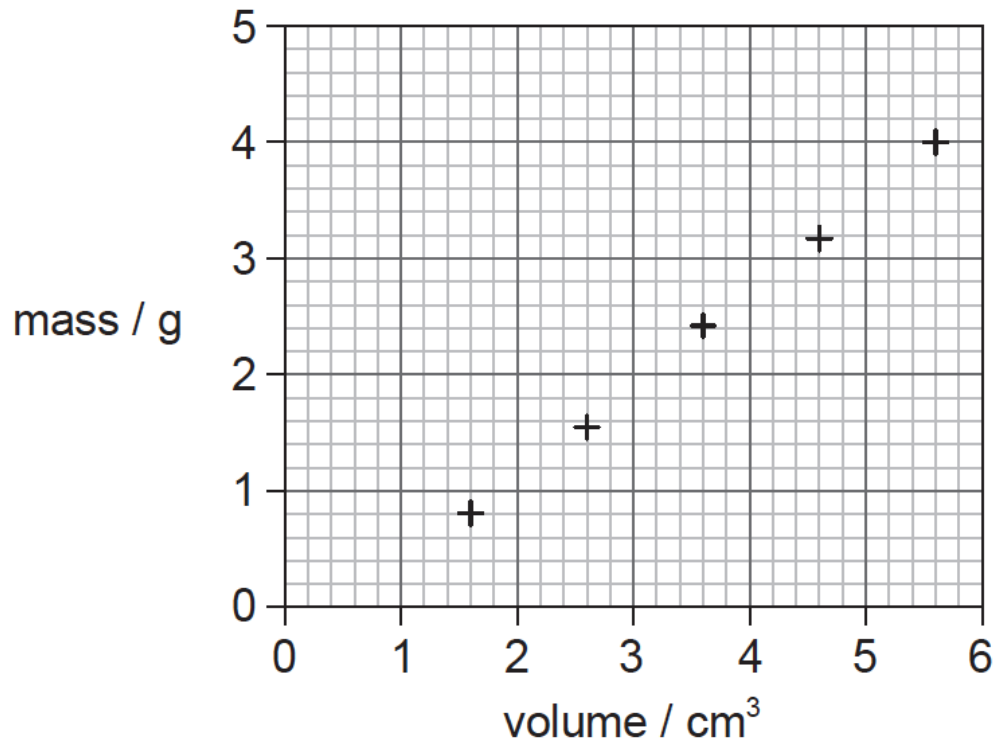
[1 mark]

- A.  $\text{kg m}^2 \text{s}$
- B.  $\text{kg m}^2 \text{s}^{-1}$
- C.  $\text{kg m}^2 \text{s}^{-2}$
- D.  $\text{kg m}^2 \text{s}^{-3}$

## Markscheme

D

23. The graph shows a set of experimental results to determine the density of oil. The results have systematic errors and random errors. [1 mark]



Using the information on the graph, what can be said about the measurements used to find the density of oil?

	<b>Systematic errors</b>	<b>Random errors</b>
A.	small	small
B.	small	large
C.	large	small
D.	large	large

## Markscheme

C

24. Which of the following expresses the units of capacitance in terms of fundamental units? [1 mark]
- A.  $s^4A^2m^{-2}kg^{-1}$
  - B.  $s^2Am^{-2}kg^{-1}$
  - C.  $s^4A^2m^{-2}$
  - D.  $s^2Am^{-2}$

## Markscheme

A

25. Which of the following is a fundamental unit? [1 mark]
- A. Ampere
  - B. Coulomb
  - C. Ohm
  - D. Volt

## Markscheme

A

26. The maximum acceleration  $a_{\max}$  of an oscillator undergoing simple harmonic motion (SHM) has a percentage uncertainty of 12%. [1 mark]  
The amplitude  $x_0$  of the oscillation has a percentage uncertainty of 20%. If  $k = \sqrt{\frac{a_{\max}}{x_0}}$  what is the percentage uncertainty in the constant  $k$ ?
- A. 4%
  - B. 8%
  - C. 16%
  - D. 32%

## Markscheme

C