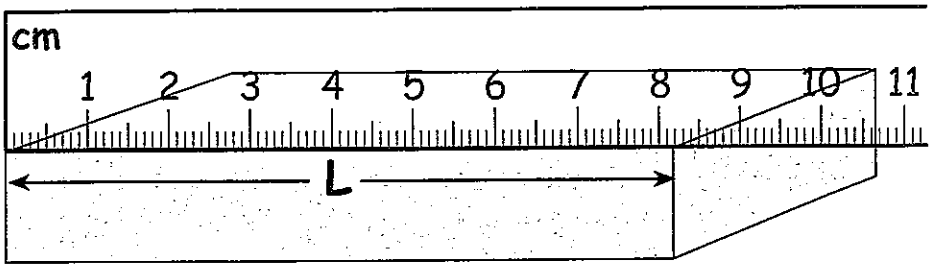
Formative Exercise

Skill 1: Measurement of Length & Time

Measuring Length

Measuring the Length of a Box



Using a Ruler

1 The diagram shows a ruler being used to measure the length L of a box.

a) Write down the length L of the box in centimetres and include the unit symbol.

8·2 cm

b) Write down the length L of the box in SI units and include the unit symbol.

0·082 m

c) Write down the length L of the box in millimetres and include the unit symbol.

82 mm

d) Write down the length L of the box in SI units and in scientific notation using as 10^{-3} as a power of 10.

0·082 m 82×10^{-3} m

2 The experimental uncertainty in a measurement may be taken as the smallest division on the instrument's scale.

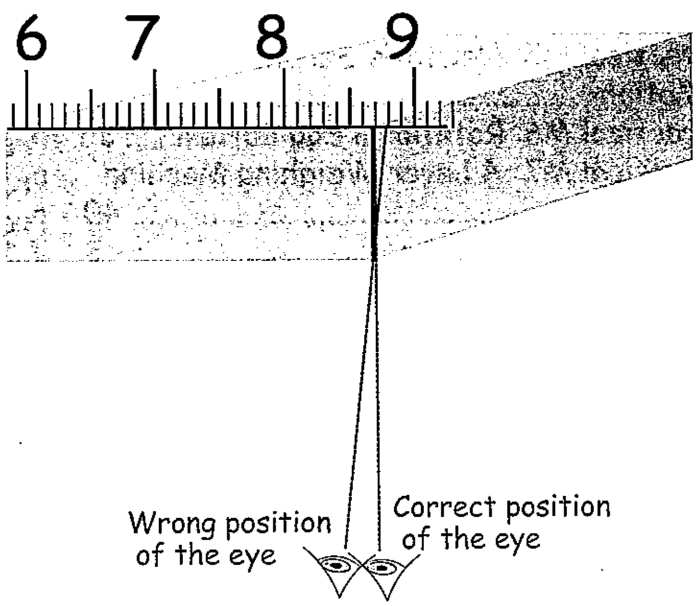
a) Write down the experimental uncertainty ΔL for the length L of the box in millimetres and include the unit symbol.

± 1 mm

b) The accuracy of a measurement is indicated by the number of significant figures quoted. Explain what is meant by the significant figures of a measurement.

The number of figures known with some confidence (last digit is estimated)

Parallax Error



c) Write down the length L of the box in SI units, with its experimental uncertainty ΔL and give the number of significant figures it is quoted to.

$L \pm \Delta L = (82 \pm 1) \times 10^{-3}$ m to 2 sf.

3 The diagram illustrates the common error of parallax when reading a ruler.

a) Explain what error is caused by placing the eye in the wrong position shown.

An inaccurate

reading of length is made

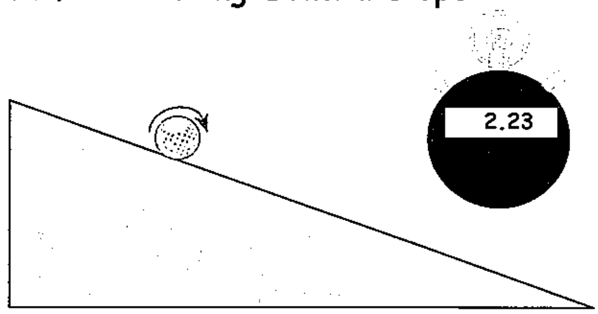
b) Explain what must be done to avoid parallax error.

Position the eye perpendicular to the scale

Measuring Time

Using a Stopwatch

Golf Ball Rolling Down a Slope



4 The diagram shows a digital stopwatch being used to measure the time t for a golf ball to roll down a slope. Several values are taken.

a) Each reading is taken by starting the stationary golf ball at the top of the slope. Why is this necessary?

Ensure a fair test (control of variables)

b) The reading shown by the stopwatch in the diagram is 2.23 s.

(i) Write down the experimental uncertainty Δt that this reading for the time t suggests.

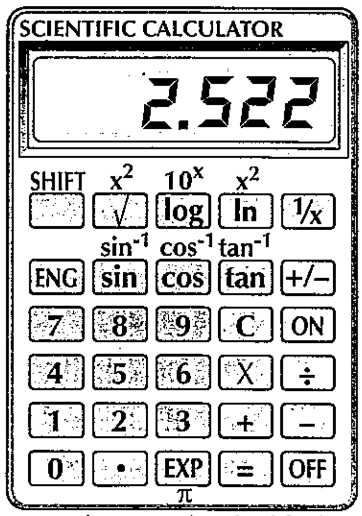
$\pm$ 0·01 s

(ii) Write down the number of significant figures this reading is accurate to.

3 sig. fig.

c) The table below shows the results of the taking several measurements.

t (s)	2.38	2.12	2.67	2.56	2.78	2.48	2.63	2.23	2.39	2.98



(i) Calculate the average value, showing your working clearly.

25·22 ÷ 10 = 2·522 s

(ii) Write down the average time to the correct number of significant figures as indicated by the above data.

2·52 s

(iii) The range **R** of the data is defined as the maximum value minus the minimum value. Calculate the range.

2·98 − 2·12 = 0·86

(iv) The experimental uncertainty Δt in the average time t is taken to be half the range **R**. Calculate Δt.

Δt = 0·86 ÷ 2 = 0·43

(v) Give an explanation why the experimental uncertainty Δt in the average time t is much larger than the 0.01 s accuracy of the stopwatch.

Δt is a result of human reaction time error.

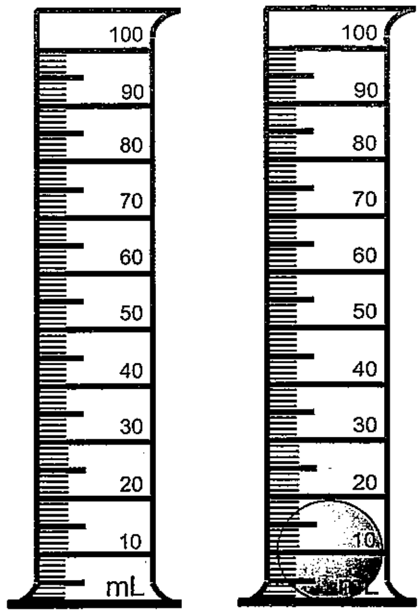
Formative Exercise

Skill 2: Reading Scales

Measuring Volume

Using a Measuring Cylinder

Volume of a Steel Ball



1 The diagram shows a measuring cylinder containing a volume V_1 of water. A steel ball is lowered carefully into the cylinder so that the volume of water is increased to V_2.

a) Write down the volume V_1 of the water in millilitres and include the unit symbol.

35 mL

b) Write down the volume V_2 of the water in millilitres and include the unit symbol.

57 mL

c) Calculate the volume V of the steel ball in millilitres, showing your working clearly.

57 − 35 = 22 mL

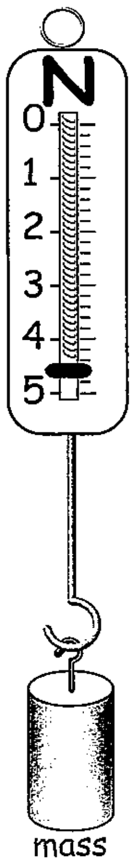
d) Write down the volume V of the steel ball in millilitres, with its experimental uncertainty ΔV and give the number of significant figures it is quoted to.

$V \mp \Delta V$ = 22 ∓ 1 mL to 2 sf.

Measuring Force

Using a Spring Balance

Spring Balance



2 The diagram shows a spring balance being used to measure the weight F_g of the suspended mass.

a) Write down the weight F_g of the suspended mass and include the unit symbol.

4·6 N

b) What unit does the unit symbol stand for?

Newton

c) Write down the weight F_g of the suspended mass, with its experimental uncertainty ΔF_g and give the number of significant figures it is quoted to.

$F_g \mp \Delta F_g$ = 4·6 ∓ 0·1 N to 2 sf.

Measuring Temperature

Using a Thermometer

3 The diagram on the next page shows a thermometer being used to measure the temperature θ of the surrounding air.

a) Write down the temperature θ of the surrounding air and include the unit symbol.

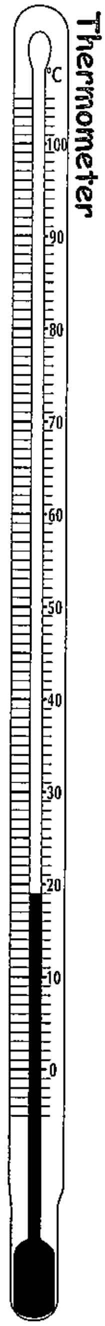
19°C

b) What unit does the unit symbol stand for?

Degrees Celsius

c) Write down the temperature θ of the surrounding air, with its experimental uncertainty $\Delta\theta$ and give the number of significant figures it is quoted to.

$\theta \mp \Delta\theta$ = 19 ∓ 1 °C to 2 sf.

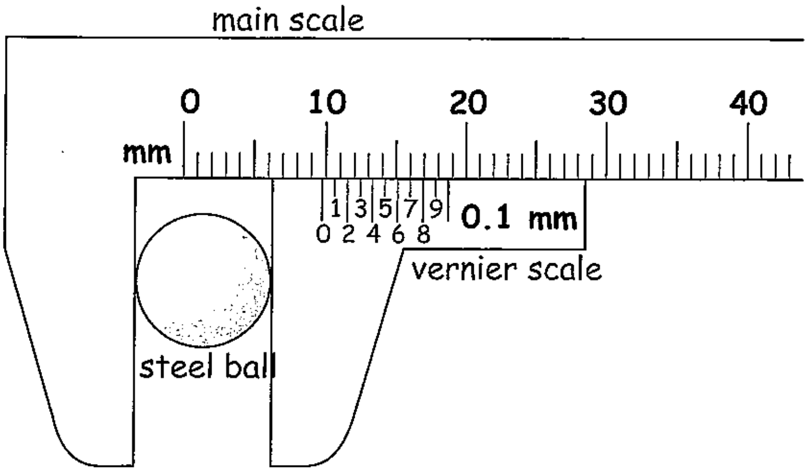


Measuring Length

Using Vernier Callipers

4 The diagram shows vernier callipers being used to measure the diameter **d** of a steel ball.

Vernier Callipers



a) Write down the diameter **d** of the steel ball in millimetres and include the unit symbol.

9.7 mm

b) Write down the diameter **d** of the steel ball in SI units and in scientific notation using as 10^{-3} as a power of 10.

0.0097 m $\quad$ 9.7×10^{-3} m

c) Write down the diameter **d** of the steel ball, with its experimental uncertainty Δ**d** and give the number of significant figures it is quoted to.

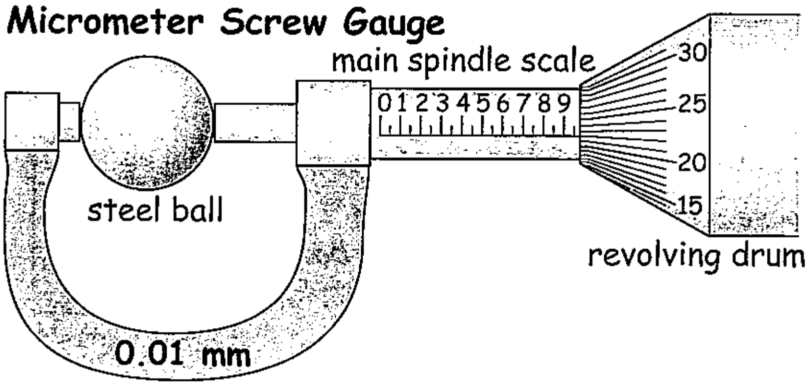
d ∓ Δ**d** = (9.7 ∓ 0.1) x 10^{-3} m to 2 sf.

Measuring Length

Using a Micrometer Screw Gauge

5 The diagram shows a micrometer screw gauge being used to measure the diameter **d** of the same steel ball as used in question 4.

Micrometer Screw Gauge



a) Write down the diameter **d** of the steel ball in millimetres and include the unit symbol.

9.72 mm

b) Write down the diameter **d** of the steel ball in SI units, with its experimental uncertainty Δ**d** and give the number of significant figures it is quoted to.

d ∓ Δd = (9.72 ∓ 0.01) x 10^{-3} m to 3 sf.

Formative Exercise

Skill 3: Plotting Graphs

Measuring Volume

Using a Syringe

1 Diagram 1 shows a syringe containing a trapped mass of air maintained at room temperature. Diagrams 2, 3 and 4 show the syringe loaded with similar books to compress the trapped air.

a) The table below is of the volume **V** of the trapped air versus the number of books **N**. By examining the diagrams carefully, complete the data table.

N (no unit)	0	1	2	4
V (mL)	80	64	54	40

b) The number of books **N** is the independent variable. Why is this?

It is manipulated

c) The volume **V** of the trapped air is the dependent variable. Why is this?

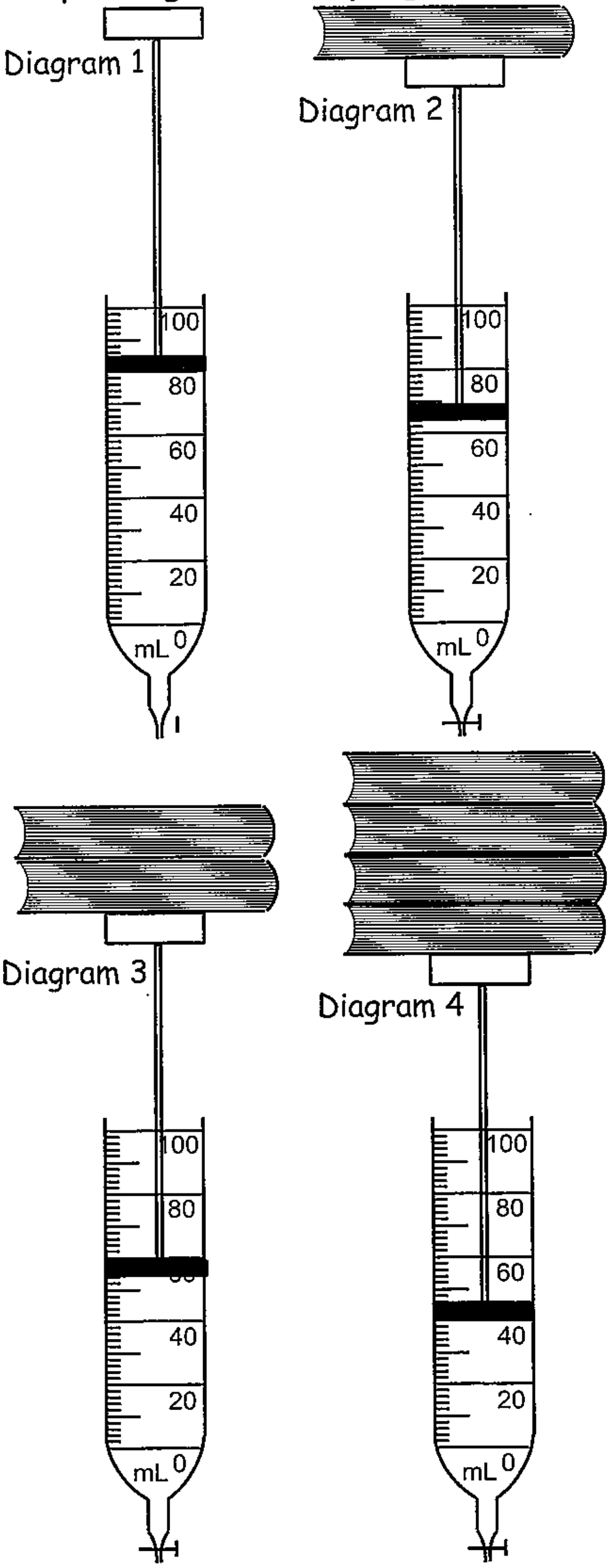
It is measured in response

d) Identify the variable to go on each axis when graphing **V** versus **N**.

N x-axis

V y-axis

Compressing Air in a Syringe



Plotting the Graph

2 Use the graph paper to plot a graph of the volume **V** of the trapped air versus number of books **N**, by following this procedure:

a) *Choose a range which covers the majority of the graph paper for both scales. The chosen range does not necessarily start from zero.* Write down the range for each axis.

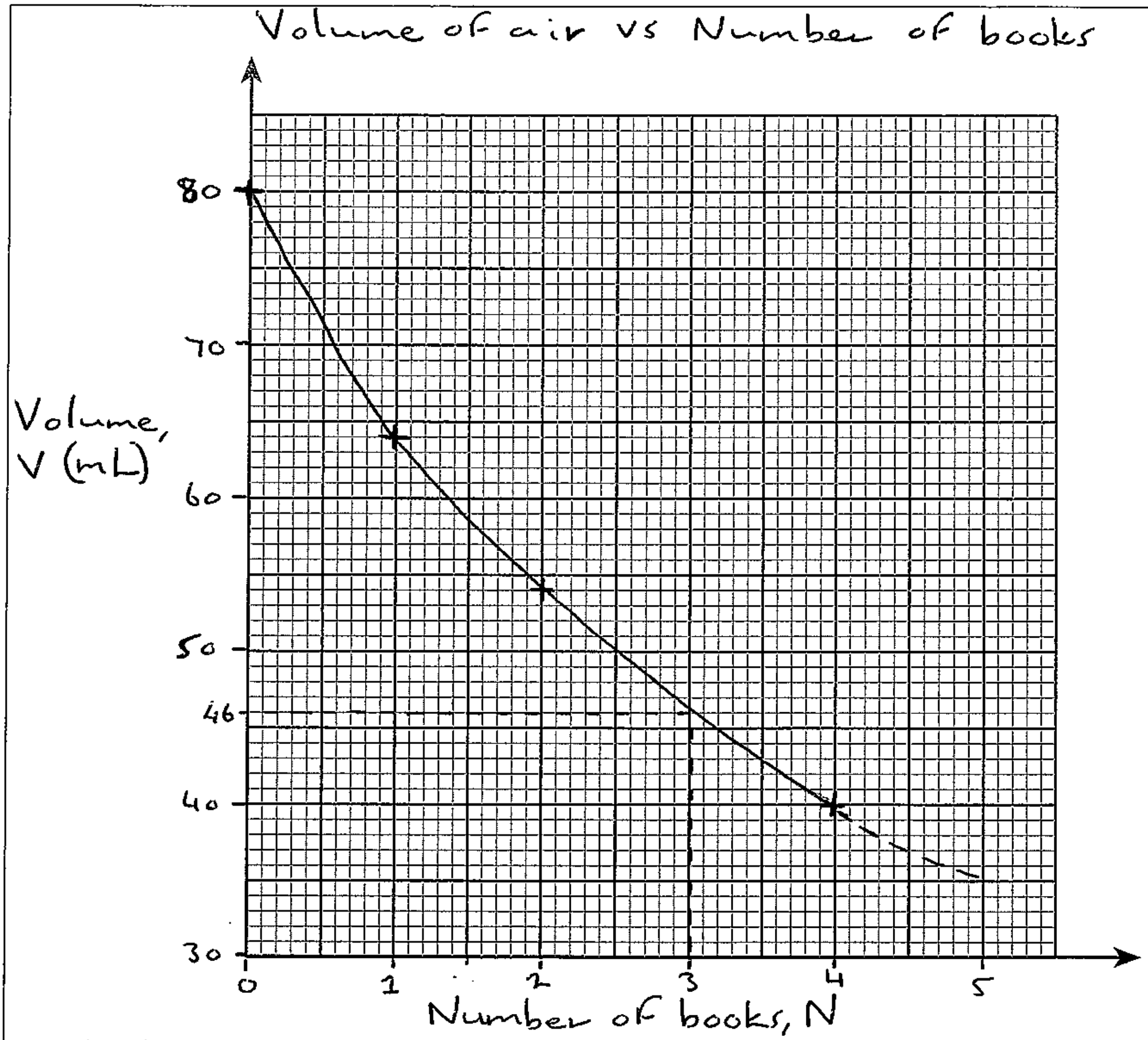
N axis: 0 to 4 V axis: 30 to 80

b) *Choose appropriate linear scales which are easy to use.* Write down the scale for each axis.

N axis: 1 main square = 1 book V axis: 1 main square = 10 mL

c) *Label each axis with the quantity, formula symbol and unit symbol.*

d) *Write an appropriate title to the graph.*



e) *Plot the data points using crosses so are clearly shown.*

f) *Draw a best-fit curve to show the shape of the graph.*

Interpolation and Extrapolation

3 The graph can produce information using the processes of interpolation or extrapolation.

a) Explain what is meant by interpolation.

The constuction of new data points within the range of known data points

b) Using interpolation and showing your working on the graph, determine the volume **V** of the trapped air when **3** books are placed on the syringe.

46 mL

c) Explain what is meant by extrapolation.

Estimating the value of a variable beyond the observable range.

d) Using extrapolation and showing your working on the graph, determine the volume **V** of the trapped air when **5** books are placed on the syringe.

35 mL

Measuring Temperature

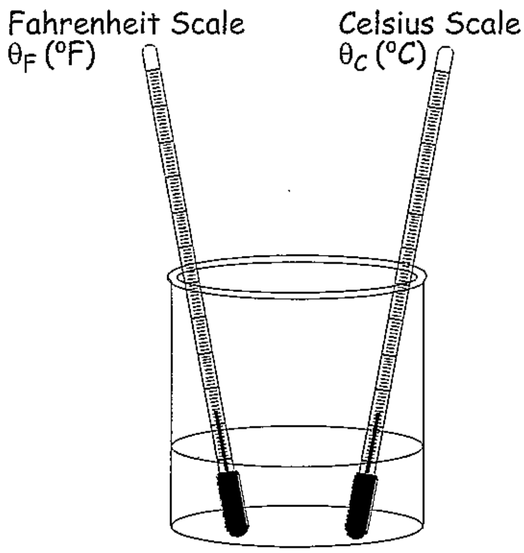
Using Fahrenheit and Celsius Thermometers

1 The diagram shows a beaker of hot water and two thermometers. One thermometer is calibrated in the Fahrenheit scale θ_F and the other in Celsius θ_C. The readings of the two thermometers are taken as the water cools. The results table is shown below.

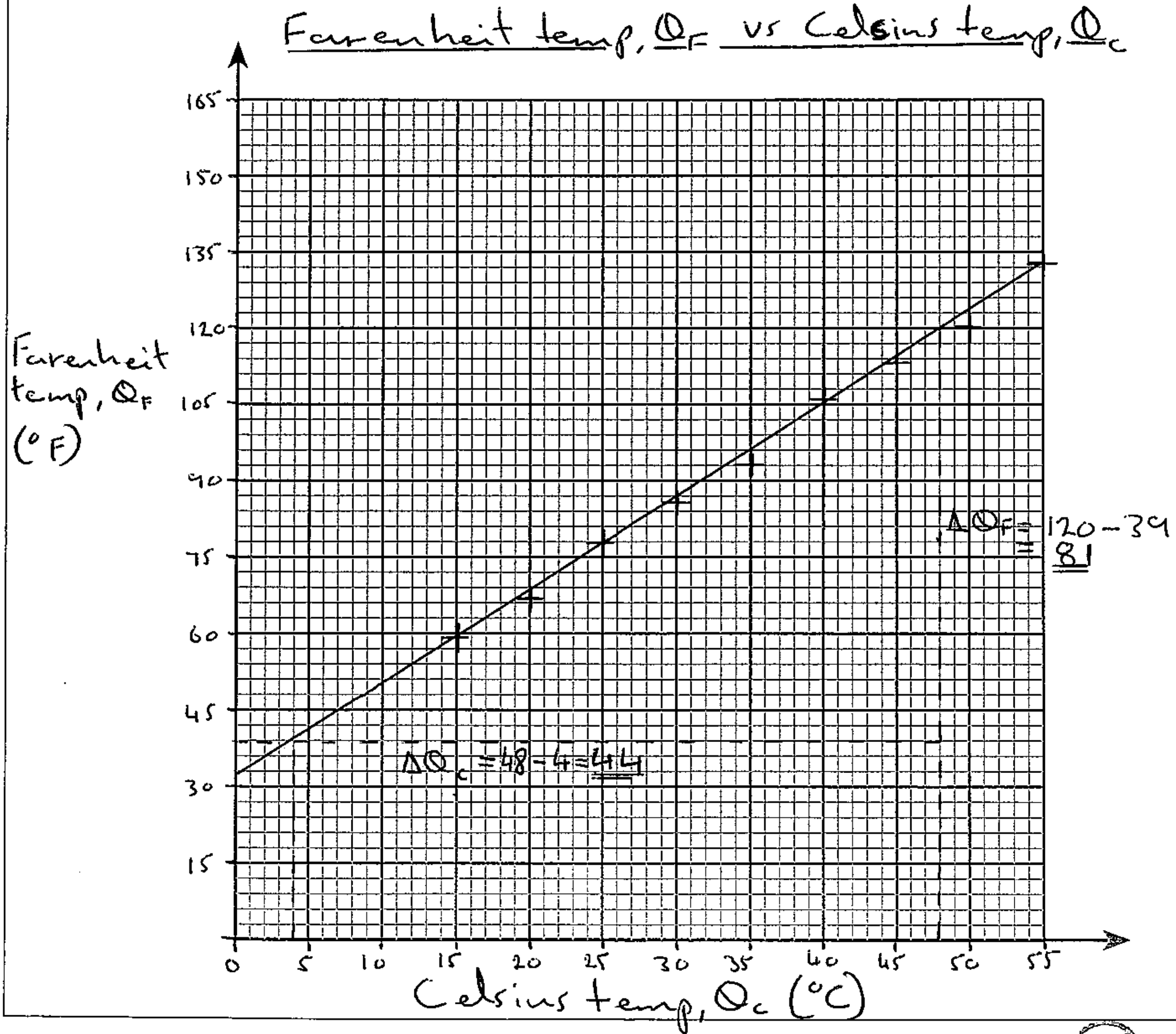
a) By examining the results table carefully, write down the independent variable. Explain your answer.

θ_c - recorded at predetermined intervals

Comparing Two Temperature Scales



θ_C (°C)	55	50	45	40	35	30	25	20	15
θ_F (°F)	133	120	113	106	93	86	78	67	59



b) Identify the variable to go on each axis when graphing θ_F versus θ_C.

θ_C on x-axis θ_F on y-axis

Plotting the Graph

2 Graph paper is supplied on the previous page.

a) Use the graph paper to plot a graph of the Fahrenheit temperature θ_F versus the Celsius temperature θ_C.

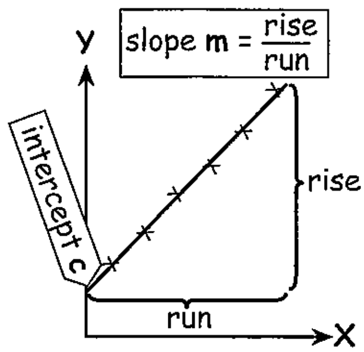
b) The relationship between the two temperature scales θ_F and θ_C is linear. Explain what this means.

When plotted, produces a straight line graph.

c) Draw a best-fit straight line through the points using a ruler.

Analysing the Graph

Straight Line Graph



3 The diagram shows a general representation of a straight line graph.

a) The general equation for a straight line graph is given by **Y** = **mX** + **c**. Write down the definitions of each of the symbols in the equation.

Y is y-axis value, X is x-axis value, m is line gradient, ~~c is y-ax~~ c is y-axis intercept

b) Analyse the θ_F versus θ_C graph by following this procedure:

(i) *Calculate the slope **m** of the graph.* ~~$\Delta\theta_F / \theta$~~ $\frac{\Delta\theta_F}{\Delta\theta_C} = \frac{81}{44} = 1.84\ °F\,°C^{-1}$

(ii) *Write down the value of the intercept **c** on the θ_F axis.*

32 °F

(iii) *Write down the general straight line equation and identify the variable symbols to replace **Y** and **X**.*

General equation for a straight line graph is $Y = mX + c$

Replacement variable symbol for **Y** is θ_F

Replacement variable symbol for **X** is θ_C

(iv) *Write down the final empirical equation for the θ_F versus θ_C graph by substituting the replacement symbols for **Y** and **X** and the values of **m** and **c** into the general straight line equation.*

General equation for a straight line graph $Y = mX + c$ becomes $\theta_F = 1.84\,\theta_C + 32$

c) Calculate the boiling point of water in °F using the final empirical equation for the θ_F versus θ_C graph and the fact the boiling point of water = 100 °C.

$\theta_F = 1.84 \times 100 + 32 = 216\ °F$

d) Calculate the equivalent temperature in °C for -40 °F.

$\theta_C = \frac{-40 - 32}{1.84} = -39.1\ °C$ (Answers vary, ≈ -40)

Power Laws

Graphical Shapes

The diagram shows the graphical shapes for four examples of power laws. The power law is represented by the statement:

$$Y \propto X^n$$

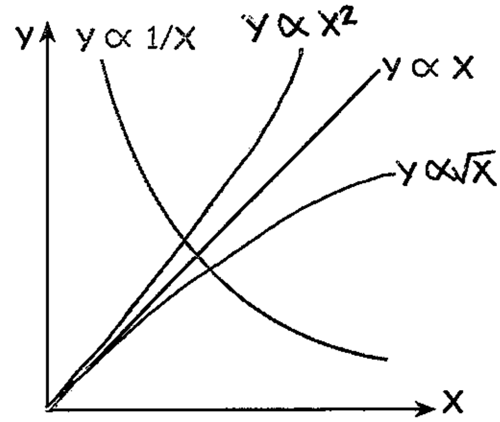
which states that the dependent variable **Y** is proportional to independent variable **X** to the power of **n**.

This statement can be written as an equation:

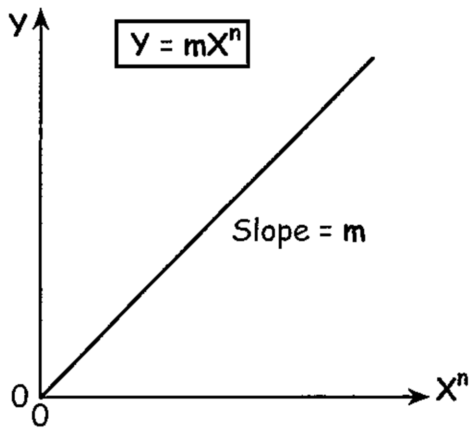
$$Y = mX^n$$

which can be verified by plotting a graph of **Y** versus X^n as shown in the diagram. The graph is a straight line through the origin whose slope = **m**.

Examples of Power Laws



Verification of a Power Law

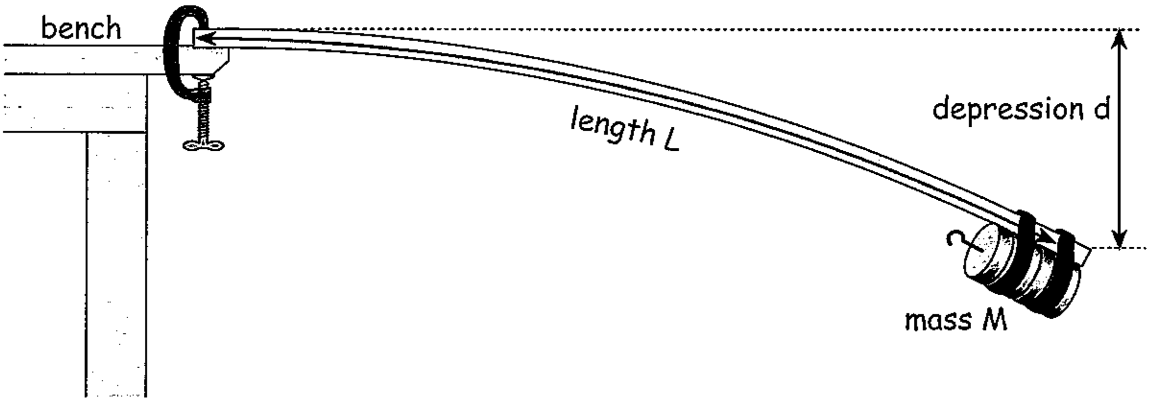


Direct Proportion

The Bending of a Ruler

1 The diagram shows the bending of a metre rule. The dependent variable is the depression **d** of the metre rule. The two independent variables are the length of the ruler **L** which is free to bend and the mass **M** of the mass-stack. The data table shown below is of **d** versus **M** for a fixed value of **L**.

Bending of a Ruler

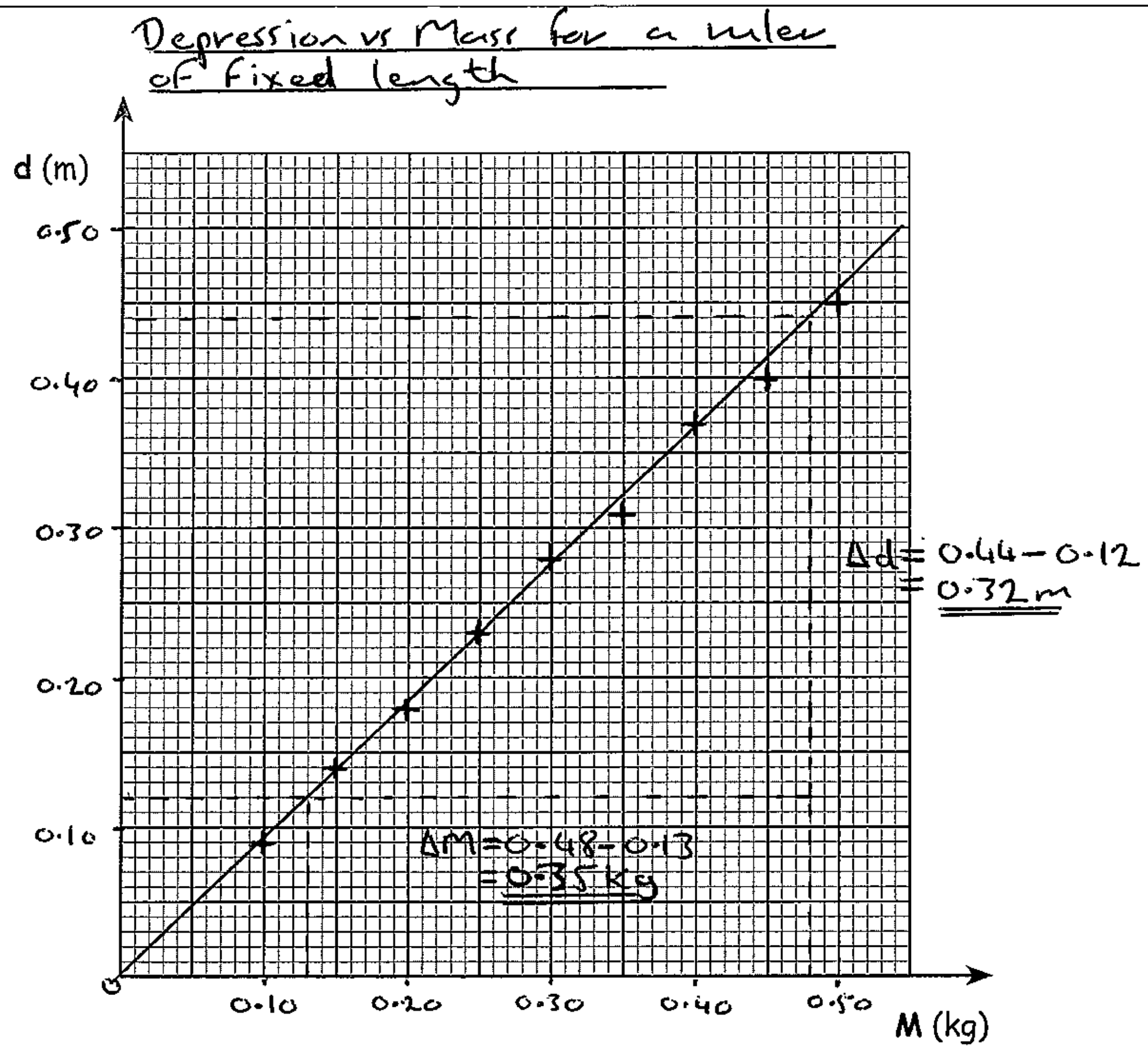


M (kg)	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
d (m)	0.09	0.14	0.18	0.23	0.28	0.31	0.37	0.40	0.45

a) Explain why a fixed value of **L** is chosen.

We only wish to investigate the relationship between M and d. L is a controlled variable.

b) Use the graph paper on the next page to plot a graph of the depression **d** of the metre rule versus the mass **M** of the mass-stack.



c) Describe the shape of the graph and the relationship between **d** and **M**.

Directly proportional, $d \propto M$

d) Calculate the slope **m** of the graph and include its unit.

$m = \frac{\text{rise}}{\text{run}} = \frac{\Delta d}{\Delta M} = \frac{0.32}{0.35} = 0.91\ \text{m kg}^{-1}$ (Answers vary $\approx 0.90\ \text{m kg}^{-1}$)

e) Write down the empirical formula connecting **d** and **M**.

$d = 0.91M$

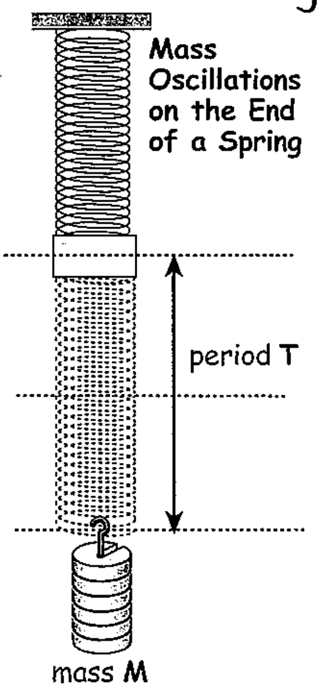
Square Root Power Law

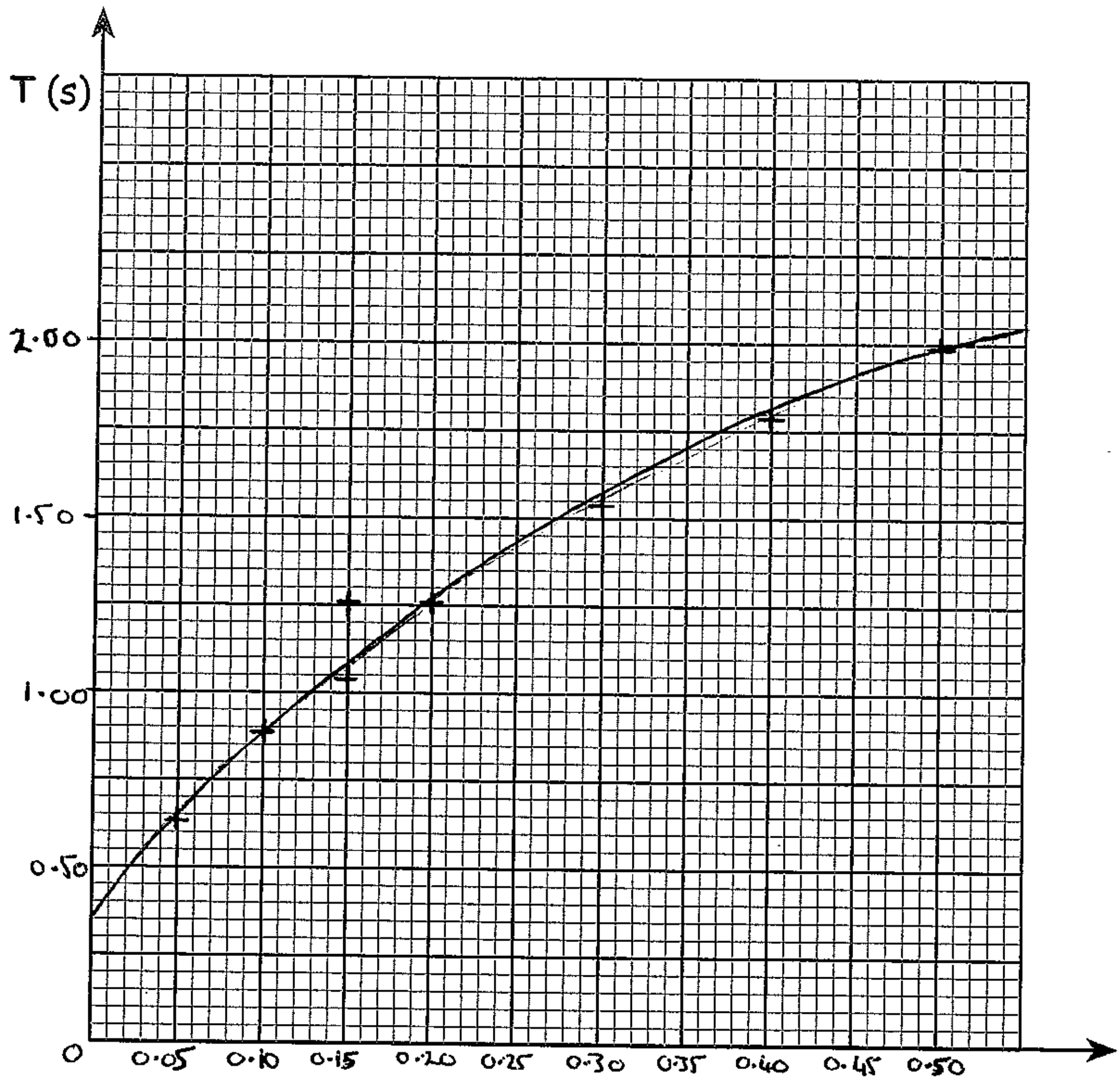
Mass Oscillating on the End of a Spring $\left(T = 2\pi\sqrt{\frac{M}{k}}\right)$

2 The diagram shows a mass-stack, of mass **M**, oscillating with period **T** on the end of a spring. The results table below shows values of the period **T** for different values of the mass **M**.

a) Use the graph paper on the next page to plot a graph of the period **T** of the oscillations versus the mass **M** of the mass stack.

M (kg)	0.05	0.10	0.15	0.20	0.30	0.40	0.50
T (s)	0.63	0.89	1.09	1.26	1.54	1.78	1.99
√M (√kg)	0.22	0.32	0.39	0.45	0.55	0.63	0.71





b) Describe the shape of the **T** versus **M** graph.

Square root relationship, $T \propto \sqrt{M}$

c) Calculate the values of √**M** in the last row of the results table.

d) Use the above graph paper to plot a graph of the period **T** of the oscillations versus √**M**.

e) Describe the shape of the **T** versus √**M** graph and the relationship between **T** and √**M**.

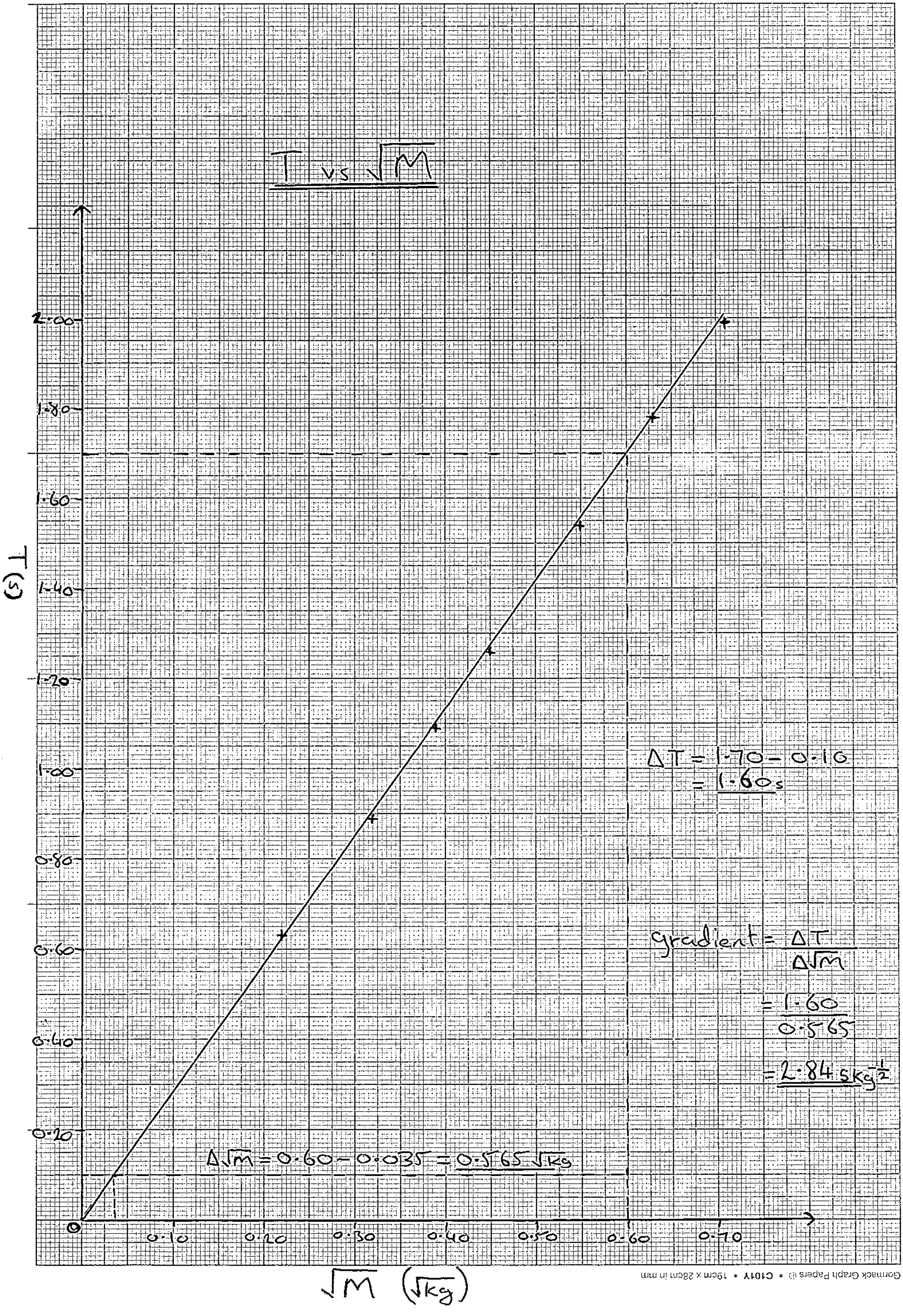
Directly Proportional, $T \propto \sqrt{M}$

f) Calculate the slope **m** of the **T** versus √**M** graph and include its unit.

$2.84\ s\,kg^{-\frac{1}{2}}$ (3 s.f.) * See graph

g) Write down the empirical formula connecting **T** and √**M**.

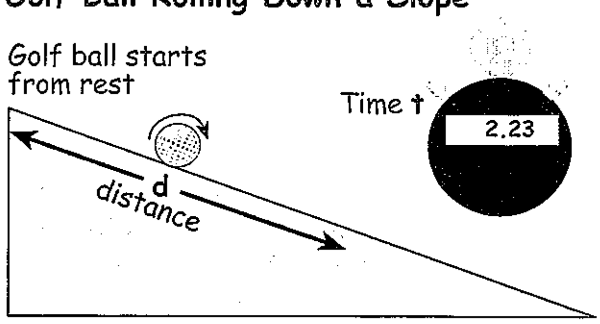
$T = 2.84\sqrt{M}$



T vs √M
T (s)
2·00
1·80
1·60
1·40
1·20
1·00
0·80
0·60
0·40
0·20
0
0·10
0·20
0·30
0·40
0·50
0·60
0·70
√M (√kg)
ΔT = 1·70 − 0·10
= 1·60 s
gradient = ΔT / Δ√m
= 1·60 / 0·565
= 2·84 s kg^-1/2
Δ√m = 0·60 − 0·035 = 0·565 √kg

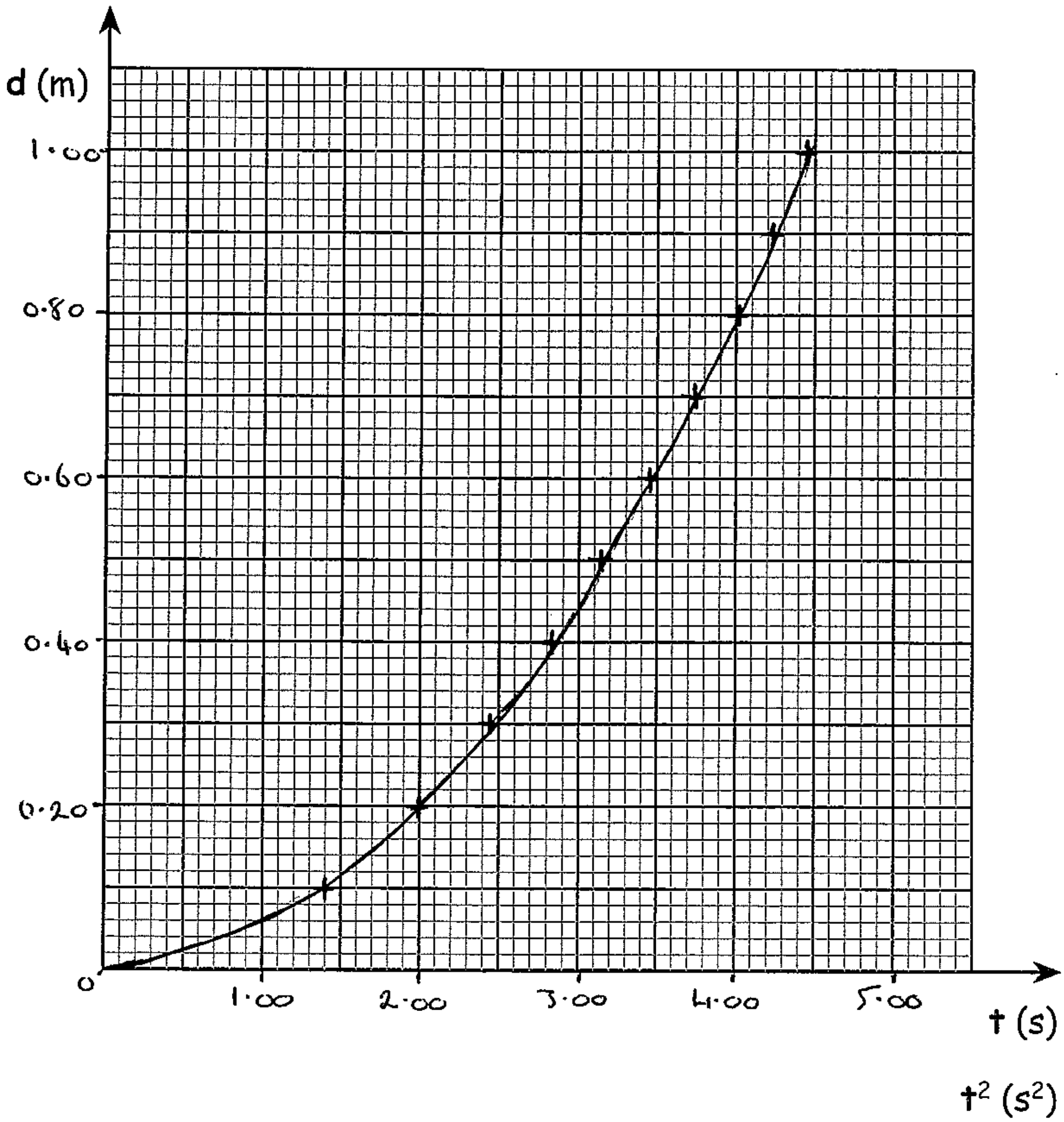
Golf Ball Rolling Down a Slope

3 The diagram shows a golf ball rolling down a slope from rest. It travels a distance **d** in time **t**. The results table below shows values of the distance **d** for different values of the time **t**.



a) Use the graph paper below to plot a graph of the distance **d** down the slope versus the time taken **t**. Though **d** is the independent variable it is plotted along the vertical axis to aid the analysis.

t (s)	1.41	2.00	2.45	2.83	3.16	3.46	3.74	4.02	4.24	4.47
d (m)	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
t^2 (s^2)	1.99	4.00	6.00	8.00	9.99	11.97	13.99	16.16	17.98	19.98



b) Describe the shape of the d versus t graph.

Square relationship (Parabola)

c) Calculate the values of t^2 in the last row of the results table.

d) Use the above graph paper to plot a graph of the distance d down the slope versus the square of the time taken t^2.

e) Describe the shape of the d versus t^2 graph and the relationship between d and t^2.

Directly proportional, $d \propto t^2$

f) Calculate the slope m of the d versus t^2 graph and include its unit.

0.050 ms^{-2} (2 s.f) * See graph

g) Write down the empirical formula connecting d and t^2.

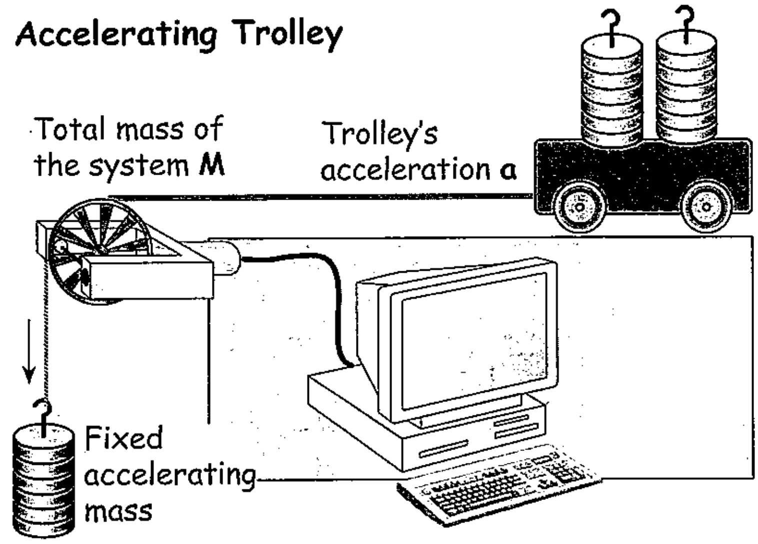
$d = 0.050t^2$

Inverse Power Law

Acceleration of a Trolley

4 The diagram shows a loaded trolley being accelerated with acceleration **a**. The computer arrangement records the acceleration **a** for different masses **M** of the system (loaded trolley plus the fixed accelerating mass). The results table below shows values of the acceleration **a** for different values of the mass **M**.

Accelerating Trolley



M (kg)	0.50	0.75	1.0	1.25	1.5	1.75	2.0
a (m s^{-2})	5.0	3.3	2.5	2.0	1.7	1.4	1.3
1/M (kg^{-1})	2.00	1.33	1.00	0.80	0.67	0.57	0.50

a) Use the graph paper on the next page to plot a graph of the acceleration **a** of the loaded trolley versus the system's mass **M**.

b) Describe the shape of the **a** versus **M** graph.

Inverse relationship

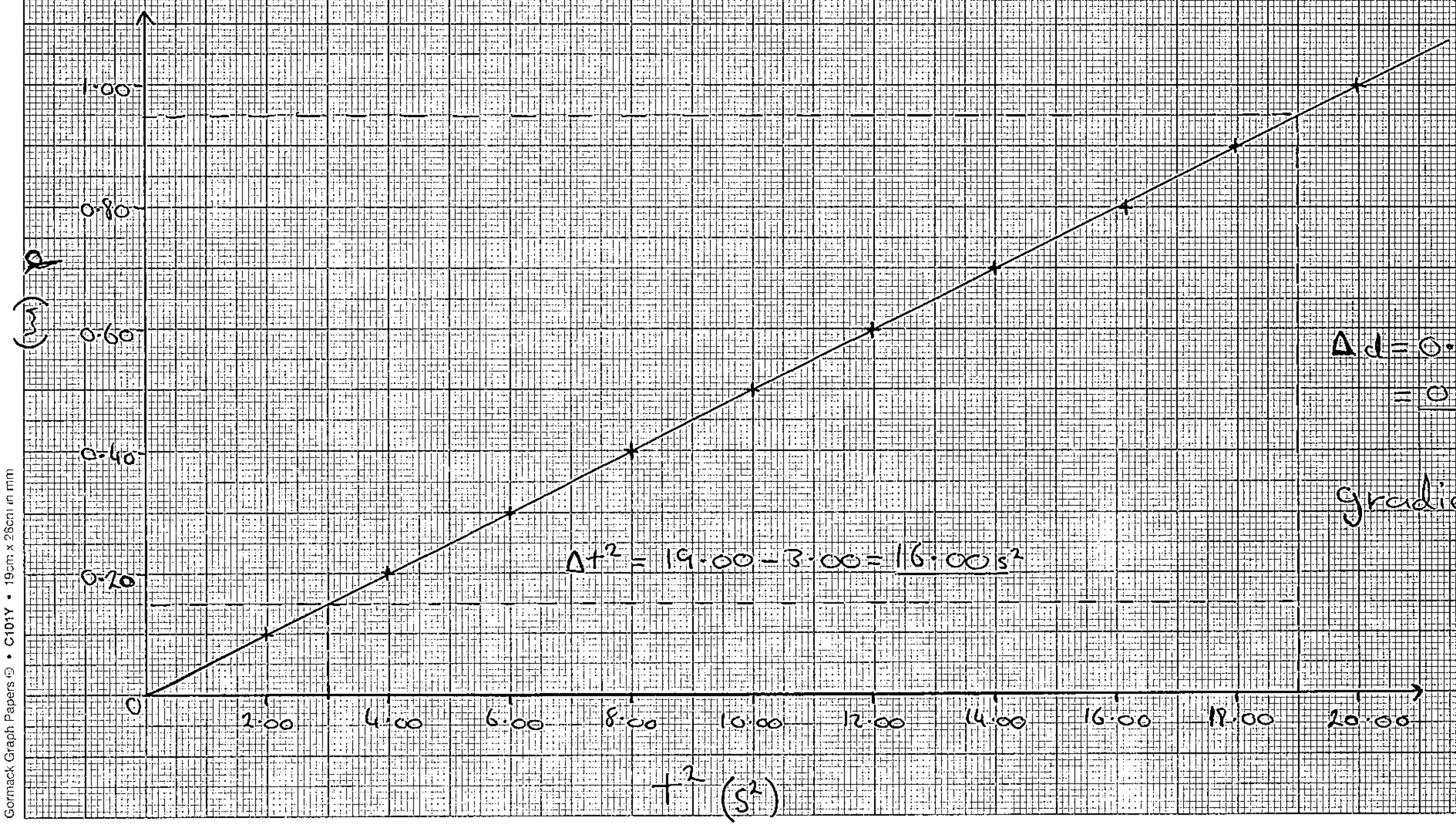
c) Calculate the values of reciprocal of the system's mass 1/**M** in the last row of the results table.

d) Use the graph paper on the next page to plot a graph of the acceleration **a** versus the reciprocal of the system's mass 1/**M**.

e) Describe the shape of the **a** versus 1/**M** graph and the relationship between **a** and 1/**M**.

Directly proportional, $a \propto \frac{1}{M}$

d vs t^2



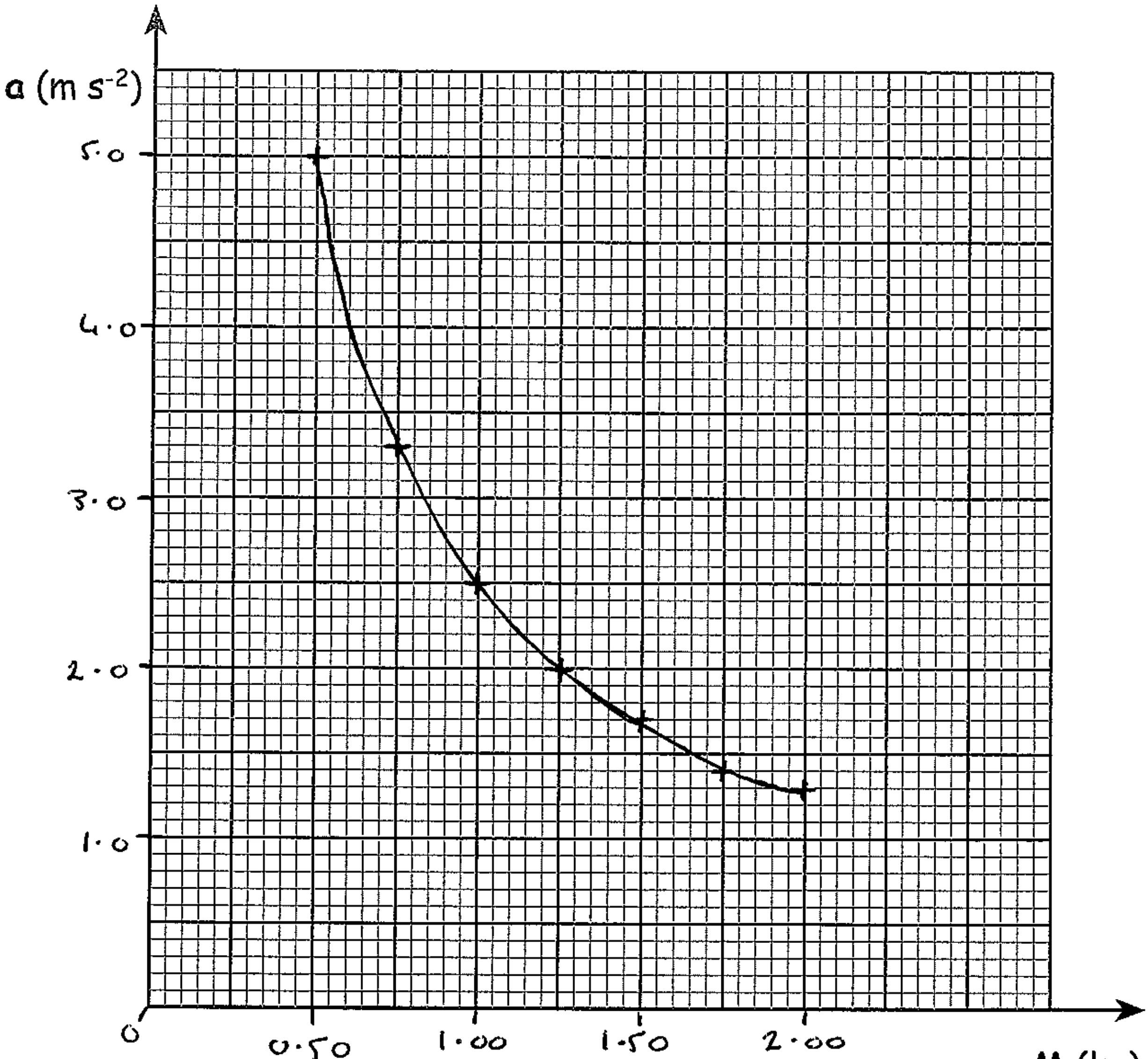
$\Delta d = 0.95 - 0.15$

$= 0.80 m$

$\text{gradient} = \frac{\Delta d}{\Delta t^2}$

$= \frac{0.80}{16.00}$

$= 0.050 ms^{-2}$

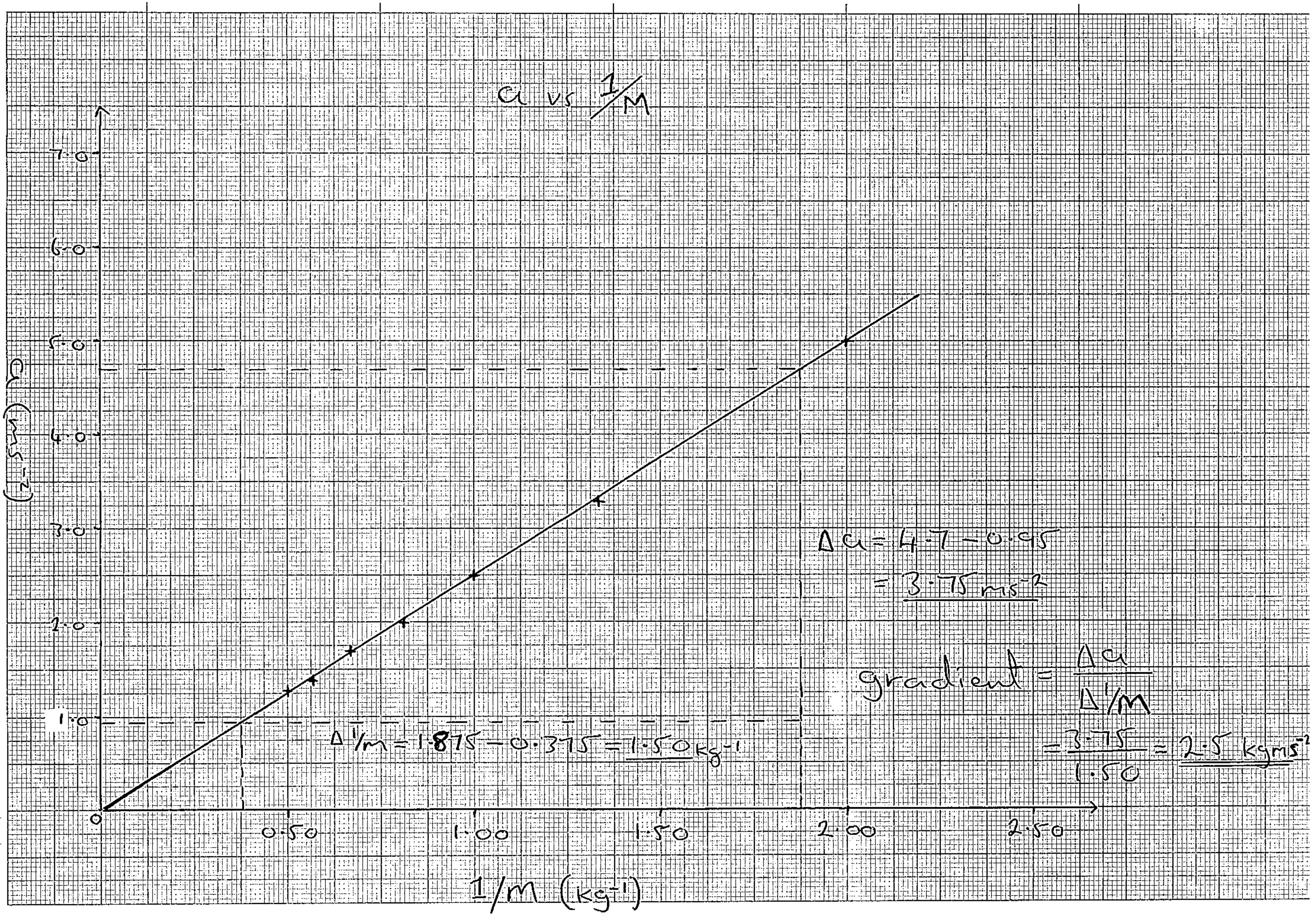


f) Calculate the slope **m** of the **a** versus 1/**M** graph and include its unit.

2.5 kgms⁻²

g) Write down the empirical formula connecting **a** and **M**.

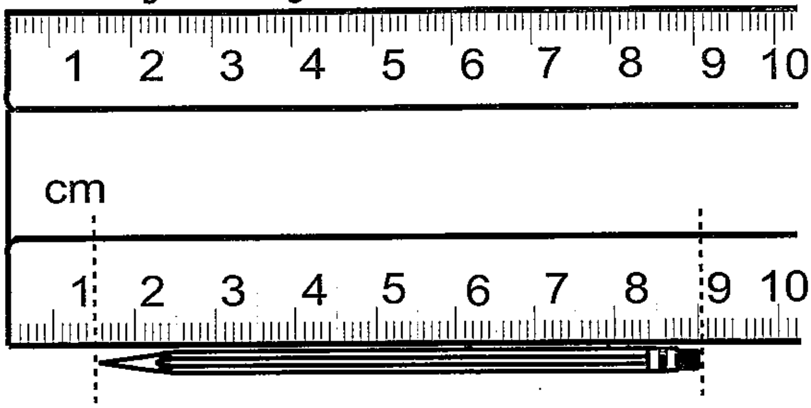
$a = 2.5 \, ^{1}/_{M}$


a vs 1/M
a (ms⁻²)
1/m (kg⁻¹)
0
0·50
1·00
1·50
2·00
2·50
1·0
2·0
3·0
4·0
5·0
6·0
7·0
Δa = 4·7 − 0·95
= 3·75 ms⁻²
Δ1/m = 1·875 − 0·375 = 1·50 kg⁻¹
gradient = Δa / Δ1/M
= 3·75 / 1·50 = 2·5 kgms⁻²

Multi-choice Assessment

The Length of a Pencil

Measuring the Length of a Pencil



1 The diagram shows a ruler being used to measure the length of a pencil.

a) The length of the pencil is:

A 1.0 cm B 7.5 cm
C 8.5 cm D 9.5 cm
E 10.0 cm [B] [1✓]

b) Place a 'T' if true or an 'F' if false beside each of the following statements.

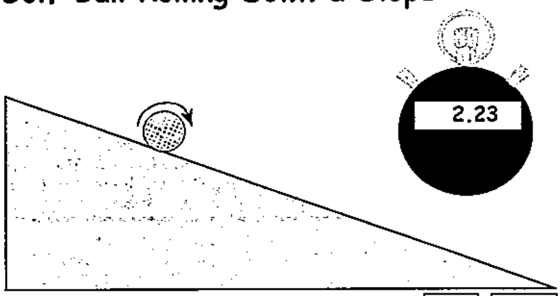
(i) 1 cm is the smallest division on the ruler. [F] [1✓]
(ii) The experimental uncertainty in the length of the pencil is 1 mm. [T] [1✓]
(iii) The length of the pencil is 75 ± 1 mm. [T] [1✓]

c) It is incorrect to write the length of the pencil as:

A 75 mm B 75×10^{-3} m C 7.5 cm D 7.5×10^{-2} cm E 0.75 m [E] [1✓]

Timing a Rolling Golf Ball

Golf Ball Rolling Down a Slope



2 The diagram shows the timing of a golf ball rolling down a slope. Three readings of the golf ball travelling the full length of the slope from rest are:

3.49 s 3.58 s 3.69 s

a) The average time is best quoted as:

A 3.5866667 s B 3.587 s C 3.58 s D 3.59 s E 3.6 s [D] [1✓]

b) Place a 'T' if true or an 'F' if false beside each of the following statements.

(i) The experimental uncertainty of the stop watch is 0.01 s. [T] [1✓]
(ii) The range of the three readings is 0.2 s. [T] [1✓]
(iii) The experimental uncertainty in the average time is about 0.1 s. [T] [1✓]

Graphing Power Laws

3 The diagram on the next page shows five graphical shapes for Y plotted against X, labelled A to E.

a) The graph that shows Y is proportional to X is: [C] [1✓]
b) The graph most likely to show that Y is inversely proportional to X is: [A] [1✓]
c) The graph most likely to show that Y is proportional to X^2 is: [B] [1✓]
d) The graph most likely to show that Y is proportional to $\sqrt{X}$ is: [D] [1✓]

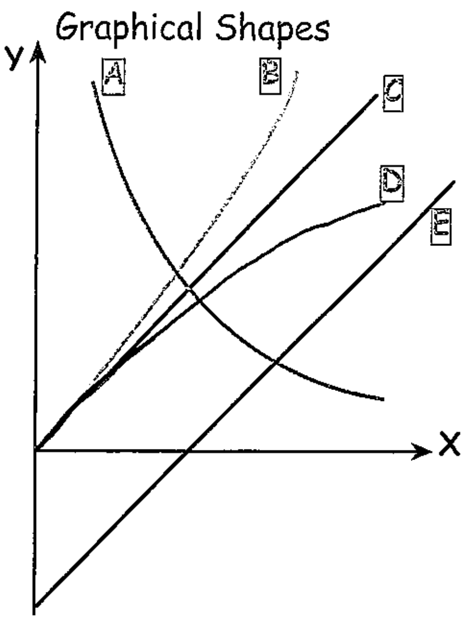
Page total = /13✓

e) The graph the most likely to show the general equation Y = mX + c is: [C] [1✓]

f) The graph the most likely to the following data is:

X	1	2	3	4
Y	1	4	9	16

[B] [1✓]



g) For the data in question f), a straight line through the origin is obtained if the following graph is plotted:

A Y versus X   B Y versus X^2 C Y versus $\sqrt{X}$
D Y versus 1/X   E Y versus $1/X^2$

[B] [1✓]

Plotting and Analysing a Graph

4 The diagram below shows a graph of Y versus X.

a) Place a 'T' if true or an 'F' if false beside each of the following statements.

(i) The axes are labelled correctly. [T] [1✓]

(ii) The scales for axes have been chosen appropriately. [T] [1✓]

(iii) The points are plotted with the correct symbol. [F] [1✓]

b) Place a 'T' if true or an 'F' if false beside each of the following statements.

(i) Y is proportional to X. [F] [1✓]

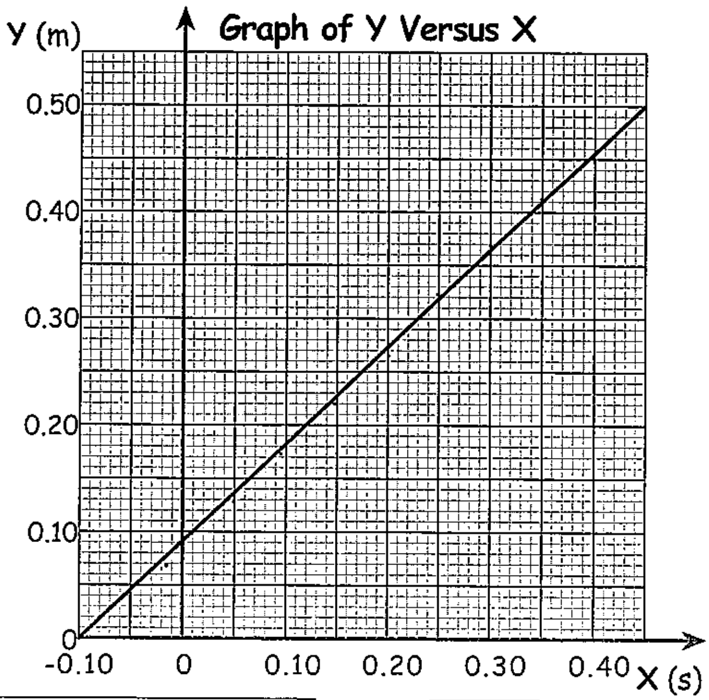
(ii) Y varies linearly with X. [T] [1✓]

(iii) The variation of Y with X is a power law. [F] [1✓]

c) The slope of the graph is:

A 1.1 m s^{-1} B 1.1 s m^{-1}
C 0.91 m s^{-1} D 0.91 s m^{-1}
E 0.09 m

[C] [1✓]



d) The empirical formula describing the variation of Y with X, using SI units is:

A Y = 0.91X + 0.09
B Y = 0.91X - 0.10
C Y = 1.1X + 0.09
D Y = 1.1X - 0.10
E Y = 0.91X + 0.10

[A] [1✓]

Test Total = ✔'s out of a maximim of 24 ✔'s

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