1. No mark scheme available

2. The list gives some quantities and units. *Underline* those which are base quantities of the International (SI) System of units.

coulomb force length mole newton temperature interval

(2 marks)

Define the volt.

Volt = Joule/Coulomb or Watt/Ampere

(2 marks)

Use your definition to express the volt in terms of base units.

Volt = J/C

= kg m^2 s^{-2}/A s

= kg m^2 s^{-3} A^{-1}

(3 marks)

Explain the difference between scalar and vector quantities

Vector has magnitude and direction

Scalar has magnitude only

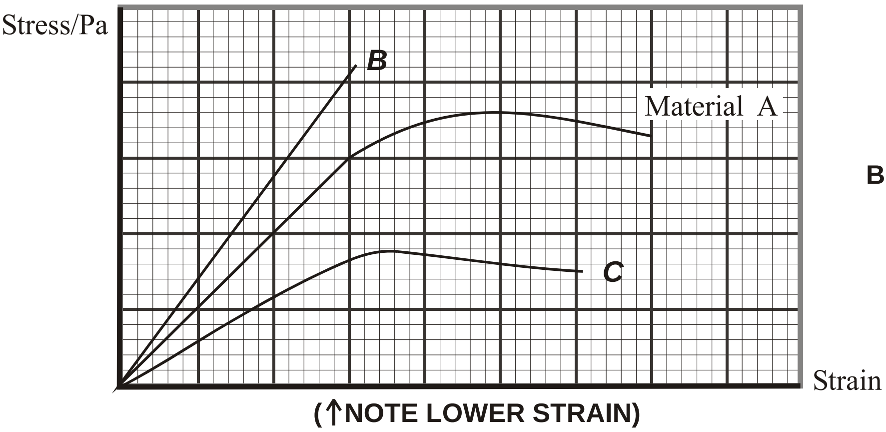
(2 marks)

Is potential difference a scalar or vector quantity?

Scalar

(1 mark)
[Total 10 marks]

3. The graph below shows the behaviour of a material A subjected to a tensile stress.



(↑NOTE LOWER STRAIN)

Brittle (1)
Plastic (1)
Both Young moduli (1)

How would you obtain the Young modulus of material A from the graph?

Find gradient of the linear region (1)
Read values off graph and divide stress by strain/equivalent (1)

(2 marks)

What is the unit of the Young modulus?

Pa/N m^{-2}/kg m^{-1} s^{-2}

(1 mark)

On the same graph, draw a second line to show the behaviour of a material B which has a *greater* Young modulus and is brittle.

Draw a third line to show the behaviour of a material C which has a *lower* value of Young modulus and whose behaviour becomes plastic at a lower strain.

[Total 6 marks]

4. Rubber is commonly described as being more elastic than steel but steel has a greater modulus of elasticity than rubber. On the axes below, sketch two graphs which illustrate the difference in behaviour of rubber and steel when subjected to stress.

Stress

Graphs to show:

(i) Steel steeper (1)

(ii) Max stress steel ≥ 2 × rubber (1)

(iii) Max strain rubber ≥ 2 × steel (1)

(iv) One of several possible shape marks
e.g. rubber becoming steeper at
large strains (1)

Strain

(4 marks)

Describe with the aid of diagrams the difference in molecular structure of rubber and steel.

One point from each line below could be on a diagram

Rubber: Long molecules/polymers/equivalent (1)
coiled/tangled/amorphous (1)

Steel: Long range order/lattice/equivalent (1)
positive ions/polycrystalline (1)

(4 marks)
[Total 8 marks]

5. With the aid of an example, explain the statement “The magnitude of a physical quantity is written as the product of a number and a unit”.

Both number and unit identified in an example (1)

followed by the idea of multiplication (1)

(2 marks)

Explain why an equation must be homogeneous with respect to the units if it is to be correct.

If the units on one side differ from those on the other, then the two sides of the equation relate to different kinds of physical quantity. They cannot be equal [or similar positive statements] (1)

(1 mark)

Write down an equation which is homogeneous, but still incorrect.

Any incorrect but homogeneous algebraic or word equation :
$2mgh = ½mv^2$, 2 kg = 3 kg, pressure =stress/strain (2 or 0)

(2 marks)
[Total 5 marks]

6. Draw a labelled diagram of the apparatus you would use to find the Young modulus of copper wire.

Diagram to show:

(i) wire fixed at one end, load at other end and length of wire implied as being at least 1 metre (1)

(ii) device to aid measurement of small extensions (simplest acceptable marker against fixed ruler) (1)

(2 marks)

State the measurements you would take.

Original length of wire
Extension / new length of wire
Diameter / radius / cross-sectional area of wire

All three (1)

(1 mark)

How would you use your measurements to obtain a value for the Young modulus?

plot stress (defined) v. strain (defined)

OR plot load v. extension

OR substitute values in *Fl*/*Ae* (1)

***E* = gradient**

OR *E*= gradient × l_0/A

OR Repeat for different loads (1)

EITHER gradient of linear region OR use *E* values to check specimen is still elastic. (1)

(3 marks)

Explain why the copper is used in the form of a long thin wire.

So that a reasonable extension is obtained

OR so it stretches with a small load. (1)

Measurements of extension will have smaller percentage uncertainty. (1)

(Accept: measurements more accurate).

(2 marks)

Two wires, X and Y, are made from the same material. Wire X is three times as long as Y and has twice the diameter of Y. When a load is suspended from X the wire extends by 8 mm. How much will wire Y extend with the same load?

Length correction × $^1/_3$ (1)

Area factor (×4 OR ÷4) (1)

Extension of wire Y = 11 mm (1)

(3 marks)
[Total 11 marks]

7. For each of the four concepts listed in the left hand column, place a tick by the correct example of that concept in the appropriate box.

A base quantity	mole	☐	length	☑	kilogram	☐
A base unit	coulomb	☐	ampere	☑	volt	☐
A scalar quantity	torque	☐	velocity	☐	kinetic energy	☑
A vector quantity	mass	☐	weight	☑	density	☐

[Total 4 marks]

8. The table and graph show the properties of TWO materials A and B.

Material	**Young modulus/ 10^{10} Pa**	**Ultimate tensile stress/10^8 Pa**	**Nature**
A	1.0	2.6	Plastic / ductile
B	0.34	3.2	brittle

Use the graph to complete the table for material A.

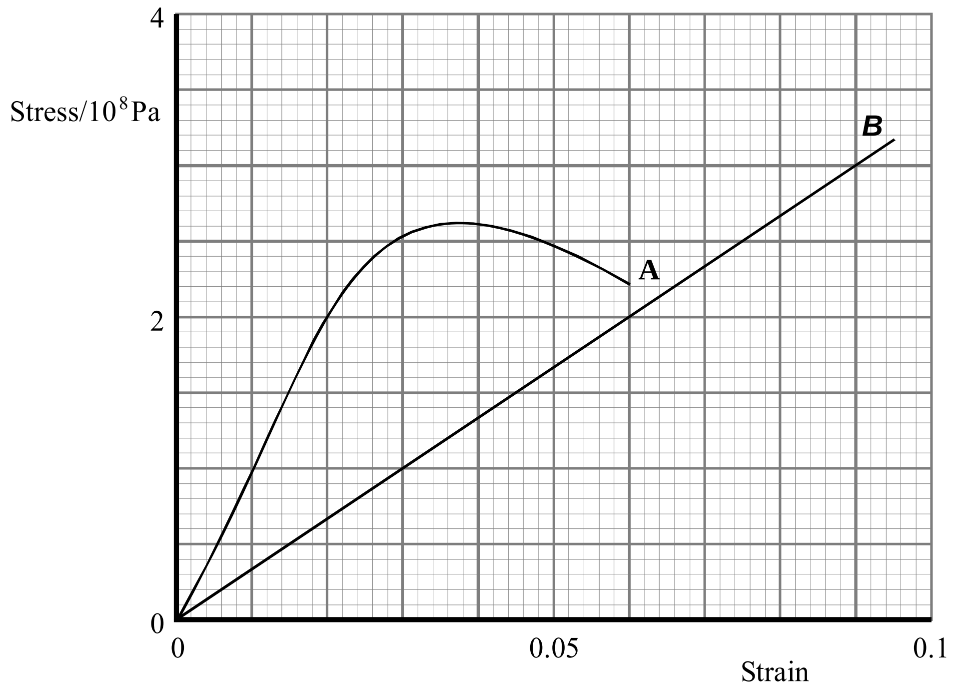
(3 marks)

Use the table to draw a graph on the grid above showing the behaviour of material B.

Straight line of appropriate gradient (1)

UTS 3.2; little plasticity (1)

(2 marks)



[Total 5 marks]

9. Classify each of the terms in the left-hand column by placing a tick in the relevant box.

[Total 6 marks]

10. Joule: kg m^2 s^{-2} **(1)**
Coulomb: Derived unit **(1)**
Time: Scalar quantity **(1)**
Volt: W × A^{-1} **(1)**

[Total 4 marks]

11. Example:

Rubber or other suitable material **(1)**

2^{nd} line on graph:
Straight line, any length **(1)**
Aiming for (0.5, 5) **(1)** 3

Description:

Crystalline diagram	Polymeric diagram **(2)**	
Ordered arrangement of atoms/ions	Long molecules/chains of atoms in random order/	
tangled/coiled **(2)**		4

[No diagrams, maximum 2/4]

[Total 7 marks]

12. Structure of a polycrystalline material:

[Diagram essential. It must be compatible with words and must convey the "jigsaw" idea, i.e. *not* a "bowl of sugar".]

Diagram and words convey idea of a number of crystals/grains

Idea of planes of atoms in different directions 2

Region on graph where copper wire obeys Hooke's law:

Hooke's law region up to (9,15)

Additional information needed:

Length and cross-sectional area

Estimate of energy stored in wire:

Sensible attempt at area up to 20 mm

Answer in range 250 → 270

0.26 J 5

[7]

13. What is meant by "an equation is homogeneous with respect to its units":
Each side/term has the same units 1

Equation $x = ut + ½ at^2$:

ut - (m s^{-1}) s = m

$at^2/2$ (m s^{-2}) s^2 = m

all 3 terms reduce to m 3

[Allow dimensions]

Explanation:

Wrong numerical constant/wrong variables

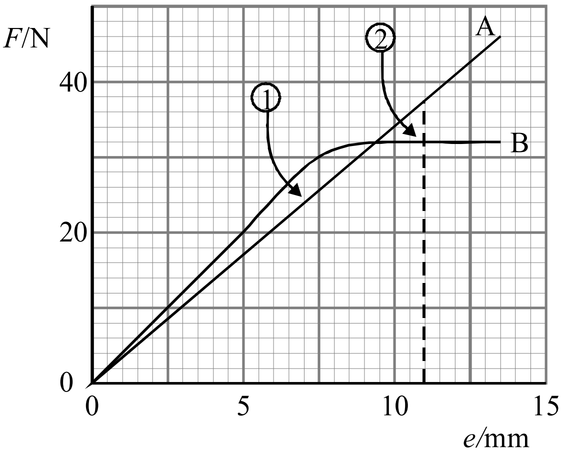
Units same, numbers wrong/

Units same, magnitudes wrong 1

Example = 1 kg + 2 kg = 5 kg

[5]

14.



It breaks/fractures at greater force/stress
Brittle material is A/straight line/linear
Just elastic/no plastic deformation 4

Wire B because area greater
Convincing argument comparing area 1 with area 2 e.g. could show vertical at 11 mm

[Last mark consequent upon previous mark] 2

[6]

15. The joule in base units:

kg m^2 s^{-2} [No dimensions] **(1)** 1

Homogeneity of formula:

ρ kg m^{-3} **(1)**

r m, $f = s^{-1}$ **(1)**

(Right hand side units = (kg m^{-3}) $(m)^5$ $(s^{-1})^2$) [Correct algebra]

= kg m^2 s^{-2} [Only if 1st two marks are earned] **(1)** 3

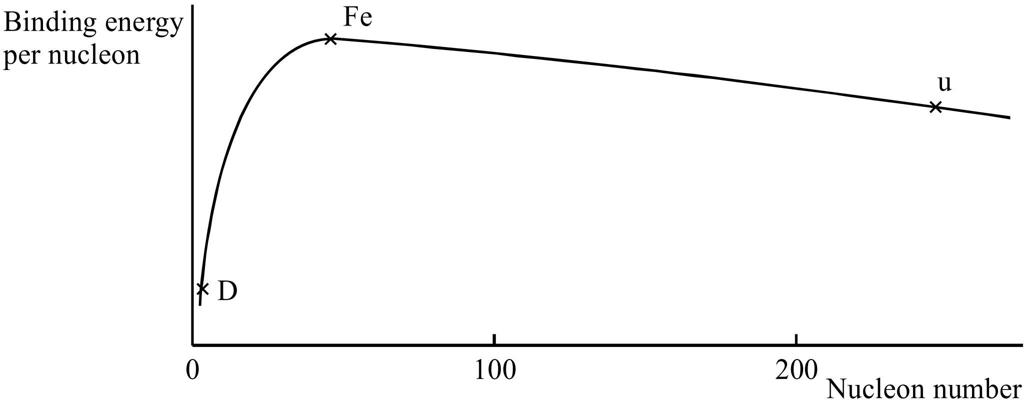
[Ignore numbers; dimensions OK if *clear*]

Why formula might be incorrect:

The $\frac{1}{2}$ could be wrong **(1)** 1

[5]

16. Labels of elements:



D close to O: AND U ≥ 200 **(1)**

Fe at peak **(1)** 2

Meaning of binding energy:

Energy needed to split/separate a nucleus **(1)**

into protons and neutrons/nucleons **(1)**

OR

Energy released when nucleus formed **(1)**

from protons and neutrons/nucleons **(1)**

OR

Energy released due to mass change/defects **(1)**

Sum of masses of protons and neutrons > mass of nucleus **(1)**

[In each of the cases above, the second mark is consequent upon the first]

Explanation:

Uranium **(1)**

Binding energy per nucleon of products is higher
OR
Products/atoms/element/nuclei nearer peak **(1)**

Therefore more stable **(1)** 5

[7]

17. Correct quantities on diagram:

Upper ellipse	capacitance	[**not** energy]	[Accept capacitance^{-1}]	**(1)**
Lower ellipse	resistance	[**not** power]	[Accept conductance/resistance^{-1}]	**(1)**

2

Explanation:

Base quantities/units [**Not** fundamental] **(1)**

Not derived from other (physical) quantities **(1)**

OR other (physical) quantities are derived from them

OR cannot be split up/broken down

2

[4]

18. Nuclear equation:

$^{32}_{15}\text{P} \rightarrow {}^{32}_{16}\text{S} + \beta^{-} \Big| {}^{0}_{-1}\beta \Big| {}^{0}_{-1}\text{e} \Big|$ e^{-} [Ignore + γ + υ] **(1)**

1

Description:

Take background count **(1)**

Take count close to source, then insert paper/card and count **(1)**

Little/no change **(1)**

[OR absorption in air: Take close reading and move counter back; no sudden reduction **(1)(1)**]

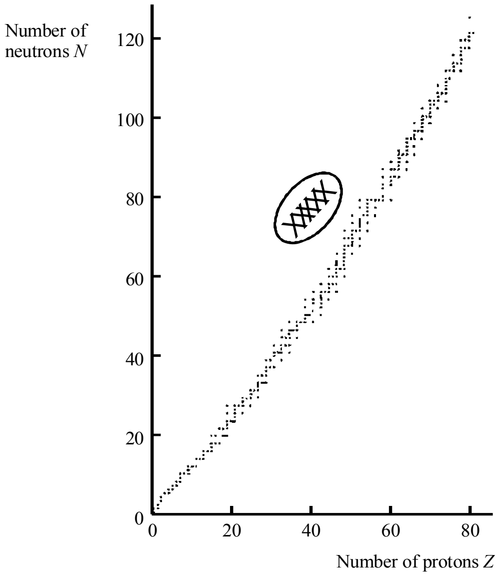
Insert sheet aluminium and count **(1)**

Down to background, or zero **(1)**

Max 4

Diagram: Any region above dots [show **(1)** or **(X)**] **(1)**

1



Explanation:

1 β⁻ decay involves a neutron → a proton Any two from: **(1)**

Any two from:

2. on the diagram this means $\downarrow^{-1}$ **(** $^{+1}$ / diagonal movement
3. so nuclide moves towards dotted line
4. decay means greater stability **(1)(1)**

[β⁻ in wrong region, (1) and (4) only available.

Decay towards drawn $N = Z$ line 1 and 2 only available]

[9]

19. Range of extensions where Hooke's law is obeyed:

(From 0 to) 9 (mm) or 9.5 (mm) **(1)**

1

Addition to diagram:

Horizontal ruler fixed to bench with marker anywhere on wire

OR

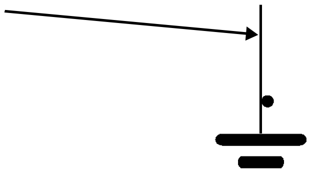
Vertical ruler with pointer on load/hanger OR closely aligned with ruler **(1)**

Length to be measured, as shown on diagram:

Length from double blocks to marker on wire

OR

Length from double blocks to just above the point where mass hanger is hung on pulley



(1)

2

Young modulus:

Use of $E = \frac{Fl}{Ae}$ OR $\frac{F}{A} \div \frac{e}{l}$ **(1)**

F, e valid pair on straight line region consistent with their answer to point 1 **(1)**

[Do not allow 10 mm 44 N. Ignore 10^n error]

$= 1.2 \times 10^{11}$ N m^{-2}/Pa/kg m^{-1} s^{-2} **(1)**

[1.1 – 1.3]

3

Energy stored in wire:

Use of ½ *Fx*/area up to 7 mm OR count squares ≈ 50 **(1)**

0.1 J [Accept Nm] **(1)**

2

One energy transformation:

GPE → elastic potential energy **(1)**

1

Tensile strength of brass:

Attempt to calculate **stress** i.e F/A **(1)**

46/47 N F_{max} off graph **(1)**

$= 3.5 \times 10^8$ ($N\ m^{-2}$) [No u.e.] **(1)**

[3.5 – 3.62]

3

[12]

20. Power = $\frac{\text{work}}{\text{time}}$ OR $\frac{\text{energy}}{\text{time}}$ OR rate of doing work OR rate of transfer of energy **(1)** 1

[Symbols, if used, must be defined]

Unit = Watt OR $J\ s^{-1}$ **(1)** 1

Base units:

$kg\ m^2\ s^{-3}$ **(1)(1)** 2

[If incorrect, possible 1 mark for energy or work = $kg\ m^2\ s^{-2}$ or for J = Nm]

[6]

21. H–R diagram:

Circle ○ S on main sequence at $L_{\odot}$ = 10° **(1)**

Circle ○ M on main sequence at top left **(1)** 2

Numbers on temperature axis showing increase ← **(1)**

Coolest 3000 ± 1000; hottest 20 000 – 50 000
[Both for the mark] **(1)** 2

Large mass stars:

They are brighter OR have greater luminosity OR are hotter (than the Sun) **(1)**

and burn up fuel/hydrogen quickly [Not energy] **(1)** 2

Calculation:

See $E = mc^2$ **(1)**

See $\dfrac{3.9 \times 10^{26} \text{ watts}}{(3 \times 10^{8} \text{ m s}^{-1})^2}$ **(1)**

$= 4.3 \times 10^{9}$ kg s^{-1} **(1)** 3

[9]

22. Advantages:

Can detect fainter stars or more distant stars OR very small amount of light **(1)**

Less time to get image OR more images per session **(1)** 2

Telescopes in space:

Any two of:

Detect wavelengths absorbed by atmosphere/wider range λ **(1)**
OR less dust/less scattering/less light pollution **(1)**
OR no refraction / twinkling **(1)** Max 2

Explanation:

1 β^- decay involves a neutron → a proton Any two from: **(1)**

Any two from:

2. on the diagram this means $\downarrow^{-1}$ **(** $^{+1}$ / diagonal movement

3. so nuclide moves towards dotted line

4. decay means greater stability **(1)(1)**

[β^- in wrong region, (1) and (4) only available.

Decay towards drawn $N = Z$ line 1 and 2 only available]

[9]

23. Pulsar is a neutron star **(1)** 1

Signals are regular (pulses) / at precise intervals **(1)**

Short / fast
[If time given, it should be of the order seconds] **(1)** 2

Quality of written communication **(1)**

Not continuous as star spins OR rotates **(1)**

When points to Earth/radio beam sweeps round OR beam passes
Earth once/twice per revolution **(1)**

Further detail e.g. lighthouse analogy / diagram/ narrow beam **(1)** Max 3

[6]

24. Red giants:

They are cool high volume stars OR cool large surface area OR cool high luminosity/bright/cool big stars **(1)**

Parallax displacement:

Compares the angle between a star and a distant star OR the position of a star relative to a distant star/relative to fixed background **(1)**

Viewed six months later **(1)** 3

[These latter two marks could be obtained from a suitably labelled diagram, but probably only 1 out of 2 for *just* a diagram.]

Period:

5 (days) ± half day **(1)** 1

- Luminosity of B greater than luminosity of A **(1)** 1

B must be further away **(1)**

Convincing reasoning, for example: [consequent on correct distance]

I same, *L* greater, hence *D* greater OR reference to formula
$I = L/4\pi D^2$ OR reference to inverse square law **(1)**
[e.c.f. wrong conclusion at *] 2

Two forces:

Gravitational/gravitation/gravity **(1)**

(Force due to) radiation/photon/electromagnetic wave pressure/forces **(1)** 2

[9]

25. (a) Work = force × distance /displacement **(1)** 1

Unit = Nm OR joule/J(1) **(1)** 1

Base units = kg m^2 s^{-2} **(1)(1)** 2

(b) Hooke's law:

Extension proportional to ($\propto$) force/load OR $F = k\Delta x$ with *F, x* defined **(1)**

below the elastic limit OR below limit of proportionality **(1)** 2

Ultimate tensile stress = 2.3 (× 10^8 Pa)

Young modulus = stress/strain [No mark]

= any pair off linear region between 0.8, 1 and 1.6, 2.1 **(1)**

= 1.3 × 10^{11} (Pa/N m^{-2}) [1.2 – 1.4] **(1)** 3

Attempt to calculate $\dfrac{250\ \text{N}}{1.7 \times 10^{-6}\ \text{m}^2}$ OR *P* correctly plotted **(1)**

Elastic because → on straight line/equivalent **(1)** 2

Point P on line at stress = 1.5×10^8 Pa [e.c.f their value of stress] **(1)** 1

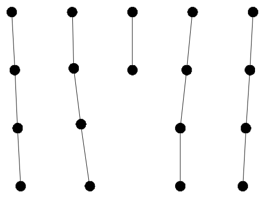
Extension of wire:

Determine strain = $1.1 \times (10^{-3})$ [OR 1.2] **(1)**

[Either by calculation or by reading off graph]

Extension = 3 × strain [e.c.f.]= $3.3\ (3.6) \times 10^{-3}$ m 2

(c) Diagram:



(1) 1

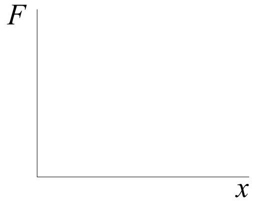
Dislocation is an extra/missing half row/plane of atoms/ions
[OR 2nd diagram showing dislocation moved] **(1)** 1

Risk of cracking:

Quality of written communication **(1)** Max 3

Dislocation moves	OR crack grows/moves	OR many dislocations tangle	**(1)**
Blunts tip of crack	stops at dislocation	no mark	**(1)**
Reduce stress	stress reduced	no mark	**(1)**

(d) Graph:



Axes and shape **(1)**

Arrow heads or labels [if axes inverted, arrows must be reversed] **(1)** 2

Warmer because:

Area represents energy or work done [may be labelled on graph] **(1)**
[Must refer to graph]

Converted to heat (in rubber band) **(1)** 2

(e) Any two of:

Composite material is two (or more) *materials* bonded/joined/ combined **(1)**

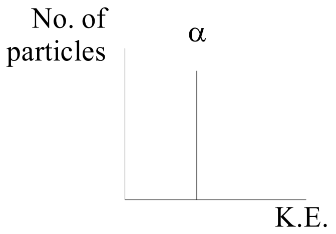
[Beware statements which describe a molecule OR a compound]

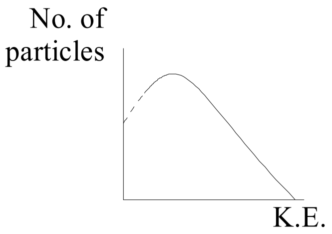
To make use of (best) properties of both **(1)**

[May be given as two specific properties, e.g. a strong and a tough material]

A named composite other than dentine as an example **(1)** Max 2
Diagrams:

Crystalline OR Polycrystalline

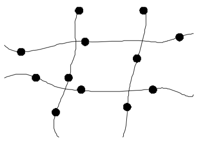




3–D attempt at lattice (2) Tight fitting “jig-saw” (1) **(1)**

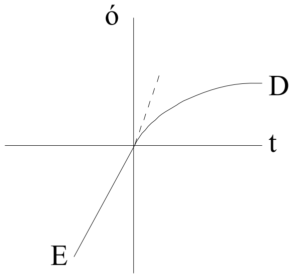
2–D attempt (1) Planes of atoms labelled (1) **(1)**

Amorphous polymer



[Several strands: if no “blobs” then must label one strand “molecule” **(1)** 3

Graph:



E Anywhere in third quadrant **(1)**

to greater stress **(1)**

D Less steep initially [Totally straight, accept] **(1)**

Large area **(1)** 4

[32]

26. Work = force × distance /displacement **(1)** 1

Unit = Nm OR joule/J(1) **(1)** 1

Base units = kg m^2 s^{-2} **(1)(1)** 2

27. Hooke’s law:Extension proportional to ($\propto$) force/load OR $F = k\Delta x$ with F, x defined **(1)**

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[Either by calculation or by reading off graph]

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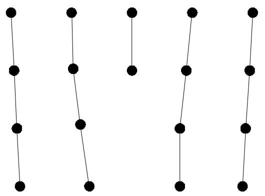
[10]

28. Diagram:



(1) 1

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[OR 2nd diagram showing dislocation moved] **(1)** 1

Risk of cracking:

Quality of written communication **(1)**

Dislocation moves	OR crack grows/moves	OR many dislocations tangle	**(1)**	
Blunts tip of crack	stops at dislocation	no mark	**(1)**	
Reduce stress	stress reduced	no mark	**(1)**	Max 3

[5]

29. Graph:

Axes and shape **(1)**

Arrow heads or labels [if axes inverted, arrows must be reversed] **(1)** 2

Warmer because:

Area represents energy or work done [may be labelled on graph] **(1)**
[Must refer to graph]

Converted to heat (in rubber band) **(1)** 2

[4]

30. Any two of:

Composite material is two (or more) *materials* bonded/joined/ combined **(1)**

[Beware statements which describe a molecule OR a compound]

To make use of (best) properties of both **(1)**

[May be given as two specific properties, e.g. a strong and a tough material]

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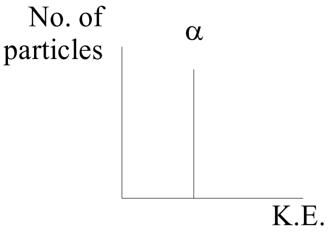

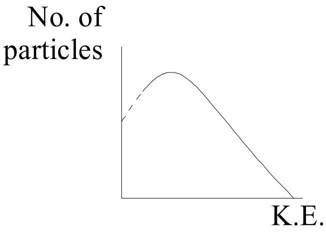

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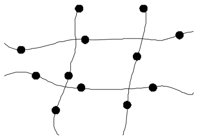
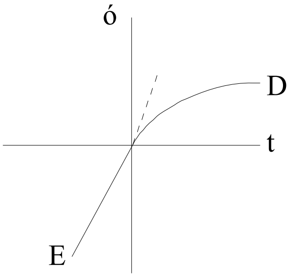


[Several strands: if no “blobs” then must label one strand “molecule” **(1)** 3

Graph:



E Anywhere in third quadrant **(1)**

to greater stress **(1)**

D Less steep initially [Totally straight, accept] **(1)**

Large area **(1)** 4

[9]

31. (a) Density = mass symbol ÷ volume OR $d = m\upsilon$ **(1)** 1

Volume ratio = $\frac{(10^{-10})^3}{(10^{-15})^3}$ [Beware $\frac{10^{-27}}{10^{-42}}$] **(1)**

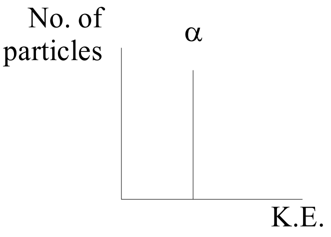
Density of gold nucleus:

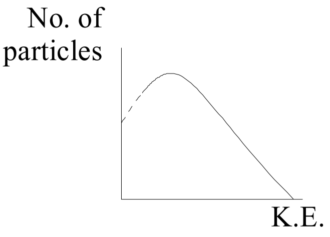
1.9×10^{19} kg m^{-3} **(1)**

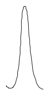
Assumption:

Mass nucleus = mass atom OR electrons negligible/zero mass **(1)** 3

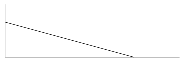
(b) Graphs:





[Accept narrow peak ] [Accept several lines/peaks] **(1)**

α shape **(1)**

β shape [Linear  only eligible for 2nd mark]

β intercept k.e. axis **(1)** 3

Equation:

$n \rightarrow p + e^- + \bar{\nu}$

e^- **(1)**

$\bar{\nu}$ **(1)** 2

Composition:

n (udd) p (uud) [Both] **(1)**

Explanation: **(1)**

Quality of written communication

Decay involves down quark → u quark **(1)**

General statement about change of flavour OR type of quark means only weak/*neither* strong *nor* e/m interaction can do this **(1)** Max 3

[No mark other than quality of language for discussion in terms of $\bar{\nu}$]

(c) *N–Z* grid

Sr at 38, 52 **(1)**

Y at 39, 51 [e.c.f. Sr incorrect → 1 diagonal move] **(1)** 2

Rb at 37, 45 **(1)**

Decays by β^+ emission/positron/α **(1)** 2

(d) Charge on strange quark = – 1/3 **(1)** 1

Conservation law:

Charge – (–1) + (+1) → (0) + X/by charge conservation **(1)**

X is neutral **(1)** 2

Particle X is a meson **(1)**

Baryon number conservation (0) + (+1) → (+1) + (0) **(1)** 2

OR discussion in terms of total number of $q + \bar{q} = 5$ OR $\Sigma q - \bar{q} = 3$

Composition of X is $s\bar{d}$ [0/3 if not $q\bar{q}$]**(1)**

Justify S quark:

This is not a weak interaction/only a weak interaction can change quark type/
this is a strong interaction/strangeness is conserved/ quark flavour cannot change **(1)**

Justify $\bar{d}$ quark:

X neutral; s – 1/3; $\bar{d}$ + 1/3. [e.c.f. if s = – 1/3 in first line.]

For the third mark accept any $q\bar{q}$ pair that creates a meson
of the charge deduced for X above. **(1)** 3

[The justification for both q and $\bar{q}$ can be done also by tracking individual quarks]

(e) Antiparticles:

e^+ (positron) $\bar{c}$ (Charmed antiquark) **(1)(1)** 2

[Also accept either π^+ OR π^- as long as it is stated that one is the antiparticle
of the other, i.e. NOT just π^+ OR π^-]

Zero charm, since quarks have equal and opposite charm OR (+1) **(1)**
charm + (–1) charm = 0 [Not equal and opposite charge] 1

Heavier version by $\bar{c}$ and c moving round each other/orbiting with **(1)**
higher energy level 1

Diagram:

A Ψ **(1)**

$$\left.\begin{array}{ll} \text{B} & \pi^+ \text{ OR } \pi^- \\ & \\ \text{C} & \pi^- \text{ OR } \pi^+ \end{array}\right\} \textbf{(1)}$$

2

Interaction: strong **(1)** 1

Exchange particle: gluon **(1)** 1

[e/m **(0)** but ecf Z° **(1)**]

[32]

32. Density = mass symbol ÷ volume OR $d = m\upsilon$ **(1)** 1

Volume ratio = $\frac{(10^{-10})^3}{(10^{-15})^3}$ [Beware $\frac{10^{-27}}{10^{-42}}$] **(1)**

Density of gold nucleus:

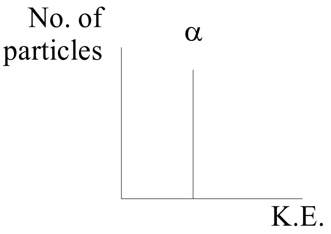
1.9×10^{19} kg m^{-3} **(1)**

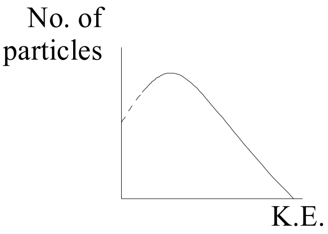
Assumption:

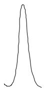
Mass nucleus = mass atom OR electrons negligible/zero mass **(1)** 3

[4]

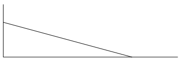
33. Graphs:





[Accept narrow peak ] [Accept several lines/peaks] **(1)**

α shape **(1)**

β shape [Linear  only eligible for 2nd mark]

β intercept k.e. axis **(1)** 3

Equation:

$n \rightarrow p + e^- + \bar{\nu}$

e^- **(1)**

$\bar{\nu}$ **(1)** 2

Composition:

n (udd) p (uud) [Both] **(1)**

Explanation: **(1)**

Quality of written communication

Decay involves down quark → u quark **(1)**

General statement about change of flavour OR type of quark means only weak/*neither* strong *nor* e/m interaction can do this **(1)** Max 3

[8]

[No mark other than quality of language for discussion in terms of $\bar{\nu}$]

34. *N–Z* grid

Sr at 38, 52 **(1)**

Y at 39, 51 [e.c.f. Sr incorrect → 1 diagonal move] **(1)** 2

Rb at 37, 45 **(1)**

Decays by β^+ emission/positron/α **(1)** 2

[4]

35. Charge on strange quark = – 1/3 **(1)** 1

Conservation law:

Charge – (–1) + (+1) → (0) + X/by charge conservation **(1)**

X is neutral **(1)** 2

Particle X is a meson **(1)**

Baryon number conservation (0) + (+1) → (+1) + (0) **(1)** 2

OR discussion in terms of total number of q + $\bar{q}$ = 5 OR Σq – $\bar{q}$ = 3

Composition of X is $s\bar{d}$ [0/3 if not $q\bar{q}$]**(1)**

Justify S quark:

This is not a weak interaction/only a weak interaction can change quark type/this is a strong interaction/strangeness is conserved/ quark flavour cannot change **(1)**

Justify $\bar{d}$ quark:

X neutral; s – 1/3; $\bar{d}$ + 1/3. [e.c.f. if s = – 1/3 in first line.]

For the third mark accept any $q\bar{q}$ pair that creates a meson of the charge deduced for X above. **(1)** 3

[The justification for both q and $\bar{q}$ can be done also by tracking individual quarks]

[8]

36. Antiparticles:

e^+ (positron) $\bar{c}$ (Charmed antiquark) **(1)(1)** 2

[Also accept either π^+ OR π^- as long as it is stated that one is the antiparticle of the other, i.e. NOT just π^+ OR π^-]

Zero charm, since quarks have equal and opposite charm OR (+1) **(1)** charm + (–1) charm = 0 [Not equal and opposite charge] 1

Heavier version by $\bar{c}$ and c moving round each other/orbiting with **(1)** higher energy level 1

Diagram:

A Ψ **(1)**

B π^+ OR π^-

C π^- OR π^+ } **(1)** 2

Interaction: strong **(1)** 1

Exchange particle: gluon **(1)** 1

[e/m **(0)** but ecf Z° **(1)**]

[8]

37. (a) Potential difference = $\frac{\text{work/energy}}{\text{charge}}$ OR $\frac{\text{power}}{\text{current}}$

OR in words: work done in moving 1 coulomb of charge between two points. **(1)** 1

Unit: volt OR J C^{-1} OR V **(1)** 1

Base units: kg m^2 A^{-1} s^{-3} **(1)(1)** 2

[2/2 possible even if final answers wrong for recognising that As = C J = Nm]

(b) Explain half life: some isotope is *removed* from the body by biological processes/decay [OR a specific example, e.g. by excretion] **(1)** 1

Effective half–life $\frac{1}{t_e} = \frac{1}{8} + \frac{1}{21}$ **(1)**

t_e = 6 (days) (5.8) [139 hours, 500 524 seconds] **(1)** 2

Number of days:

1/8 is (1 → ½ → ¼ → 1/8) 3 half–lives **(1)**

so 18 (days) [17] **(1)** 2

Reason for γ:

Can be detected outside the body OR less strongly ionising than α or β OR weakly ionising/does not interact with tissue **(1)** 1

Property:

Must be chemically appropriate for take up by the organ/part of the body concerned/non–toxic/pure γ/equivalent **(1)** 1

(c) Quality of written communication **(1)**

Any three from:

- Coupling medium excludes air between transmitter and body **(1)**
- Z_{air} and Z_{body} very different **(1)**
- Ultrasound strongly reflected at skin / equivalent **(1)**
- Little ultrasound reaches organs being investigated **(1)** Max 3

Coupling medium:

Water/gel/Vaseline/equivalent **(1)** 1

Calculation:

Distance = speed × time [or use of] **(1)**

$= 1.5 \times 10^3 \text{ m s}^{-1} \times 135 (\times 10^{-6}) \text{ s}$ **(1)**

[Accept 90 → 180] [i.e. 50 (1.8 → 3.6)]

$= 200 \times 10^{-3}$ m [± 10] **(1)**

Head = ½ × this = 0.10 m [e.c.f.] **(1)** 4

(d) Appropriate voltage:

kilovolt range [Not keV] **(1)** 1

Anode rotated:

so heat spread out/not just one point **(1)** 1

Tube evacuated:

So no collisions/obstruction/scattering of electrons with air molecules OR by atoms/particles OR equivalent **(1)** 1

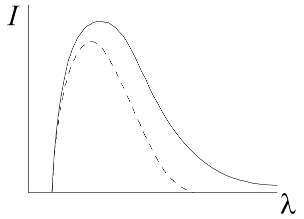
Appropriate material:

Lead **(1)** 1

(e) Heterogeneous – containing X–rays of many wavelengths/ energies/frequencies **(1)**

Hardening – removing lower energy/longer wavelength X–rays OR increase average energy OR make more penetrating OR improve quality [Beware "increase energy"] **(1)** 2

Graph:



[Identical shape shifted left or right, 0/3]

--------- Less area enclosed **(1)**

(Almost) the same at small λ **(1)**

(Much) lower at long λ **(1)** 3

More penetrating because:

The remaining X–rays have a higher average energy OR shorter average wavelength **(1)**

Any one of:·

- Long λ attenuated more than short λ
- Low E attenuated more than high E
- The beam is harder
- The beam is of higher quality **(1)** 2

Beneficial since:

Low energy X–rays are absorbed by patient **(1)**
Filtering reduces dose/equivalent to patient **(1)** 2

[Many will say much more than this which effectively implies these two points]

[32]

38. Potential difference = $\frac{\text{work/energy}}{\text{charge}}$ OR $\frac{\text{power}}{\text{current}}$

OR in words: work done in moving 1 coulomb of charge between two points. **(1)** 1

Unit: volt OR J C^{-1} OR V **(1)** 1

Base units: kg m^2 A^{-1} s^{-3} **(1)(1)** 2

[2/2 possible even if final answers wrong for recognising that As = C J = Nm]

[4]

39. Explain half life: some isotope is *removed* from the body by biological processes/decay [OR a specific example, e.g. by excretion] **(1)** 1

Effective half–life $\frac{1}{t_e} = \frac{1}{8} + \frac{1}{21}$ **(1)**

$t_e = 6$ (days) (5.8) [139 hours, 500 524 seconds] **(1)** 2

Number of days:

1/8 is (1 → ½ → ¼ → 1/8) 3 half–lives **(1)**

so 18 (days) [17] **(1)** 2

Reason for γ:

Can be detected outside the body OR less strongly ionising than α or β
OR weakly ionising/does not interact with tissue **(1)** 1

Property:

Must be chemically appropriate for take up by the organ/part of the body concerned/non–toxic/pure γ/equivalent **(1)** 1

[7]

40. Quality of written communication **(1)**

Any three from:

- Coupling medium excludes air between transmitter and body **(1)**
- Z_{air} and Z_{body} very different **(1)**
- Ultrasound strongly reflected at skin / equivalent **(1)**
- Little ultrasound reaches organs being investigated **(1)** Max 3

Coupling medium:

Water/gel/Vaseline/equivalent **(1)** 1

Calculation:

Distance = speed × time [or use of] **(1)**

$= 1.5 \times 10^3 \text{ m s}^{-1} \times 135 (\times 10^{-6}) \text{ s}$ **(1)**

[Accept 90 → 180] [i.e. 50 (1.8 → 3.6)]

$= 200 \times 10^{-3}$ m [± 10] **(1)**

Head = ½ × this = 0.10 m [e.c.f.] **(1)** 4

[8]

41. Appropriate voltage:

kilovolt range [Not keV] **(1)** 1

Anode rotated:

so heat spread out/not just one point **(1)** 1

Tube evacuated:

So no collisions/obstruction/scattering of electrons with air molecules OR by atoms/particles OR equivalent **(1)** 1

Appropriate material:

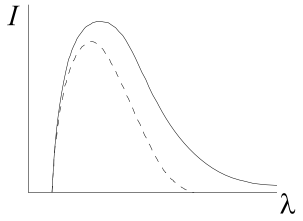
Lead **(1)** 1

[4]

42. Heterogeneous – containing X–rays of many wavelengths/ energies/frequencies **(1)**

Hardening – removing lower energy/longer wavelength X–rays OR increase average energy OR make more penetrating OR improve quality [Beware "increase energy"] **(1)** 2

Graph:



[Identical shape shifted left or right, 0/3]

--------- Less area enclosed **(1)**

(Almost) the same at small λ **(1)**

(Much) lower at long λ **(1)** 3

More penetrating because:

The remaining X–rays have a higher average energy OR shorter average wavelength **(1)**

Any one of:·

- Long λ attenuated more than short λ
- Low E attenuated more than high E
- The beam is harder
- The beam is of higher quality **(1)** 2

Beneficial since:

Low energy X–rays are absorbed by patient **(1)**
Filtering reduces dose/equivalent to patient **(1)** 2

[Many will say much more than this which effectively implies these two points]

[9]

43. (a) (i) ± 2 of supervisor's value **(1)**

D ± 1 mm of supervisor, + unit **(1)**

Suitable method for *D* using set squares **(1)(1)**
[Use of 1 set square can get (1) or slide rule/set square between turns]

± 1 mm of supervisor + unit **(1)**

Repeats for *D* and *l* [shown and averaged] **(1)**
[Penalise units once only] 6

(ii) *L* found correctly with unit and symbol ≥ 2 significant figures **(1)**

d found correctly with unit and ≥ 2 significant figures **(1)**
[but allow 21 ÷ 30 = 0.7 mm]

V found correctly with unit and ≥ 2 significant figures **(1)**
[No e.c.f. – can only get this mark if *L* and *d* correct] 3

(iii) Correct calculation based on sensible *m* **(1)**

2/3 significant figures + unit **(1)**

(7000 – 9000) kg m^{-3} **(1)**
[No e.c.f. but ignore unit] 3

(b) (i) *R* (0.5 – 1.5) Ω + unit **(1)**

"Zero" checked **(1)**

Good contact **(1)**

Avoid "shorting" **(1)**
[Any 2 precautions – can be inferred] Max 3

(ii) Correct substitution [i.e. consistent units] **(1)**

Correct calculation to 1 or 2 significant figures **(1)**

Value (1.0 – 3.0) 10^{-7} Ωm [but with consistent unit] **(1)** 3

(c) Newton meter vertical [diagram or stated] OR zero checked **(1)**

Clear indication that stretched length = distance between nails **(1)**
[i.e. 150 mm]
OR stretched length of coiled part of spring
[approximately 120 mm]

Good technique for making this measurement using nails

Sensible value for x, with unit **(1)**

by different method **(1)**

Sensible F + unit **(1)**

Correct calculation of energy with unit [no e.c.f. if F and x clearly wrong] **(1)**

[Allow Nm, but **not** N cm, N mm] Max 6

Sample results:

(a) (i) $N = 31$

D/mm: 15, 15, average 15 mm

l/mm: 22, 22, average 22 mm

(ii) $L = (31 + 4)\pi \times 0.015$ m

$= 35\pi \times 0.015$ m

= 1.65 m

$d = 22 \div 31$ mm

= 0.71 mm

$$V = \frac{\pi(0.71 \times 10^{-3})^2 \times 1.65}{4} \text{ m}^3$$

= 6.5 10^{-7} m^3

–

(iii) $m = 5.10$ g

$$\text{Density} = \frac{m}{V} = \frac{5.10 \times 10^{-3} \text{ kg}}{6.5 \times 10^{-7} \text{ m}^3}$$

= 7800 kg m^{-3}

(b) (i) Leads shorted by connecting crocodile clips (zero error = 0.3 Ω)

Coil gripped tightly, R = 1.1 Ω

$R = 1.1 - 0.3 = 0.8$ Ω

(ii) $$\rho = \frac{0.8 \times (0.71 \times 10^{-3})^2}{4 \times 31 \times 0.015}$$

= 2.2 10^{-7} Ωm

(c) Hook spring on to Newton meter and keep just above nail.

Hook spring over nail and hold tightly

Stretched length of spring = 150 mm

Unstretched length = 54 mm

$\therefore$ extension $x = 96$ mm

Applied force $F = 2.7$ N

$\therefore$ energy stored $\frac{1}{2} Fx = \frac{1}{2} \times 2.7 \times 0.096$

$= 0.13$ J

44. (a) (i) Table with columns headed with quantities and units **(1)**

Reading every ½ minute or better OR timed for every 1°C fall **(1)**

Start ≥80 °C and finish ≤ 70 °C **(1)**

Concave curve established **(1)** 4

(ii) Graph:

Scale [more than ½ grid in both directions, avoiding scales of 3 etc; **(1)** allow 60 s per square]

Axes [labelled, with units] **(1)**

Plots [accurate to ½ division] **(1)**

Line [smooth curve] **(1)** 4

(iii) Good tangent at 75°C [must be a curve for this mark] **(1)**

Large Δ [$\Delta x \Delta y \geq 64$ cm^2] **(1)**

Correct calculation + unit and > 2 significant figures [ignore sign] **(1)**

Correction + unit [W or J s^{-1}] **(1)** 4

(b) (i) Temperature sensor **(1)**

Data logger **(1)**

Computer **(1)**
[–1 if no arrows]

≤ 30 s **(1)** 4

(ii) (9.3 – 9.4) V + unit **(1)**

Potential divider [not series rheostat] OR *labelled* [or with arrow] variable power supply **(1)**

Heater **(1)**

Voltmeter **(1)**
If voltmeter in series with heater can only get first mark] 4

(iii) Any two from:

Leave datalogger operating overnight OR set time for 12 – 24 h **(1)**

Sampling rate ≤ 30 min **(1)**

Download data to computer next morning **(1)**

Any two reasons:· **(1)(1)**

- variation of room temperature
- evaporation of water
- fluctuations in power supply 4

[NB "heat lost from beaker" is not a reason]

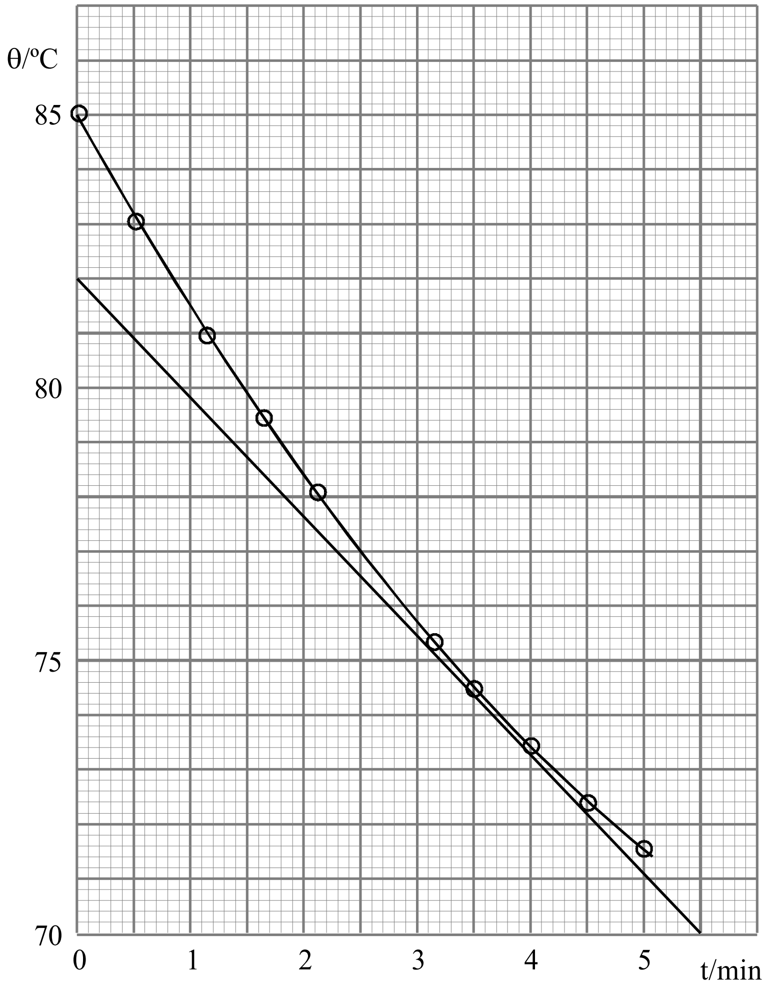
[24]

Sample results:

(a) (i)

t/min	θ °C
0.0	85.0
0.5	83.0
1.0	81.0
1.5	79.5
2.0	78.0
2.5	77.0
3.0	75.5
3.5	74.5
4.0	73.5
4.5	72.5
5.0	71.5

(ii) Graph:



(iii) $\dfrac{\Delta\theta}{\Delta t} = \dfrac{82.0 - 70.0}{5.5 - 0.0}$ K min^{-1}

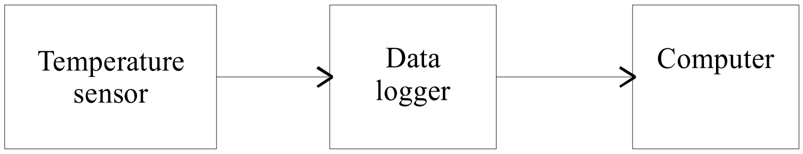
$= -\,2.2$ K min^{-1}

$= -\,0.036$ K s^{-1}

$P = 900 \times 0.036$ J s^{-1}

$= 32$ W

(b) (i)



Sampling rate of every 10 s would give 30 readings in 5 minutes

(ii) p.d. = 9.4 V

Diagram:

Set p.d. to 9.4 V as read off from curve

(iii) Set data logger to record for 24 h at sampling rate of every 30 min

Reasons:

- variation of room temperature
- evaporation of water
- fluctuations in power supply

45. (a) (i) *l* and *w* ± 2 mm of supervisor [must be mm or better precision] **(1)**

Both repeated and averaged **(1)**

t ± 0.03 mm of supervisor from at least two readings and to 0.01 mm or better **(1)(1)**

[Average values may be used in formula for *V*]
[± 0.05 from 2 (1); ± 0.03 from 1 (1)]

Zero error OR ≥ 4 readings of *t* **(1)**

Any one explanation – see sample results **(1)** 6

(ii) Correct calculation + unit
[e.c.f. wrong *l, w* or *t*] **(1)**

2 or 3 significant figures from correct calculation **(1)** 2

Value obtained is for edges only **(1)**

so cut/fold card into smaller pieces/use longer reach micrometer **(1)**

and measure the thickness of, say, 20 pieces to get a better average **(1)**
[larger number or > 10 specified] Max 2

(b) (i) Set up correctly without help **(1)(1)**
[Ignore wrong polarity] 2

(ii) Sensible value of ε to 0.01 V or better **(1)**

Sensible value of *V* to 0.01 V or better **(1)**

[Unit must be seen at least once] 2

(iii) Correct calculation of *I* with unit and > 2 significant figures **(1)**
[e.c.f. from *V*]

Correct use of, and substitution in, formula **(1)**

Correct calculation with unit and 2/3 significant figures **(1)**
[Allow e.c.f.] 3

(c) (i) Sensible θ_1 and θ_2 recorded with unit **(1)**
[Minimum value of θ_1 to be 10 °C;
maximum temperature rise, 15 °C]

Correct substitution [consistent units] **(1)**

Correct calculation with unit **(1)**

Value 300 – 500 **(1)(1)**
[Value 200 – 600, (1)]
[Value mark only scored from correct calculation] 5

(ii) Any two sources of error:

- loss of heat from washers at transfer **(1)**
- washers may not be at 100 °C **(1)**
- some water transferred with washers **(1)**
- heat lost from cup to surroundings **(1)**
- some heat gained by cup **(1)**
- some heat gained by thermometer **(1)** 2

[Not parallax in thermometer reading; generally not measurement errors]

Sample results:

(a) (i) l/mm: 297, 297, average: 297 mm

w/mm: 211, 211, average: 211 mm

t/mm: 0.98, 0.94, 0.96, 0.93, 0.94, average: 0.95 mm
[No zero error on micrometer]

Minimises error

in dimensions (particularly thickness)

Eliminates anomalous/rogue readings

(ii) $m = 37.2$ g

$$\rho = \frac{m}{V} = \frac{37.2 \times 10^{-3}}{0.297 \times 0.211 \times 0.95 \times 10^{-3}}$$

$= 625$ kg m^{-3}

Value obtained is for edges only,

so cut/fold card into smaller pieces/use longer reach micrometer
and measure the thickness of, say, 20 pieces to get a better average

(b) (i) Circuit set up correctly

(ii) $\varepsilon = 1.52$ V

$V = 1.32$ V

(iii) $I = V \div R = \dfrac{1.32 \text{ V}}{4.7\ \Omega}$

= 0.281 A [281 mA]

$r = \dfrac{\varepsilon - V}{I} = \dfrac{1.52 - 1.32}{0.281}$

= 0.71Ω

(i) $\theta_1 = 18.5$ °C

$\theta_2 = 23.3$ °C

$m_s = 36$ g

$c_s = \dfrac{0.050 \times 4200(23.3 - 18.5)}{0.036 \times (100.0 - 23.3)}$

$= 365 \text{ J kg}^{-1} \text{ K}^{-1} \text{ [J kg}^{-1} \text{ °C}^{-1}]$

$[0.365 \text{ J g}^{-1} \text{ K}^{-1}]$

(ii) Any two sources of error:·

- loss of heat from washers at transfer
- washers may not be at 100 °C
- some water transferred with washers
- heat lost from cup to surroundings
- some heat gained by cup
- some heat gained by thermometer

[24]

46. (a) Average of *t* found from ≥ 3 runs and average found with units **(1)(1)**

[2 runs →(1)]

2.0 s – 5.0 s **(1)**

[Systematic error in *t*, do not award third mark]

[All measurements to nearest second $^{-1}$]

Correct calculation and unit to ≥ 2 significant figures **(1)** 4

(b) Diagram clearly showing distance travelled
[could be from base of mass to ground] **(1)**

Using same point on trolley or falling mass **(1)**

Good method for determining starting and stopping positions of trolley, e.g. eye level, block on bench, etc. **(1)** 3

(c) Correct re–arrangement **(1)**

Correct substitution (SI units) **(1)**

Correct calculation with unit and ≥ 2 significant figures **(1)** 3

(d) Sensible Δ*m* > 30 g OR max value of *m*(100 g) **(1)**

Average *t* found from ≥ 3 runs **(1)(1)**

[From 2 →(1)]

Correct calculation (of *a*) and *F,* with units for *F* and ≥ 2 significant figures **(1)** 4

(e) Correct percentage difference with mean or either value as denominator **(1)**

Sensible conclusion based on where less or more than 10% **(1)** 2

[Allow modulus if one *F* positive and the other negative]

(f) (i) Keep *M* constant OR keep *x* constant [or measure *x*] **(1)**

Use range of value of *m* **(1)**

Find corresponding *t* **(1)**

Calculate acceleration **(1)**

(ii) Axes labelled **(1)**

Correct line **(1)**

–*F* shown on graph OR dotted extrapolation OR *F* with negative sign stated in part (iii) **(1)**

(iii) Gradient = *g* **(1)**

Intercept = –*F* [Ignore sign] **(1)**

[Accept numerical values from (c) or (d) without units] Max 8

Sample results:

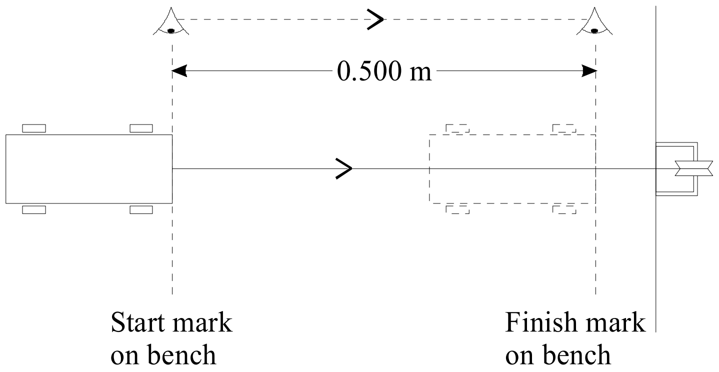
(a) $m = 40$ g [i.e. 30 g added to hanger]

t/s: 3.9, 4.3, 4.2, 3.9, 4.1 average = 4.08 s

$$a = \frac{2 \times 0.500}{4.08^2}$$

$= 0.060 \text{ m s}^{-2}$

(b) Diagram:



Pulley may be used as end point

(c) ($M = 2.42$ kg)

$F = mg - (M + m)\, a$

$= (0.04 \times 9.81) - (2.42 + 0.04) \times 0.060$

$= 0.392 - 0.147$ N

$= 0.24$ N

(d) $m \;\; = 80$ g

t/s = 2.0, 2.3, 2.1, 2.4, 2.3 Average $t = 2.22$ s

$$a = \frac{2 \times 0.500}{2.22^2}$$

$= 0.20$ m s^{-2}

$F = 0.08 \times 9.81 - (2.42 + 0.08) \times 0.20$

$= 0.785 - 0.500$

$= 0.28$ N

(e) Percentage difference = $\dfrac{0.28 \; - 0.24}{0.26} \times 100\%$

= 15% (> 10%)

So F cannot be considered as constant

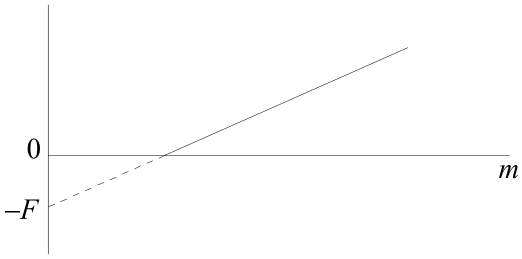
(f) (i) Keep M constant OR keep x constant [or measure x]

Use range of value of m

Find corresponding t

Calculate acceleration

(ii) $(M{+}m)a$



(iii) Gradient = g

Intercept = $-F$

[24]

47. (a) Radio
Visible 2

Examples of benefits:

Increased clarity
No atmospheric refraction/scattering

Increased range of wavelengths
No atmospheric absorption 4

(b) Earth temperature 0 –39ºC/280 - 300 K
$\rightarrow \lambda_{max} = 1.4/1.3 \times 10^{-5}$ m or 14/13 μm 2

Graph line:

Gradually rising line [no peak before 10 μm]
Never getting higher than a quarter of Sun 2

(c) Giant stars and white dwarfs marked on diagram 2

5000 K 1

Approximately $10^{2} \times 3.9 \times 10^{26}$ W = 3.9×10^{28} W 2

Power = σAT^{4}
4×10^{28} W = 5.7×10^{-8} W m^{-2} $K^{-4} \times A \times 10\,000$ K^{4}
$\therefore A = 7.0 \times 10^{19}$ m^{2}
$(4\pi r^{2} = A \ \therefore r = \sqrt{\dfrac{7.0 \times 10^{19}\,\text{m}^{2}}{4\pi}} = 1.2 \times 10^{9}\,\text{m}$ 4

(d) Steady burning on main sequence for a long time **(1)**
Core reaction pushes outer layers out **(1)**
Red giant/outer layers lost **(1)**
(Core) remnant becomes white dwarf **(1)** Max 3

Quality of written communication 1

(e) (i) 0.1 μm –1 μm
5 μm –50 μm

Advantages:

Higher quantum efficiency/responds to individual photons
No need to replace/can be used repeatedly
[One mark for operates more quickly] 4

(ii) $L = km^{3.5}/L \propto m^{3.5}$
$2.3^{3.5}$ = 18.45/18.5/18 [not 20] 3

(iii) Below a certain mass the core temperature
is not high enough for fusion/hydrogen burning 2

[32]

48. (a) Ability of a material to withstand a force without breaking,
independent of sample dimensions 1

Stress-strain graph:

Axes (Stress on ordinate, strain on abscissa)
Shape 2

Labels in correct places 3

(b) Attempt to use principle of moments
$\rightarrow T_1$ = 200 N [e.g. –1 for a.c.]
and T_2 = 360 N [e.c.f.]

(c) Young modulus = $\frac{Fl}{Ax}$

$= \frac{350\text{N} \times 0.39\text{m}}{\pi \times 0.0175^2\text{m}^2 \times 5 \times 10^{-6}\,\text{m}}$

$= 1.9 \times 10^{11}$ N m^{-2} 3

$\frac{\text{Energy}}{\text{Volume}}$

$= \frac{280 \times 4 \times 10^{-6}\,\text{m}}{\pi \times 0.0175^2\ \text{m}^2 \times 0.39\,\text{m}}$

= 2.98 J m^{-3} 4

(d) Half plane displaced
and labelled 4

In perfect crystal, all bonds under same force/ **(1)**
all must fail at same time **(1)**
with dislocations one bond/line can fail at a time **(1)** Max 2

Quality of written communication 1

(e) (i) Creep:

Continued/continual (acting over time)
Strain/extension/deformation
when subject to constant/fixed force/stress 3

(ii) N m^{-2} *and* kg m^3 **(1)**
Use of N as kg m s^{-2} **(1)**
For plastic(s) $E/\rho = \frac{1}{5} \times 1.5 \times 10^7\,\text{m}^2\text{s}^{-2}$ **(1)**
= 3 × 10^{6}m^{2}s^{-2}
$\therefore E$ plastic = (3.× 10^{6}m^{2}s^{-2}) (910 kg m^{-3}) **(1)**
= 2.7 × 10^{9}N m^{-2}/Pa **(1)** Max 4

(iii) A material which uses the properties of two (or more) materials
Fibre (composite) 2

[32]

49. (a) Gluon
Weak
Electromagnetic
Gravitational
Gravitational circled 5

(b) Marks for words in italics as shown below. 4

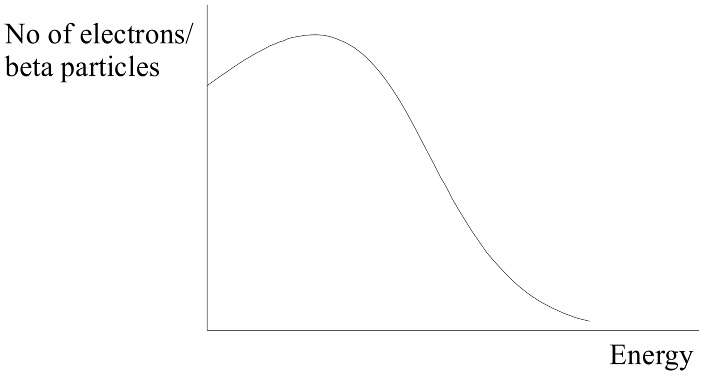
	Alpha scattering	Deep inelastic scattering
Target	*Gold atoms*	Hydrogen atoms
Incoming particles	Alpha particles	*Electrons*
Provided evidence for the existence of	*Nuclei*	*Quarks*

(c) Ω^- is a baryon [no mark]
p is a baryon/need to conserve baryon number
Strangeness – 3 needs three quarks 2

p is uud
Ω^- is sss
All Ks quark-antiquark pairs

K^- is $\bar{u}s$ K^+ is $u\bar{s}$ K^0 is $d\bar{s}$ [all right] 4

(d) ${}^{19}_{8}O \rightarrow {}^{19}_{9}X + {}^{0}_{-1}e \,/\, {}^{0}_{-1}\beta + \bar{v}$ 2



Labels **(1)**
Hump **(1)**
Good shape **(1)** Max 2

Decay process has fixed/definite/one energy **(1)**
Spread of energies **(1)**
Means some energy has gone elsewhere **(1)**
for energy to be conserved **(1)**
Quality of written communication **(1)** Max 4

(e) (i) Lots of energy needed
to produce the extra mass 2

(ii) Conservation laws:

charge
lepton number
baryon number 3

(iii) They annihilate one another
giving rise to γ ray/γ photon

Energy of γ ray
= 2(0.00055) (930 MeV)
= 1.0/1.02/1.023 MeV 4

[32]

50. (a) $P = IV = (65 \times 10^3 \text{V})\ (120 \times 10^{-3} \text{A})$
= 780 W
Correct use of 99.2 %/0.992
→ rate of heat production = 770/773.6 W 3

(b) (Average) time for ½ specified nuclei in a sample to decay.
(Av.) time for ½ the chemical in an organ to be metabolised/excreted 2

Depends on metabolic rate which varies between organs
and metabolic rate also depends on activity of patient 2

(c) Inject radioactive tracer **(1)**
Add equal amount of tracer to known volume of water **(1)**
After a time/20 min take blood sample **(1)**
Compare activity of sample with that of an equal volume of water **(1)**
Quality of written communication Max 3
1

Any suggestion of four half-lives
Approximately 6% 2

$^{131}_{53}\text{I} \rightarrow ^{131}_{54}\text{Xe} + \beta^- + \gamma$ 2

I-131
Has β
More damage to tissue 3

(d) (Specific) acoustic impedance 1

$Z_1 - Z_2$ large for empty bladder
Reflected signals strong
Insufficient transmitted 3

No tissue damage/can discriminate between soft tissues 1

(e) (i) 1 μs is 1×10^{-6} s (not just 10^{-6})
3.5 MHz is 3.5×10^6Hz
Moves in and out 3.5 times (in 1 μs)
Graph: 3½ cycles of sin/cos graph
each about 0.3 μs on axis 5

(ii) $f \propto \frac{1}{\lambda} / \lambda^{-1}$ / inversely proportional
High frequency means small wavelength
which enables smaller detail to be seen/resolved 3

(iii) Investigation: eye depth/length 1

[32]

51. Radio
Visible 2

Examples of benefits:

Increased clarity
No atmospheric refraction/scattering

Increased range of wavelengths
No atmospheric absorption 4

[6]

52. Earth temperature 0 –39ºC/280 - 300 K
→ $\lambda_{max} = 1.4/1.3 \times 10^{-5}$ m or 14/13 µm 2

Graph line:

Gradually rising line [no peak before 10 µm]
Never getting higher than a quarter of Sun 2

[4]

53. Giant stars and white dwarfs marked on diagram 2

5000 K 1

Approximately $10^2 \times 3.9 \times 10^{26}$ W = 3.9×10^{28} W 2

Power = σAT^4
4×10^{28} W = 5.7×10^{-8} W m^{-2} K^{-4} × A × 10 000 K^4
$\therefore A = 7.0 \times 10^{19}$ m^2
$(4\pi r^2 = A \; \therefore \; r = \sqrt{\dfrac{7.0 \times 10^{19}\,\text{m}^2}{4\pi}} = 1.2 \times 10^9\,\text{m}$ 4

[9]

54. Steady burning on main sequence for a long time **(1)**
Core reaction pushes outer layers out **(1)**
Red giant/outer layers lost **(1)**
(Core) remnant becomes white dwarf **(1)** Max 3

Quality of written communication 1

[4]

55. (a) 0.1 µm –1 µm
5 µm –50 µm

Advantages:

Higher quantum efficiency/responds to individual photons
No need to replace/can be used repeatedly
[One mark for operates more quickly] 4

(b) $L = km^{3.5}/L \propto m^{3.5}$
$2.3^{3.5} = 18.45/18.5/18$ [not 20] 3

(c) Below a certain mass the core temperature is not high enough for fusion/hydrogen burning 2

[9]

56. Ability of a material to withstand a force without breaking, independent of sample dimensions 1

Stress-strain graph:

Axes (Stress on ordinate, strain on abscissa)
Shape 2

Labels in correct places 3

[6]

57. Attempt to use principle of moments
$\rightarrow T_1 = 200$ N [e.g. –1 for a.c.]
and $T_2 = 360$ N [e.c.f.]

[4]

58. Young modulus = $\dfrac{Fl}{Ax}$

$$= \frac{350\text{N} \times 0.39\text{m}}{\pi \times 0.0175^2\text{m}^2 \times 5 \times 10^{-6}\,\text{m}}$$

$= 1.9 \times 10^{11}$ N m^{-2} 3

$\dfrac{\text{Energy}}{\text{Volume}}$

$$= \frac{280 \times 4 \times 10^{-6}\,\text{m}}{\pi \times 0.0175^2\ \text{m}^2 \times 0.39\,\text{m}}$$

$= 2.98$ J m^{-3} 4

[7]

59. Half plane displaced
and labelled 4

In perfect crystal, all bonds under same force/ **(1)**
all must fail at same time **(1)**
with dislocations one bond/line can fail at a time **(1)** Max 2

Quality of written communication 1

[7]

60. (a) Creep:

Continued/continual (acting over time)
Strain/extension/deformation
when subject to constant/fixed force/stress 3

(b) N m^{-2} *and* kg m^3 **(1)**
Use of N as kg m s^{-2} **(1)**
For plastic(s) $E/\rho = \frac{1}{5} \times 1.5 \times 10^7 \text{ m}^2\text{s}^{-2}$ **(1)**
$= 3 \times 10^6 \text{m}^2\text{s}^{-2}$
$\therefore E$ plastic = $(3.\times 10^6\text{m}^2\text{s}^{-2})$ (910 kg m^{-3}) **(1)**
$= 2.7 \times 10^9$N m^{-2}/Pa **(1)** Max 4

(c) A material which uses the properties of two (or more) materials
Fibre (composite) 2

[9]

61. Gluon
Weak
Electromagnetic
Gravitational
Gravitational circled

[5]

62. Marks for words in italics as shown below.

	Alpha scattering	Deep inelastic scattering
Target	*Gold atoms*	Hydrogen atoms
Incoming particles	Alpha particles	*Electrons*
Provided evidence for the existence of	*Nuclei*	*Quarks*

[4]

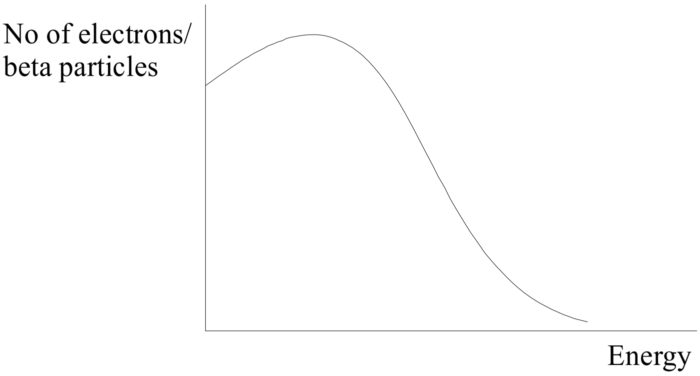
63. Ω^- is a baryon [no mark]
p is a baryon/need to conserve baryon number
Strangeness – 3 needs three quarks 2

p is uud
Ω^- is sss
All Ks quark-antiquark pairs

K^- is $\bar{u}s$ K^+ is $u\bar{s}$ K^0 is $d\bar{s}$ [all right] 4

[6]

64. $^{19}_{8}O \rightarrow ^{19}_{9}X + ^{0}_{-1}e \,/\, ^{0}_{-1}\beta + \bar{v}$ 2



Labels **(1)**
Hump **(1)**
Good shape **(1)** Max 2

Decay process has fixed/definite/one energy **(1)**
Spread of energies **(1)**
Means some energy has gone elsewhere **(1)**
for energy to be conserved **(1)**
Quality of written communication **(1)** Max 4

[8]

@ä**65.** (a) Lots of energy needed
to produce the extra mass 2

(b) Conservation laws:

charge
lepton number
baryon number 3

(c) They annihilate one another
giving rise to γ ray/γ photon

Energy of γ ray
= 2(0.00055) (930 MeV)
= 1.0/1.02/1.023 MeV 4

[9]

66. P = IV = $(65 \times 10^3 V)\ (120 \times 10^{-3} A)$
= 780 W
Correct use of 99.2 %/0.992
→ rate of heat production = 770/773.6 W

[3]

67. (Average) time for ½ specified nuclei in a sample to decay.
(Av.) time for ½ the chemical in an organ to be metabolised/excreted 2

Depends on metabolic rate which varies between organs
and metabolic rate also depends on activity of patient 2

[4]

68. Inject radioactive tracer **(1)**
Add equal amount of tracer to known volume of water **(1)**
After a time/20 min take blood sample **(1)**
Compare activity of sample with that of an equal volume of water **(1)** Max 3

Quality of written communication 1

Any suggestion of four half-lives
Approximately 6% 2

$^{131}_{53}\mathrm{I} \rightarrow ^{131}_{54}\mathrm{Xe} + \beta^{-} + \gamma$ 2

I-131
Has β
More damage to tissue 3

[11]

69. (Specific) acoustic impedance 1

$Z_1 - Z_2$ large for empty bladder
Reflected signals strong
Insufficient transmitted 3

No tissue damage/can discriminate between soft tissues 1

[5]

70. (a) 1 μs is 1×10^{-6} s (not just 10^{-6})
3.5 MHz is 3.5×10^{6}Hz
Moves in and out 3.5 times (in 1 μs)
Graph: 3½ cycles of sin/cos graph
each about 0.3 μs on axis 5

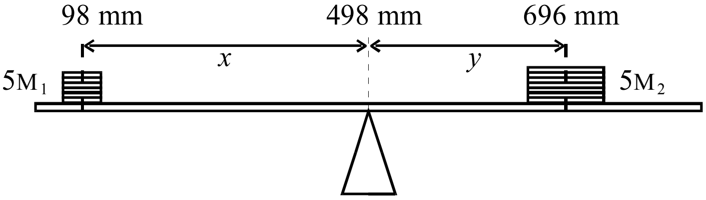
(b) $f \propto \frac{1}{\lambda} / \lambda^{-1}$ / inversely proportional
High frequency means small wavelength
which enables smaller detail to be seen/resolved 3

(c) Investigation: eye depth/length 1

[9]

71. (a) (i) Use of five coins in a row
Set square or repeat
1p: 20.0 – 20.1 mm expressed to 0.1 mm
2p: 25.8 –28.6 mm expressed to 0.1 mm 4

(ii) Good diagram showing measurements to centre of masses 1



$5m_1gx = 5m_2gy$

$m_1x = m_2y$

$$\frac{m_2}{m_1} = \frac{x}{y} = \frac{498-98}{696-498} = 2.02$$

Any two:

- Centre of mass of rule recorded **(1)**
- $x \geq 300$ mm **(1)**
- 5 coins used **(1)**
- Repeat at different x**(1)** Max 2

Correct calculation
1.9 – 2.1

If the hypothesis is correct, m_2/m_1 = 2.00.The value of 2.02 differs by only 1%which is acceptable experimental error, suggesting the hypothesis is correct. [i.e. sensible comment] 3

(b) (i) Circuit set up correctly 3

If help:

- –1 potentiometer
- –1 ammeter
- –1 voltmeter

(ii)

V/V	I/A
0.0	0.00
0.5	0.49
1.0	0.63
1.5	0.72
2.0	0.81
3.0	0.97
4.0	1.11
6.0	1.37
8.0	1.58
10.0	1.78
12.0	1.96

≥ 6 values, tabulated with units
Good distribution up to 12 V
Correct shape curve
≥ 8 values ± 0.04 A from curve 5

[5 – 7 gets **(1)**]

(iii) Graph on grid:

Plots
Line 2

(iv) When $V = 4.5$ V, $I = 1.17$ A

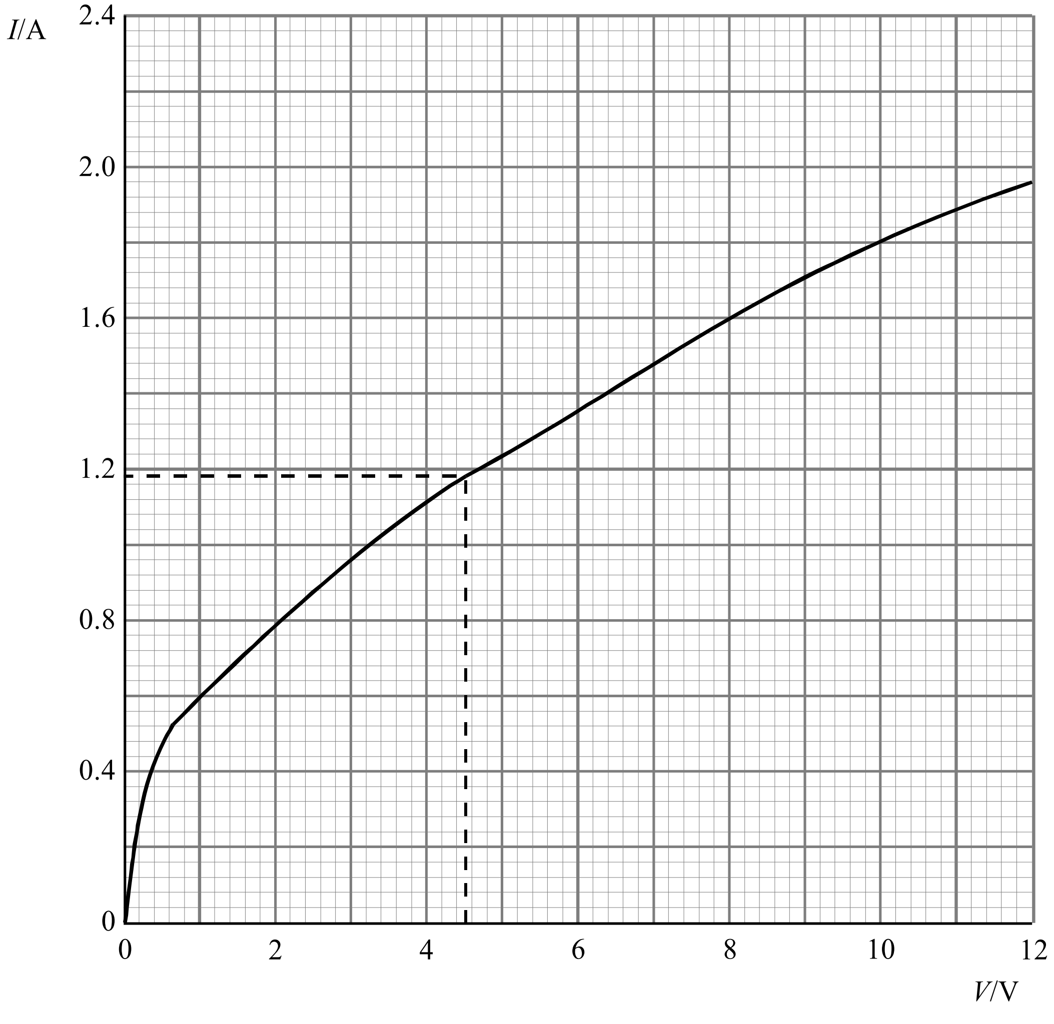
$$R = \frac{4.5\text{V}}{1.17\text{A}} = 3.8\Omega$$

Current read off at 4.5 V
R, with unit 2

(v) "12 V " means the operating voltage of the lamp, , at which it will generate 24 W of power. This would mean a current of 2 A. The experimental value was 1.96 A, which differs by 2%, which is acceptable experimental error.

24 W at 12 V explained **(1)**
Related to 2 A **(1)** 2

Graph:



[24]

72. (a) (i) Correct trigonometric method
Correct determination of θ
Value of θ: 1.30° – 1.55°

A protractor could measure to 0.5° at best, giving a 30% uncertainty. 4

(ii) t found from at least 4 runs

Typical values
t/s: 3.53, 3.64, 3.58, 3.66 $t = 3.60$ s

Short time/human error starting and stopping watch

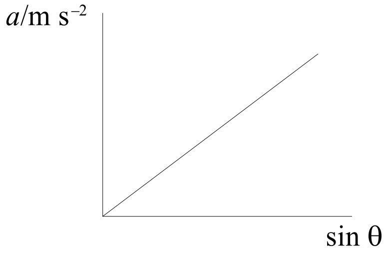
$a = \frac{2 \times 1.00}{3.60^2}$ Use of t_{av}
= 0.154 m s^{-2} 5

(iii) $a = 0.71 \times 9.8 \times \sin 1.4$
= 0.174 m s^{-2}
[–1 once for incorrect or omitted units]

Percentage difference = $\frac{0.174 - 0.154}{0.174} \times 100\%$
= 11%
air resistance
sliding/skidding 4

(b) (i) Repeat the experiment by altering the angle θ of the slope and measuring the corresponding time t for the ball to run a distance of 1.00 m down the slope.

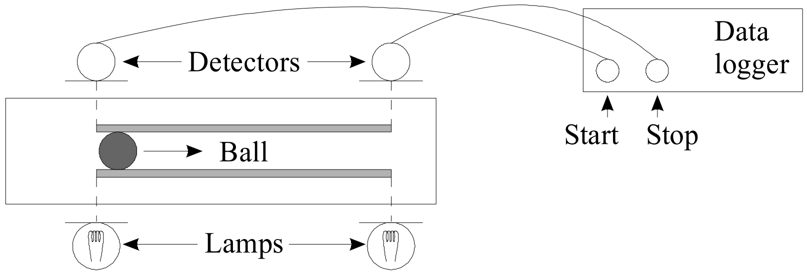
Calculate the corresponding acceleration a for each value of θ.



A straight line through the origin
with gradient 0.71 g would be expected.

If the bench were not horizontal, the graph would still have a gradient 0.71 g but would not pass through the origin. 7

(ii) Diagram:



Lamps
Detectors
Timer

Align detectors with light beam 1.00 m apart. As ball passes first beam it starts the timer and then stops the timer as it passes the second beam. 4

[24]

73. (a) Similarities – any TWO from:

- both penetrate Earth's atmosphere
- same speed [Not "similar"]
- travel through vacuum
- transverse
- electromagnetic **(2)**

[Not a property general to ALL waves, e.g. "diffract"]

Difference – any ONE from:
different wavelengths (OR frequencies)
light absorbed/scattered by cosmic dust/atmosphere: radio not:
must refer to *both* radio and light **(1)** 3

(b) Peak wavelengths:
β Ori $2.9 \times (10^{-3})$ m K
$1.1 \times (10^{4})$ K **(1)**
$= 2.6 \times 10^{-7}$ m OR 260 nm (263 nm) **(1)**
α Cet 8.1×10^{-7} m OR 810 nm (805 nm, 800 nm) **(1)**

[Penalise "Not nanometres" once only] 3

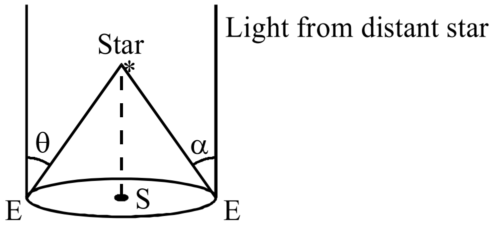
Power per square metre:
Attempt to use σT^4 (5.67 and 1.1^4 substituted) **(1)**
$= 8.3 \times 10^8$ (W m^{-2}) **(1)** 2

Labelled graph shows:
Ori peak at ~ 260 nm [e.c.f. their value] [Obviously to left of 400 nm] **(1)**
Cet peak at ~ 800 nm [e.c.f.] [Obviously to right of 700 nm] **(1)**

Area Ori » area Cet [e.c.f. their power] **(1)**
[Accept > 4 × height]
[irrespective of λ] 3

Explanation:
[NB Refer to candidate's graph]
Ori at blue end of spectrum; Ceti at red end **(1)**
BOTH outside visible region [e.g. in ultraviolet, in infra-red, "near"] **(1)**
[Apply e.c.f. if wrong λs above] 2

(c) Parallax diagram:



Labels on any FOUR of the following:

- distant stars labelled or implied e.g. by parallel lines
  [Accept without arrow heads]
- light from (nearby) star
- Earth orbiting Sun shown OR labelled June-January
- Angles α, θ labelled
- Angle P = distance Sun-Earth divided by distance to star OR
  trigonometry involving appropriate angle, sine and tangent, 1 all and D **(4)** 4

Suitability:
The difference in angles is too small to measure for
distant stars/distant stars do not move OR equivalent/we can
only measure angles to 1/100 arc sec **(1)** 1

(d) Supernova:
Quality of language **(1)**
Star → or begins as red giant **(1)**
H burning or fusion ceases/fuel used up **(1)**
Star collapses/contracts/shrinks/implodes **(1)**
Shock wave **(1)**
Blows off outer layers **(1)** Max 4

Remnant:
Becomes neutron star/black hole **(1)** 1

(e) Hertzsprung-Russell diagram:
Both axes labelled and $T \leftarrow$ **(1)**
Diagonal dots **(1)**
WD and RG regions indicated with some labelling **(1)**
[Accept absolute magnitude, → spectral type] 3

Calculation:
Time = distance/speed OR substitution

e.g. $\dfrac{7 \times (10^{8})\,\text{m}}{3 \times (10^{8})\,\text{m}\,\text{s}^{-1}}$ **(1)**

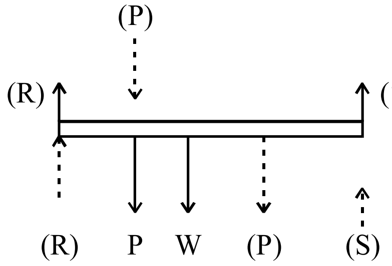
= 2 s (2.3) **(1)** 2

Why convection:
The cooler gas is more opaque to X-rays
OR X-rays are absorbed OR X-rays cannot penetrate **(1)** 1

Diagram labels:
(Dark +) pale grey region: radiative zone (by radiation) **(1)**
Unshaded region: convective zone/gas circulates **(1)**
¾ R and ¼ R labelled OR zig-zags in pale grey region
OR convection arrows in white region **(1)** 3

[32]

74. (a) Diagram:



[Ignore tension and compression IN the beam]

[Dotted lines indicate acceptable alternative positions]
[Reaction force cancels mark]
P and W correct at ¼, ½ by eye **(1)**
R and S at or close to ends **(1)**
Origin of R and S e.g. "brick pillar" NOT "tension" **(1)** 3

(b) Completion of table:

Material	Young modulus/10^{10} Pa	Ultimate tensile stress/10^{8} N m^{-2}	Nature
A	**1.2 or 1.25**	**3.1 or 3.15** **(< 3.2)**	Tough
B	3.0	3.6	Brittle

(2)

2

Line drawn on graph:
straight and stops suddenly **(1)**
at stress 3.6×10^{8} N m^{-2}) if not brittle, then peaks at this value) **(1)**
(and strain 0.012) Correct gradient for straight region
e.g. through 0.01, 3.0. **(1)** 3
Hooke's law marked up to stress 2.7 to 2.9×10^{10} Pa [must be labelled] **(1)** 1

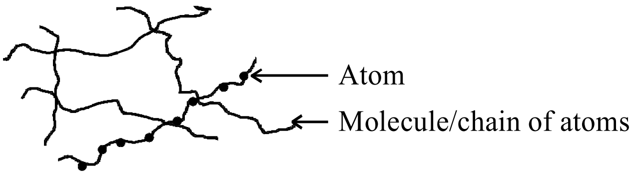
Energy stored:
[Accept stress in range 2.4 – 2.5×10^{10} Pa]
Factor ½ × **(1)**
Extension = 0.020 × 2.5 m [0.05 m] **(1)**
$F = 2.4 \times (10^{8})$ N m^{-2} $\times 8.8 \times (10^{-7})$ m^{2} **(1)**
[210 N; 220 N if stress = 2.5×10^{10} Pa]
= 5.25 J [5.5 J if using stress = 2.5×10^{10} Pa] [ue] **(1)** 4

[For middle 2 marks candidates may use stress×strain×volume, credit 1 mark for calculating stress×strain $2.4 \times (10^{8})$ N m^{-2} $\times$ 0.020 and 1 mark for volume $8.8 \times (10^{-7})$ m^{2} $\times$ 2.5 m]

(c) Description:
Idea that fibre composite is strands of something inside another material **(1)**
laminate is layers of different materials **(1)** 2

Reducing risk:
Prestressed reinforced concrete as example
Fibre OR laminate
Quality of language **(1)**
Crack grows/moves/travels **(1)**
until it reaches the boundary between layers/matrix material **(1)**
Crack spreads along boundary/tip blunted/matrix yields **(1)** Max 3

(d) Diagram:
Spaghetti-like arrangement [more than 1 strand] **(1)**
Individual strand labelled “molecule” or blob “atom” **(1)** 2



Difference:
Thermoplastic softens on heating/can be remoulded/melts **(1)**
[Not “becomes plastic”]
Thermoset decomposes/burns/does not soften/remains rigid **(1)** 2
Perspex is a thermoplastic **(1)** 1

(e) Strain energy:
is the energy stored /used/created/added/needed
when a material is under stress/strained/loaded/stretched
OR in stretched bonds OR is work done when stressed **(1)** 1

Why stress should not be beyond elastic limit:
Must return to original length when unstressed
OR must give up stored energy when unstressed OR must not deform permanently/plastically **(1)** 1

Car calculation:
Substitution in *mgh* 1200 kg × 10 m s^{-2} [9.81]× 0.03 m **(1)**
= 360 [350] J **(1)**
3 kg steel store 390 J
OR 360 J needs 2.8 kg steel **(1)** 3
[Can also be argued in terms of 390 J → 3.3 cm]

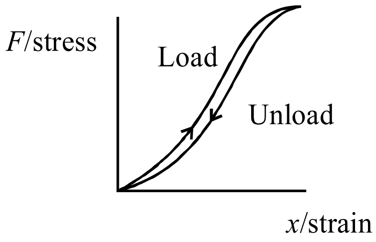
Tendons:

Will store 0.4 m × 2500 N /(1000) J **(1)**

Δh = 1.3 m [1.4 m] [e.c.f. their energy ÷ (75 × 10[9.81]) **(1)** 2

[u.e.]

Sketch graph:



Axes and shape + load line **(1)**

Arrow heads/labels + unload line **(1)** 2

[Beware inverted axes]

[32]

75. (a) Similarity – any ONE from:

- both nuclear decay products
- both charged/ionise/damage tissue
- both have momentum
- both deflected by E fields
- by B fields **(1)** 1

[Not both particles]

Differences – any TWO from:

- β fundamental, α not
- mass α >> mass β [NB much greater]
- α positive, β either
- β a lepton, α composed of hadrons
- α is He^{++}, β is e^+ or e^- **(2)** 2

[A difference must mention BOTH particles]

[If discussing spectrum shape needs "given source" idea]

(b) Show that:

Radius proportional to $A^{1/3}$ [Accept $(47/7)^{1/3}$] **(1)**

(Ratio) = $(108/14)^{1/3}$ **(1)**

Evidence of valid working leading to ≈ 2

[e.g. not $r_0 = 1$, not $4/3\pi r^3 = 108$] **(1)** 3

Explanation:

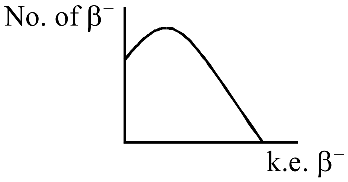
Quality of written communication **(1)**

Energy per decay is constant **(1)**

β^- has a range of energies **(1)**

Must be another particle to take missing energy **(1)**

Sketch graph:



[Be generous re shape in this instance but beware inverted axes] **(1)** Max 4

(c) Atom is neutral **(1)**
Quark composition is $\bar{u}\bar{u}\bar{d}$ **(1)**
Antiproton is (–2/3) + (–2/3) + (+1/3) (= –1) **(1)** 3

Explanation:
As soon as it touches the container/matter **(1)**
(Matter and antimatter) annihilate **(1)**
[Not "cancel"; not "react"] 2

Completion of table:

Quarks			Charge
up	charm	**TOP**	+2/3
down	strange	**BOTTOM**	–1/3

1

[OR TRUTH & BEAUTY]
[Both needed for 1 mark]

(i) Neutral strange meson: $s\bar{d}$ OR $d\bar{s}$ **(1)**

(ii) Positive charmed meson: $c\bar{d}$ OR $c\bar{s}$ **(1)**

(iii) Neutral strange baryon: uss/css/uds/cds OR any of their antiparticles, e.g. $\bar{u}\,\bar{s}\,\bar{s}$ **(1)** 3

(d) Conservation laws:

(i) Charge: (–1) + (+1) = (0) + (–1) + (+1) + (0) **(1)**
Baryon number: (0) + (+1) = (+1) + (0) + (0) + (0) **(1)**
[So possible, no mark]

(ii) Charge: (+1) + (+1) = (+1) + (+1) + (+1) + (–1) **(1)**
Baryon number: (+1) + (+1) = (+1) + (+1) + (+1) + (–1) **(1)** 4
[So possible, no mark]

(e) Photon:
Is a tiny packet of energy/of electromagnetic radiation **(1)** 1
Is exchange particle of e.m. interaction

How virtual photons differ:
Does not conserve energy

Completion of table:

Interaction	Exchange particle(s)	Mass of exchange particle(s)	Range of interaction	
Electromagnetic	Photon	**0** **ZERO** **Massless**	**INFINITE**	**(2)**
Weak	**W^+ W^- Z^0**	$\approx 90 \times m_{\text{proton}}$	< diameter nucleus	**(1)**

3

Calculation of time:

1.1×10^{-34} J s = 1.4×10^{-8} J × t [Correct substitution] **(1)**

$t = 8 \times 10^{-27}$ s[7.86] [ue] **(1)** 2

Estimation of range:

Distance = speed × time

= 3×10^{8} m s^{-1} × their time **(1)**

= 2.4×10^{-18} m [e.c.f][u.e.] **(1)**

[2.36; 2.37] 2

[32]

76. (a) Similarity – any ONE from:

- Both nuclear decay products
- Both charged
- Both have momentum
- Both deflected by E fields
- By B fields
- Both ionise
- Damage tissue
- Both particles **(1)**

Differences – any TWO from:

- β fundamental α not
- Mass α >> mass β [much greater than] **(2)**
- α positive, β either /two types β, 1 type α
- α is He^{++} β is e^+ or eα shorter range/α greater ionising power

[A difference must usually mention BOTH particles]
[If discussing spectrum, shape needs "given source" idea] 3

(b) Completion of table:

X-ray use	Typical accelerating voltage	Dependence of X-ray absorption on proton number	
Diagnosis	**KILOVOLT RANGE [Penalise eV once]**	**STRONGLY / α Z^2 / α Z^3/HIGH**	**(2)**
Therapy	**MEGAVOLT RANGE**	**LOW/WEAKLY/NO/ INDEPENDENT OF Z**	**(2)**

4

Explanation:
Use rotating beam/multiple beams/filters/vary profile/rotate patient **(1)**
so dose concentrated at particular place OR [for filter] removes low energy rays **(1)**
But spread out over so less to surrounding tissue OR [for filter] careful comment about absorption of high E in tumour **(1)**
[Any or all could be on a diagram] **(1)**
[Cover healthy tissue with lead → max 1/3 if fully described] 3

(c) Show that:
kg m^{-3} **(1)**
$\times$ m s^{-1} = kg m^{-2} s^{-1} **(1)** 2

Explanation:
Quality of written communication **(1)**
$(Z_2 - Z_1)^2 / (Z_2 + Z_1)^2$ mentioned OR difference in Zs very large **(1)**
= 0.999 [0.9995 or 1] **(1)**
so all/most u-sound is reflected **(1)**
at boundary between (air in) lungs and tissue **(1)**
"none" penetrates to organs behind lungs **(1)** Max 5

Reason:
Less damaging of cells/tissue OR non-ionising
OR can image moving parts OR can distinguish different types of soft tissue **(1)** 1

(d) Label:
A = scintillator/*NaI*/sodium iodide/etc **(1)** 1

Purpose of collimator:
To give a sharper image/only lets through rays travelling perpendicular/on a diagram/to get rid of scattered or reflected rays **(1)**
Is made of lead **(1)** 2

Description of physical process in photomultiplier:
Light releases electrons OR light converted to electrical signals [2 or 0] **(2)**
OR electrons accelerated/speeded up **(1)**
by electric field/high p.d./high voltages/positive voltages **(1)**
OR electrons collide with metal **(1)**
releasing more electrons **(1)** 2

(e) Elution:
Salt solution passing through the generator removes the tracer/Tc
[Idea of a liquid washing through] **(1)** 1

Equation:
$^{99}_{42}\text{Mo} \rightarrow {}^{99\text{m}}_{43}\text{Tc} + \beta^- / {}^{o}_{-1}\beta / e^- / {}^{o}_{-1}e$
Symbols and "–" sign **(1)**
99, 42, 99m, 43 added correctly **(1)** 2

Reason:
Because it has a short half-life **(1)** 1

Show that:
Activity down to ¼ in 134 hours (5.6 days) **(1)**
[Evidence of understanding of two half lives]
1 week = 168 hours > 134 hours so less than ¼ **(1)**
[or equivalent, e.g. in days] 2

Indication on graph:
Mark by graph; 48 hours indicated somehow **(1)** 1

Explanation of smaller peaks:
Because molybdenum is decaying/activity decreasing **(1)** 1

Why advisable to leave 1 day between elutions:
To give time for the Tc to reach its next peak / enough Tc to be produced / enough daughter isotope produced **(1)** 1

[32]

77. (a) (i) *l* to nearest mm and between 850 mm → 860 mm
or centre value ± 3 mm **(1)** 1
d ± 0.02 mm of supervisor's value and from ≥ 2 readings,
to 0.01 mm or better **(2)** 2
[±0.02 mm from 1 reading 1 mark **(1)**
± 0.05 mm from ≥ 2 readings 2 mark]
[Unit error −1 once only]
Variation in diameter 1

(ii) Correct calculation and unit and ≥ 2 significant figures **(1)**
[Allow e.c.f.]
Correct calculation and unit and 2 significant figures **(1)**
[Allow e.c.f.]
Value 8.5 – 9.5 g cm^{-3} [No e.c.f.] **(1)** 3

(b) (i) *m* giving 2.0 ≤ *t* ≤ 6.0 s with measurements to better than
1 s [Do not award these 2 marks if systematic error, e.g. 0.0305 s] **(2)**
4 values of *t* averaged **(2)**
[2/3 values 1 mark]
Correct calculation of *a* [Allow e.c.f.] **(1)**
2/3 significant figure + unit from correct calculation **(1)** 6

(ii) If trolley not at rest at start position, then 0/3 **(1)**
Start and stop positions marked in some way **(1)**
Eye level at start and end/touch marker at start and end **(1)**
Stopwatch started as trolley released and stopped after 0.500 m/
use same point on trolley at start and stop **(1)** 3

(c) (i) Zero tabulated or plotted **(1)**
4 other results (or results up to $N = 0$) tabulated and reasonable **(1)**

Graph:
Scale and plots and correct orientation **(1)**
Good curve **(2)**
[For candidates who re-start at 48 every time:
scale (probably in range 20 to 30), plots and correct orientation (1);
horizontal straight line through mean position (2)] 5

(ii) Not representation
Throws discrete – time continuous **(1)**
48 is too small to represent a large number of atoms **(1)**
Statistical error is very large with such a small number **(1)**

Reasonable representation:
Probability of decay per throw = ½ /curve decreases by equal amounts in equal times/one throw is equivalent to one half life **(1)**
Both decays are random **(1)** Max 3

[24]

Sample results:

(a) (i) $l = 0.855$ m
No zero error on micrometer
$d = 0.38, 0.38$ mm
Average $d = 0.38$ mm
Reduces random error due to variation in diameter of the wire

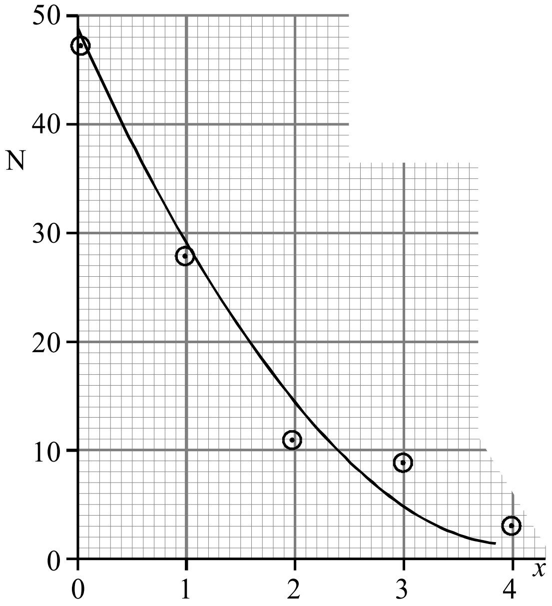
(ii) $V = \frac{1}{4}\pi\left(\frac{0.38}{10}\right)^2 \times 85.5 \quad = 0.097\ \text{cm}^3$
Mass = 0.84 g
$p = \frac{0.84}{0.097} \quad = 8.7\ \text{g cm}^{-3}$

(b) (i) $m = 50$ g
$t = 2.84, 3.16, 3.06, 3.16, 3.02$
Av. $t = 3.05$ s
$a = \frac{2 \times 0.5}{(3.05)^2} \quad = 0.108\ \text{m s}^{-2}$

(c) (i)

x	N
0	48
1	28
2	1
3	9
4	3

Graph:



78. (a) Circuit set up correctly without assistance **(2)** 2

(b) $\mathcal{E} \approx 1.5$ V to 0.01 V with unit **(1)**
$V < \mathcal{E}$ to 0.01 V and sensible with unit **(1)**
[Penalise unit error once only in (b) or (d)] 2

(c) Correct calculation of both k values **(1)**
Correct unit seen in (c) or (d) **(1)** 2

(d) (i) Same $\mathcal{E} \pm 0.02$ V **(1)**
$V_{\text{new}} < V_{\text{old}}$ and sensible **(1)**
2/3 significant figures for both k values **(1)**
[Penalise unit errors unless already penalised] 3

(ii) Smaller l gives smaller R **(1)**
$\therefore$ larger current drawn from cell **(1)**
$\therefore$ larger p.d. across r **(1)**
$\therefore$ Smaller terminal potential difference **(1)**

$\mathcal{E}$ should remain constant **(1)**

Can be reverse argument:
Larger $l \rightarrow$ larger R **(1)**
$\therefore$ smaller current drawn from cell **(1)**
$\therefore$ smaller p.d. across r **(1)**
$\therefore$ larger terminal p.d. **(1)**

$\mathcal{E}$ remains constant **(1)** 5

(e) (i) Correct calculation with average k as denominator **(1)**
[Allow e.c.f.]
Sensible conclusion related to experimental error **(1)**

(ii) Correct substitution (including average k) **(1)**
Correct calculation + unit and ≥ 2 significant figures **(1)** 4

(f) (i) Vary l **(1)**
Measure V **(1)**
(ii) Graph:

Axes labelled **(1)**
Straight line with positive intercept and positive slope **(1)**

(iii) $m = k/\mathcal{E}$ **(1)**

$c = 1/\mathcal{E}$ **(1)**

$\mathcal{E} = 1/\text{intercept}$ **(1)**

$k = \mathcal{E} \times \text{gradient}$ **(1)** Max 6

[24]

Sample results:

(a) $\mathcal{E} = 1.52$ V
$V = 1.37$ V

(b) $\frac{1.52}{1.37} = 1 + \frac{k}{0.800}$
$k = 0.0876$ m

(d) (i) $\mathcal{E} = 1.52$ V
$V = 1.25$ V
$\frac{1.52}{1.25} = 1 + \frac{k}{0.400}$
$k = 0.0864$ m

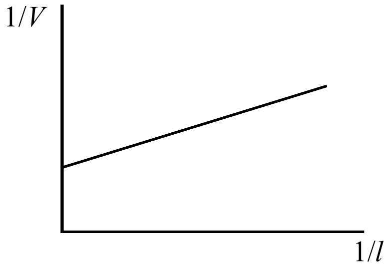
(e) (i) Percentage difference = $\frac{0.0012}{0.087} \times 100\%$
$= 1.4\%$
Less than experimental uncertainty $\therefore$ k likely to be constant

(ii) $r = \frac{4\rho k}{\pi d^2}$

$= \frac{4 \times 4.9 \times 10^{-7} \times 0.087}{\pi (0.27 \times 10^{-3})^2}$

$= 0.74\ \Omega$

(f) (i) Sketch graph:



(iii) $\frac{\varepsilon}{V} = 1 + \frac{k}{l}$

$\frac{1}{V} = \frac{k}{\varepsilon} \times \frac{1}{l} + \frac{1}{\varepsilon}$

$y = mx + c$
$\varepsilon = 1/\text{intercept}$
$k = \varepsilon \times \text{gradient}$

79. Topic A – Astrophysics

(a) Any 2 advantages from

- No background lighting/street lighting/light pollution
- Less dust/clear air
- Less twinkling due to density variations/refraction **(2)** 2
  [Not distortion]

(b) Hertzsprung-Russell diagram

x_A, x_B and x_C all marked **(1)** 1

α Ori – red giant **(1)**
Procy B – white dwarf **(1)**
β Per – main sequence **(1)** 3
[e.c.f. wrong *x* positions]

[If no *x*s on diagram, 3/3 for identifying still possible]

Calculations
Luminosity α Ori $= 6 \times 10^4 \times 3.8 \times 10^{26}$ W **(1)**

$= 5.67 \times 10^{-8}$ Wm^{-2} K^{-4} × A m^2 × $(3500)^4$K^4 **(1)**

$A = 2.7 \times 10^{24}$ m^2 **(1)**

$A = 4\ 7\pi r^2$ **(1)**
$R = 4.6 \times 10^{11}$ m [e.c.f. *A*] **(1)** 5

(c) Light year
Is the distance travelled by light in one year **(1)** 1

Show that ly is equivalent to
Distance = speed × time [no mark]
(365 × 24 × 60 × 60) s OR 3.15×10^7 s **(1)**
$\times 3 \times 10^8$ m s^{-1} $= 9.5 \times 10^{15}$ (m) OR 9.4 **(1)** 2

[Accept "working backwards", i.e. distance ÷ speed → time ≈ 3.15×10^7 s]

Explanation
A distant star does not seem to move **(1)**
against the background/with respect to a distant star **(1)**

OR

Angle between star and distant star **(1)**
does not change/difference in angles, too small to measure **(1)**

As the Earth moves over 6 months/June & January **(1)** Max 3

[Do not accept "angle too small to measure"; do not award 1 mark from top and 1 mark from bottom pair]

(d) Supernova and description

- Quality of written communication **(1)**
- A star which *suddenly* becomes **(1)**
- very bright/luminous **(1)**
- Fusion/hydrogen burning ceases/runs out of hydrogen **(1)**
- Collapse of core/collapse of star/implosion **(1)**
- Outer layers bounce off core/shock wave/explosion **(1)**
- Blowing away outer layers **(1)**
- Nuclear reactions take place in outer layers/ejected material **(1)** Max 5

Fates for the central core remnant
Neutron star **(1)**
Black holes **(1)** 2

(e) Use of Wien's law

$\lambda_{\max} \times T = \text{constant}$ **(1)**
$\lambda = 4 \times 10^{-6}$m (3.86 m) **(1)**
4000 nm > 700 nm, OR 4×10^{-6} m $> 7 \times 10^{-7}$ **(1)** 3

Why brown dwarfs are difficult to detect
Atmosphere opaque to infra-red/ground based instruments do not receive infra-red

OR

Radiation depends on T^4, hence very dim/luminosity = $\sigma A T^4$ is low **(1)** 1

Difference
A star converts hydrogen to helium/hydrogen burning/fusion of hydrogen OR p-p chain reactions **(1)**

Nuclear equation for reaction:
Li +p → 2 He [symbols] [H is alternative to p] **(1)**
7/3 + 1/1 → 4/21 [As and Zs] **(1)** 2

Why young low mass star might be mistaken for brown dwarf:
It has not existed long enough to consume all its lithium 1

[32]

80. Topic B – Solid Materials

(a) Calculation

Stress = 8.0 N / 1.5 × 10^{-7} m^2 **(1)**

= 5.3 × 10^7 Pa/N m^{-2} **(1)** 2

Graph:

Extension = 0.67 mm [Accept 0.66 to 0.68] **1**

Strain = 0.67 mm/2.6 × 10^3 mm [e.c.f extension from above]

[Ignore, 10^n error] **(1)**

= 2.6 × 10^{-4} [Do not penalise presence of unit]

Substitute in Young modulus = stress/strain [e.c.f stress from above.

e.c.f. strain, their value OR 3 × 10^{-4}] **(1)** 4

[= 2 × 10^{11} Pa/N m^{-2} (200 Gpa)] **(1)**

Calculation of work done

Find area of triangle OR use ½ kx^2 **(1)**

Substitute correct pair of values off line [ignore 10^n errors]

4.8 N/4.7 N, 0.4 mm

OR

Determine k = gradient **(1)**

= 9.6 × 10^{-4} J [± 0.2] [Accept N m] **(1)** 3

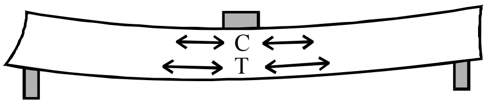
[Allow e.c.f. ONLY for grid error 4.4 N – 8.8 × 10^{-4} J gets 2/3]

Force-extension graph for wire of twice length:

Add line ½ as steep to graph [by eye] **(2)**

[Less steep, but not approx ½, 1 out of 2] 2

(b) Diagram of concrete beam



No mass: OK

Straight: OK

No supports: OK

Compression labelled inside/just above top surface **(1)**

Tension labelled inside/just below bottom surface **(1)** 2

[Words or arrows] Look for a REGION being shown. If only one point top surface and one point lower surface give 1 out of 2]

Explanation

- Quality of written communication **(1)**
- Concrete is strong in compression but weak in tension (must compare i.e. both) **(1)**
- Upper surface cracks tend to close up AND/OR lower surface cracks tend to widen **(1)**
- Further detail, e.g. reference to tension/compression, OR crack propagating across beam → fracture OR stress at tips of cracks discussed OR there are no dislocations to blunt the cracks **(1)** Max 3

(c) Bubble raft

Bubbles represent atoms OR ions **(1)**

Dislocation identified by diagonal line, circle, dot **(1)**

(d) Description of materials

Material A *is weak and stiff* **(1)**
Material B *is strong (ish)and flexible* **(1)**
Material C *is strong and stiff* **(1)** 3

[If none of the pairs are correct, possible 1 mark for one whole column correct, i.e. weak, strong, strong, weak OR stiff, flexible, stiff.]

Identification of materials
A is *polythene*;
B is ny*l*on
C is CFRP

C correct **(1)**

Other two correct **(1)** 2

CFRP is composite [ONLY] **(1)** 1

(e) **Meaning of terms**

(i) Ductile: can be drawn into a wire/rolled into a sheet/deforms plastically **(1)**

(ii) Transition temperature: the temperature at which a material changes from brittle↔ ductile behaviour **(1)** 2

Steel at risk some figure between + 15 ºC and –20 ºC **(1)** 1

Not at risk

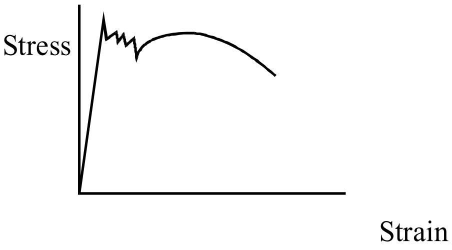
Copper

because it absorbs more/lots of energy at lower temperature OR graph slopes other way OR almost constant OR it has no transition temperature **(1)** 2

[Do not penalise if zinc *also* described/chosen]

Add to graph
A curve of similar shape as steel but shifted to the left **(1)** 1

Sketch graph



Straight line, then plastic with plastic region at least 2 × linear region **(1)**
Kink(s) between linear and plastic curve **(1)** 2

[32]

81. Topic C – Nuclear and Particle Physics

(a) Calculation of kinetic energy
Δm = 1.008665 u – (1.007276 + 0.000549) u **(1)**
ΔE = Any m value × 930 **(1)**
= 0.78 (MeV) [No e.c.f.] **(1)** 3

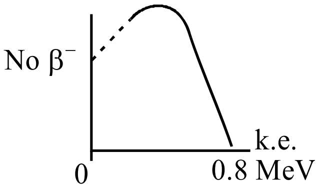
Explanation
Momentum proton + momentum electron = 0

OR

Momentum proton is equal (and opposite) to momentum electron **(1)**
Mass proton >> mass electron/protons are held in nucleus **(1)** 2

Graph
Shape [not bell-shaped] **(1)**
Cuts k.e. axis/nearly cuts axis **(1)**
[Not asymptotic] **(1)**

Scale (0) – 0.78 MeV [OR 0.8/e.c.f **(1)** 3
value above] [u.e. on k.e. axis]



Explanation

- Quality of written communication **(1)**
- Energy per decay is constant **(1)**
- Protons take no energy/all energy to electrons/β^- **(1)**
- All β^- particles should have same kinetic energy **(1)**
- β^- particles have a range of energies **(1)**
- so some other particle must take missing energy **(1)** Max 3

[Beware missing mass → mass of neutrino]

(b) Similarly
Same mass

Difference
Charge OR baryon number OR uud quarks $\rightarrow \bar{u}\bar{u}\bar{d}$ **(1)** 2

Any two lepton pairs from the following:

$e^- e^+$ **(**
$\mu^- \mu^+$ **(** NOT e.g. muon and antimuon/$\mu\,\bar{\mu}$
τ -τ +)

$\nu_e\ \bar{\nu}_e$)
$\nu_\mu \bar{\nu}_\mu$ } 0R just $\nu\ \bar{\nu}$ **(2)** 2
$\nu_\tau\ \bar{\nu}_\tau$)

Collision
Particle and antiparticle annihilate/produce a burst of energy/of photons /of gamma rays **(1)** 1

(c) Conservation laws

Δ^{++}: Charge: $(+2) \rightarrow (+1) + (+1)$

Baryon number: $(+1) \rightarrow (+1) + (0)$ (so possible) **(2)** 2

Δ^{-}: Charge: $(-1) \rightarrow (0) + (-1)$

Baryon number: $(+1) \rightarrow (+1) + (0)$ (so possible) **(2)** 2

[If attempt is in words rather than a balanced equation then it is vital that the charge or baryon number of each particle is mentioned even if it is zero.

Q or B conservation may be done in terms of $+\frac{1}{3}$ and $-\frac{1}{3}$ per quark.

Do not give marks for just tracking quarks.]
Exchange particle responsible for decay is the gluon 1

Δ^{+} is uud
Δ^{0} is udd 2

(d) Hadron
A hadron is a heavy particle/a baryon or a meson (both)/a particle made from quarks/a particle which feels the strong force **(1)** 1

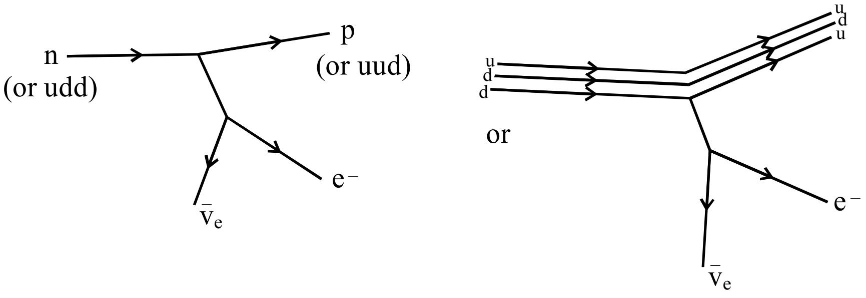
Leptons
e^{-} e^{+}, μ^{-} $^{(+}$ **(1)** 1
[Accept muons, electrons, antielectrons. Any extra particles cancels the mark] 1

Why pions unable to decay
They are the lightest hadrons **(1)** 1

Completion of sentence
Longer **(1)** 1

Quark composition of pion
$u\bar{u}$ OR $d\bar{d}$ **(1)** 1

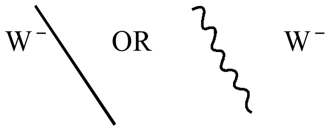
Feynman diagram



Shows n to p with something leaving junction **(1)**
Shows e^{-} and $\bar{\nu}_e$ emerging from exchange particle **(1)** 2

Why weak
Because a d quark changes to a u quark/flavour change/ν involved **(1)** 1

Label exchange particle
[Regardless of validity of diagram] **(1)** 1



[32]

82. Topic D -Medical Physics

(a) Most suitable isotope
I-123 **(1)**

Explanation
I-125 (OR they) has very/too long half life **(1)**
I-131 emits β^- which damages tissue/cells/thyroid OR highly ionising **(1)** 2

Labelling on diagram
Photomultipliers **(1)**
Scintillator/NaI **(1)**
Collimator [Not antiscatter grid] **(1)** 3

X-ray tube heat
Power = $V \times I$ (7800 W)
To heat = 99.2/100 × (65×10^3 V × 0. 12 A) [Ignore 10^n errors] **(1)**
= 7.7 kW OR 7700 W OR J s^{-1} [no e.c.f] **(1)** 3
[62.4 W OR 6240 W is 1/3 ✓ ✗ ✗

Feature of X-ray tub
Rotating anode/anode part of large copper block/anode cooled with circulating fluid **(1)** 1

X-ray use
Diagnosis **(1)**
Low voltage X-ray absorption depends on proton number
(or mass/atomic) **(1)**
so good contrast/distinguish bones and flesh/MeV needed to kill cells **(1)** 3

[If candidate chose therapy, maximum possible is 1/3 for statement, e.g. these X-rays are highly damaging to tissue/kill (cancerous) cells]

(c) Any two advantages from the following

- Can produce 3-D image/measure depth
- Less damaging/does not destroy tissue/cells
- Can distinguish different tissues
- Image immediately produced/real time imaging/can investigate moving surfaces **(2)** 2

Explanation

- Quality of written communication **(1)**
- High *f* means low $f \propto 1/\lambda$ **(1)**
- High *f* gives better resolution for eye **(1)**
- Low *f* not absorbed/more penetrating better for abdomen **(1)** Max 3
  (or high *f* is absorbed so not useful for abdomen)

Calculation

Choose appropriate $\lambda (\leq 2 \text{ mm})$ **(1)**
See $c = f\lambda$ OR use of formula **(1)**
1.5×10^{3} m s^{-1} ÷ their λ and worked out **(1)** 3

Grid
Two peaks 2½ squares wide at bottom **(1)**
Separated by 30 squares [6 big squares] **(1)** 2

Well separated
So that reflected pulse does not overlap next incoming one **(1)** 1

(d) Photographic film
Most X-rays go straight through/not absorbed by film **(1)** 1

Diagram
Ray A stops at OR in middle layer + "blob(s)" on end of it in middle layer **(1)** 1
Ray B stops in bottom layer → circle + rays **(1)**
These rays produce "blobs" on edge of film above **(1)** 2

[If A and B interchanged and both correct, 1/3]

Fluorescent
Absorbing X-radiation OR γ OR u-v and giving out light **(1)** 1

Benefit
Less time exposed/lower exposure/lower dose **(1)**
so less damage **(1)** 2

Disadvantage
Less detail OR blurred image **(1)** 1

[32]

83. (a) (i) ± 1 of Supervisor's value **(1)**
l ± 0.3 mm of Supervisor's value, with unit **(1)**
[to 0. 1 mm precision or better]
Repeat **(1)**
d calculated correctly [e.c.f]
2/3 significant figures + unit **(1)** 4
[Unit penalty *once* only]

(ii) Table with quantities and units for m and x **(1)**
2 good values < M **(1)**
2 good values > M [Supervisor's M] **(1)**
[0/2 if systematic error, e.g. l and not x]
["Good" is ±2 mm from best fit line]
M read off graph correctly, with unit
[x must be shown in table or graph] **(1)**
±10 g of Supervisor's value **(1)**

Graph:
Scale: occupying at least ½ grid each way, avoiding 3s etc
[Can ignore last point if off scale] **(1)**

Plots: penalise a serious mis-plot or two or more inaccurate **(1)**

Line: Good, sharp [Accept best straight line through points if not forced through origin] **(1)** 8

No marks for calculation of mass at this point
θ_1 and θ_f recorded with unit for both and $\Delta\theta$ 5 °C – 20 °C

Stirred water and took highest steady temperature

Any *one* of the following:

- both temperatures better than 1 °C
- thermometer not touching beaker
- eye level for thermometer or measuring cylinder **(1)**

Correct calculation with corresponding unit [allow J min^{-1}] **(1)**
2 s.f. [OR 1 s.f. if < 10 W] **(1)** 6

Masses all recorded to 0.0 1 g, including Δm **(1)**
Δm found correctly and sensible unit [~ 0.1 – 0.5 g] **(1)**
Suitable working that would lead to correct time **(1)**
Hence, correct calculation of time + unit **(1)**
Sensible comparison of power [5 W – 60 W for small lamp] **(1)**
and time **(1)** 6

[24]

Sample results:

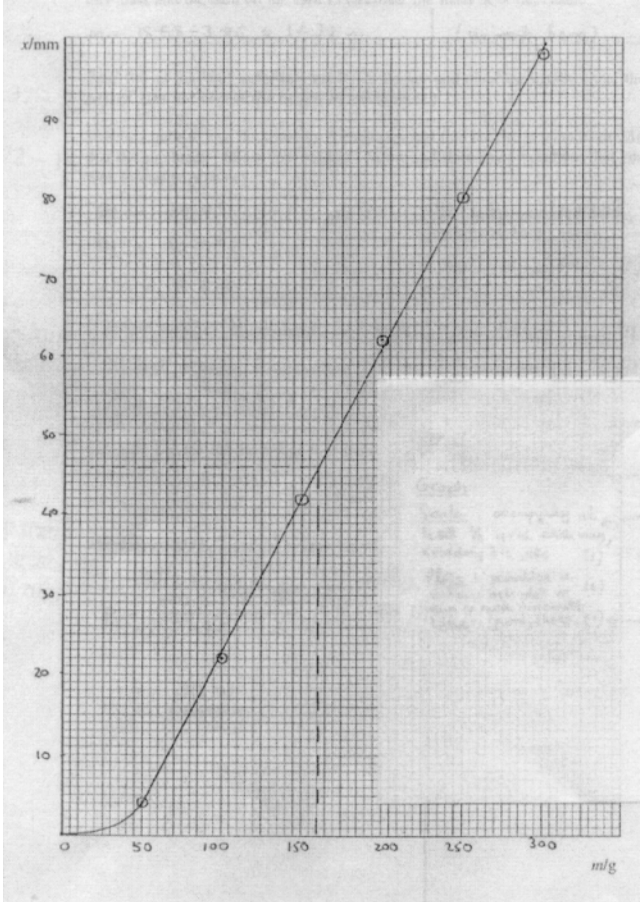
(a) (i) $N = 33$
$l = 23.7$, 23.9, average 23.8 mm.

$$d = \frac{23.8\,\text{mm}}{33} = 0.72 \text{ mm}$$

(ii)

m/g	Scale rdg/mm	x/mm
0	46	0
50	50	4
100	68	22
150	88	42
200	108	62
250	126	80
300	144	98
Block	92	46

From graph $M = 160$ g



(b) (i) $m = 18.58 - 3.86 = 14.72\text{g}$

$\theta_1 = 20.9$ °C

$\theta_f = 32.7$ °C

$\Delta\theta = 11.8$ K

Stirred water and took highest steady temperature.
Both temperatures better than 1 °C/thermometer not touching beaker/eye level for thermometer or measuring cylinder.

$$P = \frac{500 \times 11.8\ \text{J}}{5 \times 60\ \text{s}}$$

= 20W

(ii) $m' = 18.37 - 3.86 = 14.51$ g

$\Delta m = 14.72 - 14.51 = 0.21$ g

$$\frac{t}{5} = \frac{m}{\Delta m}$$

$$t = 5 \times \frac{14.72}{0.21}\ \text{min},$$

= 350 min

= 5 h 50 min

20 W is comparable to the power of a small lamp, but the experiment suggests the candle would burn for less than 6 h, which is not “all night”.

84. (a) (i) –1 per error in circuit A [Allow incorrect polarity/range]

Correct circuit without help **(3)**
Sensible values, to 0.1 mA precision **(1)**
with units for both **(1)** 5

(ii) Both V values sensible and recorded to 0.01 V with unit for both **(1)**
R_1 correctly calculated with unit and ≥ 2 s.f **(1)**
[e.c.f.]
[e.c.f. including repeat of above error]

R_2 correctly calculated and > 2 s.f. and $R_2 \geq R_1$ **(1)**
[Ω seen at least once]
R constant **(1)**
so Ohm's law obeyed **(1)**

OR

R not constant **(1)**
so Ohm's law not obeyed **(1)**

OR

Temperature changes **(1)**
so Ohm's law not relevant/not obeyed **(1)** 5
k found for each case **(2)**
[Ignore units and ≥2 s.f]

% difference using either k or average as denominator
[working must be shown] **(1)**

Related to meter uncertainty **(1)** 4

(ii) Correct circuit [–1 for each error or omission of components] **(3)**
[0/3 if not a potential divider] **(3)**
Any 4 points **(1)**
R v $\sqrt{I}$ [OR R^2 v I] **1**
Hence straight line through origin shown [or stated]
[i.e. dependent mark] **(1)**
Gradient [$\sqrt{\text{gradient}}$] [Dependent mark on correct plots] **(1)** 10

[24]

Sample results:

(a) (i) $I_{\text{max}} = 57.8$ mA, $I_{\text{min}} = 52.3$ mA

(ii) V_{min}, = 5.05 V

$$R_1 = \frac{5.05 \text{ V}}{52.3 \times 10^{-3} \text{ A}}$$

96.6 Ω

$V_{\text{max}} = 6.04$ V

$$R_2 = \frac{6.04 \text{ V}}{57.8 \times 10^{-3} \text{ A}}$$

= 104.5 Ω

The lamp does not obey Ohm's law because the resistance is not constant due to change in temperature.

(b) (i) $k_1 = \dfrac{96.6}{\sqrt{52.3 \times 10^{-3}}} = 422\ \Omega\text{A}^{-½}$

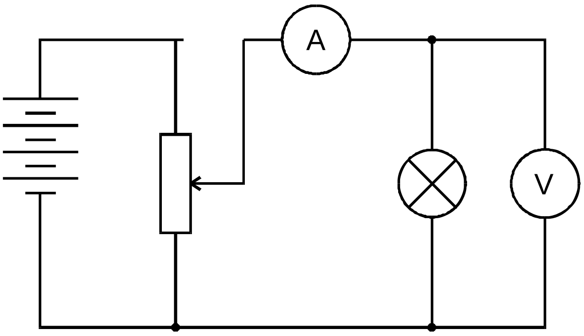
$$k_2 = \frac{104.5}{\sqrt{57.8 \times 10^{-3}}} = 422\ \Omega\text{A}^{-\frac{1}{2}}$$

$$\%\ \text{difference} = \frac{435 - 422}{428.5} \times 100\%$$

$= 3\%$

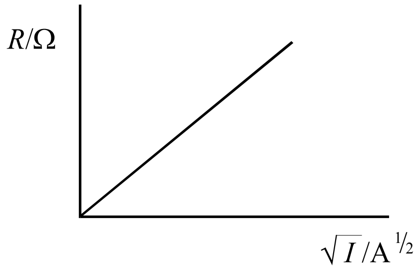
So results confirm relationship within uncertainty of meters

(ii)



Start with lowest I [or V]; vary I [or V] with resistor or potentiometer. Measure I and corresponding V. Calculate values of R.

Graph:



k would be the *gradient* of the graph

85. (a) (i) d to. 0.01 cm precison or better and ± 0.03 cm of Supervisor's value, with unit **(1)**
Repeat *or zero error check* ***(1)***
Correct V, with unit ≥ 2 s.f **(1)**
Correct calculation of ρ with unit **(1)**
$1.00 \rightarrow 1.30$ g cm^{-3} and 3 s.f. **(1)** 5

(ii) Correct calculation of V' [Ignore missing unit]
Hence volume of "space" + unit
How answer could be checked experimentally (3 points) **(3)** 5
[If a displacement method is not used 0/3]

(b) (i) Circuit correctly set up without help **(3)** 3
[Help with potentiometer, –2; help with meter location –1;
diode reversed –1 [Ignore meter polarity corrections]

(ii) Table with units [Quantity and unit] **(1)**
3 sensible values for $I < 10$ mA [2 values → 1 mark] **(2)**
5 values for $I \geq 10$ mA [4 values → 1 mark} **(2)** 5
[No values for $I < 80$ mA, – 1 from last two marks]
[Ignore any I value > 100 mA]

(iii) Graph:
Good smooth curve **(2)** 2
[–1 if serious misplot; –1 if curve slightly "wobbly" or thickish;
–1 if plots < 0.4 V not shown] [Ignore plots which are off the grid]

(iii) *I* read off correctly @ 0.70 V [Ignore missing unit] **(1)**
Correct *R* + unit [e.c.f.] **1**
Correct *I* by plotting "$R = 5\ 0\ \Omega$" line on graph, with unit. **(2)** 4
[By trial and error can get 2 marks.]
[Allow one mark if any *V* value between 0.7 V and 0.8 V is divided by 50 Ω to give correct *I* with unit.]

[24]

Sample results:

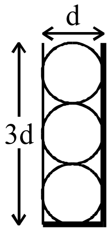
(a) (i) d/cm = 4.28, 4.28 [no zero error]
$\overline{d} = 4.28$ cm

$$V = \frac{\pi \times (4.28)^3}{6} \quad 41.1 \text{ cm}^3$$

$m = 45.3$ g

$$\rho = \frac{45.3 \text{ g}}{41.1 \text{ cm}^3} = 1.10 \text{ g cm}^{-3}$$

(ii) $V' = 3d \times d \times d = 3d^3$
$= 3 \times 4.28^3 = 235 \text{ cm}^3$
$\Delta V = 235 - 3 \times 41.1$
112 cm^3



Either

- Record volume of water in measuring cylinder
- Add water until packet brimful
- Deduce volume of water added (= volume of "space")

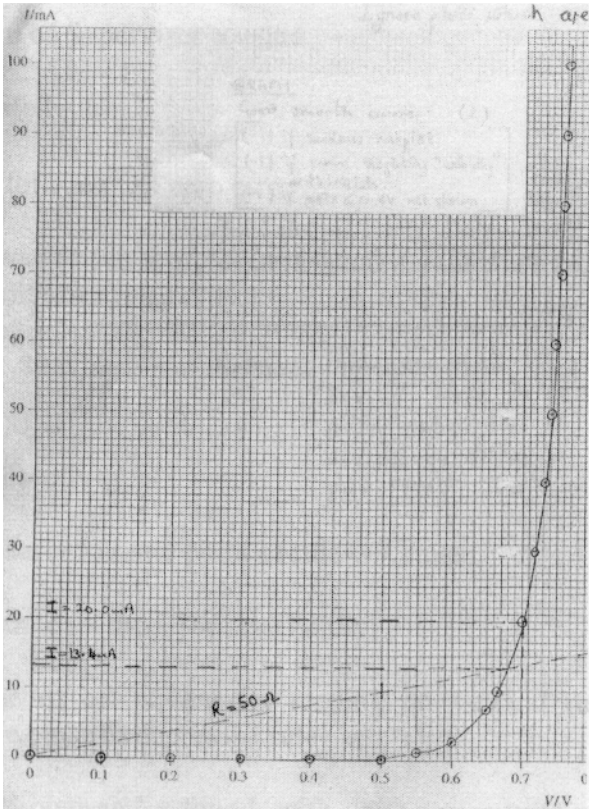
Or

- Weigh with balls in packet
- Fill to brim with water
- Re-weigh. Hence mass (and volume) of water added (= "space")

(b) (ii)

V/V	*I*/mA	*I*/*mA*	*V*/V
0.00	0.0	10.0	0.668
0.10	0.0	20.0	0.702
0.20	0.1	30.0	0.719
0.30	0.1	40.0	0.732
0.40	0.2	50.0	0.740
0.50	0.2	60.0	0.745
0.55	1.1	70.0	0.753
0.60	2.8	80.0	0.757
0.65	7.3	90.0	0.760
		100.0	0.763

(iii) Graph:



(iv) When $V = 0.70$ V, $I = 20.0$ mA

$$R = \frac{0.70\text{ V}}{20\times10^{-3}\text{ A}}$$

$= 35\ \Omega$

From graph $I = 13.4$ mA
[Check: $V = 0.68$ V

$$R = \frac{0.68}{0.0134} 0.0134 = 50.7\ \Omega]$$

86. (a) (i) $b \pm 0.3$ mm of Supervisor's value **(1)**
$d \pm 0.3$ mm of Supervisor's value **(1)**
Both repeated **(1)**
≥ 3 values for each OR zero error **(1)** 4

[Last two marks can score even if b and d values are incorrect.
Penalise unit error once only.]

(ii) Diagram showing symmetrical arrangement and mass suspended **(1)**
l shown correctly **(1)**
x shown clearly to same point of rule OR stated **(1)**
x by difference method [or seen below] **(1)**
Correct use of set square for reading on vertical rule [or vertical rule close to depressed rule] 5

(iii) h_1 and h_2 shown and x found, with unit, correctly to nearest mm or better **(1)**
Δx 1 or 2 mm and correct % with calculation shown **(1)** 2

(iv) Correct substitution in SI units **(1)**
Correct calculation [ignore unit] **(1)**
2/3 significant figures and (1–3) × 10^{10} Pa with unit 3

(b) (i) Take readings of x **(1)**
for different values of l **(1)** 2

(ii) x v l^3 [or l^3 v xl [2 or 0] **(2)**
Straight line through origin **(1)**
would show that $x \propto l^3$ **(1)** 4

(iii) $\frac{l^3}{x}$ separated from $\frac{mg}{4bd^3}$ **(1)**
Correct use of gradient of graph plotted
Graph averages (1) a number of errors (1) OR reduces **(4)**
random error (1) Max 4
Reduces systematic error (1)
Eliminates rogue values (1)

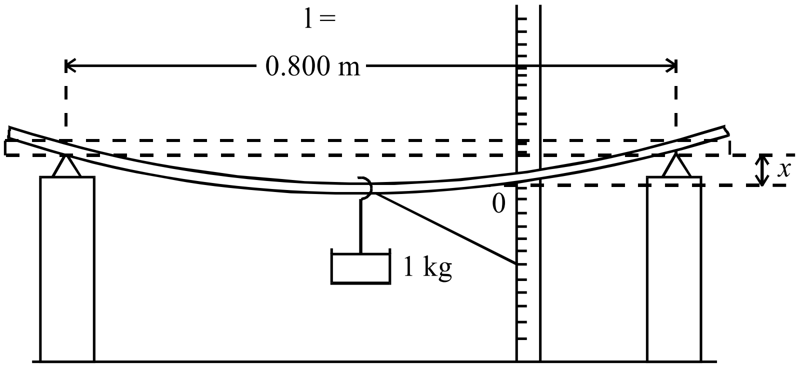
[24]

Sample results:

(a) (i) b/mm: 24.5, 24.4, 24.5, 24.4
Average: 24.4(5) mm

d/mm: 6.0, 6.0, 6.0, 6. 0
Average = 6.0(0) min
[No zero error]

(ii) Diagram:



x measured using set square against vertical rule as shown
from bottom edge of rule when unloaded and then loaded.
Difference in heights is x.

(iii) $h_1 = 283$ mm, $h_2 = 273$ mm

$x = 10$ mm

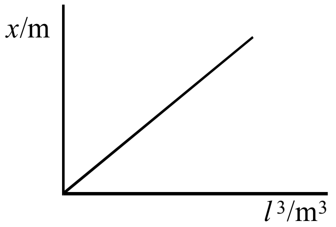
% uncertainty = $\frac{1\,\text{mm}}{10\,\text{mm}} \times 100 = 10\%$

(iv) $\frac{1.00 \times 9.81 \times 0.800^3}{4 \times 0.010 \times 0.02445 \times (6.0 \times 10^{-3})^3}$

$= 2.4 \times 10^{10}$ kg m^{-1} s^{-2}

(b) (i) Take readings of x for different values of l

(ii) Graph:



Straight line through origin would show that x is proportional to l^3

(iii) $E = \frac{mg}{4bd^3} \times \frac{l^3}{x}$

$= \frac{mg}{4bd^3} \times \frac{1}{\text{gradient}}$

OR

If x against l plotted, take readings from graph

Any four from the following:
Graph averages a number of values
Reduces random error
Reduces systematic error
Eliminates rogue values

87. (a) Luminosity of Sun

Attempt to use $I = L/4\pi D^2$

$L = 4\pi \times (1.5 \times 10^{11}\text{m})^2 \times 1.4 \times 10^3$ W m^{-2} [Ignore 10^3 error] **(1)**

= 3.96 [OR 4.0] $\times 10^{26}$ W [at least 2 s.f.] 3

Why intensity at top of atmosphere used

Atmosphere absorbs/scatters (some radiation)/reflects/filters out/equivalent **(1)** 1

Estimate of energy released for each helium nucleus created

$\Delta m = [4(1.67) - 6.64] \times 10^{-27}$ kg [Ignore 10^n error] **(1)**
$= 0.04 \times 10^{-27}$ kg **(1)**

$\Delta E = \Delta mc^2$ **(1)**
= 4 (OR 3.6) $\times 10^{-12}$ j [e.c.f. Δm] **(1)** 4

[If only ONE hydrogen atom in Δm**:** ecf to possible 3/4)]

Show number of nuclei

Number = $\dfrac{4 \times 10^{26}}{4 \times 10^{-12}} (= 1 \times 10^{38})$ **(1)**

[ecf energy above even though $\neq 1\times10^{38}$]

Mass of hydrogen

Mass = $1\times10^{38} \times 4 \times 1.67 \times 10^{-27}$ kg **(1)**

OR $1 \times 10^{38} \times 6.64 \times 10^{-27}$ kg

$= 7 \times 10^{11}$ kg (6.6) **(1)** 2

[Again ecf ONE hydrogen atom → possible 1/2. If use their value for number of nuclei → possible 1/2]

(b) Graphs: why photographic film less suitable than CCDs

Film cuts off before end of red **(1)**

so peak might be missed **(1)**

OR reverse argument – CCD extends beyond red so OK

Film not flat response OR CCD flat response/constant sensitivity **(1)**

so film might register false peak OR so CCD true reading OR film readings need correction/equivalent **(1)** Max 3

Advantage suggested by graphs

CCDs will also record some infra-red/wider range **(1)** 1

(c) Hydrogen burning process in a star

Hydrogen burning/fusion ceases/slows down / reduces **(1)**

Hydrogen burning occurs in the shell /in outer layers OR is replaced by helium burning/burning/fusion of other elements **(1)** 2

Why a red giant is more luminous

Red giant has a larger area/larger volume/radius **(1)** 1

(d) Description of how observations of Cepheid variable stars are used to estimate distance to nearby galaxies

Any five from:

Quality of language **(1)**

Varying intensity/luminosity/brightness/CV pulsates **(1)**

Period is related to luminosity **(1)**

Find time period **(1)**

Determine luminosity

Measure intensity/flux at Earth **(1)**

Use of $I = L/4\pi D^2$ **(1)**

(e) Meaning of term binary system

Two stars/masses move in (circular) orbits about common centre/each other **(1)** 1

Diagrams

At A and E small star within shaded area **(1)**

At C small star behind labelled or implied **(1)** 2

Explain why dip in curve at A is smaller than dip at C

At A (or E) small star is in front of/blocks part of large star
At C small star is behind or is blocked by large star **(1)**

Small star is a lot brighter (than large star) hence dip sizes **(1)** 2

Orbital period of binary

T = 22 hours **(1)** 1

How long it takes small star to cross disc of larger one

Value in range 0.7 – 1 hour **(1)** 1

Addition to light curve

Continuous horizontal line **(1)**

at same level as precious line OR very close to **(1)** 2

[32]

88. (a) Comparison of two metals A and B (stress-strain curves)

A is stiffer since steeper /bigger gradient/large Young modulus **(1)** 1

(i) Stronger: A since UTS/it breaks at 300 Mpa (± 20)
OR since B breaks at 190 (± 30) MPa **(1)**

(ii) More ductile: B since strain 0.25 OR since A strain = 0.15 **(1)** 2

Identify A and B

A is mild steel; B is copper **(1)** 1

Estimate of work done in stretching A to breaking point

Attempt at area [NB not just a triangle] **(1)**

300×10^6 Pa × 0.15 [Ignore 10^n error] (same stress ranges) **(1)**

$4 \rightarrow + 5 \times 10^7$ J m^{-3} **(1)** 3

Quench hardening

Heat and cool **(1)**

Rapid cool/plunge into water **(1)** 2

(b) Diagram of apparatus to determine Young modulus of copper

Were firmly fixed to ceiling/beam/end of bench **(1)**

Load and ruler/scale **(1)**

Means of reading small extensions e.g. pointer against scale/vernier **(1)** 3

Length of wire being tested

Appropriate length ≥ 2 m [Less if vernier used] **(1)**

Cross-sectional area of wire

Micrometer **(1)**

Diameter in several places **(1)** 3

Unit of *k* in Hooke's law

N m^{-1}/kg, s^{-2} **(1)** 1

Show that

$E = F/A \div e / l$ **(1)**

$= Fl/Ae$ **(1)**

but $F/e = k$/substitute $F = ke$ **(1)** 3

(c) Pre-stressed reinforced concrete beam

Any four from:

Quality of written communication **(1)**

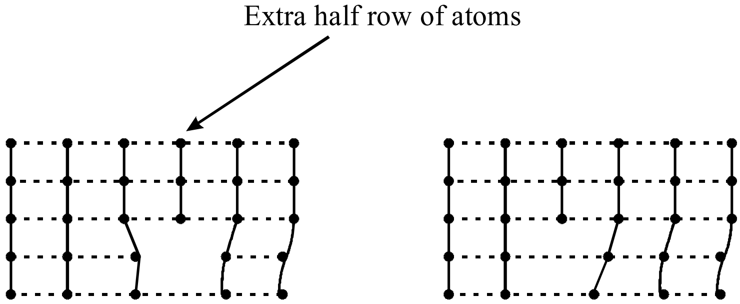
Steel **(1)**

Wires/cables/rods in tension/stretched OR heated **(1)**

Pour concrete/cement over and leave to set **(1)**

Release tension OR leave to cool **(1)** Max 4

(d) Passage: diagrams of lattice



2-D attempt at a lattice [solid lines to represent rows/planes acceptable] **(1)**

Extra half row of atoms/ions labelled **(1)**

Two diagrams OR clearly show that only one bond "flips" **(1)** 3

Differences

Filaments more closely spaced in new **(1)**

Filaments finer/thinner in new **(1)** 2

Calculation of ratio

Ratio = $\frac{\pi \times (0.5 \times 10^{-3}\,\text{m})^2}{\pi \times (5 \times 10^{-9}\,\text{m})^2}$ OR just ratio of (diameters)^2 **(1)**

[$(5\times10^{-9}$ m$)^2$ is essential component OR (10×10^{-9} m)]

= 10^{10} **(1)** 2

Advantages

They do not interfere with the movement of electrons/high conductivity retained/ do not increase resistance **(1)**

Ductility is retained/do not increase brittleness **(1)** 2

[32]

89. (a) Calculation of binding energy

Δm = 8 (1.007276 + 1.008665) u – 15.990527 u **(1)**

$\Delta E = \Delta m \times 930$ [Their Δm OR 0.137001 u) **(1)**

= 127.4 MeV [130]

[Answer in joule, max 2 out of 3] 3

Binding energy per nucleon

= answer above/16 [ecf joule also]

= 7.9 → 8.1 MeV [ecf] **(1)** 1

Graph

Steep rise and less steep fall; starts close to 0,0 and falls no more than ½ way to axis **(1)**

peaking in region 25 – 75 **(1)** 2

Positions on Graph

[for full marks. must be placed on or close to drawn line]

(i) O labelled at approximately 16 (½ way to 50) **(1)**
(ii) Fe labelled at peak, wherever it is **(1)**
(iii) U labelled at just short of 250 **(1)** 3

(b) Feynman diagram: equation for interaction

$\bar{\nu}_e + p \rightarrow e^+ + n$ **(1)** 1

Charge conservation

(0) + (+1) → (+1) + (0) [ecf their equation] **(1)** 1

Type of interaction responsible for inverse beta decay

Weak **(1)** 1

Justification

Change of quark type/flavour/u → d OR neutrino involved
[OR justify BOTH not strong AND not electromagnetic] **(1)** 1

Exchange particle

W^- OR W^+ [Z° or W OR all three gets 1 mark] **(1) (1)** 2

Why interaction is known as inverse beta decay

In β (minus) decay $n \rightarrow p + e^- + \bar{\nu}_e$

OR n → p OR d quark → u quark **(1)**

In this interaction p → n OR u quark → d quark **(1)** 2

[Other explanations acceptable depending on interpretation of diagram: see equation given immediately below]

(c) Fundamental particle

A particle which cannot be further divided/which has no "parts" inside it/one of the 12 particles of which all matter is made **(1)**

[Not "one which cannot decay to another particle"]

Circled fundamental particles in list **(2)**

Positron and muon

[If more than two circled, –1 for each extra one] 3

Explanation

Any three from:

Quality of written communication **(1)**

Mesons are composed of a q and an $\bar{q}$ **(1)**

These have charges ± 2/3 and ± 1/3 **(1)**

Shows all possibilities (+1, 0, – 1) OR other convincing arithmetic to show max +1 **(1)** Max 3

(d) Example of lepton

Any one lepton from

e^- μ^- τ^-, ν_e, ν_μ,, ν_τ , OR e+, $\bar{\nu}_e$ etc [Words or symbols, or just "neutrino"] **(1)**

Leptons carry no colour charge

Leptons do not feel the strong force OR if they carried colour charge e^- would join with nuclei **(1)** 1

Coloured quark combination

$u_Ru_Bd_G$ / $u_Ru_Gd_B$ / $u_Bu_Gd_R$

uud **(1)**

RBG **(1)** 2

Coloured quark combinations

$\bar{u}_{\text{antigreen}}\, d_{\text{green}}$ Charge: –2/3 + –1/3 = – 1 possible

Colour: antigreen + green = white/colourless/
colours cancel/possible

$d_{\text{blue}}\, \bar{d}_{\text{antiblue}}$ Charge: –1/3 + + 1/3 = 0 not possible **(1)**

$\bar{u}_{\text{antired}}\, d_{\text{blue}}$ Colour: antired + blue ≠ white not possible **(1)** 4

Particle type

A gluon is an exchange particle/boson **(1)** 1

[32]

90. (a) Nuclear equation

$\text{Te} \rightarrow \text{I} + \beta^- / e^- / {}^{0}_{-1}\beta$ / ${}^{0}_{-1}e(+\gamma)$ **(1)**

Mass and atomic numbers: Te 131/52 and I 131/53 and ${}^{0}_{-1}\beta$ **(1)** 2

[Second mark only available if equation correct]

Where reaction can be carried out

A (nuclear) reactor **(1)** 1

Three factors

Should emit only/mainly γ radiation **(1)**

Radioactive half-life long enough to complete investigation OR short enough not to damage patient **(1)**

Suitable for take-up by organ concerned **(1)** 3

Calculation of effective half-life

$1/t_e = 1/21 + 1/8$ **(1)**

$t_e = 6$ **days** [5.8] **(1)** 2

Graph

Neither graph cuts time axis; they start at same point and are falling concave curves **(1)**

P below L throughout **(1)**

Activity P = ½ activity L in the region 15 → 20 days **(1)** 3

[If not decay shaped 0/3
Possibility of ecf from wrongly calculated t_e]

(b) Labels on diagram

A – vacuum **(1)**

B – anode **(1)**

C – electrons **(1)**

Intensity calculation

Sensible attempt to use inverse square law **(1)**

Intensity = 0.21 MW m^{-2} **(1)** 2

(c) Description

Any five from:

Quality of language **(1)**

Transducer /probe plus coupling, medium **(1)**

Send pulse in and detect reflection **(1)**

Find Δt between sending, and receiving / find separation of spikes on cro **(1)**

Knowing speed calculate distance / $d = s \times t$ **(1)**

Depth = ½ distance **(1)** Max 5

Explanation

Air and tissue have very different Zs/acoustic impedances **(1)**

Almost all ultrasound is reflected at boundary/lnterface/surface of body **(1)** 2

[OR little crosses boundary OR argument in terms of coupling medium and tissue have similar Zs]

Suitable substance

Jelly / oil / water,/ Vaseline / gel etc **(1)** 1

(d) Reversible relationship

A general statement of the form A → B and B → A OR a summary of this case, i.e. stress/strain → ± pds and ± pds → stress/strain **(1) (1)** 2

[NOT tension → + and compression → –]

Diagrams

(ii) Either +s and -s scattered throughout middle OR equal nos + and – on each face OR blank as long as (iii) not also blank **(1)**

(iii) –s on top face, +s on bottom **(1)** 2

Calculation of thickness

$\lambda = 5740$ ms^{-1} / 1.5×10^6 Hz [Ignore 10^n error] **(1)**

3.8×10^{-3} m **(1)**

1.9mm [ecf ½ their λ]

Benefit

Maximum energy transfer at this frequency **(1)** 1

[32]

91. (a) (i) Use of set square against side of foil to ensure rule is perpendicular to side

OR

Repeats at different point shown on the diagram **(1)**

Both recorded to nearest mm with unit, and sensible **(1)**

Both repeated and correctly averaged **(1)** 3

(ii) Minimum 3 readings with unit and to at least 0.01 mm **(1)**

$\bar{t}$ ± 0.002 mm [of Supervisor's value] **(1)**

Δ (16*t*) found [from range or ½ range], hence correct calculation of percentage
[but allow 0.01 mm if single readings or all readings the same] **(1)**

Advantage:

Measuring, *larger thickness/average* of several thicknesses/ enable centre thickness to be measured **(1)**

So that *percentage uncertaintly* is reduced **(1)**

Disadvantage:

May be *trapped air* between the layer/not compressed enough **(1)** 6

(iii) Correct calculation [ecf 16*t* for *t* or volume of folded foil]

≥ 2 significant figures + unit **(1)**

Correct calculation with unit [ecf] [rounded to 2 significant figures] **(1)**

Value 1.8 – 2.8 g cm^{-3} and 2/3 significant figures **(1)** 3

(b) (i) Circuit set up correctly without help. [Ignore polarity errors] **(1) (1)** 2

(ii) $V \approx 3$ mV to 0.1 mV with unit (**1)**

$I \approx 6$ mA to 0.1 mA with unit **(1)**

Correct calculation with unit [Allow ecf] **(1)**

Two significant figures **(1)** 4

(iii) *Greater* than the resistance of the foil because of *resistance at the connections* between the plugs and the foil (2 or 0) **(1) (1)** 2

[OR Greater because of resistance of connecting wires, 1 out of 2]

(iv) Correct calculation ≥ 2 significant figures with unit [ecf 16*t* for *t* or wrong *t*] **(1)**

Correct substitution **(1)**
[If the candidates has attempted to convert to a consistent set of units, allow the mark.]

Correct calculation + unit **(1)**

Value 2.0 → 5.0 × 10^{-8} (Ωm) **(1)** 4

[24]

Sample results:

(a) (i) $l = 30.0, 30.0$ cm

$\bar{l} = 30.0$ cm

$w = 20.0, 20.0$ cm

$\bar{w} = 20.0$ cm

(ii) $16t = 0.24, 0.28, 0.25, 0.24, 0.19, 0.25$ mm

$\overline{16t} = 0.24$ mm

$\bar{t} = 0.015$ mm

Range = 0.09 mm in $16t$

Percentage uncertainty = $\dfrac{\frac{1}{2} \times 0.09}{0.24} \times 100 = 19\%$

Advantage

Measuring *larger thickness /* average of several thicknesses/ enable centre thickness to be measured, so that *percentage uncertainty* is reduced.

Disadvantage:

May be *trapped air* between the layer/not compressed enough

(iii) $V = \bar{l}\,\bar{w}\,\bar{t} = 20 \times 30 \times \dfrac{0.015}{10}$

$= 0.90\ \text{cm}^3$

$m = 1.72$ g

Density = $\dfrac{1.72}{0.90}$

$= 1.9\ \text{g cm}^{-3}$

(b) (ii) $V = 2.1$ mV

$I = 6.37$ mA

$R = V/I = 2.1/6.37$

$= 0.33\ \Omega$

(iii) Greater than the resistance of the foil because of resistance at the connections between the plus and the foil

(iv) $A = wt = 5 \times 10^{-3} \times 0.015 \times 10^{-3}$

$= 7.5 \times 10^{-8}\ \text{m}^2$

$\rho = \dfrac{RA}{l} = \dfrac{0.33 \times 7.5 \times 10^{-8}}{0.8}$

$= 3.1 \times 10^{-8}\ \Omega\text{m}$

92. (a) $t \approx 3$ s from ≥ 3 readings **(1) (1)**

[...≥ 2 readings, **(1)**]

[Misread stopwatch 0/2
Nearest second – 1
Unit omitted – 1
Incorrect average – 1]

Correct calculation, more than two significant figures, + unit **(1)** 3

(b) Vertical rule checked with set square **(1)**

Correct h shown **(1)**

[Ball must be shown]

Difference method shown with consistent heights, 1 m apart **(1)**

Correct calculation of Ep **(1)**

Correct calculation Of E_K [ecf incorrect m] **(1)**

[Units seen at least once In parts (b) and (c), otherwise – 1]

k: 1.5 → 3.0 **(1)** 6

[ecf systematic error in E_p or E_K]

(c) $t < t$ from (a) and from ≥ 3 readings **(1) (1)**

[≥ 2 readings, **(1)]**

[Allow ecf for stopwatch
Nearest second – 1
Units omitted – 1
Incorrect average – 1]

Correct calculation of Ep **(1)**
Correct calculation *of* E_K **(1)**

[ecf for mass only]

Value: 1.5 →.2.5**(1)** 5

[Ignore units on K. ecf is a systematic error in E_p or E_K]

(d) Correct calculation with average as denominator **(1)**

Sensible conclusion related to experimental uncertainties **(1)** 2

(i) Use blocks of different height or lab jacks/use balls of different mass

(ii) Several values of h or m indicated [≥ 5 if numerical] **(1)**

Measure t **(1)**

to travel a measured distance s **(1)**

Calculate E_P and E_K **(1)**

Use light gates to find $\bar{\upsilon}$ **(1)**

$\upsilon = 2\bar{\upsilon}$ **(1)**

(iii) E_p against E_K OR E_K against E_p stated or sketched **(1)**

Then straight line through origin shown with axes labelled **(1)**

Correct. hence gradient **(1)** Max 8

[24]

Sample results

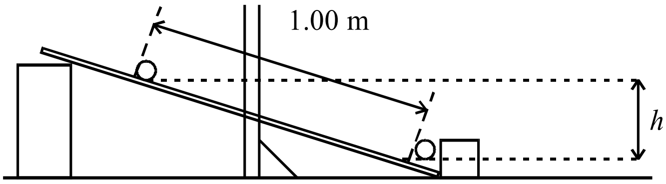
(a) $t = 2.44, 2.56, 2.43, 2.40$

$\bar{t} = 2.46$ s

$$\upsilon = \frac{2 \times 1.00}{2.46}$$

$= 0.814$ m s^{-1}

(b)



$h = 85 - 15 = 70$ mm

$m = 56$ g

$Ep = mgh = 0.056 \times 9.81 \times 0.070$
$= 0.0385$ J

$E_k = ½ m\upsilon^2$

$= ½ \times 0.056 \times (0.814)^2 = 0.0186$ J

$$k = \frac{E_P}{E_K} = \frac{0.0385}{0.0186} = 2.07$$

(c) $t = 2.04, 2.04, 1.88, 1.94$ s

$\bar{t} = 1.98$ s

$$\upsilon = \frac{2s}{t} = \frac{2}{1.98} = 1.01 \text{ ms}^{-1}$$

$h = 117 - 15 = 102$ mm
$E_p = 56 \times 10^{-3} \times 9.81 \times 0.102$
$= 0.0560$ J

$E_K = ½ \times 56 \times 10^{-3} \times (1.01)^2$

$= 0.0287$ J

$$k = \frac{0.0560}{0.0187} = 1.95$$

(d) Percentage difference $\frac{2.07 - 1.95}{1/2(2.07 + 1.95)} \times 100\%$

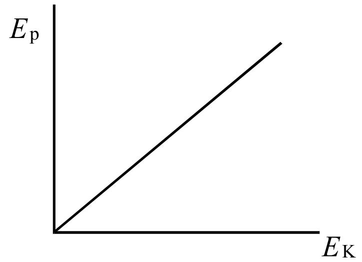
$= 6.0\%$

Difference is less than 20% (or 40%), therefore k is likely to be constant

(e) (i) Use blocks of different height or lab jacks / use balls of different mass

(ii) Several values of *h* or *m* indicated (≥ 5 if numerical)
Measure *t*
to travel a measured distance *s*
Repeat values for each h *or m*
Calculate E_p, or E_K

(iii)



(iv) Gradient = *k*

93. Topic A – Astrophysics

(a) Diagram

Nano **and** 10^{-9} 1
Micro 1
Kilo 1
Mega **and** 10^{6} 1

[Note:

- *Spellings must be correct, i.e. NOT nono, micra, kila, killa, megga etc*
- *Upper or lower case accepted*
- *n μ k M)*
) is max 2/4]
  10^{-9} 10^{6})

(b) Red giant

Quality of written communication [needs $\geq$ 2 processes] 1

Any three from:

- Hydrogen burning ceases in core
- Core collapses/star collapses
- Star swells up/star expands
- other fusion processes occur in core/hydrogen burning takes place in 'shell' /outer layers Max 3

Wien's law

Star cooler/*T* less 1

Hence Wien' s law means λ_{max} greater 1

[e.c.f. *T* increases, hence λ_{max} decreases]

Stefan's law

Law states $L = \sigma A T^4$ OR $L \propto AT^4$ 1

Larger (surface) area *A*/radius/diameter 1

Increase in $A >$ decrease in T^4 1

OR huge/massive increase in *A*/*r*/*d* makes up for/compensates for decrease in *T*
[NOT just A increases more than *T* decreases]

(c) Pulsar diagram labels

(i) axis of rotation/spinning/turning 1

(ii) (beam of) radio waves/electromagnetic waves [Accept microwaves] 1

(iii) magnetic field (lines) [Not e m field] 1

Type of star

(Pulsar is a) neutron (star) 1

Explanation of directions

Directions A and C 1

Any two from:

- Star spins on its axis
- Beam sweeps round [allow ecf from label in (ii)]
- (beam) must point towards Earth for signal to be received 2

(d) Advantages of radio telescope

Any two from:

- radio waves penetrate/not affected by the atmosphere or clouds/dust/light/daylight
- detect very weak signals/better resolution/detect distant objects/array
- gives different information about star's behaviour/greater λ range (e.g. can detect neutron stars/invisible objects) 2

[NOT "can detect radio waves", nor "detect different λ"]

Radio luminosity

Use of $I = L / 4\pi D^2$ [Any attempted use] 1
Correct substitution of *I* and *D* [i.e. with D^2] 1
Answer = $9.3 \times 10^{+25}$ [no e.c.f.] 1
Unit mark: watt/W/J s^{-1} 1

(e) Energy of photon of red light

$2.8/2.9 \times 10^{-19}$ (J) [$\geq$ 2 s.f. needed] 1

OR reverse route to 6.7×10^{-7} m

Estimate of number of photons

Use of $ns^{-1} \times 3 \times 10^{-19}J = 2.3 \times 10^{31}J\ s^{-1}$ 1

$ns^{-1} = 7.6\text{-} \rightarrow 8.2 \times 10^{49}$ AND $\leq$ 3 s.f. 1

Explanation of why answer is an approximation

Assumes only red photons are emitted OR range of $\lambda/E/f$ emitted 1

Advantages of CCDs compared with photographic film

Any two from:

- More efficient/sensitive/detect fainter or more distant stars/quicker to build image [“Quicker” + reason]
- More uniform response
- Can ‘process’ remotely/digitally/with computer
- Use repeatedly/quicker to process/real-time images/more images per session Max 2

[NOT “more accurate”, “better resolution/detail”]

[32]

94. Topic B -Solid Materials

(a) Diagram

Nano **and** 10^{-9} 1
Micro 1
Kilo 1
Mega **and** 10^{6} 1

[Note:

- *Spellings must be correct, i.e. NOT nono, micra, kila, killa, megga etc*
- *Upper or lower case accepted*
- *n μ k M) is max 2/4]*
  10^{-9} 10^{6})

(b) Stress-strain curves for two materials

(i) Tougher: B because it has larger area/greater energy density 1

(ii) Stiffer: B because steeper slope/greater Young modulus 1

(iii) More ductile: B because greater strain in plastic region 1

Line added to graph for material C

[Mark alongside graph]

Straight with sudden loop/straight line with sudden stop 1

Smallest gradient 1

Greatest stress 1

(c) Force extension graph

[Mark alongside graph]

Shape correct, both start ±2 mm origin and no obvious dips 1
Arrows or labels [correct] 1

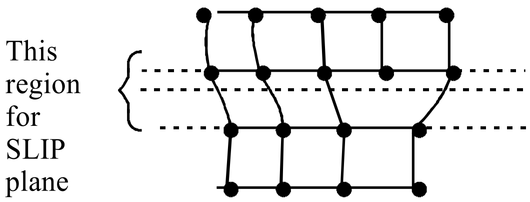
Explanation of elastic hysteresis

Quality of written communication 1

Areas/lines/energy/work different up-down/loading-unloading 1

Area of loop represents energy dissipated/heating/internal energy/increase temperature 1

(d) Diagram



Any one of those "planes" or horizontal arrow

Explanation

Plane labelled, horizontal layer with 1 less/1 more atom/in between 1
Any reference to (interatomic) bonds 1
Only one row of bonds needs to be broken (at a time) (compared with whole plane of atoms at a time) [OR could be implied, e.g. carpet ruck analogy] 1

Work hardening

Hammering/rolling/plastic deformation/hit repeatedly 1
[NOT "putting under strain", "stretching", "repeated loading and unloading]

Completion of sentence by selection of word(s)

Stronger 1
More brittle 1

[One correct, one incorrect ⇒ 1/2 ; if ≥ two circled apply -1 per error]

Process of annealing and explanation in microscopic terms

Metal is warmed/heated [NOT "melted"] 1

and cooled slowly/allowed or left to cool 1

getting rid of (log jammed) dislocations/recrystallises/creates larger crystals OR atoms become more ordered/organised 1

(e) Use of graph to calculate energy stored by foam liner

Find area of triangle or 1/2 Fx 1
Read off value, 9000 N 1
Correct value (81) [e.c.f. for value e.g. 8000 N → 72 (J) 1
Joules [Not Nm, Nmm] 1

Deceleration of a head of mass 5.8 kg

Use $F = ma$ 1
Answer 1700 (1724) m S-2 1

Helmet design requirements

Yes, with figures to justify < 200 × 9.81 m s^{-2} OR 1700/9.8 [Allow, gas 9.8 or 10] [e.c.f.] 1

Reason why a cycle helmet should be replaced after impact

Replaced because foam does not recover after crushing 1

OR equivalent, e.g. not elastic e.g. permanently damaged / cracked / fractured [NOT "damaged" or "scratched" only]

[32]

95. Topic C – Particles

(a) Diagram

Nano **and** 10^{-9} 1
Micro 1
Kilo 1
Mega **and** 10^{6} 1

[Note:

- *Spellings must be correct, i.e. NOT nono, micra, kila, killa, megga etc*
- *Upper or lower case accepted*
- *n μ k M)*
  10^{-9} 10^{6}) is max 2/4]

(b) Binding energy

Quality of written communication 1

Energy required/ put IN to separate/break up a nucleus 1

Into protons + neutrons OR nucleons 1

OR in terms of energy given OUT when making a nucleus
OR mass defect between nucleus and separate nucleons

Graph

Shape [not bell-shaped; steeper rise than fall; start near origin; fall less than half max height] 1
Peak at around 50 [40 – 70] 1

Isotopes

BE/nucleon [any reference] 1
See working out, e.g. 7.72: 7.44 [no u.e.] 1
Hence O-16 ..I 1 1

[O-16 because O-17 is radioactive gets 1/3]

(c) Table

(i) particle	(ii) quark content	(iii) antiparticle	(iv) quark content	
proton	**uud**	$\bar{\mathbf{p}}$	$\overline{\mathbf{uud}}$	**(2)**
π^-	$d\bar{u}$	π^+	$\mathbf{u\bar{d}}$	**(1)**
K^0	$d\bar{s}$	$\overline{\mathbf{K}}^0$	$\mathbf{s\bar{d}}$	**(2)**

Shaded boxes show answers: *circled* terms count as one.

Proton is **uud** 1

antiproton or $\bar{\mathbf{p}}$ is $\overline{\mathbf{uud}}$ [allow $\bar{p}^-$ or p-bar] 1

π^+ 1

Anti K^0 is $\overline{\mathbf{K}}^0$ [allow K^0-bar] 1

Quark composition is $\mathbf{u\bar{d}}$ **and** $\mathbf{s\bar{d}}$ 1

(d) Strange quark

Show that +2/3 + -1/3 + -1/3 = 0 (= charge on lambda) 1

[allow fractional charges for products if correct]

Select words

Hadron meson 1, 1
[One correct, one incorrect gets 1/2 ; if ≥ 2 circled, apply -1 per error]

Type of particle

W^- is exchange particle [Accept gauge boson] 1

Equation for decay of lambda particle

$\Lambda \rightarrow p + \pi^-$ NOT capital P 1

OR $\Lambda^\circ \rightarrow p + \pi^-$

OR uds → uud + $u\bar{d}$

$\Lambda \xrightarrow{W^-} p + \pi^-$

Conservation laws

B: +1 = +1 + 0 1

Q: 0 = (+1) + (-1) 1

Explanation

(Not strong because) strangeness is not conserved
OR because s quark → d quark/change of quark (flavour) 1

[NOT because W^-/no gluon]

(e) Equation

$^{14}_{7}\mathrm{N}+^{1}_{0}\mathrm{n}\rightarrow ^{14}_{6}\mathrm{C}+^{1}_{1}\mathrm{X}$

14/7 and 1/0 1
1/1 [no e.c.f.] 1
Hence X is H atom/H nucleus/proton/H/hydrogen 1

Estimation of age

Down to 1.9 cpm needs 3 half-lives 1
3 × 5730 1
17 000/17244 years/5.4×10^{11}s 1

Suggested problem in measuring

Background count mentioned/randomness significant 1

[OR need larger mass than one gram]

[32]

96. Topic D -Medical Physics

(a) Diagram

Nano **and** 10^{-9} 1
Micro 1
Kilo 1
Mega **and** 10^{6} 1

[Note:

- *Spellings must be correct, i.e. NOT nono, micra, kila, killa megga etc*
- *Upper or lower case accepted*
- *n μ k M)*
  10^{-9} 10^{6}) is max 2/4]

(b) Description

Quality of written communication 1

Any three from:

- Give patient drink/inject with radionuclide [not just "take"]
- In a suitable uptake medium/1abelling/radiopharmaceutical/chemical that goes to thyroid
- Use gamma camera to monitor activity of thyroid
- Over several hours/many times [i.e. ≥ 2 readings]
- Compare with phantom/model neck/lab sample/healthy neck Max 4

Three reasons why Technetium-99m is suitable for procedure

Any three from:

- (Gamma emitter so) detected outside body/by gamma camera
- gamma ⇒ low dose to patient OR no α, β damage/ionisation to patient/tissue/cells
- 6 hours is appropriate half-life for investigation: i.e. not too long to harm patient OR not to short so decays before study complete
- Tc can be produced in portable generator where required/locally/in hospital
- Decays to stable/very long $t_{1/2}$ daughter product/^{99}Tc Max 3

Nuclear equation

${}^{99}_{42}\text{Mo} \rightarrow {}^{99m}_{43}\text{Tc} + {}^{0}_{-1}\beta$ [OR β^- or e^- or ${}^{0}_{-1}e$] [Ignore γ, Q, $\bar{\nu}$, ν]

Symbols 1
Numbers [must be 99m, no e.c.f.] 1

(c) Explanation of observation

It is excreted by/removed from the body 1
[NOT just “biological half-life” or equation]

Observed activity calculation

24 days is 4 half-lives OR four halvings indicated 1
1/16 activity /6%/0.0625 1
[OR 24 more days would be 5 half-lives → 1/32 full ecf]

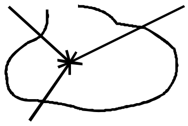
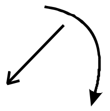
(d) Reasons

Me V absorption independent of Z or e/same by bone and tissue 1
[or inverse argument for ke V is dependent on Z]

MeV more penetrating/can reach deeper tumour or less)
dose to skin) 1

OR MeV (higher energy) **kills** cells better [not treat]

Diagram and explanation

Diagram  OR one beam rotated  1

[Penalise if some beams miss target; ignore arrows]

(Many beams/beam rotated) cancer always gets dose 1
Surrounding tissue shares dose 1

Precautions

Any two from:

- behind lead screen/ glass
- operates from /different room [i.e. increase distance]
- X-ray tube shielded with lead
- wears film badge (to monitor exposure)/photographic film Max 2

(e) X and its function

X is coupling medium/gel/other example 1
Function is to reduce reflection of u-sound at surface J/skin/body surface 1
[OR make sure u-sound enters body at J/skin]

Time delay

Time = distance/speed [Attempted use of] 1
echo idea: *d* × 2 1
= 4×10^{-5} s [no e.c.f.] 1

Frequency of pulses

5000 1
Hz/hertz [Not s^{-1} or /s] 1

Addition to grid

Pulse at 40 and 240 μs [± 1 mm] 1

- intensity < emitted intensity [i.e. not taller]
- allow wider peaks
- e.c.f. 20 μs AND 220 μs /their value

Reflections from M

Will be mixed up with (K) other reflections 1
[i.e. idea of overlap]
[NOT weaker/more attenuation/interference with emitted pulse will return after next pulse is emitted]

[32]

97. (a) (i) 10 spheres used, in channel between rules 1

Close packed/touching 1

Correct use of set squares at end or correct use of set squares to measure single diameter 1

Scale readings shown, giving *l*/*d* to nearest mm 1

d ± 0.03 cm of Supervisor's value to ≥ 3 s.f. + unit 1

(ii) Δl between 0.5 mm and 2 mm with unit

OR

correct Δl from range or 1/2 range 1

Correct calculated percentage 1

(iii) Correct calculated to more than 2 s.f. + unit 1

[Allow e.c.f.]

(iv) Use of 10 marbles [Allow 10 single values] 1

± 0.10 g of Supervisor's value 1

Correct calculation of ρ, 2/3 significant figures + unit 1

Value 2.3 → 2.7 g cm^{-3} [Rounded to 2 s.f.] 1

(b)	(i)	Measure height above bench at two places	1
		Use vertical rule	1
		Vertical rule checked with set square OR set square against stand to show string horizontal	1
		Reasonable value to 0.1 N with unit	1
		[Between 4.0 N and 5.5.N]	
	(ii)	Three forces in correct orientation	1
		[May be mirror Image]	
		Arrows on all forces correct and lines meeting at a point	1
		[Dependent on first mark]	
		Correct labels or numerical values	1
	(iii)	Correct values shown	1
		[Allow 4 N or 0.4 g and e.c.f.] [Must be evidence of a unit]	
		Scale diagram or trigonometry or use of Pythagoras	1
		Correct calculation1	1
		2/3 s.f. + unit	1
		Value 1.5 → 3.5 N	1

[24]

Sample results

(a) (i) 10 spheres used, in channel between rules
Close packed and touching

$l = 41.2 - 26.0 = 15.2$ cm

$$d = \frac{15.2}{10} = 1.52 \text{ cm}$$

(ii) $\Delta l = 0.2$ cm

$$\text{Percentage uncertainty} = \frac{0.2}{15.2} \times 100 = 1.3\%$$

(iii) $$V = \frac{\pi d^2}{6} = \frac{\pi \times 1.52^3}{6}$$

$= 1.84 \text{ cm}^3$

(iv) Mass of dish = 15.0 g
Mass of 10 marbles + dish = 60.6 g
Mass of 10 marbles = 45.6 g
Mass of 1 marble = 4.56 g

$$\text{Density} = \frac{4.56}{1.84}$$

$= 2.48 \text{ g cm}^{-3}$

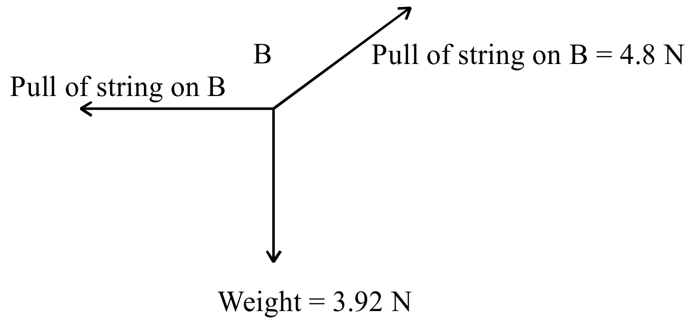
(b) (i) Measure height above bench at two places; use vertical rule

Vertical rule checked with set square OR set square against stand to show string horizontal

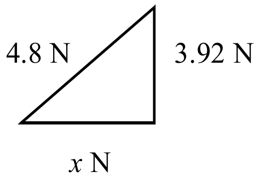
$R = 4.7, 4.9$ N

$\overline{R} = 4.8$ N

(ii)



(iii)



$x^2 = 4.8^2 - 3.92^2 = 7.67$

$x = 2.77$ N

98. (a) (i) Incorrect polarity for *T*, –1

Circuit set up correctly without help 2

$I_1 \approx 80$ mA and read to 1 mA or better, with unit 1

$V \approx 6$ V and read to 0.1 V or better, with unit 1

(ii) $I_2 \approx 27$ mA to 1 mA or better, with unit 1

$V_2 > V_1$ to 0.1 V or better + unit 1

[Unit penalty once only for each quantity]

[Allow results to be interchanged, but max 2/4 if two sets of identical results]

(b) Stated or implied 2

Correct calculation ≥ 2 s.f. + unit 1

Value 200 → 240 Ω [dependent on correct calculation] 1

(c) (i) Use of V_1 1

Correct calculation of *I* through $R_2 \geq 2$ s.f. + unit 1

[Allow *VI, V2* or 6 V in calculation, OR I_2 and e.c.f. in R_2] .

(ii) Correct calculation of *I* through R_1 OR $I_1 - I_2 \geq 2$ s.f. + unit 1

[Apply unit penalty once only]

	(iii)	Subtraction of 0.7	1
		Correct calculation of $R_1 \geq 2$ s.f. + unit	1
		Value 90 → 110 Ω	1
(d)	(i)	Circuit showing correctly drawn potential divider with correct positions for ammeter and voltmeter	1
		Change *V;* measure *I* and *V* (with *T* positive)	1
		Repeat with connections to box reversed	1
	(ii)	*I* against *V* OR *V* against *I*	1
		Reverse quadrant shown	1
		Straight line of positive slope and through origin shown in reverse quadrant	1
		Similar line to 0.7 V shown in forward quadrant	1
		Diode curve in forward quadrant	1
		Explanation	1

[24]

Sample results

(a) (i) $I_1 = 80.5$ mA

$V_1 = 6.11$ V

(ii) $I_2 = 28$ mA

$V_2 = 6.20$ V

(b) When *T* negative only R_2 conducts, i.e. use results from (a)(ii)

$$R_2 = \frac{6.2}{0.028} = 221\ \Omega$$

(c) (i) I through $R_2 = \frac{V_1}{R_2} = \frac{6.11}{221} = 0.0276$ A (=27.6 mA)

(ii) Current through R_1 and diode = 80.5 – 27.6 = 52.9 mA

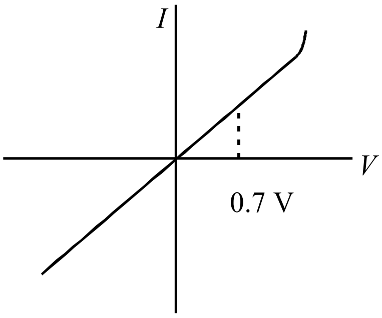
(iii) $R_1 = V/I = \frac{6.11 - 0.7}{0.0529}$

= 102.Ω

(d) (i) Circuit with potential divider, ammeter and voltmeter in correct positions

Change *V,* measure *I* and *V.* Repeat with connections to box reversed.

(ii)



$R_2 = \frac{\Delta V}{\Delta I}$ or $\frac{V}{I}$ provided that linear section used

99.	(a)	(i)	Three or more readings ± 0.2 s of Supervisor's value	2
			[Two readings – 1 mark]	
		(ii)	Mark, or correct use of metre rule [shown]	1
			Same point used on trolley	1
			Eye level with point on trolley	1
			[OR other good technique]	
		(iii)	Δt from range of ½ range (> 0.05 s)	1
			Correct calculation [e.c.f..]	1
		(iv)	Correct calculation $\geq$ 2 s.f. + unit	1
		(v)	Correct calculation [e.c.f.] + unit	1
			Positive value and 1 or 2 s.f.	1
	(b)	(i)	Potential divider set up correctly	2
			Ammeter, voltmeter and polarity of X correct	1
		(ii)	V_1 (4.0 $\rightarrow$ 4.8) V to 0.1 V or better, with unit	1
		(iii)	V_2 (3.0 $\rightarrow$ 3.5) V to 0.1 V or better, with unit	1
			[Unit penalty once only]	
		(iv)	Use of V_1 and 20 mA	1
			Calculation + unit	1
			Value 200 $\rightarrow$ 240 Ω. [No e.c.f..]	1
		(v)	Use of V_2R_2 [e.c.f.]	1
			Correct calculation $\geq$ 2 s.f. + unit [dependent mark]	1
			Correct calculation of I + unit	
			[Penalise omission of unit once only]	
			Correct calculation of V [(V_2 – 0.7) seen anywhere]	1
			Correct calculation $\geq$ 2 s.f. [dependent mark] + unit	1
			Value 90 $\rightarrow$ 110 Ω [No e.c.f.]	

[24]

Sample results

(a) (i) $t = 1.82, 1.96, 1.94$ s

Average $t = 1.91$ s

(ii) Use marker which is 0.800 m from end of runway

Put in front of trolley level with marker

Release and start stopwatch, stop when front of trolley at end of runway

Keep eye level with front of trolley

(iii) Range of $t = 0.14$ s

$$\text{Percentage uncertainty} = \frac{\frac{1}{2}\times 0.14}{1.91}\times 100 = 3.7\%$$

(iv) $$a = \frac{2\times 0.8}{1.91^2}$$

$= 0.439 \text{ m s}^{-2}$

(v) $\theta = 3.1°$, $m = 1.00$ kg

$F = 1 \times 9.81 \sin 3.1° - 1 \times 0.439$

$= 0.531 - 0.439 = 0.092$ N

(b) (i) Circuit set up correctly

(ii) $V_1 = 4.45$ V

(iii) $V_2 = 3.25$ V

(iv) $$R_2 = \frac{4.45}{0.02} = 223\ \Omega$$

(v) $$I \text{ through } R_2 = \frac{3.25}{223} = 0.0146 \text{ A } (= 14.6 \text{ mA})$$

I through $R_1 = 40 - 14.6 = 25.4$ mA

$$R_1 = \frac{(3.25 - 0.7)}{0.0254} = 100\ \Omega$$

100. (a) Measure height above bench at two places 1

Use vertical rule 1

Vertical rule checked with set square 1

[OR set square used between stand and string]

Reasonable value to 0.1 N (4.0 – 5.5 N) with unit 1

(b)	*h* and *1* recorded to nearest mm or better	1
	Scale readings shown	1
	Measured height above the bench at Band C	1
	with vertical rule	1
	Correct calculation of cosθ to 2/3 s.f.	1
	Hence value 0.70 → 0.98	1
(c)	[Using $g = 9.8$]	
	Correct calculation of *W/R*	1
	2/3 s.f. and NO unit [dependent mark]	1
	W/R and cos θ within 0.05 [no e.c.f.]	1
	Correct calculation of percentage uncertainty	1
	Correct calculation of percentage difference [OR range of values]	1
	Sensible comment [Must be quantitative]	1

(d) (i)

Method 1	Method 2	
• Change *M*	• Keep *M* constant	1
• Adjust height of newton-meter until AB horizontal	• Adjust Separation of clamps until AB horizontal	1
• Record *R* and *h*	• Record R and h	1+1
• Evaluate cosθ and *W/R*	• Evaluate cosθ and I/*R*	1

[OR inferred from graph]

(ii)	Correct graph with axes labelled		1
	Straight line through origin expected	)	1
		) Dependent mark	
	Gradient	)	1

[24]

Sample results

(a) Measure height above bench at two places
Use vertical rule
Vertical rule checked with set square [or set square used between stand and string]
R = 4.7, 4.9 N
Average R = 4.8 N

(b) *1* = 30.0 cm

h = 44.5 -19.0 = 25.5 cm

Measured height above the bench and B and C with vertical rule

$$\cos\theta = \frac{h}{l} = \frac{25.5}{30} = 0.85$$

(c) $\frac{W}{R} = \frac{0.4 \times 9.81}{4.8} = 0.82$

Percentage uncertainty in $R = \frac{0.2}{4.8} \times 100\% = 4.2\%$

Percentage difference between values =

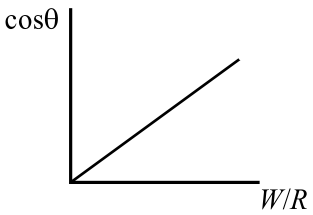
$$\frac{0.85 - 0.82}{\frac{1}{2}(0.85 + 0.82)} \times 100\% = 3.6\%$$

Difference is less than percentage uncertainty, hence good agreement between cosθ and *W/R*.

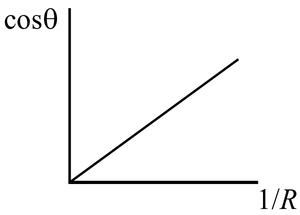
(d) (i)

Method 1	Method 2
• Change *M*	• Keep *M* constant
• Adjust height of newton-meter until AB horizontal	• Adjust Separation of clamps until AB horizontal
• Record *R* and *h*	• Record R and h
• Evaluate cosθ and *W/R*	• Evaluate cosθ and 1/*R*

(ii)



Gradient = 1



Gradient = *W*

101. (a) Stefan-Boltzmann law
T = absolute or Kelvin temperature/K **(1)**
[Not °K or k]
of surface **(1)**
Unit luminosity: watt/W **(1)** 3

(b) Graph
State Wien's law OR see evidence of $\lambda_{max} \times T$ **(1)**
at two different points to give same product [Ignore 10^{-6}] **(1)**
More than two points and allow $2.8 - 3.0 \times 10^{-3}$ (mK) **(1)** 3
[No ue]

Surface temperature of star

Temperature = 7300 [7000 to 7500] [No ue] **(1)** 1

Luminosity calculation

Use of T^4 [7300 K^4] [e.c.f] **(1)**

$A = 4\pi r^2$ substitution correct **(1)**

(5.67×10^{-8} W m^{-2} K^{-4}) $\sigma T^4 A$ used [ecf any A, T] **(1)**

= $(1.4 \rightarrow 1.8) \times 10^{25}$ (W) [No ecf] **(1)** 4

(7000 K) (7500K) [No ue]

Matter consumed

$\Delta E = c^2 \Delta m$ **(1)**

Substitute their L and 9×10^{16} m^2 s^{-2} [Beware $\Delta E = c\Delta m$ used] **(1)**

Mass = 1.8×10^8 (kg s^{-1}) [No ue] [ecf] [Range: $1.5 – 2.0 \times 10^8$ allowed] **(1)** 3

(c) Select words

Cool **(1)**
High **(1)**
Surface area **(1)**
Off the main sequence **(1)** 4

Hertzsprung-Russell diagram

(i) Temperature scale "←" **(1)**

Values in range (20 000 K to 60 000 K) and (2000 K to 4000 K) and non-linear showing at least 3 values **(1)** [e.c.f. scale in wrong direction]

(ii) Level with 10° marked Xs [Check with ruler if unsure] **(1)**

(iii) Region below MS marked W **(1)**

(iv) Region above MS marked R **(1)** 5

(d) Recognition of supernova

Extremely bright star [not "explosion"] **(1)**
Suddenly appearing/time reference **(1)** 2

How supernova is formed

Any three from:

- quality of written communication
- when star collapses/implodes
- shock wave / explosion blows outer layers away [both needed]
- (H) fusion ceases/other fusion begins
- protons combine with electrons to form neutrons **(1) (1) (1)** Max 3

(e) Light year

Distance travelled by light in one year **(1)** 1

Show that 1600 light years = distance 1.5×10^{19} m

s/year (365 × 24 × 60 × 60 s) **(1)**

Method: multiply 1600 by 3×10^8 m s^{-1} × t **(1)** 2

Indirect evidence

No radiation/nothing can escape from them **(1)** 1

[Not just "no light" or "no matter"]

[32]

102. (a) Expression

Energy density = joule/m^3 **(1)**

Stress = N/m^2 **(1)**

Strain = m/m OR no unit stated **(1)**

J = N m / kg m^2 s^{-2} **(1)** 4

(b) Hooke's law

Tension/force proportional to extension
OR formula with symbols defined **(1)**

Up to a certain limit/limit of proportionality **(1)** 2
[Accept elastic limit]

Calculation of Young, modulus of brass

Stress = 34 N/1.5×10^{-7} m^2 OR $E = \frac{Fl}{A\Delta l}$ used **(1)**

Strain = 5.3×10^{-3} m/2.8 m [ie substitution]

[ignore 10^n] **(1)**

Young modulus = 1.2×10^{11} [No ecf] **(1)**
Pa / N m^{-2} [Not kg m^{-1} s^{-2}] **(1)** 4

Graph

[Mark alongside]

Straight line from origin to 46 N **(1)**

going through 34 N, 5.3 mm **(1)** 2

Energy stored

By finding area/area shaded/ ½ Fx up to 24 N **(1)** 1

Second wire

Less energy stored **(1)**

Less extension **(1)**

Smaller area under graph OR smaller ½ Fx **(1)** 3

(c) Differences in behaviour

Any five from:

- Quality of written communication
- Perspex brittle
- Polythene large plastic deformation / tough
- Perspex stiffer/polythene smaller Young modulus [not just gradient]
- Perspex stronger/polythene smaller breaking stress / UTS
- Perspex higher limit of proportionality/obeys Hooke's law to higher stresses than polythene/similar or inverse **(1) (1) (1) (1) (1)** Max 5

(d) Diagram

A tangle of squiggles **(1)**
with (long) molecule or atoms identified on a squiggle /
polymer chain **(1)** 2

Differences in molecular structure

Thermoset has strong cross links **(1)** 1

(e) Tempering

Heat *and* (allow to) cool **(1)** 1

How properties change

Make softer / less hard / less brittle **(1)** 1

Completion of sentence

Stronger **(1)** 1

Use of graph to determine tensile strength

$1/A = 8$ (mm^{-2}) **(1)**
Strength = 1.1×10^9 Pa [ue] **(1)** 2

Strength of glass fibre and its safety

See or use $W = mg$ (196 → 200 N) **(1)**

Stress = $200/0.125 \times 10^{-6}$ Pa [Ignore 10^n error] [No ue] **(1)**

1.6×10^9 compared with value above *and* yes/no **(1)** 3

[OR reverse argument to 14 kg]

[32]

103. (a) Homogeneity

p = mass × velocity **(1)**
p units N s or kg m s^{-1} [This alone implies above mark] **(1)**
E unit (J) N m or kg $\text{m}^2\ \text{s}^{-2}$ **(1)**
c unit m s^{-1} **(1)** 4

(b) Diagram

β^- close to line [mark by diagram] [+5 mm max] **(1)** 1

Explanation of region choice

Any three from:

- quality of written communication
- in β^- decay neutron → proton
- so moves downwards and to right OR ↘
- closer to dotted line OR more stable **(1) (1) (1)** Max 3

[Discussion in terms of N = Z line, max 1/3 + I QOWC]

(c) Classification of particles

Ξ^- is a baryon **(1)**
Λ is a baryon **(1)**
π^- is a meson **(1)** 3
[Allow bbm]

Charge of strange quark

Show that –1 = –1/3(d) + –1/3(s) + –1/3 (s) **(1)** 1

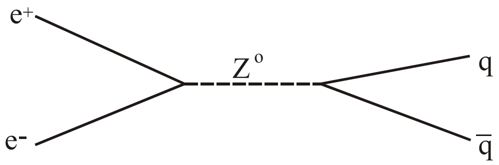
Λ particle

Λ is neutral **(1)**
+2/3 + –1/3 + –1/3 = 0 and uds
OR charge conservation (–1) = 0 + (–1) **(1)** 2

Why decay is a weak interaction
An s quark changes to a u quark / change of quark flavour / type **(1)**

Exchange particle is W^- **(1) (1)** 3
[W+, Z°, W or Z gets **(1) (0)**]

(d) Label diagram



Electron and positron IN **(1)**

Quark and antiquark OUT **(1)** 2

[Type given, must be a pair, e.g. uū]

Calculation of mass
Any 3 from:

- Total energy Z° = 91.2 GeV / ×2
- 1000 ÷ 930 [or ÷ 0.93]
- ⇒ 98 u
- u = 1.66×10^{-27} kg [seen]
- 1.6×19^{-25} (kg) **(1) (1) (1)** Max 3

How mass compares with that of a proton

This is approximately 100 × mass proton [ecf] **(1)** 1

(e) Four fundamental interactions

Three correct **(1)**
Fourth correct **(1)**
(Strong, weak, electromagnetic, gravitational]

Strong does not act between electrons **(1)**
Acts upon quarks and electrons
Weak, gravitational, electromagnetic **(1) (1)** 5
[All 3 correct **(1) (1) ;** only 2 correct **(1)]**

(f) Identification of diagrams

Left hand charged current interaction AND right hand neutral current interaction **(1)**
Left hand W^+ OR W^- OR W **(1)**
Right hand Z° **(1)** 3

Equation

$n + v_{\mu}. \rightarrow \mu^- + p$ **(1)** 1

[32]

104. (a) eV to joules and speed of an electron

$20 \times 10^3 \times 1.6 \times 10^{-19}$ (= 3.2×10^{-15}) **(1)**

$E = \frac{1}{2} mv^2$ **(1)**

= 3.2×10^{-15} J **(1)**

$m = 9.11 \times 10^{-31}$ kg **(1)**

$v = 8.4 \times 10^7$ m s^{-1} **(1)** 5

(b) How anti-scatter grid improves sharpness of an X-ray image

Quality of written communication **(1)**

X-rays scattered / deflected (by patient) **(1)**

cattered X-rays but are stopped by grid **(1)** 3

Material of anti-scatter grid

Lead **(1)** 1

(c) Description of ultrasound A-scan

send PULSE in **(1)**
detect reflection **(1)**
time between in and out / find Δt between reflections from opposite sides of head
use distance = speed × time **(1)**
divide by 2 **(1)** 5

Why ultrasound of 1.2 MHz not suitable for purpose

Use $c = f \times \lambda$ [i.e. see subs ignoring 10^n errors] **(1)**

$\lambda = 1.25 \times 10^{-3}$ m **(1)**

Too big to give detail/resolve eye **(1)** 3

(d) Homogeneous

One wavelength only [or f or E] **(1)** 1

HVT

1.5 mm – 1.6 mm **(1)** 1

Use of graph to justify statement

Two drops compared correctly **(1) (1)** 2

Calculation

400 → 50 is 3 half thicknesses **(1)**

so 7.2 mm **(1)** 2

Why absorbers of specific shapes and thicknesses needed

To allow high dose in desired place **(1)**

To protect healthy organs **(1)** 2

(e) Nuclear equation

$^{131}_{53}\mathrm{I} \rightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\beta^{-} + \gamma$ [OR $^{0}_{-1}\mathrm{e}$]

Symbols **(1)**

Numbers [×6] **(1)** 2

Labelled diagram

Mark by diagram

Any five from:

- circuitry
- photomultipliers
- scintillator (NaI crystal) [not just crystal]
- collimator (grid)
- patient
- source inside patient **(1) (1) (1) (1) (1)** Max 5

[32]

105. (a) (i) Initial level of water below height of plasticene
OR
Sensible trial and error shown
OR
Beaker used to collect correct volume of water
OR
Plasticene removed with pencil explained **(1)**
Plasticene fully immersed **(1)**
Correct volume by difference method, with unit **(1)**
[Ignore incorrect conversion to m^3]
[Accept readings to 0.5 cm^3]
Two precautions given **(1)** **(1)**
Correct calculation, 2/3 significant figures + unit **(1)**
Value 1.6 – 2.0 g cm^{-3} **(1)** 7
[OR ± 0.2 on centre value]

(ii) Sensible ΔV **(1)**
[1 cm^3 or 2 cm^3 or ½ range or range of values]
Correct calculation of percentage from sensible ΔV **(1)**
Correct calculation of percentage difference with 1800 (1.8) as denominator **(1)**
Sensible comment based on their percentage difference and the manufacturer's specification [±10%] **(1)** 4

(b) (i) Circuit set up correctly without help **(1)** **(1)** 2
[Ignore polarity errors]

(ii) $V_{AC} \approx 3$ V to 0.1 V or better, with unit **(1)**
$V_{BC} < V_{AC}$ to 0.1 V or better, with unit **(1)**
[Use unit penalty once only]
Correct difference <u>calculated</u> with unit **(1)**
Correct calculation to more than 2 significant figures + unit **(1)**
Correct calculation to more than 2 significant figures + unit **(1)** 5

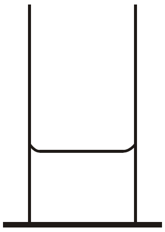
(iii) $V_{BC} > V_{BC}$ in part (ii) and > 2 V and to 0.1 V with unit **(1)**
[Allow $V_{BC} \approx V_{AC}$]
V_{BC} increases because **(1)**
resistance of LDR increases **(1)**
as light intensity reduced/when LDR is covered **(1)**
[dependent on previous mark because $\frac{V_{BC}}{V_{AB}} = \frac{R_{LDR}}{1k\Omega}$ **(1)**]
so share of voltage increases OR circuit current reduces so p.d. **(1)**
across 1 kΩ reduces ∴ p.d. across LDR increases **(1)** 5

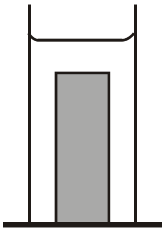
Correct calculation of R_{LDR} with unit, using ratios OR current method and ≥ 2 significant figures **(1)** 1

[24]

Sample results:

(a) (i) $m = 75.0$ g





All volumes must be measured by measuring cylinder, else 0/2

Volume of water and Plasticene = 95 cm^3
Volume of water = 53 cm^3
Volume of Plasticene = 42 cm^3

Any two precautions from:
Tilt the measuring cylinder/lower the Plasticene carefully to avoid splashing
Eye level with meniscus/when taking surface of water readings
Repeat readings seen
Carefully exclude air when shaping
Tap the measuring cylinder to remove air bubbles

$$\text{Density} = \frac{75}{42} = 1.79 \text{ g cm}^{-3}$$

(ii) $\Delta V = 1 \text{ cm}^3$
Percentage uncertainty = $1 \div 42 \times 100 = 2.4\%$

$$\text{Percentage difference} = \frac{0.01}{1.8} \times 100$$

$= 0.6\%$

Percentage difference is smaller than 10% ∴ well within manufacturer's specification

(b) (i) Ignore polarity errors

(ii) $V_{\text{AC}} = 3.08$ V
$V_{\text{BC}} = 0.95$ V
$V_{\text{AB}} = 3.08 - 0.95 = 2.13$ V

$$I = \frac{V}{R} = \frac{2.13}{1000} = 2.13\ 10^{-3} \text{ A}$$

$$R = \frac{V}{I} = \frac{0.95}{2.13 \times 10^{-3}} = 446\Omega$$

OR

$$\frac{V_{BC}}{V_{AB}} = \frac{R}{1000}$$

$$I = \frac{V_{BC}}{R} = \frac{V_{AB}}{1k\Omega} = \frac{V_{AC}}{R + 1000}$$

(iii) $V_{BC} = 2.68$ V

V_{BC} increases because:

resistance of LDR increases as light intensity reduces/when the LDR is covered, so *either* share of voltage increases *or* circuit current reduces so p.d. across 1 kΩ reduces, therefore p.d. across LDR increases.

$$\frac{V_{BC}}{V_{AC}} = \frac{R_{LDR}}{1.0 + R_{LDR}}$$

$$\frac{2.68}{3.08} = 0.87 = \frac{R_{LDR}}{1.0 + R_{LDR}}$$

$$\therefore 0.87 + 0.87\ R_{\text{LDR}} = R_{\text{LDR}}$$

$$0.13\ R_{\text{LDR}} = 0.87$$

$$R_{\text{LDR}} = 6.7\ \text{k}\Omega$$

106. (a) Mean time ≈ 2 s and from ≥ 3 readings, with unit **(1) (1)**

[≥ 2 readings, 1 only]

Correct calculation ≥ 2 s.f + unit **(1)** 3

(b) Start and stop defined **(1)**

Use of point on trolley for start and stop **(1)**

Eye level with point on trolley at start or stop **(1)** 3

(c) [Calculation of *h* – 0/2]

Height shown for length of 0.8 m **(1)**

Use of set square to check rule vertical [Horizontal line needed] **(1)**

Sensible height to the nearest mm with unit **(1)**

Correct calculation of $E_p \geq 2$ s.f. + unit **(1)**

Correct calculation of $E_k \geq 2$ s.f. + unit [allow ecf] **(1)**

Correct calculation of *k* giving sensible positive *k* to 2 or 3 s.f. + unit **(1)** 6

(d) Use blocks of different height or release trolley from different points along runway or move block further under runway, or add masses to the trolley or use trolley of different mass **(1)**

Use at least five different values for *h*/mass etc [May be evidence of this from table or graph.] **(1)**

Measure *t* **(1)**

to travel a distance *s* **(1)**

Calculate υ, E_p and E_k **(1)**

E_p against E_k plotted **(1)**

Straight line, positive gradient and intercept **(1)**

Intercept when $E_k = 0$ **(1)** 8

(e)

Motion sensor	Light gate at end of 0.8 m	**(1)**
Description, e.g. ultra-sonic waves reflected off metal plate attached to trolley	Card attached to trolley	**(1)**

Output connected to datalogger/timer **(1)**

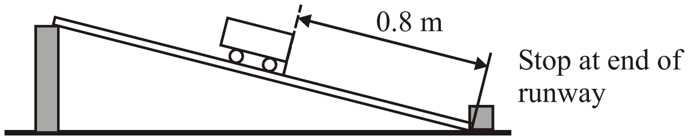
Correct υ by calculation or from computer **(1)** 4

[24]

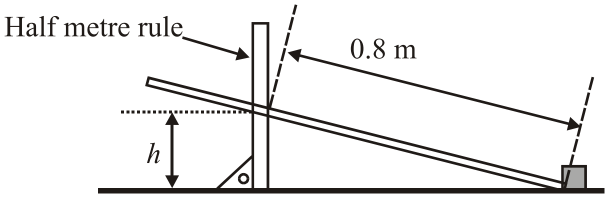
Sample results:

(a) t = 1.91, 1.91, 1.96, 1.90 s
Mean t = 1.92 s
$\upsilon = \dfrac{2 \times 0.80}{1.92} = 0.83 \text{ m s}^{-1}$

(b) Start and stop defined
Use of same point on trolley for start and stop
Eye level with point on trolley at start or stop

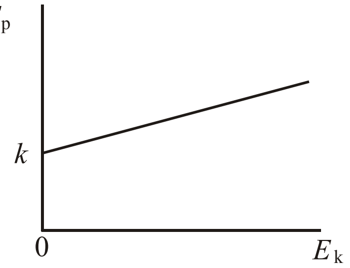


(c) h = 38 mm



$E_p = mg\Delta h = 1.0 \times 9.81 \times 38 \times 10^{-3} = 0.373$ J
$E_k = \frac{1}{2} m\upsilon^2 = \frac{1}{2} \times 1.0 \times (0.83)^2 = 0.347$ J
$k = 0.373 - 0.347 = 0.026$ J

(d) Use blocks of different height or release trolley from different points along runway or move block further under runway, or add masses to the trolley or use trolley of different mass
Use at least five different values for h/mass etc [May be evidence of this from table or graph.]
Measure t to travel a distance s
Calculate υ, E_p and E_k



Find k by intercept when $E_k = 0$

(e)

Motion sensor	Light gate at end of 0.8 m
Description,e.g. ultra-sonic waves reflected off metal plate attached to trolley	Card attached to trolley

Output connected to datalogger/timer **(1)**

Correct υ by calculation or from computer **(1)**

107. (a) Higher efficiency

Idea of "less light to get image" / more useful energy out **(1)**
Lower intensity light triggers a CCD
Greater intensity needed to expose a grain of emulsion **(1)**

Advantage

Detect fainter/more distant objects

OR
less time to get image/more images per session **(1)** 3

(b) COBE

Apply Wien's law correctly [Ignore 10^n] **(1)**
Temperature of space = 2.6 K [Not mK, °K, k] **(1)** 2

Electromagnetic spectrum
Microwaves/infra-red **(1)** 1

(c) Ways in which white dwarf star differs from main seguence

Lower mass/volume/radius/(surface) area **(1)**

Fusion (burning) finished [Not luminosity] **(1)** 2

Fate of star after it has become a white dwarf
Cools (gradually)
until no longer visible/becomes dimmer/changes colour **(1)** 2

[Allow brown dwarf]

HR diagram

Any two from:

- temperature scale in reverse direction
- at least two reasonable *T* values shown/ eg 40 000, 10 000,4000)
- indication of log scale **(1)** **(1)** Max 2

(Single) star selected at $L/L_\odot = 1$ [≈ ± 2mm vertically by eye] **(1)** 1
(Region) W clearly below MS [No ecf on *T*] **(1)** 1
M to include top of MS **(1)** 1

Explanation

Quality of written communication **(1)**
Greater mass means greater luminosity or greater temperature or greater gravitational forces **(1)**

Burns hydrogen/fuel much faster **(1)**
Runs out of fuel quicker **(1)** 4

(d) Temperatures of the two stars

They are similar/same **(1)**
because of Wien's law/same λ/f **(1)** 2

Greater radius

Deneb **(1)**
More luminous **(1)**
Refer to $\sigma A T^4$ and state *T* similar **(1)** 3

Which star will appear brighter?
Vega **(1)**
Use of $I = L/4\pi D^2$ **(1)**
One correct value: D = 8.8 OR V = 29 (× 10^{-9} W m^{-2}) **(1)**
Second correct value with unit **(1)** 4

(e) Show that Gemini has more than 10× the light gathering power

Substitutions in πr^2 $(8.0\text{ m})^2 \div (2.4\text{ m})^2 / 4^2 \div 1.2^2$ **(1)**
Answer 11 times **(1)** 2

Situation
Studying faint OR distant objects **(1)** 1

Suggested disadvantage
Not steerable/exposed to weather **(1)** 1

[32]

108. (a) Area under graph

It represents energy (stored) per unit volume/energy density **(1)** 1

Volume of seat belt

1.8×10^{-4} (m^3) **(1)** 1

Kinetic energy

Attempt to use ½ mv^2 **(1)**
= 15.8 (kJ)/15 800 (J) **(1)** 2

Energy per unit volume

8 or 9 × 10^7 J m^{-3} (88 MJ m^{-3})
OR
2nd answer divided by 1st with **correct unit (1)** 1

Belt satisfactory

Attempt to find area under graph / ½ $\varepsilon\sigma$ used **(1)**
Value ≥ 9.6 × 10^7 (J m^{-3}) (so total area is greater than above) **(1)** 2

Design change

Wider or thicker or harness shaped belt/more straps **(1)**

Need greater volume/need to reduce pressure on driver/need to absorb more kinetic energy [Not faster] **(1)** 2

(b) Graph

Shape (hysteresis shown) **(1)**
Arrow heads or labels **(1)** 2

Explanation

Quality of written communication **(1)**

Area indicates work done / energy (density) **(1)**

Relaxed area / work / energy density < stretched area / work / energy density OR area of loop **(1)** 3

(c) Fatigue failure

Fracture/cracking/breaking after many cycles of stress OR
repeated tension/loading **(1)** 1

Explanation for fatigue failure

Any THREE from:

- aircraft subjected to repeated stresses
- because of temperature/pressure changes (during flight)
- stress concentrations at rivet holes/corners of windows
- these cause cracks (to propagate) **(1) (1) (1)** Max 3

(d) Composite material

Two materials combined to use the properties of both **(1)** 1

Labelled diagrams

Any four from:

- Chipboard shows random bits (of wood) [Not unlabelled dots or lines]
- Label says ‘glued’ or ‘in matrix’ AND wood/chips
- Plywood shows layers (of wood)
- Label says ‘crossed grain’ AND (layers of) wood **(1) (1)**
- Particle composite = chipboard AND laminate = plywood **(1) (1)** Max 4

(e) Energy conversions

GPE to KE **(1)**
to EPE or internal energy/strain/elastic **(1)** 2

Three properties

Strength, toughness, elasticity

Any TWO correct **(1)**

Third property correct 2

[–1 per incorrect answer if ≥ three circles]

Calculation of theoretical extension of rope

Correct substitution in $A = \pi r^2$ / 9.5×10^{-5} m^2 **(1)**

Sensible use of any TWO from:

- Stress = $F \div A$ [Ignore 10^n, ecf A]
- E = stress ÷ strain
- Strain = $\Delta l \div l$ **(1) (1)**

Answer: 2.0 m [No ecf] [ue] **(1)** 4

Suggested reason why rope should be replaced

May have exceeded its elastic limit or may have deformed plastically or
may have been damaged on sharp rock/ fibres may be broken **(1)** 1
[NOT rope has broken]

[32]

ã **109.** (a) Experiments

(i) Deep inelastic scattering/SLAC 1969/Friedman, Taylor,Kendal **(1)**

(ii) Rutherford (or alpha) scattering/Geiger and Marsden or Manchester 1909/1910/1911 **(1)** 2

Radius

Use of $r = r_0 \sqrt[3]{40}$ **(1)**

$r = (1.2 \times 10^{-15}$ m $\times \sqrt[3]{40}$ =) 4.1×10^{-15} (m) **(1)** 2

Density of calcium nucleus

Mass = $40 \times 1.66 \times 10^{-27}$ kg **(1)**

Volume = $4\pi/3 \times (4.1 \times 10^{-15}$ m$)^3$

[OR $\dfrac{1.66 \times 10^{-27}}{4\pi/3\,(1.2 \times 10^{-15})^3}$ for first two marks]

Use of $d = m/V$ to give answer (2.3 or 2.5) × 10^{17} kg m^{-3}**(1)** 3

(b) Emission - written above arrows

$\alpha \quad \beta^- \quad \beta^- \quad \alpha \quad \alpha$

All five correct [Allow e^-, $^4He^{2+}$] **(1)** **(1)** 2

[For each error –1]

[$\alpha \quad \beta \quad \beta \quad \alpha \quad \alpha$ gets 1/2]

Number of alpha particles emitted

Five **(1)** 1

(c) Graph

Correct shape (*y*-axis – fall) [NOT bell shaped] **(1)**

Meets KE axis **(1)** 2

Explanation of how energy spectrum led to prediction of existence of the antineutrino

Quality of written communication **(1)**

Energy per decay is constant / conservation of energy **(1)**

β^- have a range of energies **(1)**

(anti)neutrino / other particle takes missing energy **(1)** 4

(d) Comparison between antiparticle and its particle pair

Similarity: same mass as its particle pair (magnitude of charge) **(1)**

Difference: opposite charge/baryon number/(Iepton number / spin) **(1)** 2

Quark composition

$\bar{u}\ \bar{u}\ \bar{d}$ [OR anti-down etc] **(1)** 1

Baryon number

–1 **(1)** 1

Why difficult to store antiprotons

As soon as they contact protons/matter **(1)**

they annihilate **(1)** 2

Maximum possible mass

×2 **(1)**
÷ 0.93 or equivalent [OR by using $E = mc^2$ to 1.6×10^{-25} kg] **(1)**
96 (u) OR 97 (u) **(1)** 3
[48u x **(1) (1)**]

Two reasons why interaction cannot take place

Q/charge not conserved **(1)**
B/baryon number not conserved **(1)** 2

(e) Completion of table

	Fundamental interaction	Exchange particle	
Decay (i)	Strong	Gluon	**(1)**
Decay (ii)	Weak	W^-	**(1) (1)**
Decay (iii)	Electromagnetic	Photon / γ / gamma	**(1)**

[Ignore “nuclear” or “ray” or “virtual” anywhere] 4

Fundamental interaction

Gravitational [ecf] [NOT “gravity”] **(1)** 1

[32]

110. (a) Half lives

8000 → 4000 → 2000 → 1000 is 3 half lives **(1)**
40 hours [ecf 13.3 × number above] **(1)** 2

Graph

Decay curve starting at 8000 **(1)**

Decay curve not cutting time axis **(1)**
One approx correct point e.g. 40, 1000 **(1)** 3

Activity

Less because some excreted or equivalent **(1)** 1

(b) Equation

$^{99}_{42}\text{Mo} \rightarrow {}^{99\text{m}}_{43}\text{Tc} + \beta^- / {}^{0}_{-1}\beta / \text{e}^- / {}^{0}_{-1}\text{e}$ [+ anti-neutrino] **(1)** 1

Where produced

Elution cell/alumina beads **(1)** 1

Description of what happens when tap is opened

Saline solution is forced through cell [NOT just goes] **(1)**
dissolving any Tc AND not Mo **(1)**
and transferring Tc to collection bottle **(1)** 3

Suitable material

Lead/Pb **(1)** 1

Advantage

Can be produced on the spot OR is still active when required OR can produce fresh, single dose per patient OR portable **(1)** 1

Two reasons

Not too long to wait for it to recharge **(1)**

Reasonable time before needing a replacement/(Not so short that it decays too quickly) **(1)** 2

(c) Function of parts of X-ray tube

(i) Filament releases electrons/thermionic emission **(1)**

(ii) High voltage accelerates electrons **(1)**

(iii) Tube enables a vacuum to be created **(1)** 3

Protection of radiographer

Any TWO from:

- wears lead apron
- lead shield round tube/machine
- leaves room while on / operates from behind leaded window / lead shield
- wears film badge to monitor exposure **(1)** **(1)** 2

Explanation of X – ray photograph

Quality of written communication **(1)**

X-ray absorption depends on proton number/Z **(1)**

X-rays expose film / picture / image making it dark **(1)**

Bone absorbs X-rays (so none reach film so not dark) AND lungs/air spaces/air does not absorb (so reach film so dark) **(1)** 4

(d) Coupling medium

To avoid (surface) reflections/more penetration **(1)** 1

Energy loss

Scattering/absorption [NOT reflection] **(1)**
Heat / internal energy / molecular vibrations **(1)** 2

Calculation of reflection coefficient

$(Z_1 - Z_2)^2 \div (Z_1 + Z_2)^2$ **(1)**
$(7.8 - 1.7)^2 \div (7.8 + 1.7)^2$ **(1)**
= 0.41/41% **(1)** 3

How much of intensity enters bone

0.6 I is not reflected [ecf] **(1)**
0.6 × 0.5 I enters (= 0.3 I) **(1)** 2

[32]

111. (a) (i) Diameter to 0.01 mm precision and ± 0.4 mm of
Supervisor's value **(1)**
Three values with unit **(1)**
Checked at points along length **(1)**
and in two perpendicular (different) directions **(1)** 4
[Can get both the last two marks from diagram]

(ii) Height of rod above bench near each end measured **(1)** 1
[Allow "different points"]

(iii) x and y to mm precision and unit *and* T to 0.1 N or better, with unit **(1)**
W correctly calculated to 2/3 significant figures plus unit **(1)**
W ± 2 N of Supervisor's value
[W± 3 N gets 1 mark] **(1) (1)** 4

(iv) $\Delta y \pm 1$ mm or ± 2mm **(1)**
[or > 2 mm if from range]
Correct calculation of percentage [ecf] **(1)**
Difficult to know the exact point about which the base pivots
OR
Difficulty in making measurement due to difference in
levels of A and C **(1)** 3

(b) (i) –1 if polarity of cell was changed for candidate
[No penalty if "polarity of meter(s)"]
Circuit set up correctly without help **(1) (1)** 2

(ii) All units correct **(1)**
$V \approx 1.5$ V to 0.01 V or better and $I_{AB} \approx 20$ mA and
$I_{BA} \approx 15$ mA, both to 0.1 mA or better **(1)**
Correct calculation of R to 2/3 significant figures [ecf] **(1)**
$R_{BA} = 100\ \Omega \pm 5\ \Omega$ [No ecf] **(1)** 4
As $R_{BA} \approx 100\ \Omega$ **(1)**
it is circuit K [dependent mark] **(1)**
No current through diode in reverse OR why other circuits
are eliminated **(1)** 3

(iv) Correct numerical parallel formula **(1)**
Indication somewhere that diode arm = $R_D + 200$ **(1)**
Correct calculation **(1)** 3
OR
I in diode arm = $I_{AB} - I_{BA}$ **(1)**
Calculation of resistance of diode arm (using either V) **(1)**
$R_D = R - 200$ **(1)** 3
[In both cases, ecf from part (iii), even if answer negative or silly]

[24]

Sample results

(a) (i) Diameter/mm = 12.65, 12.67; 12.67,12.67; 12.67, 12.66
Checked at points along length and in two perpendicular directions

(ii) Height of rod above bench near each end measured

(iii) $x = 16.6$ cm
$y = 59.5$ cm
$T = 3.7$ N

$$W = \frac{3.7(16.6 + 59.5)}{16.6} = 17.0 \text{ N}$$

(iv) $\Delta y = 0.2$ cm

$$\% \text{ uncertainty} = \frac{0.2}{59.5} \times 100 = 0.3\%$$

(b) (i) Circuit set up correctly

(ii)

X connected to	Y connected to	Current/mA	Voltage/V	Resistance/Ω
A	B	19.6	1.51	77.0
B	A	15.3	1.52	99.3

(iii) As $R_{BA} \approx 100\ \Omega$
it is circuit K
No current through diode in reverse

(iv) $$\frac{1}{x} + \frac{1}{99.3} = \frac{1}{77}$$
$\Rightarrow$ X = 343 Ω
$R_D = 343 - 200\ \Omega$
= 143 Ω

112. (a) All temperatures recorded with units **(1)**
$\Delta\theta \approx (5 \rightarrow 15)$ K [Need not be calculated] **(1)**
Some attempt at temperatures better than 1°C **(1)**
Precautions (Max 2): **(1) (1)** 5

- stirred water
- took θ_i just before water added
- recorded θ_f immediately after rapid fall
- equilibrium between water and thermometer

(b) Correct re-arrangement and substitution **(1)**
Correct calculation, 2/3 significant figures and no unit **(1)**
Value 0.15 to 0.30 or centre value if > 0.30 **(1)** 3

(c) Discard 20 cm^3 into the waste beaker **(1)**
Add further 20 cm^3 into the hot/warm water **(1)**
Temperatures recorded, with units and $\theta_i < \theta_f$ from previous value **(1)**
Correct calculation ≥ 2 significant figures and no unit **(1)**
Value ± 0.04 of previous *k* **(1)** 5
[Dependent mark]

(d) Correct calculation with average as denominator **(1)**
Sensible comparison with 10% **(1)**
Sensible conclusion [Dependent mark] **(1)** 3

(e) (i) Description:

- Keep volume of hot water constant at 100 ml **(1)**
- Volume of added water constant at 20 ml **(1)**
- Discard (20 ml) each time so that initial volume remains constant **(1)**
- (Measure $\Delta\theta$) by measuring θ_i and θ_f **(1)**
- for several values of θ_i **(1)**

Any two sensible precautions (eg lagging/lid/larger
volumes/check θ_0 **(1) (1)** (Max 5)

(ii) Axes labelled correctly **(1)**
Straight line through origin **(1)**
OR
if $\Delta\theta$ against θ_f straight line negative intercept **(1)**

(iii) *k* = gradient [Dependent mark] **(1)** Max 8

[24]

Sample results

(a) $\theta_o = 18.5$ °C
$\theta_i = 85.0$ °C

$\theta_f = 75.0$ °C

$\Delta\theta = 10.0$°C

(b) $k = \frac{\Delta\theta}{\theta_f - \theta_0} = \frac{10.0}{75.0 - 18.5}$

$= 0.177$

(c) Discard 20 cm^3 into the wastebeaker

Add further 20 cm^3 into the hot/warm water

$\theta_i = 57.5$ °C

$\theta_f = 51.5$ °C

$\Delta\theta = 6.0$ °C

$k = \frac{6}{51.5 - 18.5} = 0.182$

(d) % difference = $\frac{0.182 - 0.177}{1/2(0.182 + 0.177)} \times 100\%$

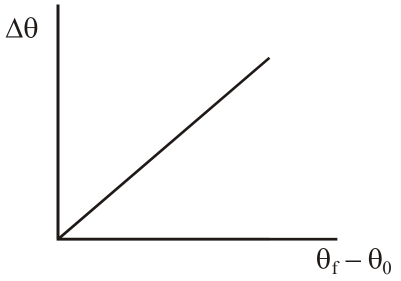
=3.6%

Difference is less than 10% ∴ relationship is supported

(e) (i)
- Keep volume of hot water constant at 100 ml
- Volume of added water constant at 20 ml
- Discard (20 ml) each time so that initial volume remains constant
- (Measure $\Delta\theta$) by measuring θ_I and θ
- for several values of θ_I

Any two sensible precautions: eg lagging/lid/larger volumes/check θ_0

(ii)



(iii) k = gradient

113. (a) (i) W± 0.3 mm of Supervisor's value, with unit **(1)**
t ± 0.3 mm of Supervisor's value, with unit **(1)**
[W and t both to 0.1 mm or better]
Both from ≥ 3 readings **(1)**
at different points along the rule **(1)** 4
[May score mark from diagram]
[Use unit penalty once only]

(ii) x and y to mm precision, with unit seen at least once **(1)**
y by difference method **(1)**
W correct, 2/3 significant figures, + unit **(1)**
± 0.1 N of Supervisor's value **(1)** **(1)** 5
[± 0.2 N gets 1 mark only]

(iii) Check heights vertical by using set square on bench [may be on diagram] **(1)**
For x place rule on bench and note positions vertically below X and Y **(1)**
Statement of how it was ensured that positions were vertically below X and Y **(1)** 3
[Last two marks can by scored by using Pythagoras with XY = 80 cm]

(b) (i) Circuit set up correctly without help **(1)** **(1)** 2
[Ignore meter polarity errors.
Polarity of cell –1]

(ii) All units correct **(1)**
$V \approx 1.5$ V both to 0.01 V or better and $I_{AB} \approx 16$ mA and
$I_{BA} \approx 8$ mA, both to 0.1 mA or better **(1)**
Correct calculation of R 2/3 significant figures [ecf] **(1)**
$R_{BA} = 200\ \Omega \pm 10\ \Omega$ [no ecf] **(1)** 4

(iii) $R_{BA} \approx 200\ \Omega$ **(1)**
Hence circuit L **(1)**
Either
Diode arm does not conduct when B positive **(1)** 3
Or
For circuit J, $R_{BA} = 50\ \Omega$ and circuit K $R_{BA} = 100\ \Omega$ **(1)**

(iv) Correct formula **(1)**
Diode arm resistance = $R_D + 100\ \Omega$ **(1)**
[Allow ecf from wrong circuit]
Correct calculation of diode resistance [ecf] **(1)** 3

[24]

Sample results

(a) (i) W = 28.4, 28.1, 28.1, 28.2 mm
$\overline{W}$ = 28.2 mm
t = 6.3, 6.3, 6.0, 6.2 mm
$\bar{t}$ = 6.2 mm

(ii) $x = 797 - 30 = 767$ mm
$y = 400 - 196 = 204$ mm

$$W = 2 \times 0.2 \times 9.81 \times \frac{204}{767}$$

= 1.04 N

(iii) Check heights vertical by using set square on bench. For x place rule on bench and note positions vertically below X and Y.
Statement of how it was ensured that positions were vertically below X and Y.

(b) (i) Circuit set up correctly without help.

(ii)

X connected to	Y connected to	Current/mA	Voltage/V	Resistance/Ω
A	B	16.5	1.55	93.9
B	A	7.9	1.57	199

(iii) $R_{BA} \approx 200\ \Omega$
Hence circuit L
Either
Diode arm does not conduct when B positive
Or
For circuit J, $R_{BA} = 50\ \Omega$ and circuit K $R_{BA} = 100\ \Omega$

(iv) $\frac{1}{X} + \frac{1}{199} = \frac{1}{93.9}$
[Candidates may write 1/200 for second term]
X = 178 Ω
Resistance of diode = X – 100
= 178 – 100
= 78 Ω

114. (a) Sensible volume with unit, from difference method or a series of small additions **(1)**
Temperature recorded to better dm 1°C with unit **(1)** 2

(b) Sensible values to at least 1 d.p. plus units **(1)**
Table with units **(1)**
Readings at least every 30 s/0.5 min
Some attempt at better than 1°C **(1)**
Straight line of S shaped curve **(1)** 5

(c) Sensible scale with data occupying more than half page in both directions **(1)**
Labelled and units **(1)**
Plots and straight line **(1)** 3

(d) $\Delta x > 6$ cm **(1)**
Correct calculation 2/3 s.f. + unit **(1)**
Correct calculation ≥ 2 s.f. + unit **(1)**
Correct re-arrangement [ignore units] **(1)**
Correct conversion of $\frac{\Delta\theta}{\Delta t}$ to °C s^{-1} here or above **(1)**
Correct calculation 2/3 s.f + unit 6

(e) Not all of the power supplied by the heater goes to the water (ie p to water is smaller than above value) OR heat is lost to the surroundings **(1)**
Hence, value is too high **(1)**
Improved accuracy, any two from:

- Lag the beaker
- Cover the beaker
- Increase the power supply voltage to give larger temperature rise
- Take account of s.h.c. of beaker
- Increase the time of the experiment **(1) (1)** 4

(f) All of circuit diagram correct **(1) (1)**
[–1 each error or omission]
[No penalty if thermistor and resistor are reversed]
Block diagram:
Temperature sensor [Do not accept thermometer] **(1)**
Datalogger and computer **(1)** 4

[24]

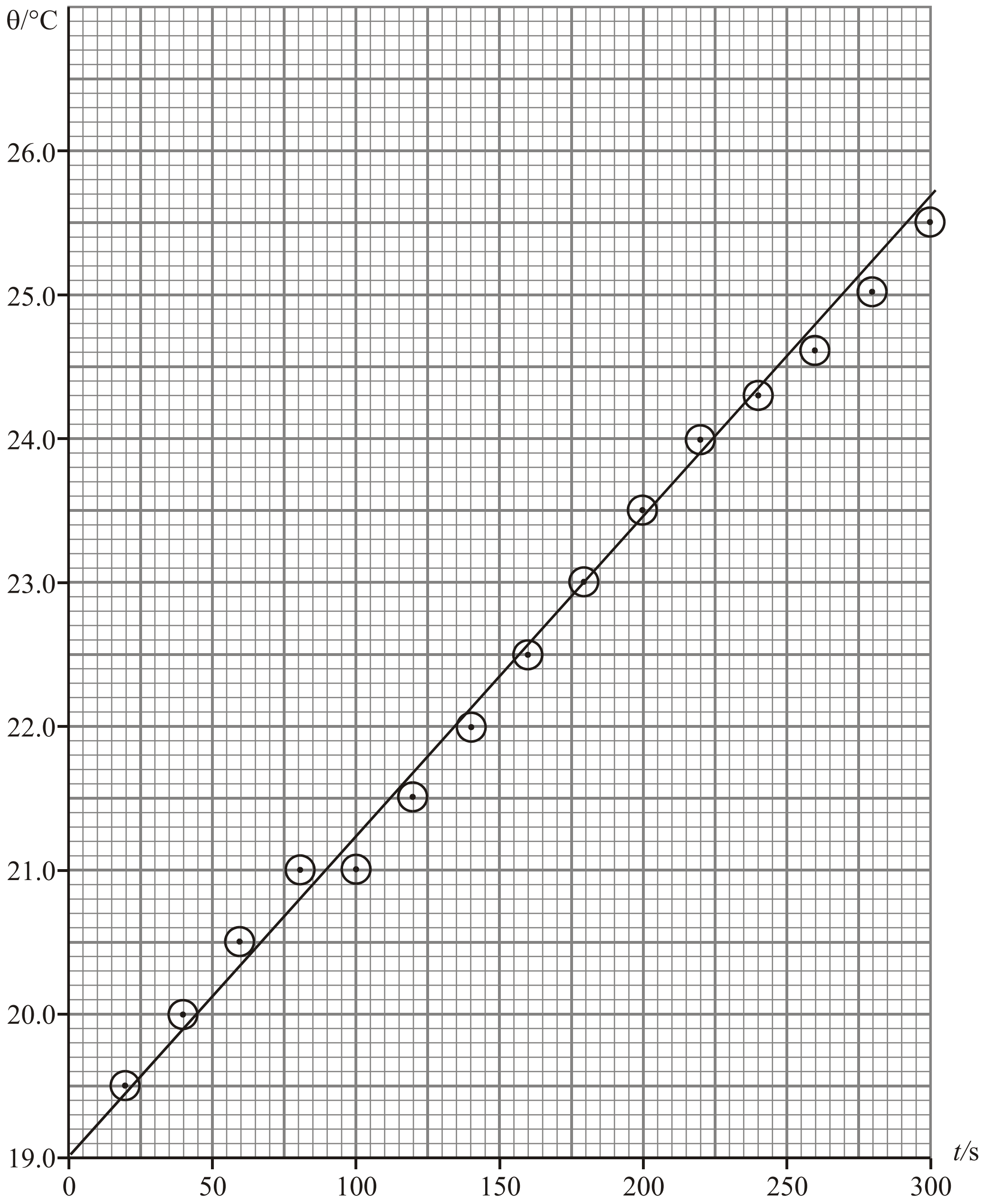
Sample results

(a) $V = 100 - 57 = 43$ ml
Filled cylinder to 100 ml and poured water into beaker until wire just covered.
Recorded amount of water left in the cylinder.
$\theta_0 = 19.0$ °C

(b) $I = 1.07$ A $V = 6.72$ V

t/s	θ/°C
0	19.0
20	19.5
40	20.0
60	20.5
80	21.0
100	21.0
120	21.5
140	22.0
160	22.5
180	23.0
200	23.5
220	24.0
240	24.3
260	24.6
280	25.0
300	25.5

(c) Graph



(d) $\frac{\Delta\theta}{\Delta t} = \frac{25.675 - 19.0}{300}$

$= 2.23 \times 10^{-2}$ °C s^{-1}

$P = IV = 1.07 \times 6.72$

$= 7.19$ W

$c_W = \frac{P}{m_W \, {\Delta\theta}/{\Delta t}} = \frac{7.19}{43 \times 10^{-3} \times 2.23 \times 10^{-2}}$

$= 7500$ J kg^{-1}°C^{-1}

(e) Not all of the power supplied by the heater goes to the water (ie P to water is smaller than above value) or heat is lost to the surroundings.
Hence value is too high

- Lag the beaker
- Cover the beaker
- Increase the power supply voltage to give larger temperature rise
- Take account of s.h.c. of beaker
- Increase the time of the experiment

(f) Block diagram:

115. (a) Graph

Falling concave curve **(1)**

Not intercepting x–axis or y–axis **(1)** 2

Two reasons

- light is scattered by dust (or air molecules)/refraction **(1)**
  [allow twinkling]
- some wavelengths are absorbed by atmosphere **(1)** 2

(b) Two spectra

β_{car} is bluish; β_{And} is reddish [not just different colours] **(1)** 1

Read off $\lambda_{max} \approx (760 - 770)$ nm [Beware 680 nm] **(1)**

Use of Wien's law **(1)**

Answer $T = 3800$ K [allow 3600 K to 4000 K] **(1)** 3

Calculation

Use $L = \sigma A T^4$ **(1)**

$A = 2.0 \times 10^{28}$ W ÷ (9300 K$^4 \times 5.67 \times 10^{-8}$ W m^{-2} K^{-4}) **(1)**

$= 4.7 \times 10^{19}$ m^2 **(1)** 3

Estimate

Attempt at areas giving ~ 7 × [(×5 – ×8) allowed] **(1)**

$= 1.4 \times 10^{29}$ W [$(1.0 - 1.6) \times 10^{29}$ W allowed] **(1)** 2

(c) What is mean by MS star

One burning/fusing (H as fuel) **(1)** 1

Outline

Quality of written communication **(1)** 1

- fuses He/other elements AND becomes red giant **(1)**

[OR ≤0.4 $M_\odot$ not red giant/becomes white dwarf]

- ceases fusion AND becomes white dwarf **(1)**
- white dwarf fades to cold lump/becomes (specified colour) dwarf/no longer visible **(1)** Max 3

What determines whether ms star becomes a white dwarf

The mass of the star **(1)**

if mass star < 8 $M_\odot$ OR if mass core remnant < 1.4 $M_\odot$ **(1)** 2

(d) Calculation of rate

$\Delta E = c^2 \Delta m$ **(1)**

$$\frac{\Delta m}{t} = \frac{9.96 \times 10^{27}\ \text{W}}{(3 \times 10^{8}\ \text{m s}^{-1})^2}\ \mathbf{(1)}$$

$= 1.1 \times 10^{11}$ **(1)**

kg s^{-1} **(1)** 4

(e) Determine period of pulsation of star A

2.4 to 2.7 days **(1)**

with evidence of averaging **(1)** 2

Addition to graph

B is approximately the same height **(1)**
B has a longer period **(1)**
Shape – more steeply up than down **(1)** 3

Description

Measure period and hence work out luminosity **(1)**

Measure intensity **(1)**

Use $I = L/4\pi D^2$ **(1)** 3

[32]

116. (a) Graph

Use of $\sqrt[3]{A}$ for $A \geq 50$ / use of $(r/r_0)^3$ for $A \geq 50$ **(1)**

Comparison with corresponding value [± 1 mm of r/r_0 or A] **(1)**

Repeat of this comparison, also $A \geq 50$ **(1)** 3

(b) Calculation of density of this nucleus of tin

$\rho = m/\upsilon$ **(1)**

Mass = $119 \times 1.66 \times 10^{-27}$ kg **(1)**

Volume = $4/3\pi \times (6 \times 10^{-15}\ \text{m})^3$ **(1)**

= 2.2×10^{17} kg m^{-3} **(1)** 4

(c) Explanation of binding energy

Energy required to separate a nucleus **(1)**

into nucleons **(1)**

What this tells about an iron nucleus

Iron is the most stable nucleus **(1)** 3

(d) Nuclear equation for decay

$^{14}_{6}\text{C} \rightarrow {}^{14}_{7}\text{N} + {}^{0}_{-1}\beta / {}^{0}_{-1}\text{e} + \overline{\nu}$

Symbols [C → N + β] **(1)**
Numbers [14, 6, 14, 7, 0, –1] **(1)**

Antineutrino / $\overline{\nu} / \overline{\nu}_e$ **(1)** 3

Estimate of age of a fossil

3 half–lives **(1)**

giving 17 000 years to 18 000 years **(1)** 2

(e) Diagram

Weak interaction **(1)**
because neutrino involved OR must be charged particle **(1)** 2

W^- on diagram on or near dotted line **(1)** 1

(f) Particle X

Positive **(1)** 1

Is a baryon **(1)** 1

Quark compositions

Proton uud; neutron udd BOTH **(1)** 1

Explanation and deduction of identity of X

Quality of written communication **(1)**

Strong / not weak interaction **(1)**

One strange quark on each side / no flavour change **(1)**

X is a proton **(1)** 4

(g) Name particles

Hadron: neutron or … **(1)**

Lepton: muon or neutrino or … **(1)** 2

Whether hadrons are fundamental particles

No because more than one quark/made of quarks **(1)**

Quark + antiquark combinations: 3 or 2 **(1)** 2

[OR a discussion of fractional nature of quark charge 1/3 means 3 or 2 to make +1, 0, +2 etc]

Calculation of minimum value of *E*

Use of 1u = 930 MeV **(1)**

Multiply by 98 **(1)**

45 600 (MeV) / 46 000 (MeV) **(1)** 3

[OR by $E = mc^2$ to 45 800 MeV]

[32]

117. (a) Graph

Falling concave curve **(1)**

Not touching either axis **(1)** 2

Calculation of intensity

Use of inverse square law **(1)**

Correct substitution(s) **(1)**

= 0.07 MW m^{-2} **(1)** 3

(b) Table

	α	β	γ		
Useful for imaging			✓	**(1)**	
Useful for therapy	(✓)	✓	✓	**(1)**	
Most damaging to tissue	✓			**(1)**	
Least penetrating	✓			**(1)**	4

Equations

$^{32}_{15}P \rightarrow ^{32}_{16}S + \beta^-$

$^{24}_{11}Na \rightarrow ^{24}_{10}Ne + \beta^+$ **(1)**

32 and 64 **(1)** 3

$\left.\begin{array}{l}16\\10\end{array}\right\}$ [14, 12 scores ½] **(1)**

(c) Patient's blood volume

Quality of written communication **(1)**

- after > ten minutes / allow dilution **(1)**
- remove known quantity of blood from patient **(1)**
- make comparison sample (= quantity mixed with water) **(1)**
- take same volume sample for comparison and compare activities **(1)** 5

(d) Calculation of wavelength

Use of $c = f \times \lambda$ **(1)**

= 2.6 [Ignore power of ten] **(1)**

$\lambda = 0.26$ mm / 2.6×10^{-4} m **(1)** 3

Whether suitable

Yes, because small enough λ for detail/resolution **(1)** 1
[ecf "no" if wavelength calculated > 1 mm]

Reflection coefficient

$(Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ **(1)**

Substitute 1.70 and 1.59 **(1)**
$= 1.12 \times 10^{-3}$ **(1)** 3

Investigation of blood flow in muscle

Almost no reflection between brain and blood/much smaller reflection than muscle and blood **(1)**

Detectable reflection between muscle and blood **(1)** 2

(e) Operating voltage

120 000 V **(1)** 1

What happens to most of the energy of these electrons

Becomes heat energy in target anode **(1)** 1

Two features of anode in an X–ray tube

Any two of: rotates / is cooled / shaped to focus X rays /
made of tungsten / copper heat sink **(1)** **(1)** 2

Use of X–rays

Diagnostic **(1)**

Therapy needs MV / much higher voltage/MeV electrons **(1)** 2

[32]

118. (a) (i) Masses recorded to 0.1 g or better with unit seen at least once **(1)** and $m \approx 5$ g

Total ≥ 190 cm^3 with unit and ≤ 200 cm^3 **(1)**
Correct calculation of density to 3/4 significant figures + unit **(1)** 3

(ii) Use of ≥ 90 cm^3 from correct volume measured using measuring cylinder **(1)**

Mass difference clear [balance can be tared] **(1)**

Correct substitution and calculation leading to density **(1)**

Correct density (ii) < correct density (i) **(1)**

Density difference between 1% and 2% with (ii) < (i) **(1)** 5

(iii) Sensible ΔV **(1)**
[0.5 ml or 2.0 ml per fill]

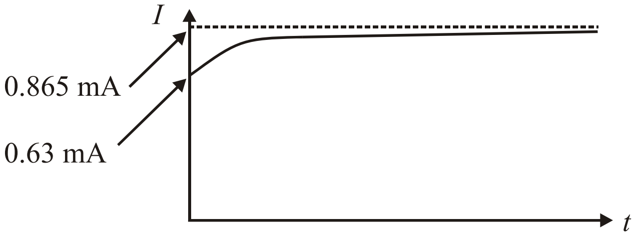
Correct calculation of percentage [allow e.c.f.] **(1)**
Correct calculation with average as denominator **(1)**

Sensible comment related to their uncertainty **(1)** 4

(b) (i) Circuit set up correctly without help 2

(ii) $V \approx 3$ V measured to 0.1 V or better + unit **(1)**
$I \approx 0.6$ mA measured to 0.01 mA or better + unit **(1)**
Correct calculation ≥ 2 significant figures + unit
Allow e.c.f. from wrong I, or V **(1)** 3

(iii) $V_f \approx V$ to 0.1 V or better + unit
Change in I to 0.01 mA or better + unit [e.c.f. wrong unit] **(1)**
Correct calculation ≥ 2 significant figures + unit [e.c.f. wrong unit] **(1)**
Both R sensible and 2/3 significant figures **(1)**



Rise or fall depending on results **(1)**
Correct curve of I against t **(1)**
Reaching a steady value **(1)**
Non–zero intercept **(1)** 7
[I against V mark on scheme then –2 for error of physics]

[24]

Sample results

(a) (i) $m_b =$ 97.1 g
$m_t = 102.9$ g
$m = 102.9 - 97.1 = 5.8$ g

First volume transferred to beaker = 99 cm^3
Second volume transferred to beaker = 99 cm^3
Total volume transferred to beaker = 99 + 99 = 198 cm^3

Total mass = 198 + 5.8 = 203.8 g
Total volume = 198 cm^3

$$\text{Therefore density} = \frac{203.8}{198}$$

$$= 1.029 \text{ g cm}^{-3}$$

(ii) Mass of measuring cylinder + 100 cm^3 of solution = 229.4 g
Mass of measuring cylinder = 128.1 g

Mass of solution = 101.3 g
Density = mass / volume = 101.3 / 100
= 1.013 g cm^{-3}

–

(iii) $\Delta V = 0.5\ \text{cm}^3$

Percentage uncertainty = $\frac{0.5}{100} \times 100\ \%$
= 0.5 %

Percentage difference = $\frac{1.029 - 1.013}{1/2(1.029 + 1.013)} \times 100\ \%$
= 1.6 %

Greater than experimental uncertainty which suggests that there is a change in volume when the salt dissolves.

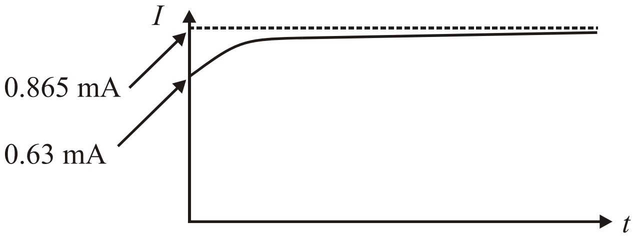
(b) (i) Circuit set up correctly without help

(ii) $V = 3.08$ V
$I = 0.63$ mA

$$R = V / I = \frac{3.08}{0.63 \times 10^{-3}}$$
= 4890 Ω

(iii) $V_\text{f} = 3.08$ V
$I_\text{f} = 0.865$ mA

$$R_\text{f} = \frac{3.08}{0.865 \times 10^{-3}}$$
= 3560 Ω

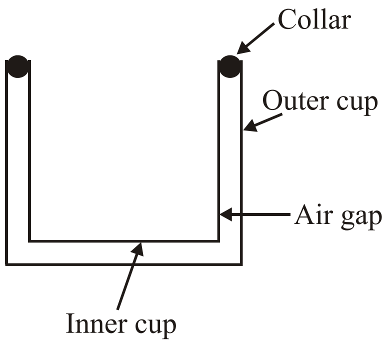


119. (a) (i) Table with units **(1)**
Temperature to better than 1 °C **(1)**
Readings every 0.5 minutes or less up to 5 minutes **(1)**
Cooling curve established **(1)**
8 points ± 0.5 °C from your best curve **(1)** 5

(ii) Data must occupy more than ½ page in both directions
Scale [Allow scale of 1 cm ≡ 30 s] **(1)**
Axes labelled + unit **(1)**
Plots **(1)**
Line **(1)** 4

(iii) $\Delta x \Delta y \geq 64$ cm^2 or as large as possible **(1)**
Correct calculation ≥ 2 significant figures **(1)**
[Tangent at the correct point and sides read correctly]
[Ignore sign and unit]
Correct calculation [allow J/min] [allow e.c.f. from gradient] **(1)**
2/3 significant figures + unit from calculation **(1)** 4

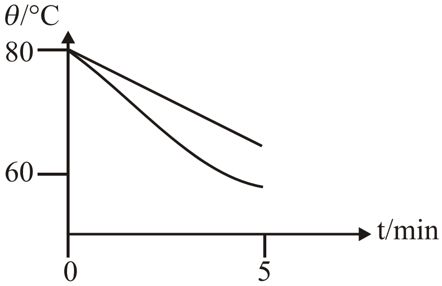
(b) (i)



Correct arrangement with collar **(1)**
Collar and air gap labelled **(1)** 2

(ii) Same volume of water **(1)**
Same place on bench **(1)**
Same starting temperature **(1)**
Stir water **(1)**
Extend the time range/same temperature range **(1)**
Compare temperature falls after 5 minutes/compare times to reach same temperature **(1)** Max 3

(iii) Correctly labelled and double cup curve above single cup curve **(1)**
Concave curves **(1)**
Single curve always steeper than double curve **(1)** 3



(iv) Take gradient of the curves at <u>the same temperature</u> **(1) (1)**
[OR Time for same temperature fall measured / temperature fall for the same time measured **(1)**]
EITHER
Gradient of the double cup should be half (or less) than the single cup **(1)**
OR For same starting temperature [stated or seen] the time for a given $\Delta\theta$ will be twice as big for the double cup **(1)** 3

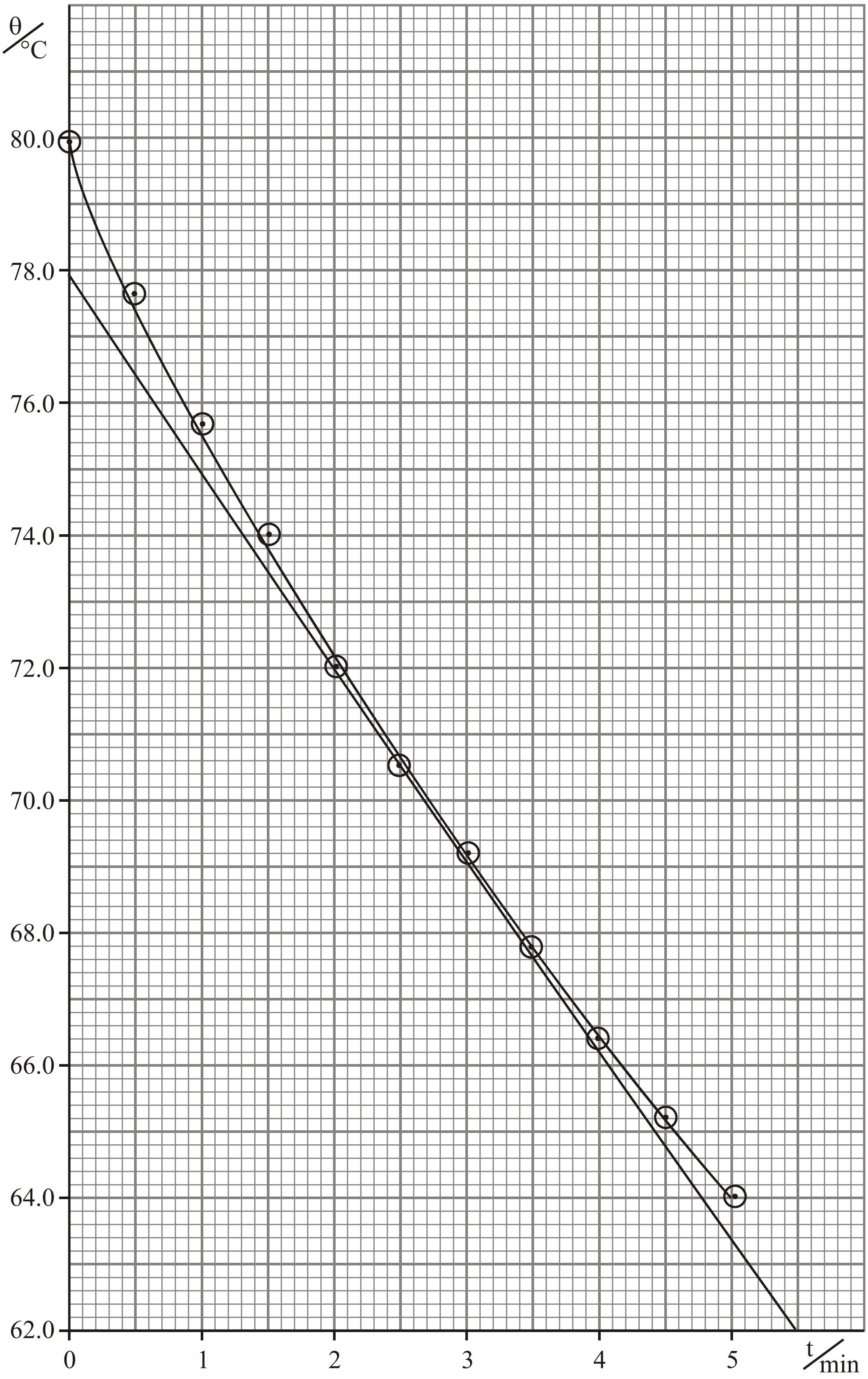
[24]

Sample results

(a) (i)

θ/°C	t/min
80.0	0.0
77.7	0.5
75.7	1.0
74.0	1.5
72.0	2.0
70.5	2.5
69.3	3.0
67.8	3.5
66.5	4.0
65.2	4.5
64.0	5.0

(ii) Graph



(iii) $\dfrac{\Delta\theta}{\Delta t} = \dfrac{62.0 - 77.9}{5.48 - 0}$

$= -2.90°\text{C min}^{-1}$

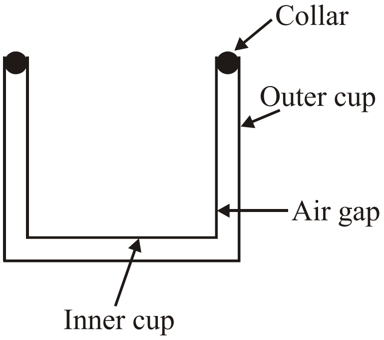
$$\frac{\Delta Q}{\Delta t} = mC\frac{\Delta\theta}{\Delta t}$$

$= 100 \times 4.2 \times 2.9$

$= 1220 \text{ J min}^{-1}$

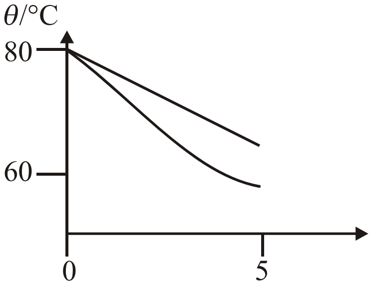
$= 20.3 \text{ W}$

(b) (i)



(ii) Same volume of water
Same place on bench
Same starting temperature
Stir water
Extend the time range/same temperature range
Compare temperature falls after 5 minutes/compare times to reach same temperature

(iii)



(iv) Take gradient of the curves at <u>the same temperature</u>
[OR Time for same temperature fall measured / temperature fall for the same time measured]
EITHER
Gradient of the double cup should be half (or less) than the single cup
OR For same starting temperature [stated or seen] the time for a given Δθ will be twice as big for the double cup

120. (a) Base units of intensity

(i) $W = \text{J s}^{-1}$ / N m s^{-1} or $P = E / t$ or $P = F v$ **(1)**

$\text{J} = \text{kg m}^2 \text{ s}^{-2}$ or $\text{kg m s}^{-2} \text{ m}$ **(1)**

Algebra to kg s^{-3} shown (e.g. $\text{kg m}^2 \text{ s}^{-2} \text{ s}^{-1} \text{ m}^{-2}$) **(1)** 3

Luminosity calculation

(ii) Correct substitution **(1)**
3.82 or 3.8 [ignore 10^n] **(1)**
hence 3.8(2) × 10^{26} W [ue] [allow 3.9 or 4] **(1)** 3

(b) CCD advantages

(i) Any three from:

- Higher (quantum) efficiency / more sensitive
- Detect fainter or more distant stars
- More linear response
- Digital / link to computer / remote imaging
- No processing time / use repeatedly / real–time imaging
- Quicker image collection (i.e. quicker & reason) **(1) (1) (1)**
- Greater range of wavelengths

(ii) CCD disadvantage

Resolution / pixel size larger **(1)** Max 4

(c) Satellite advantages

Quality of written communication **(1)**

No atmosphere (for radiation to pass through / above atmosphere) **(1)**

Idea of no absorption (of i.r.) **(1)** 3

(d) Forces within star

(i) 1. Fusion forces [allow 'pressure from nuclear reactions' or **(1)**
'hydrogen burning'] or radiation / photon pressure

2. Gravitational / Weight (not just gravity) **(1)**

(ii) Equal **(1)** 3

(iii) White dwarf & red giant differences

Any three from:

- Temperature: T_{wd} (6000K – 30000K) > T_{rg} (2000K – 5000K)
- Volume: $V_{rg} > V_{wd}$ – allow A / d / r / bigger
- Mass: e.g. $M_{wd} < 1.4\ M_{\odot}$ AND ($0.4M_{\odot}$ <) $M_{rg} < 8m_{\odot}$
- Fusion (of He / heavier elements) in rg / no fusion in wd
- Luminosity: L_{rg} [$10^2 - 10^6$] > L_{wd} [$10^{-2} - 10^{-4}$] in terms of $L_{\odot}$
- Wd is (core) remnant of rg / rg before wd stage
- Density: $\rho_{wd} > \rho_{rg}$ **(1) (1) (1)** Max 3

[no numerical values for any property – max 2/3]

(iv) Neutron star

Core remnants' mass **(1)**

Must be > 1.4 $M_{\odot}$ or < 2.5 $M_{\odot}$ **(1)** 2

(e) When Sun was formed

(i) Attempted use of $L_{\odot} = 1.4\ L$ **(1)**
2.8 × 10^{26} W **(1)**

(ii) 1.06^2 used **(1)**
5.5 × 10^{18} m^2 / 5.5 × 10^{12} km^2 **(1)** 4

Show temperature change

(iii) $L = \sigma T^4 A$ (or implied) **(1)**

Correct substitution [ecf] **(1)**

Hence 5500 (K) [no ecf] **(1)**

Hence 5800 − 5500 [or 330, 308, 310] **(1)** 4

Wien's law

(iv) Use of $\lambda_{(\max)}T = 2.90 \times 10^{-3}$ m K **(1)**
530 nm or 500 nm [no ue] **(1)**
$\Delta\lambda$ = 30 nm (when rounded to 1 s.f.) **(1)** 3

[32]

121. (a) Base units of energy density

(i) J m^{-3} or N m^{-2} **(1)**

J = kg m^2 s^{-2} or N = kg m s^{-2} **(1)**

Algebra to kg m^{-1} s^{-2} shown (i.e. kg m^2 s^{-2} m^{-3} or kg m s^{-2} m^{-2}) **(1)** 3

(ii) Energy density calculation

200×10^6 used **(1)**

Energy density = ½ $\sigma\,\varepsilon$ (or implied) **(1)**

Correct substitution to 95 000 [no ue] **(1)** 3

(b) Rubber band graph

(i) Clear labels (or arrows up & down) **(1)** 1

(ii) Hysteresis **(1)** 1

Maximum stress

(iii) Use of F/A with 12 (N) **(1)**

2×10^6 Pa / N m^{-2} [ue, no ecf] **(1)** 2

(iv) Internal energy gain

Any attempt at area / 0.5 $F\,x$ **(1)**

Correct values approximated [ignore 10^n] [allow counting squares] **(1)** [ecf]

(½ ×) 12 N × 500 × 10^{-3} or counted squares conversion to energy **(1)**
(1cm^2 : 0.2 J)
3 J [when rounded to 1sf, ue, no ecf] **(1)** 4

(v) Hence show loop area

Attempt at loop area / attempt at area under unloading line **(1)**

Hence working to show 1 J **(1)** 2

Mechanism

(vi) Creep **(1)** 1
Hooke's law

(vii) (Loading) force is proportional to extension
OR may be $F = k\Delta x$ with symbols defined] **(1)** 1
Force–extension apparatus

(viii) Valid diagram **(1)**
Clamp and rubber band, both labelled **(1)**
Ruler and masses/weights, both labelled **(1)**
Accuracy technique (eye-level, clamp ruler, use set-square) **(1)** 4

(c) (i) Glass properties

Brittle **(1)**

Stiff **(1)** 2

[–1 per error if more than two properties circled]

(ii) Extension calculation

Any three from:

- S.I. conversion of d and l
- $\sigma = F / A$ and $\varepsilon = \Delta l / l$ [or $E = F\, l / A\, \Delta l$ (may be implied)]
- Any use of $E = \sigma / \varepsilon$ [or use of $E = F\, l / A\, \Delta l$, allow incorrect A]
- Correct use of πr^2 / $¼\pi d^2$ (no 10^n penalty) **(1) (1) (1)**

3.0×10^{-4} m **(1)** 4

(d) Cross-linked polymers

Quality of written communication **(1)**

Diagram showing cross-links **(1)**

Polythene / Polymer chains / long molecules **(1)**
[may be as a label in diagram]

Describe bonds between chains **(1)** 4

[32]

122. (a) Base units of eV

(i) Reference to joule **(1)**

Useful energy equation / units shown [e.g. $½mv^2$, mgh, mc^2, Fd, *not QV or Pt*] **(1)**

Algebra to J = kg m^2 s^{-2} shown (e.g. kg (m s^{-1})^2 or kg m s^{-2} m) **(1)** 3

(ii) Energy released

146 shown or used **(1)**
Δm calculation [1.9415, ecf] **(1)**
Multiply by 930 [allow $E = mc^2$ with mass in kg] **(1)**
1800 MeV [no ue] **(1)** 4

(b) Nuclear forces

Strong (nuclear) **(1)**

Electromagnetic (not electrostatic) **(1)**

Nucleons or neutrons and protons for strong AND protons for elcetromagnetic **(1)**

Within nucleus, infinite/beyond nucleus [allow inverse square law] **(1)** 4

(c) (i) N–Z plot

α – top right [above and to right of N=100 intersect with plot] **(1)**

β^- – above plots AND β^+ – below plots **(1)**

Both β regions near [< 5 mm] stability line [ecf if β swapped] **(1)** 3

(ii) Central region

Quality of written communication **(1)**

Region of stability / nuclei do not decay in stable region **(1)**
Nuclei decay to / move to this region **(1)** 3

(d) (i) Decay numbers

${}^{1}_{1}p$ and ${}^{1}_{0}n$ **(1)**

${}^{0}_{1}\beta^+$ and ${}^{0}_{0}\nu$ **(1)** 2

(ii) Tick the boxes

Proton: baryon and hadron only **(1)**

neutron: baryon and hadron only **(1)**

β^+: lepton and antimatter only **(1)**

ν: lepton only **(1)** 4

[only penalise once for including meson] [if both baryon correct but no hadrons 1 mark out of 2 and vice versa]

(e) (i) Conservation laws

B: 1 = 1 + 0 **(1)**
Q: 1 = 1 + 0 **(1)** 2

Diagram

(ii) First u and W^- **(1)**
d and ū **(1)** 2

(iii) proton / H^+ / hydrogen nucleus / Δ^+ [mark is dependent on seeing uud on X in diagram] **(1)** 1

W^- particle

(iv) Exchange particle **(1)** 1

(v) Change in quark flavour / strangeness not conserved **(1)**
Charge conservation requires negative particle **(1)** 2

(vi) Σ^+ decay

3. due to charge conservation **(1)** 1

[32]

123. (a) Base units of intensity

(i) W = J s^{-1} / N m s^{-1} or $P = E / t$ or $P = F v$ **(1)**
J = kg m^2 s^{-2} or kg m s^{-2} m **(1)**
Algebra to kg s^{-3} shown (e.g. kg m^2 s^{-2} s^{-1} m^{-2}) **(1)** 3
Inverse square law

(ii) (Use of) Id^2 = constant **(1)**
Substitution correct **(1)**
1.1 m (1.07 m) 3
OR
calculate P [11.5] **(1)**
2nd substitution correct **(1)**
1.1 m (1.07 m) **(1)**

(b) Electron energy and speed

(i) Use of $W = QV$ and 1.60×10^{-19} C **(1)**
1.04×10^{-14} [no ue] **(1)** 2

(ii) Use of $\frac{1}{2}mv^2$ **(1)**
Correct substitution with 9.11×10^{-31} kg **(1)**
1.51×10^8 m s^{-1} [or 1.48 or 1.5] **(1)** 3

(iii) Electron energy

Heat / Internal energy **(1)**
X-rays **(1)** 2

(iv) Target features

Rotates / Made of tungsten /
Copper heat sink / oil–cooled **(1) (1)** 2

(c) Ultrasound image

(i) B-scan **(1)** 1

(ii) Quality of written communication **(1)**

Any four from:

- (B =) brightness
- Transducer and gel/oil/coupling medium
- Pulse goes in and comes out
- (Transducer) rocked / array
- Image: brighter areas (white areas) = (more) reflections

(1) (1) (1) (1) 5

(d) (i) Radioactive tracer terms

(Average) time for activity to half / half the radioactive atoms to disintegrate/decay **(1)**
Time for biological processes / excretion to remove half of the **(1)**
tracer from body [*not* organ]
Time for activity to half due to (combination of) other two half **(1)** 3
lives / within patient [organ acceptable] OR equation and definition in words

(ii) Biological half life calculation

$1/t_e = 1/t_r + 1/t_b$ [seen or implied] **(1)**
Correct substitution **(1)**
22 (21.8) days (2×10^6 s) **(1)** 3

(iii) Decay curves

Two curves – start together on *y*–axis, do not cut *x*–axis [≥ 50 days needed] **(1)**
Decay curve P below decay curve L **(1)**
Half–lives of ~ 16 and 60 days attempted (not 22 days) **(1)** 3

(iv) Radiation type for tracer

(γ) to penetrate skin / be detected outside body / by gamma camera **(1)**
to minimise dose / damage / least ionisation to patient / cells / **(1)** 2
tissue

[32]

124. (a) (i) Approximately 1.5 V measured to 0.01 V or better + unit **(1)** 1

(ii) Circuit set up correctly without help 2

(iii) ≈ 0.8 V to 0.01 V or better + unit **(1)**
7.0 mA → 12.0 mA to 0.1 mA or better + unit **(1)**
Correct calculation to 2 to 4 significant figures + unit **(1)** 3
[allow ecf]

[Apply unit penalty once only for each quantity (*I*, *V* and *R*)
in part (a)]
[*R* values to 2 to 4 significant figures else –1 once only]

(iv) Value + unit **(1)**
Correct percentage difference with expected value as denominator **(1)** 2

(v) Sensible values ($V_2 < V_1$, $I_2 > I_1$) with *V* to 0.01 V or better **(1)**
and *I* to 0.1 mA or better + units
Correct calculation to 2 to 4 significant figures + unit **(1)**
[allow ecf from wrong *I* and *V* or R_1]
Value + unit **(1)** 3

(vi) Any 3 of:
Resistor values will have a tolerance;
Potential difference across connecting wires / wires in the circuit will have resistance;
Ammeter will have resistance / potential difference across ammeter;
Cell has / potential difference across internal resistance of cell;
Error in meters including not accurate;
Voltmeter has finite resistance / current in voltmeter **(1) (1) (1)** Max 3
[Do not accept resistors heating up]

(b) (i) $d_i = \pm 0.03$ cm from Supervisor's value from repeat measurements **(1) (1)**
[± 0.05 cm from repeats **(1)** or ± 0.03 cm from single reading **(1)**]

$d_e = \pm 0.03$ cm from Supervisor's value from repeat measurements **(1) (1)**

[± 0.05 cm from repeats **(1)** or ± 0.03 cm from single reading **(1)**]

Checked in perpendicular directions **(1)**) Max
[Allow different directions]) 1 5
Zero error check here or in (ii) **(1)**)

[Allow centre average value if no Supervisor's data]

(ii) ± 0.03 mm from Supervisor's value from repeat measurements **(1) (1)**
[± 0.05 mm from repeats **(1)** or ± 0.03 mm from single reading **(1)**] 2

(iii) Correct calculation ≥ 2 significant figures + unit **(1)**
Correct substitution into mass / volume, **(1)**
Value ≥ 2 significant figures + unit and in range
$6.0 \rightarrow 10.0$ g cm^{-3} or ± 2.0 g cm^{-3} of Supervisor's density **(1)** 3

[24]

Sample results

(a) (i) $E = 1.52$ V

(iii) $V_1 = 0.76$ V
$I_1 = 10.62$ mA
$R_1 = 0.76 / 10.62 \times 10^{-3}$
$= 71.6\ \Omega$

(iv) Expected value = 68 Ω
$(71.6 - 68 / 68) \times 100\%$
$= 5.3\%$

(v) $V_2 = 0.38$ V
$I_2 = 15.93$ mA
$R_2 = 0.38 / 15.93 \times 10^{-3}$
$= 23.9\ \Omega$
Expected value
$= 1/3 \times 68 = 22.7\ \Omega$

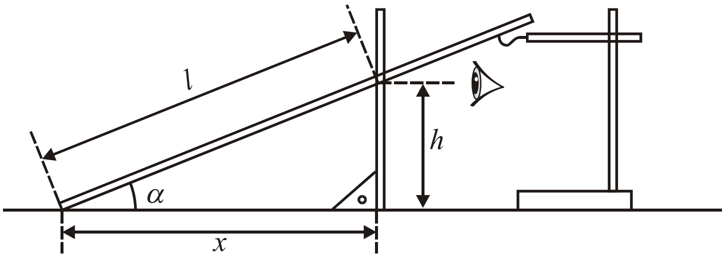
(b) (i) d_i = 1.66 cm, 1.66 cm
average d_i = 1.66 cm
d_e = 3.47 cm, 3.47 cm
average d_e = 3.47 cm

(ii) Thickness 1.81 mm, 1.79 mm, 1.85 mm
average t = 1.81 mm

(iii) $V = ¼\pi (3.47^2 - 1.66^2) \times 0.181$
$= 1.32 \text{ cm}^3$
$m = 10.32$ g
Density = 10.32 / 1.32
$= 7.8 \text{ g cm}^{-3}$

125. (a) Box suspended [allow box on rule] and 10 g used [on diagram or in calculation] **(1)**
Lengths to centres of mass **(1)**
b found (490 mm to 510 mm) (245 mm to 255 mm for ½ metre rule) **(1)**
$x \geq 400$ mm (≥ 200 mm for ½ metre rule) **(1)**
Repeat **(1)**
Correct moments used to give **(1)**
m_0 + unit **(1)** 7

(b)



h shown accurately from bench to bottom of ramp **(1)**

l or x shown accurately **(1)**

Set square shown **(1)**

h and l (or x) recorded to mm or better **(1)**

Repeat / eye level with reading **(1)**

Correct calculation of μ and μ in range 0.20 → 0.50 and $\geq$ 2 significant figures + no unit **(1)**

Correct calculation **(1)** 7

(c) Values of m_s found with unit **(1)**
Repeat or attempt at interpolation**(1)**
Correct calculation of μ and μ in range 0.20 → 0.50 and $\geq$ 2 significant figures + no unit [allow ecf] **(1)** 3

(d) Sensible Δm_s (2 g → 10 g) **(1)**
Correct calculation of percentage **(1)** 2

(e) (i) Change M (by adding a further 10 g mass to the box) **(1)**
Find (corresponding) m_s (for box to slide) **(1)**

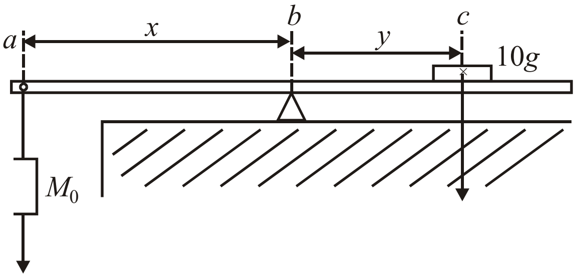
(ii) Plot m_s against M **(1)**
Or
F against R
Calculate F from $F = m_sg$ and calculate R from $R = Mg$ and **(1)**
plot F against R
Straight line through origin stated or shown **(1)**

(iii) Gradient = μ **(1)** 5

[24]

Sample results

(a)



a = 8 mm

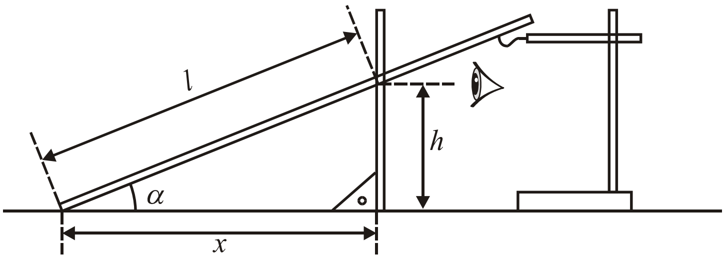
b = 498 mm

c = 610 mm

$$m_0 = 10 \times \frac{(610 - 498)}{498 - 8}$$

= 2.3 g

(b)



h = 169 mm, 155 mm average h = 162 mm

l = 458 mm, 458 mm

sin α = 162 / 458

= 0.354

∴ tan α = 0.38

$$\text{Percentage uncertainty} = \frac{0.02}{0.38} \times 100 = 5.3\ \%$$

(c) $m_s = 20$ g – no movement

$m_s = 30$ g – slides easily

$\therefore m_s = 25$ g

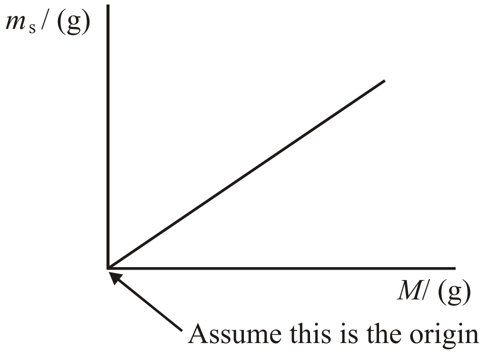
$$\mu = \frac{25}{(60 + 2.3)}$$

$= 0.40$

(d) Percentage uncertainty $= \frac{5}{25} \times 100 = 20$ %

(e) (i) <u>Change M</u> (by adding a further 10 g mass to the box)
<u>Find</u> (corresponding) <u>m_s</u> (for box to slide)

(ii)



(iii) Gradient = μ

126. (a) (i) Circuit set up correctly without help **(1) (1)** 2

(ii) ≈ 1.8 V to 0.01 V or better + unit **(1)**
Sensible values to 0.1 mA or better + unit **(1)**
Correct calculation to 2 to 4 significant figures + unit **(1)** 3
[allow ecf]

(iii) V_g › V_r and ≈ 2 V to 0.01 V or better + unit **(1)**
I_g ‹ I_r and sensible value to 0.1 mA or better + unit **(1)**
Correct calculation to 2 to 4 significant figures + unit and
R_g › R_r **(1)** 3
[Apply V unit penalty, I unit penalty, R unit penalty and
significant figure penalty once only in part(a)]

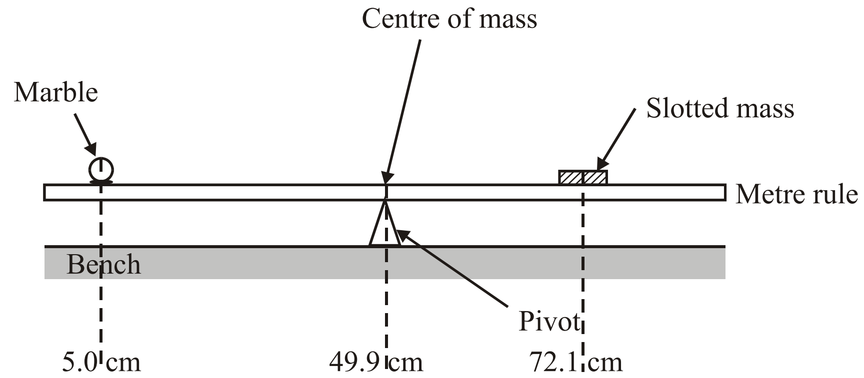
(iv) V_{r}' › V_{r} and ≈ 2 V to 0.01 V + unit **(1)**
$I_{\mathrm{r}}' \approx 2I_{\mathrm{r}}$ and to 0.1 mA + unit **(1)**
V_{g}' › V_{g} and ≈ 2 V to 0.01 V + unit **(1)**
I_{g}' ‹ $\mathrm{I_r}'$ and ≈ 2 I_{g} to 0.1 mA or better + unit **(1)**
Correct trend in R values
R_{r}' ‹ R_{r}, R_{g}' ‹ R_{g} and R_{r}' ‹R_{g} **(1)** 5

(v) Any 3 of:

Resistance of LED changes;
It decreases as current in it increases (or vice versa);
Resistance of a green LED is greater than resistance of a red LED ;
– at a given current ;
As current doubles: resistance <u>of LED</u> approximately halves / voltage across LED remains ≈ constant;
Brightness of LED increases as current through it / voltage across it increases **(1) (1) (1)** Max 3

(b) (i) ± 0.03 cm of Supervisor's value to 0.1 mm from <u>repeat</u> **(1) (1)**
measurements + unit
[± 0.05 cm from Supervisor's value **(1)**]
At least two perpendicular directions <u>or</u> zero error check **(1)** 3

(ii) All measurements to nearest mm or better (allow 5 cm) **(1)**



(iii) Centres of mass clearly shown on diagram **(1)**
Scale readings shown **(1)**
Correct calculation giving m ± 0.3 g of Supervisor's value **(1) (1)**
[± 0.05 g from Supervisor's value **(1)**]
[No ecf, –1 if no unit] 5

[24]

Sample results

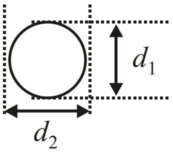
(a) (i) Circuit set up correctly without help

(ii) $V_r = 1.87$ V
$I_r = 8.48$ mA
$R_r = 1.87 / 8.48 \times 10^{-3}$
$= 221\ \Omega$

(iii) $V_g = 1.96$ V
$I_g = 8.28$ mA
$R_g = 1.96 / 8.28 \times 10^{-3}$
$= 237\ \Omega$

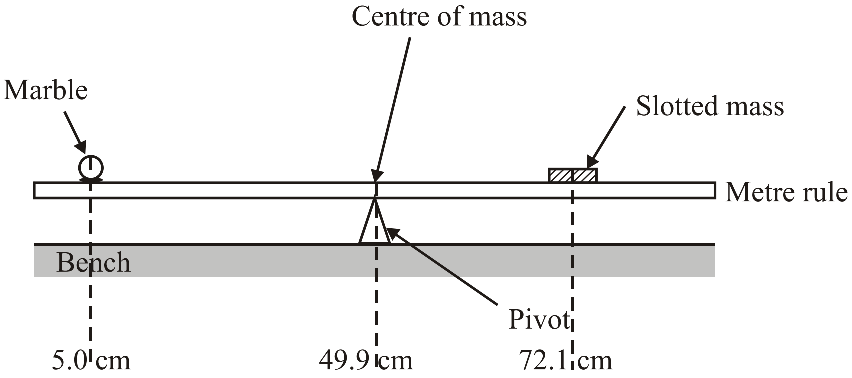
(iv) $V_r' = 2.00$ V
$I_r' = 17.0$ mA
$R_r' = 2.0 / 17 \times 10^{-3}$
$= 118\ \Omega$
$V_g' = 2.06$ V
$I_g' = 16.77$ mA
$R_g' = 2.06 / 16.77 \times 10^{-3}$
$= 123\ \Omega$

(b) (i) $d = 1.55$ cm, 1.54 cm, 1.545 cm
average $d = 1.545$ cm
Measured in at least 2 perpendicular directions



(ii) Scale reading at centre of mass = 49.9 cm

(iii)



$10\ (72.1 - 49.9) = x\ (49.9 - 5.0)$
$x = 10 \times 22.2 / 44.9$
$= 4.94$ g

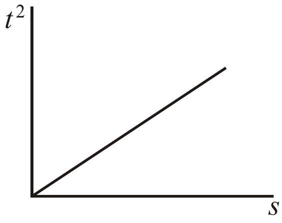
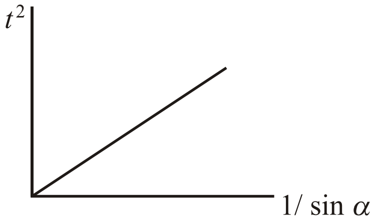
127. (a) Correct use of set squares **(1) (1)**
d to mm and in range 36 → 40 mm from at least 2 values + **(1)**
unit
Correct calculation
2 / 3 significant figures + unit **(1)** 5

(b) 1.00 m shown from same point on ball (or lower stop) **(1)**
Use of rules as runway or use of set squares or eye level **(1)**
Two h (values) shown to top surface on diagram correctly **(1)**
$t = 2.5 - 3.5$ s from ≥ 3 values **(1) (1)**
[≥ 2 values **(1)**][–1 mark if no unit]
43 mm → 47 mm **(1)**
Correct value **(1)** 7

(c) For v correct calculation ≥ 2 significant figures + unit **(1)**
For E_k correct calculation ≥ 2 significant figures + unit **(1)**
Correct calculation ≥ 2 significant figures + unit and $E_p > E_k$ **(1)** 3
[allow ecf if m in g in both energies]

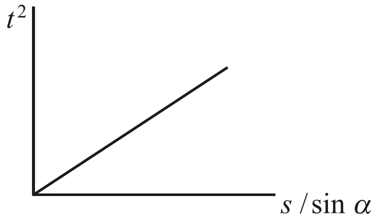
(d) Correct calculation ≥ 2 significant figures + unit **(1)**
[allow ecf on sin α only]
Correct calculation of percentage difference **(1)**
[accept either t or average as denominator]
Sensible comment **(1)** 3

(e)

Either	Or
- keep α constant	- keep s constant **(1)**
- vary s	- vary α **(1)**
- find t	- find t **(1)**
	
- plot t^2 against s	- plot t^2 against 1/sin α **(1)**
- expect straight line through origin	- expect straight line **(1)** through origin
- gradient = 10 / 3g sin α	- gradient = $10s / 3g$ **(1)**

<u>Or</u>

- vary s and vary α **(1)**
- calculate s / sin α **(1)**
- find t **(1)**

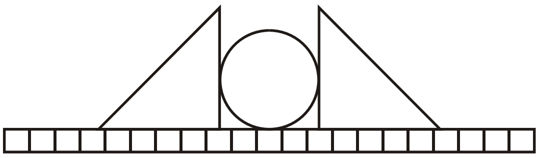


- plot t^2 against s / sin α **(1)**
- expect straight line through origin **(1)**
- gradient = 10 / 3g **(1)** 6

[24]

Sample results

(a)



$d = 338 - 300 = 38$ mm

$d = 438 - 400 = 38$ mm

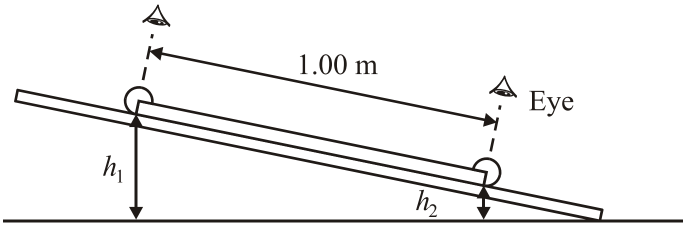
average $d = 38$ mm

$I = md^2 / 6$

$= 2.37 \times (3.8)^2 / 6$

$= 5.7$ g cm^2

(b)



$t = 2.74, 2.79, 2.80, 2.84$ s
average $t = 2.79$ s
$h = 69–24$ mm
$= 45$ mm
sin $\alpha = 45 /1000$
$= 0.045$

(c) $v = 2 \times 1.00 / 2.79$

$= 0.72 \text{ m s}^{-1}$

$E_k = ½ \times 2.37 \times 10^{-3} \times (0.72)^2$

$= 6.1 \times 10^{-4} \text{ J}$

$E_p = mgh = 2.37 \times 10^{-3} \times 9.81 \times 45 \times 10^{-3}$

$= 1.05 \times 10^{-3}$

(d) $t^2 = \dfrac{10 \times 10}{3 \times 9.81 \times 0.045}$

$= 7.55$

$t = 2.75$ s

Percentage difference = $\dfrac{(2.79 - 2.75)}{2.75} \times 100$

$= 1.5\ \%$

This is acceptable experimental error, confirming the relationship.
(10% or less confirms relationship)

128. (a) Background wavelength

Use of $\lambda_{max} T = 2.90 \times 10^{-3}$ m K **(1)**

Correct substitution **(1)**

1.06 (or 1.1) $\times 10^{-3}$m **(1)** 3

Part of spectrum

Microwave or infra-red **(1) (1)**

(b) Main sequence star definition

(Fusion of) hydrogen (nuclei) / protons to helium (nuclei) **(1)**

stably / in equilibrium / in core **(1)** 2

Hertzsprung-Russell diagram

Diagonal falling line **(1)**

Correct curvature above 20 000 K **and** below 5000 K **(1)** 2

X on line and level with 10^0 (to ± 1 mm) [must be clearly indicated] **(1)** 1

Dwarfs and Giants

(i) bottom left quadrant **(1)** 1

(ii) top right quadrant **(1)** 1
[no region indicated max. **(1) x**]

T consistent with diagram at centre of region **and** $2500 < T/K < 10000$ **(1)** 3

(c) More MS stars

(i) γ Cas **(1)**

(ii) α Cen B **(1)** 2

Diameter of Sirius A

$26 \times 3.9 \times 10^{26}$ **(1)**

1.0×10^{28} W (ue) **(1)** 2

$L = \sigma T^4 A$ (or implied by substitution) **(1)**

$A = 2.46$ (or 2.43 or 2.45) $\times 10^{19}$ (m^2) **(1)** 2

Use of $\pi d^2/4\pi r^2/1.4 \times 10^9$ m **(1)**

2.8×10^9 m[no ecf] **(1)** 2

(d) Supernova processes

Quality of written communication **(1)**

Heavier elements fused / fusion occurs in outer shells (around core) **(1)**

Runs out of fuel to fuse/fusion ceases thus implosion / core collapse **(1)**

Protons + electrons form neutrons OR Shock wave (or explosion) blows **(1)** away outer layers

Neutron star / pulsar / black hole **(1)** 5

(e) Hydrogen fusion

Mass subtraction of 4p – He **(1)**

4.7×10^{-29} (kg) **(1)** 2

$E = mc^2$ seen/implied **(1)**

4.2 (or 4.5) $\times 10^{-12}$ J **(1)** 2

Percentage mass loss

4.7×10^{-29} divided by $4 \times 1.673 \times 10^{-27}$ (allow 5×10^{-29} or 6.645×10^{-27}) **(1)**

7×10^{-3} **(1)**

% conversion: 0.7% / 0.75% (ecf) **(1)** 3

[32]

129. (a) (i) Young modulus

Any reference to gradient or E = stress / strain [or implied] **(1)**

Substitution of correct values for either straight line [to ± 1 mm] **(1)**

$1.25 - 1.45 \times 10^{11}$ and > 3.s.f **(1)** 3

(ii) Energy density

Any area attempted **(1)**

Triangle area: ½ × 300 × 1.5 or 13.5 cm^2 squares [or equivalent area chosen **(1)**]

Rectangle area: 300 × 1.5 or each of 100 (MPa) **(1)**

6.5 – 7.0 and 10^5 (J m^{-3}) **(1)** 4

Strongest material

A **(1)**

Highest UTS / tensile stress **(1)** 2

(b) Crosses and materials

Three crosses at end of straight line regions **(1)**

A = high carbon steel

B = mild steel

C = copper

All correct [1 or 2 correct score **(1) x**] 2

High carbon steel /A [if A = h.c.s.] **(1)** 4

Molecular structure of metals

Quality of written communication **(1)**

Elastic – atomic separation increases and reversible / atoms do not **(1)** change (relative) position

Plastic – bonds between atoms broken / dislocations move / atoms **(1)** change position permanently / relatively

Fracture – plane of bonds break **(1)** 4

Rubber line to scale

(Horizontal) line starting from origin (max 40 MPa at 3.0 × 10^{-3}) **(1) (1)**

(c) Pre-stressed reinforced concrete beam

Steel / iron **and** rod / cable / wire **(1)**

Tension / loaded / stressed **(1)**

Concrete cast / poured over (not cement) **and** allowed to set / solidify **(1)**

Tension forces removed [NOT rods contract] **(1)**

(Leaving) steel in tension **and** concrete in compression **(1)** 5

(d) Elastomer

Materials which can be stretched considerably / to high strain (or >100%) **(1)** 1
AND still return to their original length when stress is removed

Molecular structure of rubber

Tangled chain molecules **(1)**

(Easy to stretch at start) chains are straightened out
(Harder to stretch when) straight chains (or bonds) being stretched **(1)** 3

(e) Castle drawbridge

W= 19 620 N/20 000 N **(1)**

Weight acting at 1.5 m, vertically downwards **(1)** 2

Principle of moments stated or implied [“in equilibrium” not required] **(1)**

Substitution with cos 45° or sin 45° (allow 2T here, ecf) **(1)**

7 kN (no ecf) **(1)** 3

[32]

130. (a) Neutron Capture Equation

$^{238}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{239}_{92}\mathrm{U}$ **(1) (1)**

Beta minus decay

$^{239}_{92}\mathrm{U} \rightarrow ^{239}_{93}\mathrm{Np} + ^{0}_{-1}\beta + \bar{v}$

$\mathrm{U} \rightarrow \mathrm{Np} + \beta^-$ **(1)**

Hence all six numbers correct **(1)**

antineutrino **(1)** 3

(b) (i) Binding energy per nucleon graph

Nucleon number / mass number **(1) (1)**

(ii) Nuclei on graph

H at start of curve (< 3 MeV), Fe at peak of curve (at 56),
U at end of curve (at 235) [to ± 1mm]

any two **(1)**

all three **(1)**

(iii) Fe (ecf) **(1)** 3

(iv) Binding energy of U

7.5/7.6(ecf) **(1)**

× 235 **(1)**

1.8 (GeV) [allow 1.76 – 1.80, no e.c.f] **(1)** 3

(c) Positronium charge and mass

neutral / zero **(1)**

charges of + 1 AND – 1 cancel **(1)** 2

Electron and positron are antimatter versions of each other **(1)** 1

Antimatter interaction

Annihilation **(1)**

γ/ energy /photon **(1)** 2

Possible interactions

Quality of written communication **(1)**

Electromagnetic force affects charged particles – hence yes **(1)**

Weak force affects all particles C hence yes **(1)**

Gravitational force negligible / affects masses hence yes OR strong **(1)** force affects quarks / hadrons only hence no 4

Similarities and differences

Any two from: Made of matter and antimatter / short lifetime / unstable / neutral charge [not made of fundamental particles] 2

Lepton vs. quarks / different mass / meson affected by strong force **(1)** 3

(d) Conservation laws

Baryon **(1)**

– 1 **(1)**

Q: (–1) + (+1) = (0) + (+1) + (X) **(1)**

B: (0) + (+1) = (0) + (0) + (X) **(1)** 4

Quark content

uud **(1)**

$u\bar{s}$ **(1)** 2

Particle X

Quark equation ($s\bar{u} + uud \rightarrow d\bar{s} + u\bar{s} + X$) [allow ecf] **(1)**

Correct cancelling of quark flavours **(1)**

sss [‘sss’ alone scores 3/3] **(1)** 3

[32]

131. (a) Radiation effects on cells

Destruction / kills cells [not just damage] **(1)**

Mutation **(1)** 2

(b) Nuclear equation

Correct symbols: I → Xe + β + γ **(1)**

0 and –1 for β **(1)**

131, 53 **and** 131, 54 correct for I and Xe **(1)** 3

(c) Technetium symbols

metastable / excited state **(1)**

will emit γ / energy / photon **(1)** 2

Time scale

One day per cycle **(1)** 1

Elution graph shape

Quality of written communication **(1)**

(Rise:) Mo decays to generate Tc **(1)**

(Fall:) “milking” of cell / elution process / Tc flushed out / Tc removed from cell **(1)**

Peak height falls as Mo decays **(1)** 4

(d) Nature of ultrasound

High frequency (wave / sound) / frequency above human hearing **(1)**

Above 20 000 Hz [or correct example given] **(1)** 2

Sonar principle

Pulse / short ultrasound wave sent **(1)**

Detect echo / reflection **(1)**

(Information gained from) time delay / signal amplitude **(1)** 3

Specific acoustic impedance of soft tissue

Use of $c = f\lambda$ and $\times 10^6$, 10^{-3} conversion **(1)**

1545/1550 ($\mathrm{m\ s^{-1}}$) **(1)** 2

Correct substitution in $Z = cp$ **(1)**

$1.64 \times 10^6\ \mathrm{kg\ m^{-2}s^{-1}}$ [allow $1.59 \times 10^6\ \mathrm{kg\ m^{-2}\ s^{-1}}$] **(1)** 2

Percentage transmission

Use of α **(1)**

Substitution (should be $(4.9/8.1)^2$, ecf their Z) **(1)**

0.36 / 0.37 [no ecf, beware 60% from incorrect equation] **(1)**

64% / 63% [ecf on reflected value] **(1)** 4

(e) X-ray energy

Diagnosis keV AND therapy MeV **(1)**

Any point from: keV: Preferential absorption / Z dependence for absorption [or MeV absorption not Z dependent] **(1)**

MeV: More penetrating / kill cells **(1)** 3

X-ray image explanation

White = bone **and** grey (allow black or darker areas) = soft tissue **(1)**

White = no X-rays reach film (to darken it) / Grey = some X-rays reach film (to darken some of it) **(1)**

Attenuation / absorption (strongly) dependent on proton number **(1)**

20 > 9 (or implied) means greater attenuation for bone than tissue **(1)** 4

[32]

132. (a) (i) $\bar{t}$ 1.8 to 2.1 mm [when rounded to 2 significant figures] or better with unit to 0.1 mm **(1)**

$n\bar{t}$ 14.4 to 16.8 mm with unit to 0.1 mm or better **(1)**
[unit penalty once only. Ecf unit]

Repeat of both [recorded] **(1)**

Sensible n between 6 and 10 [integer value] from correct calculation **(1)** 4
[ecf wrong values]

(ii) Correct arrangement including centre (of mass of rule) and sensible marked distances **(1)**

Centre of mass found to nearest mm or better in range 490 to 510 mm with unit [can be seen in calculation] **(1)**

x and y (shown) to centre of coins and recorded to the nearest mm **(1)**

Method for x and y e.g. readings at side of coins **(1)**

Correct calculation from correct method giving n 7.5 → 8.4

Hence n = 8 **(1)** 6

(iii) Error in method (i): Variable thickness of coin/coins
Rim at edge
Thickness of overlapping tape **Any one (1)**

Error in method (ii): x is a very short distance
mass of tape **Any one (1)** 2

(b) (i) Circuit set up correctly without help **(2)** 2

ε and V recorded to 0.01 V or better, with $V < \varepsilon$, and correct order of magnitude, with unit seen on at least one value and $V \geq 1.0$ V **(1)**

Correct calculation with unit and 2/3 significant figures [not negative] **(1)** 2

(ii) R0 0.5 → 5.0Ω with unit to a precision of 0.1 Ω without help on range by Supervisor **(2)** 2

[If help given by Supervisor only 1 mark out of 2 for correct R_0]

(iii) Circuit set up correctly without help **(1)**

I to 0.01 A or better with unit and in the range 0.12 A to 0.18 A **(1)**
[No penalty for mA]

Correct calculation [candidate $V \div$ candidate I] with unit and 2/3 significant figures [No penalty for mA] **(1)**

Comparison with R and sensible conclusion **(1)** 4

(iv) Correct calculation of ratio with no unit and > 2 significant figures **(1)**

T read off correctly within ½ square with unit **(1)**

<u>OR</u>

A sensible comment on ratio provided R_0 is in range **(2)** 2

[24]

Sample results

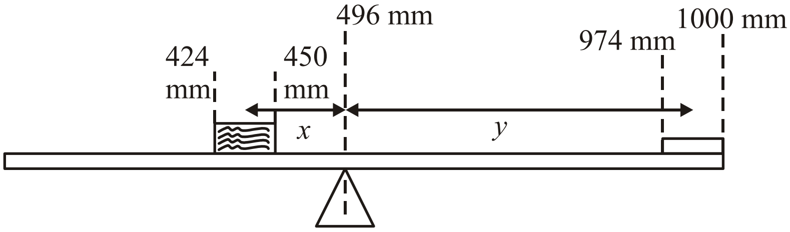
(a) (i) $t = 2.0, 1.9$ mm $\bar{t} = 1.95$ mm

$nt = 15.9, 15.9$ mm $\overline{nt} = 15.9$ mm

$$n = \frac{15.9}{1.95} = 8.15$$

$\therefore\ n = 8$ coins

(ii)



Centre of gravity at 496 mm mark

$x = 496 - 437 = 59$ mm

$y = 987 - 496 = 491$ mm

$$n = \frac{491}{59} = 8.3 = 8$$

(b) (i) Error in method (i): Variable thickness of coin/coins
Rim at edge
Thickness of overlapping tape

Error in method (ii): x is a very short distance mass of tape

(i) Circuit set up correctly without help

(ii) $\varepsilon = 1.48$ V

$V = 1.44$ V

$$r = \left[\frac{1.48}{1.44} - 1\right]10$$

$= 0.28\ \Omega$

$R_0 = 1.1\ \Omega$

(iii) Circuit set up correctly without help

$I = 0.162$ A

$R_T = \dfrac{1.44}{0.162} = 8.89\ \Omega$

It is reasonable to use $V = 1.44$ V because the resistance of the lamp is approximately equal to R in the first circuit

(iv) $\dfrac{R_T}{R_0} = \dfrac{8.89}{1.1} = 8.1$

= 1585 K = 1590 K (to 3 significant figures)

133. (a) (i&ii) Units shown in table or on graph axes **(1)**

Temperatures taken every 0.5 mins or more frequently **(1)**

At least one attempt at better than 1 °C in each run **(1)**

Overall fall in temperature greater for 250 ml beaker **(1)**

6 good points for θ_1 **(1)**

6 good points for θ_2 **(1)**

[Good ± 0.5 °C of examiners curve] 6

(b) Sensible scales [Allow 2 cm = 60 s] **(1)**

Axes and curves labelled **(1)**

Plots [check the plot furthest from each curve] **(1)**

At least one best fit smooth curve **(1)** 4

(c) Good tangent at common temperature with at least 2 points either side of tangent. **(1)**

$\Delta x \Delta y \geq 64\ \text{cm}^2$ or max possible **(1)**

Correct reading of sides of triangle **(1)**

Hence correct calculation to 2/3 significant figures **(1)** 4

(d) (i) Use more than 2 beakers **(1)**

Of different diameter **(1)**

Which are lagged/insulated **(1)**

Use same volume of water in each beaker **(1)**

Measure temperature as a function of time **(1)**

Measure diameter of beakers to find area OR describe suitable **(1)** technique for finding diameter

Same starting temperature **(1)**

(ii) Plot θ against t for each beaker **(1)**

Measure gradient at same temperature for all beakers used

Plot gradient against area OR calculate $\dfrac{\text{gradient}}{\text{area}}$ **(1)**

(iii) Graph should be a straight line through origin OR $\dfrac{\text{gradient}}{\text{area}}$ = constant **(1)**

[Must have more than 2 beakers] 10

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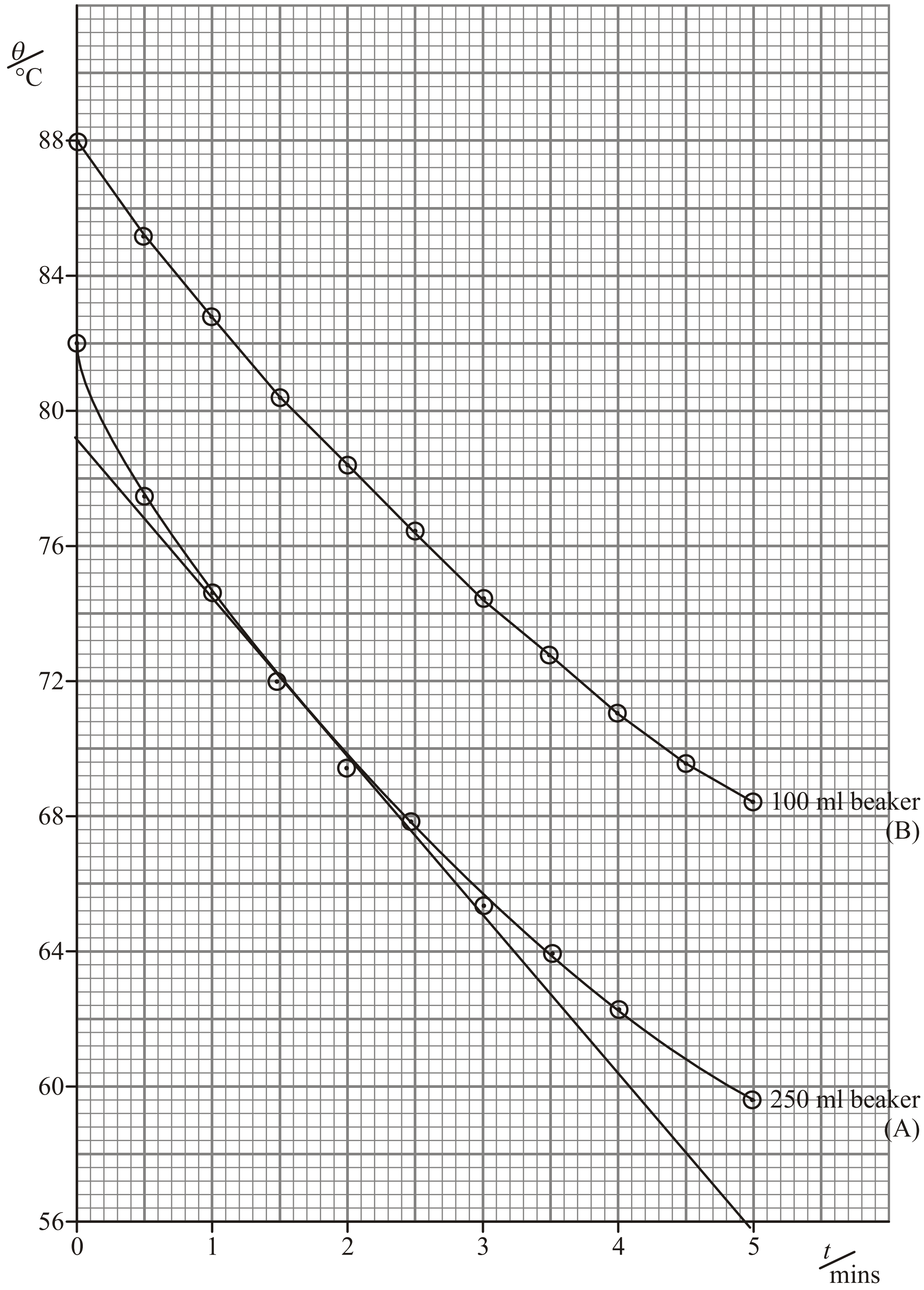
Sample results

(a) (i&ii)

Time t / mins	Temperature θ_1 of the water in the 250 ml beaker / °C	Temperature θ_2 of the water in the 100 ml beaker/°C
0.0	82.0	88.0
0.5	77.0	85.0
1.0	74.5	82.5
1.5	72.0	80.5
2.0	69.5	78.5
2.5	67.8	76.5
3.0	65.5	74.5
3.5	64.0	73.0
4.0	62.5	71.0
4.5	60.8	69.5
5.0	59.5	68.5

Note: When the experiment was being trialled the 100 ml beaker was used first.

(b)



(c) 72 °C chosen because at least 3 points either side of this on both curves

Gradient = $\frac{79.1 - 56}{4.95}$ = 4.67 °C/min

(d) (i) Use <u>more than 2</u> beakers

Of different <u>diameter</u>

Which are lagged/insulated

Use same volume of water in each beaker

Measure temperature as a function of time

Measure diameter of beakers to find area

Same starting temperature

(ii) Plot θ against t for each beaker

Measure gradient at same temperatures for all beakers used

Plot gradient against area / calculate $\frac{\text{gradient}}{\text{area}}$

(iii) Graph should be a straight line through origin / $\frac{\text{gradient}}{\text{area}}$ area constant [Must have more than 2 beakers]

134. (a) <u>H–R Diagram</u>

(i) L and T ***(1)***
$L_\odot$ and K **(1)** 2

or L and $L_\odot$ ***(1)***, T and K **(1)**, not W]

(ii) Any 2 correct [of 10^2, 1 or 10°, 10^{-2}] **(1)**
All 3 correct **(1)** 2

(iii) 20 000 and 5 000 **(1)** 1

<u>Identify stars</u>

(iv) Red giant = (B and) C **(1)**
Low mass ms star = E [ignore X] **(1)** 2

<u>Zeta Tauri Luminosity</u>

(v) Use of $L = 4\,\pi\,D^2\,I$ **(1)**
Correct substitution **(1)**
$3.8(2) \times 10^{30}$(W) **(1)** 3

<u>Zeta Tauri identification (ecf)</u>

(vi) $3.8(2) \times 10^{30}$ W ÷ 3.9×10^{26} W [or 4×10^{30} W used] **(1)**
Correct ratio [e.g. 9700, 9800, 10300 or 10^4, etc.] **(1)**
Hence A [from answer in range 9700 to 10300] **(1)** 3

(b) (i) <u>Fusion calculations</u>
Mass difference substitution [$(2 \times 5.0055) - (6.6447 + 2 \times 1.6726)$] **(1)**
2.11×10^{-29} kg [or 0.0211×10^{-27} kg] **(1)** 2

(ii) $E = mc^2$ seen **(1)**
1.9×10^{-12}J[ecf] **(1)** 2

(c) Pulsars

(i) Neutron star **(1)**
Core remnant **(1)**
Supernova **(1)**
1.4 [accept 0.4 and 1.4] **(1)** 4

Binary pulsar system

(ii) Quality of written communication **(1)**
(Varying) radio signals **(1)**
(Regular) pulses **detected** [like lighthouse] **(1)**
Idea of two overlapping pulses (from same location) **(1)** 4

(iii) Black hole **(1)** 1

(d) White dwarf density

(i) $M \div \frac{4}{3} \pi r^3$ [allow M, m, R, r] **(1)** 1

(ii) Any pair of values correctly read [may be implied, ignore 10^6] **(1)**
Any correct substitution [with 2.0×10^{30} and 10^6, ecf on (i)] **(1)**
Two correct answers [in kg m^{-3}, no statement required] **(1)** 3

White dwarf future

(iii) Cools / temperature decreases **(1)**
Becomes dimmer / changes colour [not brown dwarf] **(1)** 2

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135. (a) Stress – strain graph

(i) Stress **(1)**

Pa/MPa/GPa/Nm^{-2} **(1)** 2

(ii) Use of $E = \sigma \div \varepsilon$ / E = gradient **(1)**
Any correct substitution [for linear region] **(1)**
Suitable scale: 1, 2, 3, 4, 5 and $\times 10^9$ / G **(1)** 3

UTS and yield stress

(iii) 5GPa [ecf] **(1)** 1

(iv) The stress at which plastic deformation begins / beyond elastic region [not just 'beyond Hooke's law'] **(1)** 1

(v) Y at or just beyond end of straight line on graph [$0.03 < \varepsilon < 0.04$] **(1)** 1

Second material

(vi) Lower gradient initially **(1)**
Straight line to right-hand edge of graph **(1)** 2

Energy density and Work done

(vii) Any reference to area [may be implied] **(1)**
Correct technique: rectangle (and triangle) or counting squares **(1)**
$7.5 - 8.5 \times 10^8$ J m^{-3} [no ecf] **(1)** 3

(viii) 8×10^8 J $m^{-3} \times 3.8 \times 10^{-7}$ m^3 [ecf on energy density from (vii)] **(1)**
Correct answer [300 J, ecf] **(1)** 2

(b) Crystal lattice dislocations

(i) XY = Slip plane **(1)** 1

(ii) Quality of written communication **(1)**
Layers / planes (of atoms) slip over each other / move **(1)**
Bonds break one at a time (along XY / slip plane) **(1)**
Less force (or stress) required (to do this) **(1)** 4

(c) Pole vault energy

(i) AB: chemical to... **(1)**
BC: kinetic to elastic / strain / g.p.e. **(1)**

CD: ...to gravitational potential / g.p.e. **(1)** 3

(ii) 8.0 m s^{-1} **(1)** 1

(iii) $m\,g\,h = 2100$ (J) [or 3.3 seen] **(1)**

(3.3 + 0.9 + 1.2 =) 5.4 (m) **(1)** 2

(d) Pole material

(i) Made of more than one material [ignore benefits here] **(1) (1)**

(ii) to gain (beneficial) properties of each material [not just 'stronger'] **(1)** 1

(iii) Pole properties
Elastic **(1)**
Flexible **(1)**
Strong **(1)** 3

[–1 penalty per error if > 3 circled]

(iv) No plastic deformation (or almost none) / only deforms elastically
[not just 'breaks easily'] **(1)** 1

[32]

136. (a) Energy spectrum graph

(i) Number of β^- / particles **(1)**
Kinetic energy [accept k.e.] **(1)**
MeV **(1)** 3

Antineutrino evidence

(ii) Quality of written communication **(1)**
0.78 = maximum energy / ΔE of reaction **(1)**
Expect single energy for β^- / energy conservation **(1)**
(Anti)neutrino / other particle takes away missing energy **(1)** 4

(b) β – decay equations

(i) n = udd and p = uud **(1)**

β^- and $\bar{\nu}$ have no quarks / are leptons / are fundamental **(1)** 2

(ii) p → n **(1)**

β^+ and ν [on RHS, allow e^+] **(1)** 2

Weak interaction

(iii) Change of quark flavour / type **(1)**
d → u (in β^-) AND u → d (in β^+) [accept "vice versa"] **(1)**
(anti) neutrino only affected by weak interaction **(1)** 3

(iv) $\beta^- = W^-$ **(1)**
$\beta^+ = W^+$ **(1)** 2

[just W's, or W^- W^+ swapped gets **(1) (0)**]

(c) Nuclear density

(i) use of $\rho = m \div V$ **(1)**
$\frac{4}{3}\pi(5.34 \times 10^{-15}\,\text{m})^3 \,/\, 6.38 \times 10^{-43}\,(\text{m}^3)$ **(1)**
1.46×10^{-25} kg **(1)** 3

Nucleon number and radius

(ii) 1.46×10^{-25} kg ÷ 1.66×10^{-27} kg [ecf] [or 88 × 1.66×10^{-27} kg] **(1)**
hence 87.99 / 88 [accept integer 88] [or hence 1.46×10^{-25} kg] **(1)** 2

(iii) $r = r_0 A^{1/3}$ [sen or implied by substitution, or $\frac{4}{3}\pi r^3$ route] **(1)**

5.34×10^{-15} m ÷ $88^{1/3}$ [must be shown] **(1)**
1.2×10^{-15}m **(1)** 3

(d) Hydrogen
baryon and hadron **(1)**
lepton **(1)** 2

(e) Antihydrogen

(i) Antiproton [or anti–up quark, anti–down quark] and positron **(1)** 1

(ii) $\bar{p}$ = –1 and e^+ = +1 [accept correct $\bar{u}$, $\bar{d}$ charges for $\bar{p}$] **(1)**
$\bar{u}\,\bar{u}\,\bar{d}$ (e^+ fundamental / no quarks) [ecf from (b), credit if in (i)] **(1)** 2

(iii) zero / neutral **(1)** 1

Antimatter storage

(iv) Annihilates **(1)**
(On contact) with matter / container / protons / H
OR Not charged: not affected by magnetic fields **(1)** 2

[32]

137. (a) Decay graph

(i) Time / t **(1)** 1

(ii) Use of t_r line shown on graph **(1)**

5, 10, 15, 20 at marks / 6, 12, 18 clearly marked AND hours / h
[at least 2 added values required from one set shown here] **(1)** 2

Biological half-life

(iii) Correct reading of t_e = 4 hours [ecf] **(1)**

Use of $1/ t_e = 1/ t_r + 1/ t_b$ [only this, i.e. not $\lambda t_{½} = 0.69$] **(1)**

12 hours [no ecf, accept 720 min or 43200 s] **(1)** 3

(b) Molybdenum

(i) ${}^{99}_{42}\text{Mo} \rightarrow {}^{99\text{m}}_{43}\text{Tc} + {}^{0}_{-1}\beta$ [accept ${}^{0}_{-1}\text{e}$, ignore $\bar{\upsilon}$, γ or Q] **(1)** 1

(ii) (nuclear) reactor **(1)** 1

Elution method

(iii) Quality of written communication **(1)**

(saline) solution washed / flushed / pushed **through** (elution cell) **(1)**

Tc dissolves / is removed (from cell) **(1)**

Mo insoluble **(1)** 4

Technetium daughter

(iv) ${}^{99\text{m}}_{43}\text{Tc} \rightarrow {}^{99}_{43}\text{Tc} + \gamma$ [ecf on proton number] **(1)** 1

(v) Minimise dose / damage / radiation to patient / cells **(1)**

(Very) low activity / relatively stable / excreted before
it can cause damage **(1)** 2

(c) Proton number Z

(i) Z = proton number (or atomic number) **(1)** 1

(ii) $Z_{\text{bones}} > Z_{\text{tissue / air}}$ [comparison required, may be non-specific] **(1)**
Bones absorb more X-rays due to high(er) *Z* **(1)** 2

X-ray tube

(iii) 1 = Vacuum **(1)**
Allows electrons to pass through tube **(1)**
2 = High voltage (supply) **(1)**
To **accelerate** electrons (from cathode to anode) [not attracts] **(1)**
3 = (Rotating tungsten) anode [accept positive electrode] **(1)**
Emits X–rays (when struck by electrons) **(1)** 6

(d) Ultrasound Z's

(i) (specific) acoustic impedance **(1)**
of two materials / media [conditional on SAI] **(1)** 2

(ii) $[\rho] = \text{kg m}^{-3}$ or $[c] = \text{m s}^{-1}$ **(1)**
$\text{kg m}^{-3} \times \text{m s}^{-1}$ **(1)** 2

Reflection coefficient calculation

(iii) Correct substitution **(1)**
1.1×10^{-3}/ 0.0011/0.11% AND no unit **(1)** 2

<u>Transmitted percentage</u>

(iv) 1 – α / 100% – 0.11% [ecf] **(1)**
99.9% [ecf] **(1)** 2

[32]

ã **138.** (a) (i) *l* 65.0 cm to 75.0 cm and recorded to nearest mm or better **(1)**
w 29.0 cm to 31.0 cm and recorded to nearest mm or better **(1)**

[Ignore *l* and *w* reversed] [Unit error once only]
[For precision of l and *w* over half of the reading must be to correct precision]

Both repeated **(1)**

Measurements taken perpendicular/parallel to the <u>edge</u> of the foil / eye vertically above <u>edge of</u> foil **(1)** 4

(ii) 16*t* recorded to 0.01 mm or better + unit and 0.15 mm to 0.30 mm

Repeat readings shown **(1)**

Zero error checked **(1)**
Other precaution e.g. smoothed foil at each fold to <u>exclude air</u>/careful folding to <u>avoid wrinkles</u> 4

(iii) Sensible Δ(16*t*)

Sensible Δ (16*t*). Expect range or half range of values. If identical reading or only one reading allow scale division or half scale division of instrument.
1st mark can be obtained if $\Delta t = \frac{\Delta(16t)}{16}$ shown.
2nd mark can be obtained if $\frac{\Delta t}{t}$ used.

Correct calculation of percentage **(1)** 2

(iv) Attempt at density = $\frac{\text{mass}}{\text{volume}}$ **(1)**

Correct substitution into volume formula with consistent and correct *l*, *w*, and *t* **(1)**

Value 2.3 to 3.0 g/cm^3 and > 2.s.f. + unit **(1)**
[$2.3 \times 10^{-3} \rightarrow 3.0 \times 10^{-3}$ g/mm^3 or 2300 → 3000 kg/m^3] 3

(b) (i) Circuit set up correctly without help **(2)** 2

(ii) *I* to nearest mA or better and 40 mA to 55 mA with units **(1)**
V repeated for same *x* **(1)**
V to 0.1 mV or better with unit **(1)** 3

(iii) Correct substitution into *R* ***(1)***
Correct calculation, 2/3 s.f. + unit **(1)** 2

(iv) b to nearest mm or better and 8.0 mm to 12.0 mm with unit **(1)**
b repeated **(1)**
Correct substitution with consistent units for b, t, and x **(1)**
Correct calculation, consistent and correct unit **(1)** 4

[24]

Sample results

(a) (i) $\underline{l}$ = 67.0,67.2, 66.8 cm
l = 67.0 cm

$\underline{w}$ = 29.7, 29.7, 29.7 cm
w = 29.7 cm

(ii) 16t = 0.15, 0.16, 0.15, 0.16 mm

$\overline{16t}$ = 0.155 mm

$$\overline{t} = \frac{0.155\,\text{mm}}{16} = 0.0097\ \text{mm}$$

(iii) Δ (16t) = 0.01 (mm)

$$\text{Percentage uncertainty} = \frac{0.01\,\text{mm}}{0.155\,\text{mm}} \times 100\%$$

$$= 6.5(\%)$$

(iv) Mass = 5.68 g

$$\text{Density} = \frac{5.68\text{g}}{67.0\ \text{cm} \times 29.7\ \text{cm} \times 0.00097\ \text{cm}}$$

$$= 2.94\ \text{g/cm}^3$$

(b) (ii) I = 50 mA
V = 6.5, 6.7, 6.9 mV $\overline{V}$ = 6.7 mV

(iii) $$R = V / I = \frac{6.7\,\text{mV}}{50\,\text{mA}}$$

$$= 0.134\ \Omega$$

(iv) b = 1.0, 0.8, 1.2 cm
b = 1.0 cm

$$\rho = \frac{Rbt}{x} \qquad \frac{0.134 \times 0.01 \times 9.7 \times 10^{-6}}{0.3}$$

$$= \underline{4.3 \times 10^{-8}\ \Omega\ \text{m}}$$

139. (a) Measure <u>the height of</u> the string above the <u>bench in two places</u> **(1)**

Use right angle of set square against bench to ensure
vertical height measured <u>or</u> correct use of set square alone **(1)** 2

(b) h_1 and h_2 recorded to nearest mm or better with unit seen once **(1)**

l = 98.0 cm ± 0.5 cm and height difference between 33 and 63 cm **(1)**
Correct calculation of sin θ **(1)**
θ found with unit **(1)** 4

(c) *T* recorded to 0.1 N and in range 3.5 N to 8.0 N **(1)**

Correct substitution [allow g = 10 N/kg] **(1)**

Correct calculation 2/3 s.f. + unit

Supervisor's value ± 0.5 N 4

(d) 100 g mass > 20 cm from pivot **(1)**

2 distances or 3 scale readings shown on diagram with at least one reading to nearest mm **(1)**

Distances or scale readings shown to the centres of the mass and the rule **(1)**

Correct calculation *of W or m* [ignore units] **(1)**

Value ± 0.10 N of Supervisor's value with unit and > 2s.f. **(1)** 5

(e) (i) Vary *m*

Increase separation of the clamps/change height of the newtonmeter/change the height of the nail **(1)**

String (BC) horizontal **(1)**

Record the reading on the newtonmeter/*T* **(1)**

Record the heights h_1 and h_2 **(1)**

Find/measure θ or sin θ **(1)** Max 5

(ii) Using several/many/ 5 or more/ range readings **(1)**
[5 or more can be scored from table or graph]

Plot suitable graph e.g. $T \tan \theta$ against mg **(1)**

Straight line with positive gradient and with positive intercept [or intercept consistent with expected graph] **(1)**

(iii) Intercept = 1/2 *W* or consistent with graph **(1)** 9

If experiment in part(d) used. **(1)**
Vary *m* ($mgx = Wy$) **(1)**
Plot suitable graph e.g. *m* against y/x **(1)** **Max 4**
Straight line through origin **(1)**
Suitable gradient e.g. W/g **(1)**

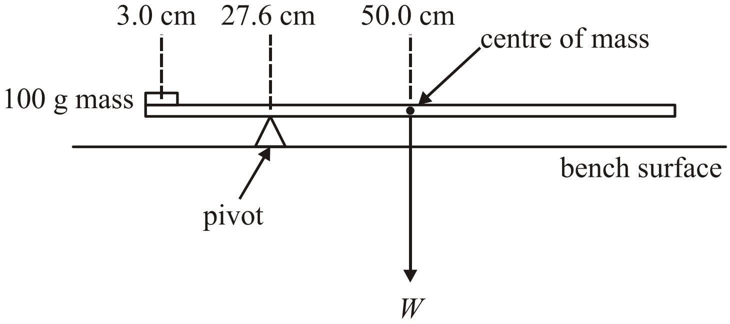
[24]

Sample results

(b) h_1 = 68.5 cm
h_2 = 10.5 cm
l = 98.0 cm
$\sin \theta = (68.5 - 10.5)/98.0$
$= 0.592$
$\therefore\ \theta = 36.3°$

(c) T = 4.3 N
$W = 2 \times 4.3\ \text{N} \times \tan(36.3) - 0.5\ \text{kg} \times 9.81\ \text{m s}^{-2}$
= 1.41 N

(d)



100 (27.6 – 3.0) = m × (50 – 27.6)

$\therefore\ m = 109.8$ g

$\therefore\ W = 0.1098 \times 9.81$

= $\underline{1.08\ \text{N}}$

140. (a) (i) d to 0.01 mm or better and ± 0.03 mm of Supervisor's [unit seen somewhere]

Repeat shown **(2)**

Other precaution e.g. measured in 2 perpendicular directions/ measured in different places/ used ratchet to avoid overtightening micrometer/ avoided kinks in wire **(1)** 3

(ii) Sensible Δd consistent with $\overline{d}$ **(1)**
Correct calculation of percentage **(1)** 2

(iii) Sensible mass and correct formula for density **(1)**

Correct substitution into volume formula with consistent length units **(1)**

Density to 2/3 s.f. + unit **(1)**

Value 8.4 → 9.8×10^x **(1)**

Correct x value **(1)** 5

$$\left(\begin{array}{l}\text{e.g. } -3 \text{ for g mm}^{-3} \\ \quad\quad 0 \text{ for g cm}^{-3} \\ \quad\quad +3 \text{ for kg m}^{-3}\end{array}\right)$$

(d) (i) Circuit set up correctly without help 2

(ii) I to nearest mA or better and approximately 50 mA with unit **(1)**

V to nearest mV or better and in range 50 mV to 90 mV with unit **(1)**

V repeated **(1)** 3

(iii) Correct calculation of R **(1)**

R from $\frac{V}{I}$ to 2/3 s.f. + unit **(1)** 2

(iv) $I \leq I_1$, to nearest mA or better + unit **(1)**

$V = 3 \times$ to $4 \times V_1$ to nearest mV or better + unit **(1)**

Correct calculation of $R \geq 2$ s.f. + unit **(1)** 3
[Only penalise a particular unit error once in (ii), (iii) and (iv)]

(v) Correct calculation of R **(1)**
Correct substitution for ρ with consistent length units **(1)**
Unit of ρ **(1)**
Value $4.2 \rightarrow 5.2 \times 10^{-7}$ Ω m and ≥ 2 s.f. **(1)** 4

[24]

Sample results

(a) (i) $m = 2.74$ g
$d = 0.31, 0.31, 0.31$ mm
$\overline{d} = 0.31$ mm

(ii) $\Delta d = 0.01$(mm)

Percentage uncertainty $= \dfrac{0.01\,\text{mm}}{0.31\,\text{mm}} \times 100\%$
$= 3.2(\%)$

(iii) $$V = \frac{\pi(0.31\times10^{-3}\ \text{m})^2 \times 4.0\,\text{m}}{4}$$

$= 3.02 \times 10^{-7}\text{m}^3$

$$\rho = \frac{2.74\times10^{-3}\ \text{kg}}{3.02\times10^{-7}\,\text{m}^3}$$

$= \underline{9080\ \text{kg m}^{-3}}$

(b) (ii) $I = 49$ mA
$V = 89, 90, 88$ mV
$\overline{V} = 89$ mV

(iii) $R_1 = \dfrac{89\,\text{mV}}{49\,\text{mA}}$
$= 1.82$ Ω m

(iv) $I = 48$ mA
V = 266, 265, 267 mV
$\overline{V} = 266$ mV
$R_2 = \dfrac{V}{I} = \dfrac{266\,\text{mV}}{48\,\text{mA}} = 5.54\ \Omega$

(v) $R = 5.54\ \Omega - 1.82\ \Omega = 3.72\ \Omega$

$$\rho = \frac{3.72\Omega \times \pi \times (0.31\times10^{-3}\text{m})^2}{4\times0.6\,\text{m}}$$

$= 4.7 \times 10^{-7}$ Ω m

141. (a) Recorded to the nearest mm with unit **(1)** 1
(b) 100 g mass > 20 cm from pivot **(1)**
3 scale readings or 2 clear distances shown on diagram
[at least one to nearest mm] **(1)**

Distances or scale readings shown to centres **(1)**

Correct calculations of *W* with unit **(1)**
Value ± 0.05 N of Supervisor's value and > 2 s.f. **(1) (1)**
[If ± 0.10 N **(1)**] 6

[If mass unit used for *W,* penalise calculation of W but give range marks appropriate to value]

[Allow g = 10 m s^{-2} in (b)]

(c) Measure the height of the rule above the bench in 2 places **(1)**
Use the right angle of the set square against the bench to ensure the vertical height is measured **(1)** 2

(d) *T* recorded to 0.1 N or better with unit and 2/3 s.f. **(1)**
[and approximately 6 N]

x and *y* recorded to nearest mm or better + unit **(1)**

Correct calculation of *W with* unit and 2/3 s.f. **(1)**

Value ± 0.5 N of Supervisor's value **(1)** 4

(e) Correct calculation of percentage difference **(1)**
First value is more accurate **(1)**
because newtonmeter uncertainty is likely to be large **(1)**

Or

because the effect of the suspended 1 kg mass on the **(1)** 3
newtonmeter reading > >effect of mass of rule

(f) (i) Keep *m* and *x* constant **(1)**

(ii) Move position of newtonmeter **(1)**

Obtain different values of *y* **(1)**

Ensure newtonmeter is vertical **(1)**

Adjust height of newtonmeter/clamp to make rule horizontal **(1)**

Record reading on newtonmeter **(1)**

(Obtain) several/many/5 or more/ range of reading **(1)**
[5 or more can be scored from table or graph]

Adjust newtonmeter to set zero correctly **(1)**

(iii) Plot *T* against 1/*y* **(1)**

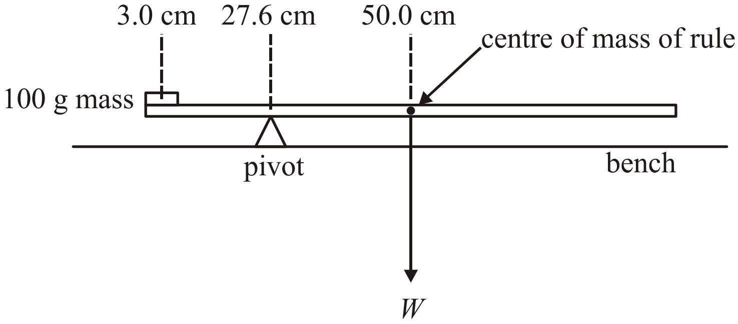
(iv) Straight line through origin expected **(1)**
Slope = $(W + mg)\,x$ **(1)** 8
[Wrong experiment max 5]

[24]

Sample results

(a) Position of centre of mass = 50.0 cm

(b)



0.1 kg × 9.81 m s^{-2} × (27.6 cm – 3.0 cm)
= W (50.0 cm – 27.6 cm)
$\underline{W = 1.08 \text{ N}}$

(d) T = 5.9 N
x = 50.0 cm – 1.0 cm = 49.0 cm
y = 95.0 cm – 1.0 cm = 94.0 cm
(W + 9.81 N) 49.0 cm = 5.9 N × 94.0 cm
W+ 9.81 N = 11.32 N
$\therefore$ W = 11.32N – 9.81N
= 1.51 N

(e) Percentage difference = $\dfrac{1.51\,\text{N} - 1.08\,\text{N}}{\frac{1}{2}(1.51\,\text{N} + 1.08\,\text{N})}$ × 100 %

= 33 (%)