1. B

[1]

2.

density, mass **(1)**
tough, energy **(1)**
compressive, tensile **(1)**

[3]

3. (a) As skydiver speeds up, air resistance will increase **(1)**
Net force on skydiver will decrease, reducing acceleration **(1)** 2

(b) Parachute greatly increases the size of the air resistance **(1)**
When air resistance = weight of skydiver, skydiver is in equilibrium **(1)** 2

(c) Use of as $v^2 = u^2 + 2as$ **or** $\frac{1}{2}mv^2 = mg\Delta h$ **(1)**

Correct answer [7.7 m s^{-1}] **(1)**

<u>Example of calculation:</u>
$v = \sqrt{2 \times 9.81 \times 3} = 7.7$ m s^{-1} 2

[6]

4. Spelling of technical terms must be correct and the answer must be organised in a logical sequence **(QWC)**
Mixing of layers leading to eddies/whorls **(1)**
Air circulates around at edge of platform **(1)**
Passenger may be pushed over due to eddies/whorls **(1)**

[3]

5. (a) Proportional / Hooke's law limit **(1)** 1

(b) Stiffness of sample **(1)** 1

(c) Work done / strain energy **(1)**
To stretch (OR strain) wire to fracture **(1)** 2

[4]

6. (a) Use of $\frac{4}{3}\pi r^3 \rho$ **(1)**
Correct answer [1.44×10^{-6} kg] **(1)**

Example of calculation:

$m = \frac{4}{3}\pi r^3 \rho = \frac{4}{3}\pi(0.7\times10^{-3})^3 \times 1000 = 1.44\times10^{-6}$ kg 2

(b) Use of mg = $6\pi\eta$rv **(1)**
Correct answer [1.2 m s^{-1}] **(1)**

Example of calculation:

$v = \frac{mg}{6\pi\eta r} = \frac{1.44\times10^{-6}\times9.81}{6\pi\times8.90\times10^{-4}\times0.7\times10^{-3}} = 1.2\ \text{m s}^{-1}$ **(2)** 2

[4]

7. (a) Length and breadth of the thin cross section to calculate area **(1)**
Digital callipers / micrometer **(1)** 2

(b)
- Small extensions can be measured accurately **(1)**
- Large data set / easy processing of data **(1)** 2

[4]

8. (a) (i) Assumption: spring obeys Hooke's Law **(1)**
Use of F = kx **(1)**
Correct answer [60N] **(1)**

Example of calculation:

$\frac{F_2}{F_1} = \frac{x_2}{x_1}$

$F_2 = \frac{50}{5} \times 6 = 60$ N 3

(ii) Use of W = F_{av}.x **(1)**

Correct answer [75J] **(1)**

Example of calculation:
W = F_{av}.x

$W = 5 \times \frac{60}{2} \times 0.5 = 75$ J 2

(b) (i) Attempt at estimation of area under graph / average force **(1)**
0.5 m extension used **(1)**
Correct answer [53 → 57J] **(1)**

Example of calculation:
Energy represented by 1 square =10 × 0.02 = 0.2 J
280 squares × 0.2 J = 56 J

Treating the area as a large triangle
W = 0.5 × 205 × 0.5 = 51 J 3

(ii) Spelling of technical terms must be correct and the answer must be organised in a logical sequence **(QWC)**
Energy returned is less than the work done in stretching the cords **(1)**
Energy must be conserved, so internal energy of cords must increase **(1)**
Rubber cords will get warmer **(1)** 3

[11]

9. (i) **Fence wire cross-section**

Use of πr^2 and 10^{-3} m **(1)**

4.9 × 10–6 (m2) [do not accept m] **(1)**

$A = \pi r^2$
$= \pi \times (0.5 \times 2.50 \times 10^{-3})^2$ 2

(ii) **Stress calculation**

Substitution: 1500 N / 4.9 [or 5] × 10^{-6} m^2 **(1)**

310 MPa [accept 300, ecf] **(1)**

$\sigma = F / A$
$= 1500 \text{ N} / 4.9 \times 10^{-6} \text{ m}^2$
$= 3.1 \times 10^8$ Pa 2

(iii) **<u>Extension calculation</u>**

$E = \sigma / \varepsilon$ and $\varepsilon = \Delta l / l$ (or $E = F\,l / A\,\Delta l$) **(1)**

Substitution in $E = \sigma / \varepsilon$ and $\varepsilon = \Delta l / l$ [or in $E = F\,l / A\,\Delta l$, ecf, ignore 10n] **(1)**

0.048 (m) [ecf] **(1)**

48 mm [accept 47 – 49 mm, bald answer scores 4/4] **(1)**

$E = F\,l / A\,\Delta l$

$\Delta l = (1500\text{ N} \times 33\text{ m}) / (210 \times 10^9\text{ Pa} \times 4.9 \times 10^{-6}\text{ m}^2)$
$= 0.048\text{ m} = 48\text{ mm}$ 4

[8]

10. (i) **<u>Young modulus experiment</u>**

(G–) clamp [vice], <u>wire</u>, pulley, mass / weight / load

three correct **(1)**

all four correct **(1)** 2

(ii) **<u>Labelling of *l*</u>**

Accurate indication of *l* [to 1 mm] **(1)**

Length 2 m to 6 m **(1)** 2

(iii) **<u>Additional apparatus</u>**

Micrometer (screw gauge) / (digital) callipers **(1)**

Ruler or similar [e.g. tape measure, metre stick] **(1)** 2

[6]

11. (a) (i) <u>Type of behaviour:</u>
Plastic
Correct definition of circled word:
Ductile: can be pulled into a long thin shape
Elastic: returns to original shape/size (once force removed)
Plastic: does not return to original shape/size (once force removed)

Tough: can withstand dynamic loads / shocks / impacts / absorbs a lot of energy before breaking 2

(ii) <u>Brittle:</u>
Snaps / cracks / shatters / breaks without (plastic) deformation (when subjected to a force) 1

(iii) Strong:
Large force / stress required to break it 1

(b) (i) Breaking stress:
Use of $\sigma = \varepsilon \times E$
Correct answer [2×10^8 Pa]

Eg.
$\sigma = 2 \times 10^{11} \times 0.001$
$= 2 \times 10^8$ Pa 2

(ii) Force to break wire:
Use of $A = \pi r^2$
Use of $F = \sigma \times A$
Correct answer [157 (N)]
[allow 156 – 157 (N) for rounding errors – no u.e]

Eg.
$A = \pi \times (1 \times 10^{-3}/2)2 = 7.9 \times 10^{-7}$ m^2
$F = 2 \times 10^8 \times 7.9 \times 10^{-7}$ m^2
Weight (= F) = 157 N 3

(iii) Force to break Biosteel fibre:
3.1×10^3 N [allow 3.1×10^3 N – 3.2×10^3 N]

eg.
20 × 157 = 3140 N (3200 N if 160 N used) 1

(iv) Assumption:
Elastic limit (of both materials) not reached / elastic behaviour / Hooke’s law obeyed / Young modulus still holds at breaking point / Area remains constant / best Biosteel scenario / 20 × stronger 1

[11]

12. (a) Graph:
Line of best fit drawn as straight line through origin

Stiffness:
Use of $k = F/x$
$k = 22$ N m^{-1} (allow 21 –23 N m^{-1})
[allow ecf from graph]

eg.
$k = 110/5.0 = 22$ N m^{-1} 3

(b) <u>Energy stored in rope:</u>
Use of E = area under graph = ½ Fx
[also allow $E = ½ kx^2$ / $E = F^2/2k$]
Correct answer [514 J (511J if k = 22 Nm–1 is used]
[allow 505 – 522 J]

E = ½ × 150 × 6.85
= 514 J — 2

(c) <u>Less extension with child:</u>
Any one of:
- Rope connected to sheet as (many) parallel sections (making it stiffer)
- Each section of rope supporting (much) less than full weight
- Work done / energy lost to friction with trampoline fram — Max 1

(d) <u>New rope dimensions:</u>
Rope needs to be thicker / shorter
As stiffness would have to be increased / reference to
$E = Fl/Ax$ / as it would have to withstand a greater stress /
otherwise extension would be (much) greater — 2

[8]

13. (i) <u>Stress-strain graph regions</u>

Neckings C or D **(1)**

Elastic deformation = A or B **(1)**

Plastic flow = E [ignore extra C or D] **(1)** — 3

(ii) <u>Young modulus calculation</u>

Attempt at gradient / stress ÷ strain **(1)**

Sensible pair of values [from linear region, ignore × 10^n] **(1)**

1.35 [allow 1.30– 1.40] **(1)**

× 10^{11} Pa [or N m^2] **(1)** — 4

(iii) <u>Second material</u>

Straight line [allow slight curvature at end] **(1)**

Less steep than original line **(1)**

Stops at $\varepsilon = 2.6 \times 10^{-3}$ **(1)** — 3

[10]

14. (a) <u>Force arrow diagram:</u>
Weight and upthrust correctly labelled **(1)**
Tension in string shown downwards **(1)** 2

(b) <u>Upthrust on balloon:</u>
Knowledge of: upthrust = weight of displaced air **(1)**
Use of upthrust = $\rho g V$ **(1)**
Correct answer (0.18 N) [allow 0.2 N] **(1)**

Example:
Upthrust =1.30 kg m^{-3} × 9.81 m s^{-2} × 4/3 π(0.15 m)^3
= 0.18 N 3

(c) (i) <u>Airflow diagram:</u>
Diagram showing at least three continuous lines around the balloon **(1)** 1

(ii) <u>Type of airflow:</u>
Streamline / laminar **(1)** 1

(d) (i) <u>Word equation:</u>
Weight + (viscous) drag = upthrust **(1)** 1

(ii) Terminal velocity:
$\frac{4}{3}\pi r^3 \rho g$ = upthrust = value obtained in (b) [or 0.2 N] **(1)**
correct substitution into $mg + 6\pi r \eta v = \frac{4}{3}\pi r^3 \rho g$ **(1)**
Correct answer (202 m s^{-1}) [196 – 202 m s^{-1} to allow for rounding errors] [if 0.2N is used v = 590 m s^{-1}] **(1)**

Example:
v = (0.18 – 0.17) / (6π × 1.8 × 10^{-5} × 0.15)
= 202 m s^{-1} 3

(iii) <u>Comment:</u>
Any one of:
Air pressure also acts on balloon / becomes less with height
Air becomes less dense with height
Upthrust becomes less with height
Relationship only valid for small objects **(1)** Max 1

[12]

15. (a) Deformation of spring:
As spring must return to original length when (compressive) force is removed **(1)**
Elastic (conditional on 1st mark) **(1)** 2

(b) Graph:
4 points plotted correctly **(1)**
all points plotted correctly (to within +/– ½ square) **(1)**
straight line of best fit through points and origin **(1)** 3

(c) Stiffness:
Use of stiffness = F/x taking any pair of values from the table or graph **(1)**
= 0.53 N mm^{-1} (530 Nm^{-1}) [allow 0.52 – 0.54 N mm^{-1}] **(1)** 2

(d) Force exerted:
Correct reading from graph
= 3.2 N [allow 3.1 – 3.3 N] **(1)**

OR
$F = kx$ = 0.53 × 6 = 3.2 N [allow ecf] **(1)** 1

(e) Elastic energy:
Energy stored = area under graph **OR** Energy stored = ½ Fx **OR**
Energy stored = ½ kx2 **(1)**
Correct values substituted [ignore powers of 10] **(1)**
Correct answer (9.6 × 10^{-3} J) [allow 9.3 – 9.9 × 10^{-3} J] **(1)** 3

Example:
Energy stored = ½ (3.2 × 6 × 10^{-3}) = 9.6 × 10^{-3} J
OR
Energy stored = ½ × 530 × (6 × 10^{-3})2 = 9.6 × 10^{-3} J

(f) New force to compress:
Half of the original force / 1.6 N [allow ecf] **(1)** 1

[12]

16. (a) Elastic and Plastic behaviour

Plastic = permanent AND elastic = reversible [may be implied anywhere] **(1)**

Elastic: bonds stretch but not broken / atoms move apart but then return **(1)**

Plastic: bonds broken (when stressed) / atoms do not return to original position (after stress) **(1)** 3

(b) (i) Ultimate tensile strength

(3.6 – 3.7) × 10^8 N m^{-2} / Pa **(1)** 1

(ii) Young modulus calculation

Attempt at gradient / stress ÷ strain [ignore 10^n] **(1)**☐

Valid pair of readings taken from graph [10^8 and 10^{-3} required] **(1)**☐

8.0 to 9.0 × 10^{11} N m^{-2} / Pa **(1)** 3

(iii) Tough or brittle explanation

Tough **(1)**

Any reference to plastic behaviour **(1)**

(Large area under) non-linear part of graph referred to **(1)** 3

[10]

17. Definitions

(i) Stress = force ÷ area AND strain = extension ÷ original [initial] length **(1)** 1

(ii) E = stress ÷ strain [accept symbols here] **(1)**

$E = \frac{F / A}{\Delta l / l}$ **(1)** 2

(iii) Radius "show that" calculation

Correct substitution in $E = \frac{Fl}{A\Delta l}$ / $A = 2.7 \times 10^{-7}$ (m^2) **(1)**

$A = \pi r^2$ **(1)**

2.9×10^{-4} m / 0.29 (mm) **(1)** 3

[6]

18. (a) Material properties:

Strength – Force/ load/stress required to **break** / Strong – large force required to **break** **(1)**

Brittle – shatters/snaps/fractures / cracks (under force) / breaks with no/little plastic deformation/breaks with little strain [ignore reference to size of force needed eg. cracks easily – mark awarded for 'cracks'] **(1)**

Plastic – does not return to original length (when load removed) / deformation is permanent **(1)** 3

(b) Maximum force:

Use of $A = \pi r^2$ **(1)**

Use of $F = \sigma \times A$ **(1)**

Correct answer [193 (N)] **(1)** 3
[accept 190 – 193 N to allow for rounding errors] [no u.e]
[2 out of 3 for correct reverse working out]

Example:
$F = \sigma \times A$
$A = \pi r^2 = (0.127 \times 10^{-3})^2 \times \pi$
$= 5.07 \times 10^{-8}\ \text{m}^2$
$F = 3.8 \times 10^9\ \text{Pa} \times 5.07 \times 10^{-8}\ \text{m}^2$
$= 193\ \text{N}$

(c) Extension calculation:

Use of $\varepsilon = \sigma / E$ **(1)**
Correct answer for ε [0.015] **(1)**
Correct answer for extension [0.017 m] **(1)**
[allow 0.016 – 0.017 m to allow for rounding errors]
[allow 1st 2 marks for correct substitution into E = Fl/xA] 3

Example:
$\varepsilon = \sigma / E$
$= 2.00 \times 10^9\ \text{Pa} / 1.31 \times 10^{11}\ \text{Pa}$
$= 0.015$
extension = ε × length = 0.015 × 1.1m = 0.017 m (1.7 cm)

(d) Polymer:
Long chain **(1)**
Of repeating units / of monomers / molecule /atoms **(1)**
[1 mark only for long chain of molecules] 2

[11]

19. (a) High viscosity flow:
Slower (than low viscosity flow) / greater time taken to
flow the same distance / flows less distance in the same time **(1)** 1

(b) Measurement of viscosity:
Distance travelled by lava in a set time / time taken to travel a
set distance / speed of lava flow **(1)** 1

(c) Effect of cooling:
(viscosity) increases **(1)** 1

(d) Laminar/Turbulent flow:
Any 3 points –

- Laminar – smooth
- Shown by at least 2 straight-ish lines
- Turbulent – flow causes whirlpools /eddies (or explanation involving energy)
- Turbulent flow shown on diagram with at least 3 lines resulting in eddies **(1)(1)(1)** — Max 3

(e) Viscosity graph:
Use a log scale / powers of 10 scale **(1)** — 1

[7]

20. Property definitions

(i) Tough: absorbs energy (before breaking) **(1)**

by plastic deformation **(1)**

Strong: high(er) UTS / high(er) stress (before breaking) **(1)** — 3

Force calculation

(ii) Attempted use of $\sigma = F / A$ [accept use of r instead of A for 1/3] **(1)**

Use of $A = \pi r^2$ (ignore 10^n) **(1)**

3.8 (or 4) × 10^{-3} N **(1)** — 3

$\sigma = F / A = F / \pi r^2$
$F = \sigma \pi r^2$
$= 3 \times 10^8 \text{ Pa} \times \pi (2.0 \times 10^{-6} \text{ m})^2$
$= 3.8 \times 10^{-3} \text{ N}$

Stiffest part of curve

(iii) Initial slope indicated **(1)** — 1

Young modulus calculation

(iv) Any attempt at gradient / stress ÷ strain **(1)**

Correct pair of values for linear region above stress 0.25 / Extended gradient at start of curve **(1)**

5.5 GPa [5.2 – 5.6 with GPa or GNm^{-2}] **(1)** — 3

[10]

21. (a) (i) Type of airflow:
Laminar / streamline **(1)** 1

(ii) Airflow diagram:
At least two streamlines drawn in front of the skier **(1)**
At least two streamlines continuous around and behind the skier **(1)**
[Maximum of 1 mark if the streamlines cross or touch] 2

(iii) Skier's equipment:
Smooth / tight–fitting / not baggy / elastic **(1)** 1

(b) (i) Desirable property:
Elastic **or** Tough **(1)** 1

Reason:
Correct reasoning in line with property, ie.
Will return to original shape (once load removed) **(1)**
or
Can withstand shock / impact (without breaking) **(1)** 2

(ii) Undesirable property:
Plastic **(1)**

Reason:
Will remain deformed (once load removed) **(1)** 2

[8]

22. (a) Graph:

(i) Line of best fit completed curving between 5.0 and 5.5 mm **(1)**

(ii) **X** marked correctly on line (by eye) between 5.0 – 5.5 mm **(1)** 2

(b) (i) Energy stored calculation:
Energy = ½ Fx or area under graph to intercept line **(1)**
Correct reading of x from graph **(1)**
Correct answer from graph in Joules **(1)** 3

eg. Energy = ½ Fx
$= ½ \times 20 \times 4 \times 10^{-3}$
= 0.04 J

(ii) Gradient of graph:
Stiffness of wire **(1)** 1

(c) Thicker wire:
Any 2 of the following:
- Steeper gradient
- More force required to produce the same extension
- Limit of proportionality at a larger force **(1)(1)** Max 2

[8]

23. 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

[15]

24. Complete table:

Plastic: Not desirable **(1)**
Reason: Would remain deformed(once load is removed) **(1)**

Tough: Desirable **(1)**
Reason: To withstand dynamic loads/impacts/shocks **(1)**

Brittle: Not desirable **(1)**
Reason: Would crack / shatter / snap / break with no(plastic) deformation **(1)** 6

Calculate stress:

Use of $m \times g$**(1)**
[g = 10 m s^{-2} will **not** be penalised]
Correct answer [1.9×10^4 Pa] **(1)** 2

e.g.
Force = 80 × 9.81 = 785 N
$\sigma = F/A = 785/4.2 \times 10^{-2}$
$= 18686 = 1.9 \times 10^4$ Pa

[allow 1.8 – 2.0×10^4 Pa and allow Nm^{-2} as units]

Running athlete:

On one foot / part of foot **(1)**
As less(surface) area **(1)**
OR
When landing/pushing off **(1)**
As the force is greater **(1)** 2

[10]

25. Airflow diagram:

At least two **continuous** lines drawn around and **beyond** sky diver **(1)** 1
[Ignore turbulence around feet – lines must not touch]

Force diagrams:

Weight arrow vertically downwards [allow W, mg and gravitational force] **(1)**
(Viscous) Drag **and** Upthrust arrows upwards **(1)** 2
[Allow air resistance for drag and u for upthrust]
[Upthrust must be vertically upwards]

Forces relationship:

Weight = Drag + Upthrust OR in equilibrium**(1)** 1
[Allow symbols or formulae for any of these quantities]

Why Stokes' law not valid:

Sky diver not spherical / flow not laminar**(1)** 1

Upthrust:

Use of Upthrust = Weight of displaced air **(1)**
Use of Mass = density × volume **(1)**
Correct answer [4.1(N) or 4.2(N) if g = 10 m s^{-2} is used] **(1)** 3

e.g.
Weight = 1.2 × 0.35 × 9.81
= 4.1 N

Comment on size of force:

Smaller than weight / small**(1)**
Very little effect on terminal velocity / **small** decrease in terminal velocity **(1)** 2

Airflow:

Turbulent/slower **(1)** 1

[11]

26. Add forces to diagram

Downward arrow labelled weight / mg **(1)**

Upward arrow labelled (viscous) drag **(1)** 2

Expression for upthrust

Upthrust = weight of displaced fluid **(1)**

= volume × density × g **(1)** 2

Relationship between forces

Upthrust + (viscous) drag = weight **OR** $F + U = W$ **(1)** 1
[ecf. From diagram – must be 3 forces]

Expression for velocity

$F = W – U$

$6\pi\ \eta rv = 4/3\pi r^3\ \rho_s g – 4/3\ \pi r^3 \rho_w g$ (ecf) **(1)**

$6\eta rv = 4/3\ r^3 g\ (p_s – p_w)$

$v = \dfrac{2r^2 g(\rho_s - \rho_w)}{9\eta v}$ **(1)** 2

Velocity change with temperature

Velocity will increase **(1)**

As viscosity will decrease with temperature/as velocity increases with decreasing viscosity / as density of wine decreases **(1)** 2

Explanation of what is meant by laminar

Diagram showing at least 3 reasonably parallel and straight lines **(1)**

No abrupt change in direction/no whorls/no eddies **(1)** 2
[Both marks may be awarded from the diagram.]

[11]

27. Material property

Tough **(1)** 1

Crosses on graph

P at end of straight line section [allow 2.6 – 2.8 m extension] **(1)**

E: accept between P and maximum force value **(1)** 2
If P not shown allow 2.6 – maximum force value]

Stiffness of rope

$k = F/x$; k = gradient of graph **(1)**

= 7 kN ÷ 2.25 m = 3.1 kNm^{-1} **(1)** 2

Breaking strain

From graph, maximum extension = 3.4 m **(1)**

Breaking strain = 3.4/50 = 0.07 (0.068 or 6.8%) **(1)** 2
[allow ecf. from extension]

Energy stored in the rope

Force = 90 kg × 9.81 =883 N (900 N) **(1)**

Extension for this force from graph = 0.28 m **(1)**
(allow 0.25 → 0.3 m)

Energy = ½ *Fx* [**OR** area under graph] **(1)**

= 124 J (allow 110 → 132 J) **(1)**
[112 → 135 J if 900 N is used]

OR alternative method:

Force = 90 kg × 9.81 =883 N [900 N] **(1)**

Extension found by substitution: $x = F/k$ **(1)**

Energy = ½ Fx **OR** ½ $F \times F/k$ **(1)**

– 125 J [128 J if 900 N is used] **(1)** 4
[allow ecf for value of k used]

[11]

28. 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 σ ε (or implied) **(1)**

Correct substitution to 95 000 [no ue] **(1)** 3

[6]

29. 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

[16]

30. Stress on thread

(*Weight*) = 1.0 × 10^{-3} kg × 9.81 m s^{-2} **(1)**

Use of $A = \pi r^2$ OR 7.9 × 10^{-11} m^2 **(1)**

Stress = 1.2 × 10^8 Pa **(1)** 3

Maximum stress

Use of $\sigma = \varepsilon \times E$ **(1)**

ε = 0.001 (if incorrect no further marks for this section) **(1)**

σ = 0.001 × 2 × 10^{11} Pa = 2 × 10^8 Pa **(1)** 3

Weight

$F = \sigma \times A$ = 2 × 10^8 Pa × 3 × 10^{-4} m^2 **(1)**

= 6 × 10^4 N (allow ecf) **(1)** 2

Comparison with spider silk

Larger **(1)**

Discussion of figures in table, eg E ~ 3 times smaller, but ε_{max} ~ 300 times larger/calculation of breaking force on silk (5.4×10^6 N allow ecf on ε value)/comparison of stress values ($\sigma silk = 1.8 \times 10^{10}$ Pa allow ecf on ε value) **(1)** 2

Assumption

Young modulus still holds at breaking point/elastic limit not reached/elastic behaviour/obeys Hooke's law **(1)** 1

[11]

31. (a) Show that energy stored can be written as in formula

$W = ½ Fx$ [allow x or Δx] **(1)**

$F = kx$ **(1)** 2

Graph

Rising curve [either shape] **(1)**

starts at origin and correct shape, i.e. gets steeper **(1)** 2

(b) Young modulus of copper

Read valid pair off straight line region **(1)**

1.3 [when rounded to 2 s.f.] **(1)**

correct power of 10, i.e. $\times 10^{11}$ **(1)**

Correct unit: Pa OR N m^{-2} 4

Copper wire

Obtain reasonable extension/reduce uncertainty **(1)** 1

Calculation of stress

Use of πr^2 **(1)**

Substitution in F/A i.e. allow 280 N/r [OR their A] **(1)**

1.8×10^8 Pa [No e.c.f.] **(1)** 3

Point P

Point P marked on graph [e.c.f.] 1

Justification

Behaviour is elastic since on straight line region [e.c.f.] 1

[14]

32. <u>Forces on sphere (diagram)</u>

Weight [downwards] *W*/*mg* **(1)**

Upthrust [upwards] *U* **(1)**

(Viscous) drag [upwards]/*D*/*R* **(1)** 3

<u>Comparison</u>

Weight is greater than upthrust and (viscous) drag **(1)** 1

<u>Volume</u>

$4/3\pi r^3 = 7.2 \times 10^{-6}$ m^3 **(1)** 1

<u>Mass</u>

Volume × density

$= 7.2 \times 10^{-6} \times 1020$

$= 7.3. \times 10^{-3}$ kg [e.c.f.] **(1)** 1

<u>Upthrust</u>

Weight of liquid displaced **(1)**

$= 7.6 \times 10^{-3} \times 9.81$

$= 7.2 \times 10^{-2}$ N [no e.c.f.] **(1)** 2

<u>Explanation of where sphere found</u>

Overall force upwards $U > W$ **(1)**

so sphere accelerates upwards / higher **(1)** 2

[OR stays at the top]

<u>Properties</u>

Any two from:

- Viscosity / temperature
- density **(1)** **(1)** 2

[12]

33. (i) <u>Tough</u>

Can withstand dynamic loads / shock / impact / repeated deformation **(1)**

(ii) <u>Material</u>

Polythene / Kevlar / rubber / carbon fibre / steel **(1)** 2

<u>Meaning of elastic</u>

Return to original shape after force removed **(1)** 1

Calculation

(i) Force:

Use of $F = kx$ **(1)**

$= 1250 \times 0.090$

= 113 N **(1)**

(ii) Energy:

Use of $E = ½ Fx$ [OR $½ kx^2$] **(1)**

$= ½ \times 113 \times 0.090$

= 5.1 J **(1)** 4

Calculation and discussion

Weight of child = 30 × 9.81 = 294 N **(1)**

Any two from:

- Child will fully compress the spring if landing on handle bar or 113 N implied
- time of impact longer
- impact force felt by child less
- some energy absorbed by spring **(1) (1)** 3

Why incorrect

Any two from:

- spring and wire are different
- length of "spring" is not equal to length of metal/material used
- area of "spring" is not the cross sectional area of the material used
- YM = $F \times 1/Ae$
- as 1 is longer, A is smaller value of YM above would be underestimate **(1) (1)** 2

[12]

34. <u>Area under graph</u>

It represents energy (stored) per unit volume/energy density **(1)** 1

<u>Volume of seat belt</u>

1.8×10^{-4} (m^3) **(1)** 1

<u>Kinetic energy</u>

Attempt to use ½ $m\upsilon^2$ **(1)**
= 15.8 (kJ)/15 800 (J) **(1)** 2

<u>Energy per unit volume</u>

8 or 9 × 10^7 J m^{-3} (88 MJ m^{-3})
OR
2nd answer divided by 1st with **correct unit (1)** 1

<u>Belt satisfactory</u>

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

[9]

35. <u>Energy conversions</u>

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]

<u>Calculation of theoretical extension of rope</u>

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]

[9]

36. Weight

mg

= 70 × 9.81

= 690 N **(1)** 1

Meaning of upthrust

There is an upward force **(1)**

in a fluid / equal to weight of air displaced **(1)** 2

Upthrust in newtons

Upthrust = mass of air displaced × g

= volume of air displaced × density of air × g **(1)**

= V × 1.29 × 9.81

= 12.65V **(1)** 2

Weight of helium

Volume × density × g

= 0. 18 $V g$ (= 1.77 V) **(1)** 1

Total volume of balloons

Upthrust = weight of man + weight of helium **(1)**

$12.65V = 690 + 0.18Vg$ **(1)**

$10.88V = 690$

$V = 63\ m^3$ [Allow ecf] **(1)** 3

Why viscous force can be ignored

Any two from:

- Quote of $6\pi\eta r\upsilon$
- υ is small

η is small **(1) (1)** 2

[11]

37. Meaning of terms

(i) Hard
Difficult to scratch or dent **(1)**

(ii) Brittle:
Breaks without plastic deformation / shatters / cracks **(1)**

(iii) Tough:
Can withstand deformation/dynamic loads/shock/impact **(1)**
Plastic **(1)** 4

How electrons can be used to examine arrangement of atoms

Any three from:

- electrons have wave properties
- beam of electrons directed at the specimen
- electrons diffract by spaces between atoms
- superposing constructively / series of dots seen
- pattern can be used to determine arrangement of atoms
- no (or irregular) pattern indicates an amorphous structure
- pattern seen on a fluorescent screen as electrons hit it **(1) (1) (1)** 3

[7]

38. 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

[4]

39. 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]

<u>Calculation of Young, modulus of brass</u>

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

<u>Graph</u>

[Mark alongside]

Straight line from origin to 46 N **(1)**

going through 34 N, 5.3 mm **(1)** 2

<u>Energy stored</u>

By finding area/area shaded/ ½ Fx up to 24 N **(1)** 1

<u>Second wire</u>

Less energy stored **(1)**

Less extension **(1)**

Smaller area under graph OR smaller ½ Fx **(1)** 3

[12]

40. <u>Dinosaur</u>

Weight on each leg = 2.5 × 10^5 N **(1)**
Area = 3.14 × 0.15^2 = 0.071 **(1)**
(Use of stress = F/A)
= 3.5 × 10^6 N m^{-2} OR consistent units **(1)**

Can stand up OK **(1)** 4

Compression of leg bone

Use of YM = stress/strain, e.g. $1 \times 10^{10} = 3.5 \times 10^{6}$/strain [Allow e.c.f] **(1)**

Strain = 0.00035 **(1)**

Compression = 1.4 mm **(1)** 3

Physics principles underlying claim

Would place all weight onto two legs [Fewer than 4]: this halves stresses **(1)**

Correct use of $F = mv/t$ OR ma **(1)**
As t small,
then v/t or a is (much) larger than 9.8 or F larger (than weight) **(1)** 3

Reduction of compressive forces

Upthrust/upward force acts **(1)**

Equal to weight of water displaced **(1)**

Reduces resultant downward force **(1)**

Upthrust will be significant compared with weight **(1)**

Swampy muddy water – larger density than water – larger U **(1)**

Decreases stresses calculated earlier **(1)** Max 3

[13]

41. Topic B -Solid Materials

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

[6]

42. Graph

Suitable readings from graph **(1)**

Gradient = 9.5 (no u.e) **(1)** 2

Equation

Use of $y = mx + C$ or $\upsilon = u + at$ **(1)**

leading to $\upsilon = 9.5t + 2$ **(1)** 2

Weight of ball

$W = mg$ = 0.25 x 9.81 = 2.5 N [2.4N] **(1)** 1

Validity of statement

$(F = 6\pi\eta r\upsilon) = 6\pi \times 0.040 \times 1.71 \times 10^{-5} \times 32$ **(1)**

$= 4.1 \times 10^{-4}$ (N) [No u.e.] **(1)**

[OR

$\upsilon = F /I\ 6\pi\eta r = 2.5 / 6\pi \times 0.040 \times 1.71 \times 10^{-5} = 1.9 \times 10^{5}$ m s^{-1} **(1)**
from graph υ 32 m s^{-1} **(1)**]

Therefore, viscous drag is not equal to the actual weight **(1)** 3

Completion of diagram

At least two streamlines drawn below ball **(1)**

At least one eddy drawn above ball **(1)** 2

[10]

43. Flow behaviour

Viscous **(1)** 1

Definitions

Any two from:

- elastic – **is** elastic **-** it returns to original length after stretching
- brittle – **not** brittle **-** it extends a lot before breaking
- hard – **not** hard **-** does not scratch other materials
- durable – **is** durable – can be repeatedly loaded/unloaded without change in properties
- stiff – **not** stiff – force vs extension graph has a low gradient **(2)** 2

Graph

Realisation that this is area under (top) graph **(1)**

29 – 32 squares **(1)**

× 5 × 10^{-3} N m **(1)**

= 0.15 – 0.16 N m (J) [allow ecf from wrong scaling factor / no.of squares] **(1)** 4

Work done by rubber band

e.g. less energy given out than stored, OR it can do less work than that required to stretch it, OR less than the work done stretching it **(1)** 1

Why tyres become hot

This energy difference is stored as internal energy (heat) in the tyre **(1)** 1

[9]

44. 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 → + 5 × 10^7 J m^{-3} **(1)** 3

Quench hardening

Heat and cool **(1)**

Rapid cool/plunge into water **(1)** 2

[9]

45. 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

[10]

46. Preferred airflow

Streamlined/laminar flow **(1)** 1

Diagrams

At least one continuous curve drawn above body of cyclist **(1)**

Turbulence shown behind cyclist **(1)** 2

Advantage

Less drag on cyclist behind **(1)**

OR airflow above bodies more streamlined

OR less work needs to be done by following cyclists

Material of bodysuit and explanation

Elastic **(1)**

e.g. stretch around body in use/nothing loose to cause turbulent flow **(1)** 2

Material of helmet and explanation

Tough **(1)**

e.g deforms plastically before breaking **(1)** 2

Deformation

(In crash **energy, deform s/absorbed by** helmet rather than causing injury **(1)** 1

[9]

47. Weight of submarine

Weight = mg = 2110 kg × 9.81 m s^{-2} = 20 700 N **(1)** 1

Submarine at rest

(i) 20 700 N [ecf from previous part] **(1)**

(ii) Forces in equilibrium, since submarine at rest **(1)** 2

Adjustment of weight of submarine

(i) Expel some water from/ add air to buoyancy tanks **(1)**

(ii) Use of $F = 6 \pi \eta \upsilon r$ **(1)**

$= 6 \pi \times 1.2 \times 10^{-3}$ kg m^{-1} s^{-1} × 0.5 m s^{-1} × 0.8 m

= 0.0090 N **(1)**

(iii) Flow not streamlined [or equivalent] **(1)** 4

Strain calculation

Use of Strain = stress ÷ E **(1)**

Strain = 1.1×10^6 Pa/3.0×10^9 Pa

$= 3.7 \times 10^{-4}$ **(1)** 2

[9]

48. Topic B – Solid Materials

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

[11]

49. Properties of gold

Malleable **(1)**

Ductile **(1)** 2

E.g. elastic, stiff 1

Definitions

Hard: material not readily scratched/indented **(1)**

Plastic behaviour: material remains in stretched/
deformed shape when force removed **(1)** 2

[5]

50. 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 $2.4 - 2.5 \times 10^{10}$ 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]

[10]

51. 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.]

[7]

52.

	Desirable	Not desirable	Reason
Elastic	**(1)**		Rod returns to original shape/position on unloading **(1)**
Brittle		**(1)**	Rod should not snap/shatter(when lifting a heavy fish) **(1)**
Hard	**(1)**		Rod will not scratch/dent with a large force **(1)**
Tough	**(1)**		Rod can withstand a sudden impact or dynamic load **(1)**

[Two marks for each line]

[8]

53. Crosses on graph:

P at end of straight line section **(1)**

Y – accept between P and maximum force value **(1)**   2

Young modulus calculation:

Calculation of stress (with force up to 1000 N)

$= \frac{F}{A} = \frac{1 \times 10^3 \text{ N}}{3 \times 10^{-5} \text{ m}^2} = 3.3 \times 10^7 \text{ (N m}^{-2}\text{)}$ **(1)**

Calculation of strain (with corresponding extension from straight line graph)

$= \frac{x}{L} = \frac{0.2 \text{ m}}{4.0 \text{ m}} = 0.05$ **(1)**

$E = \frac{\text{stress}}{\text{strain}} = \frac{3.3 \times 10^7 \text{ N m}^{-2}}{0.05} =$ 6.7×10^8 Pa **(1)** 3

–

Lines on graph:

(i) *L* graph: twice extension for given force [Ignore end] **(1)**

(ii) *A* graph: 3 × force for given extension [Ignore end] **(1)**

Reasoning based on rearranged equation e.g. $F = Eax/L$ and E constant implied in:

2*L* gives 2*x* for same *F* **(1)**

3*A* gives 3*F* for same *x* **(1)** 4

Energy stored in the rope:

Energy = ½ *Fx* = ½ × 1000 N × 0.2 m **(1)**

= 100 J **(1)** 2

Why a longer rope is less likely to break:

Any one point from:

- greater extension for same force
- larger area under graph
- more energy stored 1

[12]

54. 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

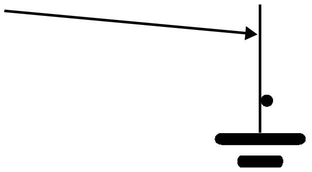
Vertical ruler with pointer on load/hanger OR closely aligned with ruler **(1)**

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]

55. 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 ($\times 10^8$ 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 $\frac{250 \text{ N}}{1.7 \times 10^{-6} \text{ m}^2}$ 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:

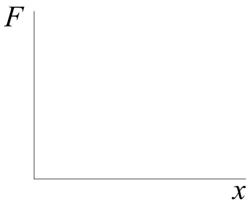
Determine strain = $1.1 \times (10^{-3})$ [OR 1.2] **(1)**

[Either by calculation or by reading off graph]

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

[10]

56. 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]

57. Speed of raindrop:

$\upsilon = u + at = 0 + 9.81 \text{ m s}^{-2} \times 0.2 \text{ s} = 1.96 \text{ m s}^{-1} \approx 2 \text{ m s}^{-1}$ **(1)** 1

Explanation:

Air resistance **(1)**
Drag force increases with (speed) **(1)**

So resulting accelerating force/acceleration drops **(1)**

Terminal velocity when weight = resistance (+ upthrust) **(1)** Max 2

Mass of raindrop:

Mass = volume × density

substitute $1.0 \times 10^{3} \text{ kg}^{-3} \times 4\pi \times (0.25 \times 10^{-3} \text{ m})^{3} /3$ **(1)**

6.5×10^{-8} (kg) **(1)** 2

Terminal velocity:

Viscous drag = weight **(1)**

$V_T = (6.54 \times 10^{-8} \text{ kg} \times 9.81 \text{ m s}^{-2}) / (6\pi \times 1.8 \times 10^{-5} \text{ kg m}^{-1} \text{ s}^{-1} \times 2.5 \times 10^{-4} \text{ m})$ **(1)**
[Allow e.c.f. for m and r]

So terminal velocity = 7.56 m s^{-1} **(1)** 3

Graph:

Line drawn which begins straight from (0,0) **(1)**
Then curves correctly **(1)**
to horizontal **(1)**
Scale on velocity axis **(1)**
[More than 2 sensible values and unit] Max 3

Explanation:

V_T increases (because of greater mass) **(1)** 1

[12]

58. How stiffness calculated:

Stiffness = force/deformation OR $k = F/x$ **(1)** 1

Difference :

Stiffness is for one particular sample **(1)**

Young modulus is for any sample of a material
using $E = Fx/A\Delta x$ **(1)** 2

Stress :

F/A = 30 kg × 9.8 m s^{-1} **(1)**
/$\pi(2 \times 10^{-2}$ m$)^2$ [$A = 1.26 \times 10^{-3}$ m^2] **(1)**
= 2.3×10^5 N m^{-2} **(1)** 3

Suitability of material:

The polymer is not so stiff/will undergo too much compression and **(1)**
will unbalance the body **(1)**

Young modulus smaller [OR different] **(1)** Max 1

Hence not suitable **(1)** 1

[8]

59. Use of definitions:

$$\text{Stress} \times \text{strain} = \frac{\text{force}}{\text{area}} \times \frac{\text{extension}}{\text{length}} \quad \textbf{(1)}$$

$$= \frac{\text{energy to stretch belt}}{\text{volume of belt}} \quad \textbf{(1) (1)}$$ 3

Use of graph to show energy stored per unit volume of seat belt material:

Energy stored = area under graph **(1)**

≈ 15 ½ (± 1) large squares (2 cm × 2 cm) **(1)**

≈ 15.5 × 8 × 10^6 J M^{-3} = 1.2×10^8 J m^{-3} **(1)** 3

(i) Kinetic energy = $\frac{1}{2}mv^2$ = ½ × 60 kg × (20 m$s^{-1})^2$ =12 000 J 1

(ii) Volume = energy ÷ energy per unit volume **(1)**

= 12 000 J ÷ 1.2×10^8 J m^{-3} = 1.0×10^{-4} m^3 **(1)** 2

(iii) Area = volume ÷ 2 m = 1.0×10^{-4} m^3 ÷ 2 m

= 5×10^{-5} m^2 **(1)**

so dimensions could be 50 mm × 1 mm **(1)** 2

[Width limits: 24 – 100 mm, thickness limits: 0.4 – 2 mm]

[11]

60. Meaning of *whorl:*

An eddy/circular flow/whirlpool OEP **(1)** 1

Diagram and description of flow patterns:

Laminar

At least 3 reasonably parallel and straight lines **(1)**

No abrupt change in direction/no whorls/eddies **(1)** 2

Turbulent flow

No order shown in the flow/small broken circular shapes or similar **(1)**

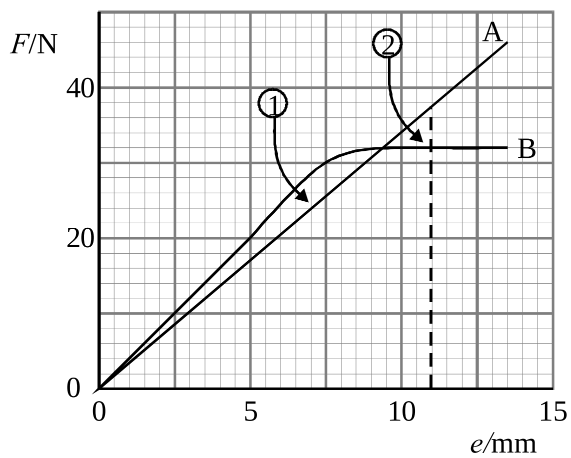
Mixing between layers of liquid/whorls/whirlpools/
eddies occur along the flow **(1)** 2

Explanation of statement in terms of energy transfers:

Kinetic energy, of motion of eddies becomes kinetic energy of molecules in liquid; overall kinetic energy reduces and flow slows/ordered kinetic energy → disordered kinetic energy **(1)** **(1)** 2

[7]

61.



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]

62. 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:

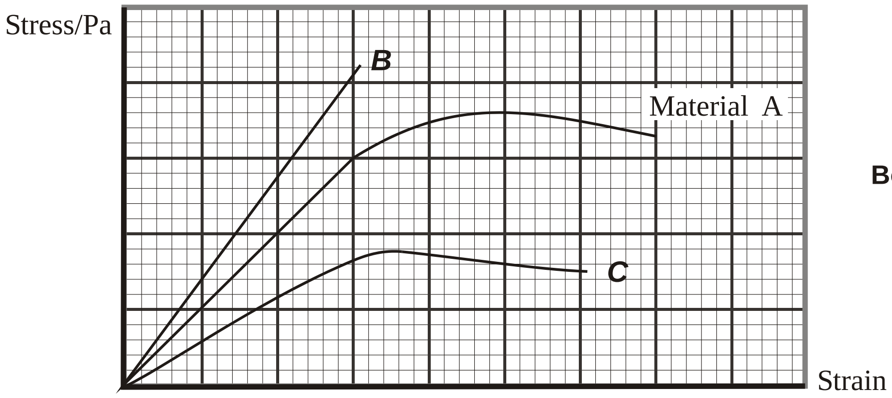
Sensible attempt at area up to 20 mm

Answer in range 250 → 270

0.26 J

[5]

63. 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]