1. (a) line of best fit is not straight / line of best fit does not go through origin; 1

(b) smooth curve;
that does not go outside the error bars; 2
Ignore extrapolations below n = 1.

(c) (i) absolute uncertainty in diameter D is ±0.08cm;
giving a relative uncertainty in D^2 of $2 \times \frac{0.08}{1.26} = 0.13$ ***or*** 13%; 2
Award **[2]** *if uncertainty is calculated for a different ring number.*

(ii) it is possible to draw a straight line that passes through the origin (and lies within the error bars);

or

the ratio of $\frac{D^2}{n}$ is constant for all data points; 1

(iii) gradient = k;
calculation of gradient to give 0.23 (*accept answers in range 0.21 to 0.25)*;
evidence for drawing or working with lines of maximum and minimum slope;
answers in the form $k = 0.23 \pm 0.03$; 4
Accept an uncertainty in k in range 0.02 to 0.04.
First marking point does not need to be explicit.

(iv) cm^2; 1

[11]

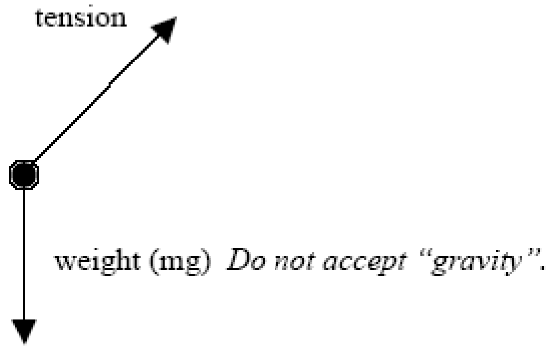
2. B

[1]

3. A

[1]

4. (a) (i) ***[1]*** each for correct arrow <u>and</u> (any reasonable) labelling; 2



*Award **[1 max]** for arrows in correct direction but not starting at the ball.*

(ii) no;
because the two forces on the ball can never cancel out / there is a net force on the ball / the ball moves in a circle / the ball has acceleration/it is changing direction;
*Award **[0]** for correct answer with no or wrong argument.* 2

(b) $T\left(=\frac{mg}{\cos 30°}\right) = 2.832\ \text{N}$;

$\frac{mv^2}{r} = T \sin 30°$;

$v = \left(\sqrt{\frac{Tr \sin 30°}{m}} = \sqrt{\frac{2.832 \times 0.33 \times \sin 30°}{0.25}}\right) = 1.4\ \text{m s}^{-1}$;

or

$T \cos 30° = mg$;
$T \sin 30° = mg$;

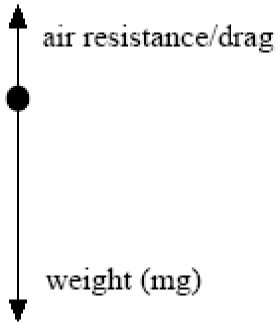
$T \sin 30° = \frac{mv^2}{r}$;

$v = (\sqrt{gr \tan 30°} = \sqrt{9.81 \times 0.33 \times \tan 30°}) = 1.4\ \text{m s}^{-1}$; 3

[7]

5. (a) the area under the curve; 1

(b) (i) arrows as shown, with up arrow <u>shorter</u>; 1



Do not accept "gravity".

(ii) drawing of tangent to curve at $t = 2.0$ s;
calculation of slope of tangent in range 3.6–4.4 m s^{-2}; 2
Award **[0]** *for calculations without a tangent but do not be particular about size of triangle.*

(iii) calculation of F = ma = 0.50 × 4 = 2N
$R(= mg - ma = 0.50 \times 9.81 - 0.50 \times 4) \approx 3$N; 2

(iv) the acceleration is decreasing;
and so R is greater;

or

air resistance forces increase with speed;
since speed at 5.0 s is greater so is resistance force; 2

(c) (i) loss of potential energy is $mg\Delta h = 0.50 \times 9.81 \times 190 = 932$ J;
gain in kinetic energy is $\frac{1}{2}mv^2 = \frac{1}{2}0.50 \times 25^2 = 156$ J;
loss of mechanical energy is 932–156;
≈ 780J 3

(ii) $mc\Delta\theta = 780$ J;
$\Delta\theta = \left(\frac{780}{0.5 \times 480}\right) \approx 3$K / 3 °C; 2

(iii) all the lost energy went into heating just the ball / no energy transferred to surroundings / the ball was heated uniformly; 1

[14]

6. B

[1]

pý**7.** A

[1]

8. A

[1]

9. (a) internal energy is the total kinetic and potential energy <u>of the molecules</u> of a body;
thermal energy is a (net) amount of energy transferred between two bodies;
at different temperatures; 3

(b) (i) $60 \times [\,\theta - 45]$; 1
Allow this correct expression to be equated to another (could be incorrect) expression. Award this mark (b)(i) if correct expression appears in (b)(iii).

(ii) $(2.0 \times 10^3 \times 29) = 5.8 \times 10^4$ J; 1

(iii) $60 \times [\theta - 45] = 5.8 \times 10^4$;
$\theta = 1000$°C; (*allow 1010°C to 3 sig fig)* 2

[7]

10. D

[1]

11. A

[1]

12. (a) (i) the amplitude is constant; 1

(ii) period is 0.20s;

$$a_{\max} = \left(\left[\frac{2\pi}{T}\right]^2 x_0 = 31.4^2 \times 2.0\times10^{-2}\right) = 19.7 \approx 20 \text{ m s}^{-2};$$

Award ***[2]*** *for correct bald answer and ignore any negative signs in answer.*

(iii) displacement at t = 0.12 cm is (–)1.62 cm;

$$v\left(=\frac{2\pi}{T}\sqrt{x_0{}^2 - x^2}\right) = 31.4\sqrt{(2.0\times10^{-2})^2 - (1.62\times10^{-2})^2} = 0.37 \text{ m s}^{-1};$$

Accept displacement in range 1.60 to 1.70 cm for an answer in range 0.33 m s^{-1} *to 0.38 m s*$^{-1}$.

or

$$v_0 = \frac{2\pi}{T}x_0 = 0.628 \text{ m s}^{-1};$$

$$|v| = \left(\left|-v_0 \sin\left[\frac{2\pi}{T}t\right]\right| \Rightarrow |v| = |-0.628\sin[31.4\times0.12]| = |0.37|\right) = 0.37 \text{ m s}^{-1};$$

or

drawing a tangent at 0.12 s;
measurement of slope of tangent; 2
Accept answer in range 0.33 m s^{-1} *to 0.38 m s*$^{-1}$.

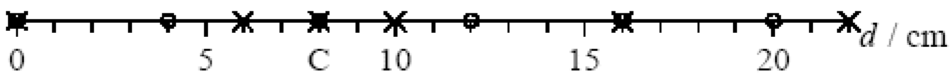
(iv) to the right; 1

(b) (i) use of $f = \frac{1}{T}$;

and so $f\left(=\frac{1}{0.20}\right) = 5.0$ Hz; 2

(ii) wavelength is 16 cm;
and so speed is $v(= f\lambda = 5.0 \times 0.16) = 0.80$ m s^{-1}; 2

(c) (i) points at 0, 8 and 16 cm stay in the same place;
points at 4 and 20 cm move 2 cm to the right;
point at 12 cm moves 2 cm to the left; 3



(ii) the point at 8 cm; 1

[14]

13. C

[1]

14. (a) (i) $L = 4\lambda$ ***or*** $\lambda = \frac{L}{4}$; 1

(ii) two antinodes labelled;
with separation of integral number of wavelengths; 2

(b) $f\lambda$ is the speed of the wave;
standing wave formed by interference of an incident and a reflected progressive wave;
speed is the speed of this progressive wave; 3

[6]

15. C

[1]

16. A

[1]

17. C

[1]

18. C

[1]

19. D

[1]

20. A

[1]

21. C

[1]

22. (a) $\frac{1}{2}$ th mass of an <u>atom</u> of carbon–12/^{12}C; 1

(b) (254.1001 × 931.5 =) 236.7(GeV c^{-2}); (*only accept answer in GeV c^{-2}*) 1

(c) (i) proton / hydrogen nucleus / H^{+} / $^{1}_{1}$H/$^{1}_{1}$p ; 1

(ii) Δm = (16.8383 – [3.7428 + 13.0942] =) 0.0013(GeV c^{-2});
energy required for reaction = 1.3 (MeV);
KE of $^{17}_{8}$O + **X** = (7.68 – 1.3 =) 6.4 (6.38) MeV; (*allow correct answer in any valid energy unit)* 3

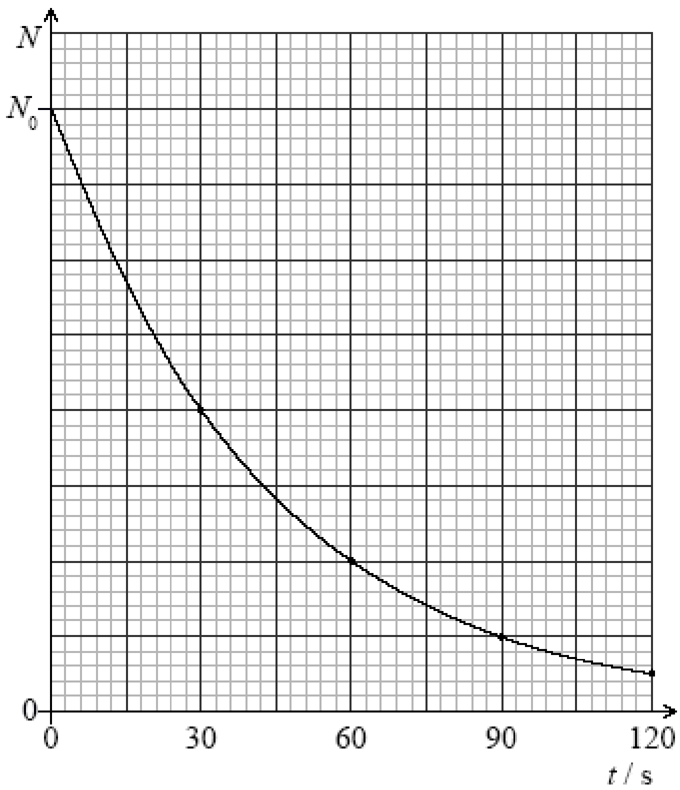
(d) (i) (nuclei of same element with) same proton number,
different number of neutrons / *OWTTE*; 1

(ii) the time for the activity of a sample to reduce by half / time
for the number of the radioactive nuclei to halve from original value; 1

(e) scale drawn on t axis; *(allow 10 grid squares = 30 s or 40 s)*

smooth curve passes through $\frac{N_0}{2}$ at 30 s, $\frac{N_0}{4}$ at 60 s, $\frac{N_0}{8}$

at 90 s, $\frac{N_0}{16}$ at 120 s (to within 1 square); (*points not necessary)* 2



[10]

23. (a) ejection of electron from metal surface following absorption of em radiation/photon; 1

(b) (i) energy of one photon = $6.67 \times 10^{-34} \times 8.7 \times 10^{14}$(= 5.8×10^{19} J);

number of electrons released from surface per second = $\frac{9.0\times10^{-6} \times1.1\times10^{-3}}{5.8\times10^{-19}}$

= 1.7×10^{10};

current = $1.7 \times 10^{10} \times 1.6 \times 10^{-19}$;

= 2.7 nA 3

(ii) 2.4 eV ***or*** 3.9×10^{-19} J; 1

[5]

24. (a) (i) $h = \frac{v^2}{2g}$;

to give $h = 3.2$ m; 2

(ii) 0.80 s; 1

(b) time to go from top of cliff to the sea = 3.0 – 1.6 = 1.4 s;

recognize to use $s = ut + \frac{1}{2}at^2$ with correct substitution,

$s = 8.0 \times 1.4 + 5.0 \times (1.4)^2$;
to give $s = 21$ m; 3

Candidates might find the speed with which the stone hits the sea from $v = u + at$, (42 m s^{-1}) and then use $v^2 = u^2 + 2as$.

[6]

25. C

[1]

26. (a) (i) *internal energy:*
the total (potential energy and) kinetic energy of the (copper) molecules/ atoms/particles;

or

amount of stored energy in the copper;

heating:
the (non-mechanical) transfer of energy;
(from the surroundings/source) to the copper; 3

(ii) $c = \frac{\Delta Q}{m\Delta T}$;

$= \left[\frac{1.2 \times 10^3}{0.25 \times 20}\right] = 240 \text{ J kg}^{-1} \text{ K}^{-1}$; 2

(b) (i) $Q = \Delta U + W$
$Q = +623$;
$W = +249$;
$\Delta U = [623 - 249] = 374$ J; 3

(ii) $C = \frac{Q}{\Delta T}$;

$= 20.8 \text{ J K}^{-1}$; 2

(c) less;
because (at constant volume) all the thermal energy supplied goes to increasing the internal energy;
and so the increase in temperature in the constant volume case is greater; 3

[13]

27. C

[1]

28. (a) (i) proper length is measured by observer at rest relative to object / Carrie is at rest relative to spaceship; 1

(ii) $\gamma = \left(\frac{100}{91} =\right) 1.1$;

evidence of algebraic manipulation *e.g.* $\frac{v^2}{c^2} = 1 - \frac{1}{1.1^2}$ to give

$v = 0.42$ c;
≈ 0.4 c 2

(b) travel time measured by Peter = (10 × γ =) 11 years;
4.6 ly ***or*** 4.4 ly *(if 0.4 c used)*; 2

(c) moves away at 0.42 c so is 4.2 ly away when signal emitted; (*allow ECF from* (*a*)(*ii*))
signal travel time t where $ct = 4.2 + 0.42ct$;
7.2 y ***or*** 7 y (*if 0.4 c used)*; 3

[8]

29. (a) *particle A*: (the total energy is) the rest mass energy;
particle B: (the total energy is) the rest mass energy plus the kinetic energy;
Do not accept $E^2 = p^2c^2 + m_0^2c^4$ *as answer.* 2

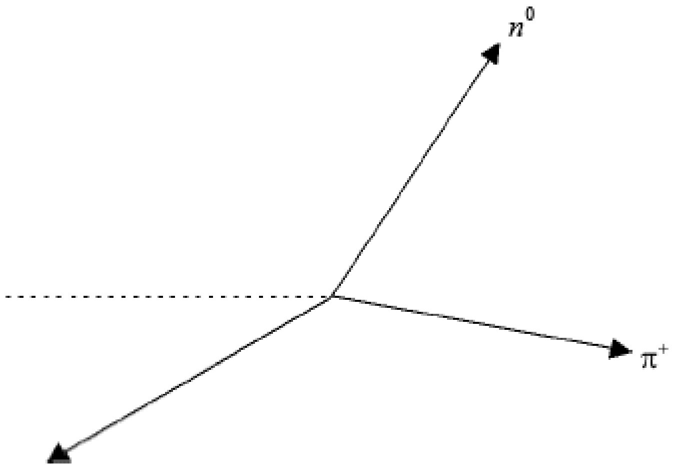
(b) (i) $= \frac{0.960 + 0.960}{1 + 0.960^2}$;
= 0.999c; 2

(ii) γ = 3.57;
$E = (\gamma m_0 c^2 =)$ 3.57 × 938 MeV;
= 3.35 GeV 2

(c) (i) energy before collision = (3.35 + 3.35 =)6.70 GeV;
energy of $p + n$ = (6700 – 502 =) 6.20 GeV; 2

(ii) $502^2 = p^2c^2 + 140^2$;
p = 482 Me V c^{-1}; 2

(d)



1

as shown; *(accept between 7 o'clock and 9 o'clock)*

[11]