1. D **[1]**

2. D **[1]**

3. C **[1]**

4. D **[1]**

5. A **[1]**

6. B **[1]**

7. B **[1]**

8. (a) (i) Use of $E_k = \frac{1}{2}mv^2$

Correct answer [0.44] **(1)**

<u>Example of calculation:</u>

$$\frac{E_{20}}{E_{30}} = \frac{(20)^2}{(30)^2} = 0.44$$ 1

(ii) Collision energy is more than halved **(1)**, so claim is justified **(1)** 2

(b) Calculation of collision energy [60 kJ] **(1)**
Use of W = Fx **(1)**
Correct answer [500 kN] **(1)**

Example of calculation:

$E_k = \frac{1}{2}mv^2 = 0.5 \times 1200 \times (10)^2 = 60{,}000$ J

W = Fx so $F = \frac{W}{x} = \frac{60{,}000}{0.12m} = 500kN$ 3

(c) Crumple zone increases displacement of car during crash so collision force is reduced **or** crumple zone increases collision time and so decreases the acceleration (and force) **(1)** 1

[7]

9. (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)**

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

[6]

10. (a) Use of $\frac{4}{3}\pi r^3 \rho$ **(1)**

Correct answer [1.44×10^{-6} kg] **(1)**

Example of calculation:

$m = \frac{4}{3}\pi r^3 \rho = \frac{4}{3}\pi (0.7 \times 10^{-3})^3 \times 1000 = 1.44 \times 10^{-6}$ kg 2

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

Example of calculation:

$$v = \frac{mg}{6\pi\eta r} = \frac{1.44 \times 10^{-6} \times 9.81}{6\pi \times 8.90 \times 10^{-4} \times 0.7 \times 10^{-3}} = 1.2\ \text{m s}^{-1}$$ **(2)** 2

[4]

11. (a) Reference to free fall whilst bungee is slack
Idea of KE increasing as GPE is transformed
Idea of work being done against frictional forces
GPE converted into EPE (and KE) once bungee stretches
KE (and GPE) converted into EPE beyond equilibrium point
At lowest point all of the KE has been converted into EPE Max 4

(b) Use of F = m a **(1)**
Correct answer [6.25 m s^{-2}] **(1)**

Example of calculation:

$$a = \frac{F}{m} = \frac{785 - 285}{80} = 6.25\ \text{m s}^{-2}$$ 2

[6]

12. (a) Use of s = ut + ½ at^2 **(1)**
Correct answer [1.1 s] **(1)**

Example of calculation:

$$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 1}{1.6}} = 1.1\ \text{s}$$ 2

(b) Use of v = u + at **(1)**
Correct answer [1.8 m s^{-1}] **(1)**

Example of calculation:
$v = u + at$ = 1.6 × 1.1 = 1.8 m s^{-1} 2

[4]

13. (a) Use of v sin θ **(1)**
Correct answer [4.2 ms-1] **(1)**

Example of calculation:
v sin θ = 10 sin 25 = 4.2 m s^{-1} 2

(b) Use of at v = u + at **(1)**
Correct answer [0.43 s] **(1)**

<u>Example of calculation:</u>
v = u + at 0 = 4.2 – 9.8 × t

$t = \frac{4.2}{9.81}$ = 0.43 s 2

(c) Use of $s = ut + \frac{1}{2}at^2$ **or** $s = \frac{(u+v)}{2}.t$ **(1)**
Correct answer [0.90 m] **(1)**

<u>Example of calculation:</u>

$s = ut + \frac{1}{2}at^2 = 4.2 \times 0.43 - 0.5 \times 9.81 \times (0.43)^2 = 1.81 - 0.91 = 0.90\text{ m}$

or $s = \frac{(u+v)}{2}.t = \left(\frac{4.2+0}{2}\right) \times 0.43 = 0.90\text{ m}$ 2

[6]

14. (a) Idea that no resultant force acts (e.g. forces are balanced / cancel) **(1)** 1

(b) Use of w = mg **(1)**
Correct answer [640 N] **(1)**

<u>Example of calculation:</u>
w = mg = 65 × 9.81 = 638 N 2

(c) (i) Tension in rope marked **(1)**
Push from rock face marked **(1)**
Weight marked **(1)** 3

(ii) Use of T = w.sin40 **(1)**
Correct answer [410 N] **(1)**

Example of calculation:
T = w.sin40 = 640 × sin40 = 410 N 2

(d) Spelling of technical terms must be correct and the answer must be organised in a logical sequence **(QWC)**
Rigid/stiff exterior to resist deformation under small forces **(1)**
Must undergo plastic deformation under large forces **(1)**
so that collision energy can be absorbed **(1)**
Low density so that helmet is not uncomfortably heavy **(1)** 4

[12]

15. D

[1]

16. Add missing information

For three correct responses in the 'vector or scalar' column **(1)**
For the 'base unit' column:
3 correct responses **(2)**
2 correct responses **(1)** 3

Quantity	Base unit	Vector or scalar
	m	vector
	kg m^2 s^{-2}	scalar
	kg m^2 s^{-3}	scalar
	kg m s^{-1}	vector

[3]

17. (a) (i) Describe motion

Constant / uniform acceleration or (acceleration of) 15 m s^{-2} **(1)**

(Followed by) constant / uniform speed / velocity (of 90 m s^{-1}) **(1)** 2

(ii) Show that distance is approximately 800 m

Any attempt to measure area under graph or select appropriate equations of motion required to determine **total** distance **(1)**

Correct **expression** or **value** for the area under the graph between either 0-4 s [240 m] or 4-10 s [540 m] **(1)**

Answer : 780 (m) **(1)**

Eg distance $= 60 \text{ m s}^{-1} \times 4 \text{ s} + 90 \text{ m s}^{-1} \times 6 \text{ s}$
$= 240 \text{ m} + 540 \text{ m}$
$= 780 \text{ (m)}$

Eg distance in first 4 s

$$s = \frac{v+u}{2}t = \frac{90 \text{ m s}^{-1} + 30 \text{ m s}^{-1}}{2} 4 \text{ s} = 240 \text{ m}$$

Distance in final 6 s

$s = ut = 90 \text{ m s}^{-1} \times 6 \text{ s} = 540 \text{ m}$

Total distance = 240 m + 540 m = 780 (m) 3

(b) Sketch graph

Graph starts at 760 m – 800 m/their value and initially shows distance from finishing line decreasing with time **(1)**

The next two marks are consequent on this first mark being awarded

Curve with increasing negative gradient followed by straight line **(1)**

Graph shows a straight line **beginning** at coordinate (4 s, 540 m) **and** finishes at coordinate (10 s, 0 m) **(1)** 3

[8]

18. (a) (i) Give expression

$W = R + F$ **(1)** 1

(ii) Complete statements

……. surface / ground **(1)**

……. Earth (¯s mass) [Only accept this answer] **(1)**

……. gardener(¯s hands) / hand(s) **(1)** 3

(b) (i) Add to diagram

Line inclined to the vertical pointing to the left and upwards **(1)** 1

(ii) Explain change in direction and magnitude

The force (at X) will have a magnitude greater than F or the force (at X) must increase. **(1)**

This is because the wheelbarrow / it has to be lifted / tilted/ supported/ held up (by the vertical component) **(1)**

And also because the wheelbarrow / it has to be moved (forward by the horizontal component) **(1)** 3

[8]

19. (i) appreciation that area of (first) rectangle / *at* gives speed υ **(1)**

$\Delta\upsilon_{accel} = (3 \text{ m s}^{-2})(8 \text{ s})$ / 30 small squares each worth 0.8 m s^{-1} **(1)**

$\Rightarrow 24 \text{ m s}^{-1}$ **(1)**

(ii) appreciation that area of second is of same area as first / $\Delta\upsilon_{decel} = (4 \text{ m s}^{-2})(6 \text{ s})$ [negative idea *not* needed] **(1)** 4

(iii) use of $P = IV$ / $E = IVt$ **(1)**

use of $P = Fv$ / $E = Fvt$ **(1)**

(3000 N)v = (96 A)(750 V) / equating the Ps or Es **(1)**

$\Rightarrow v = 24 \text{ m s}^{-1}$ 3

[7]

20. (a) Comment on use of weighing

Clear statement correctly identifying weight or mass (or their units)
e.g. kg a unit of mass, not weight **(1)** 1

(b) Calculation to check statement

Use of equation of motion to show time or distance **(1)**
Answer to 2 sig figs [120 m or 4.5 s] [no ue] **(1)**

Example of calculation:

$s = ut + \frac{1}{2}at^2$
$s = 0 + \frac{1}{2} \times 9.81 \text{ m s}^{-2} \times (5\text{s})^2$ OR $100 = 0 + \frac{1}{2} \times 9.81 \text{ m s}^{-2} \times t^2$
$s = 123$ m OR $t = 4.5$ s 2

(c) Calculation of kinetic energy
Either
Use of equation(s) of motion which allow(s) v2 or v to be found **(1)**
Recall of ke = $\frac{1}{2} mv^2$ **(1)**
Answer [69 000 J] **(1)**

OR
Recall of $E_p = mgh$ **(1)**
Substitution **(1)**
Answer [69 000 J] **(1)**

Example of calculation:
$v^2 = u^2 + 2as$
$v^2 = 0 + 2 \times 9.81 \text{ m s}^{-2} \times 100$ m
$v^2 = 1962 \text{ m}^2 \text{ s}^{-2}$
ke = $1/2\, mv^2$
= 69 000 J (68 670 J)

OR
gpe = mgh
gpe lost = 70 kg × 9.81 N kg^{-1} × 100 m
gpe lost = 69 000 J (68 670 J)
[so ke = 69 000 J because ke gained = gpe lost] 3

[6]

21. (a) Formula for C6

$v = u + at$ OR $v = 10.7 - (9.81 \times 0.2)$ [units need not be given]
OR C6 = C5 – 9.81*A6 **(1)** 1

(b) Explain B5 to B16 constant
g affects vertical motion only / no horizontal force **(1)** 1

(c) Significance of negative values
The ball moving downwards **(1)** 1

(d) (i) Completion of diagram
Vertical arrow has 6.8 added, horizontal arrow has 10.7 added **(1)** 1

(ii) Calculation of velocity at time $t = 0.4$ s

Use of Pythagoras

Answer for magnitude of v [12.7 m s^{-1}] [ecf from diagram]

Use of trigonometrical function [ecf from magnitude]

Answer for direction [32.4°] [ecf from diagram]

Example of answer:
$v^2 = (6.8 \text{ m s}^{-1})^2 + (10.7 \text{ m s}^{-1})^2$
$v = 12.7 \text{ m s}^{-1}$
$\tan\theta = 6.8 \text{ m s}^{-1} \div 10.7 \text{ m s}^{-1}$
$\theta = 32.4°$

[For scale drawing– components drawn correctly to scale**(1)**, resultant shown correctly **(1)**, answer for v ± 0.5 m s^{-1} **(1)**, angle to ± 2°**(1)**] 4

(e) (i) Calculation of components for new angle

Answer for vertical component [8.7 m s^{-1}] **(1)**
Answer for horizontal component [12.5 m s^{-1}] **(1)**

[1 mark only if answers reversed]

Example of answer:
vertical component = $v \sin\theta = 15.2 \text{ m s}^{-1} \times \sin 35° = 8.7 \text{ m s}^{-1}$
horizontal component = $v \cos\theta = 15.2 \text{ m s}^{-1} \times \cos 35° = 12.5 \text{ m s}^{-1}$ 2

(ii) Suggest reason for greater distance

Examples – greater horizontal component of velocity; easier to throw at higher speed closer to the horizontal; launching from above ground level affects the range; force applied for longer; more force can be applied **(1)** 1

[11]

22. (a) Show that the speed is approximately 30 m s^{-1}

Sets $E_K = mg\Delta h$ **(1)**

Substitution into formulae of 9.8**(1)** m s^{-2} or 10 m s^{-2} and 50 m. **(1)**
[Also allow substitution of 60 m for this mark]
Answer [31 m s^{-1}. 2 sig fig required. No ue.] **(1)**

Eg $\frac{1}{2}mv^2 = mg\Delta h$

$v^2 = 2gh = 2 \times 9.81 \text{ m s}^{-2} \times 50 \text{ m}$

$v = 31.3$ (m s^{-1}) Answer is 31.6 m s^{-1} if 10 m s^{-2} is used

Also allow the following solution although this is not uniformly accelerated motion.

$v^2 = u^2 + 2as$

$v^2 = 0 + 2 \times 9.81 \text{ m s}^{-2} \times 50\text{m}$

$v = 31.3$ (m s^{-1}) 3

(b) (i) Average braking force [ecf value of vl

For the equation $\frac{1}{2}mv^2$ **(1)**

[give this mark if this is shown in symbols, words or values]
Attempts to obtain the difference between two energy values that relate to with and without the braking system or for setting an energy value equal to
Force × 80 m **(1)**
Answer [800 N if 30 m s^{-1} used; If 31.3 m s^{-1} or 31.6 m s^{-1} are used accept answers in the range 1100 N – 1300 N; If 34 m s^{-1} is used answer is 2000 N] **(1)**

Eg $(367875 \text{ J})_{\text{ke after free fall}} - (273375 \text{ J})_{\text{ke at 27m/s}} = 94500 \text{ J}$

$F \times 80 \text{ m} = 94500 \text{ J}$

$F = 1180 \text{ N}$

Also allow the following solution.

Selects $v^2 = u^2 + 2as$ and $F = ma$ **(1)**
Attempts to obtain the difference between two forces / accelerations that relate to with and without the braking system. **(1)**
Answer [800 N if 30 m s^{-1} used; If 31.3 m s^{-1} or 31.6 m s^{-1} are used accept answers in the range 1100 N – 1300 N; If 34 m s^{-1} is used answer is 2000 N] **(1)**

Eg Braking force = (–) $750\left(\frac{(31.3\,\mathrm{m\,s^{-1}})^2 - (0)^2}{2 \times 80\,\mathrm{m}} - \frac{(27\,\mathrm{m\,s^{-1}})^2 - (0)^2}{2 \times 80\,\mathrm{m}}\right)$
= (–) 1175 N 3

(ii) <u>Why braking force of this magnitude not required</u>
Air resistance (would also act to reduce speed) **(1)**
Or Number and/or mass of passengers will vary
Or Friction [ignore references to where forces act for this mark. A bald answer ie 'friction' is acceptable]
Or Accept some (kinetic) energy is transferred [not 'lost'] to thermal energy [accept heat] (and sound)
Or Work is done against friction 1

(iii) Explain whether braking force would change
QWOC: **(1)**
Either
The kinetic energy will be greater (because the mass of the passengers has increased) **(1)**
(hence) more work would have to be done(by the braking system) **(1)**
(The distance travelled, P to Q, is the same therefore) greater (braking) force is required **(1)**

Or
Momentum (of the truck) will be greater (because the mass of the passengers has increased) **(1)**
Rate of change of momentum will be greater or [allow] the time taken to travel (80 m) will be the same [if the candidate writes ‘constant’ allow this if you feel they mean ‘same’] **(1)**
(Therefore) greater (braking) force is required **(1)**

Or
(Allow) Change in velocity and the time taken (for the truck to travel 80 m) will be the same or (Average) deceleration / acceleration will be the same [accept ‘constant’ if they mean ‘same’. Also accept any fixed value for acceleration eg 9.8 m s^{-2}] (for greater mass of passengers) **(1)**
(since) F = ma and mass has increased **(1)**
A greater (braking) force is required **(1)** 4

[11]

23. (a) (i) Additional height
Answer [5 (m)] **(1)**

Eg distance = area of small triangle = 0.5 × 1 s × 10 m s^{-1} = 5 m 1

(ii) Total distance travelled [Allow ecf of their value]
Distance travelled between 1 s and 4s [45 m] **(1)**
Answer [50 m] **(1)**

Eg distance fallen = area of large triangle
= 0.5 × 3 s × 30 m s^{-1}
= 45 m
total distance =45m + 5m = 50m 2

(b) Objects displacement
40 m **(1)**
Below (point of release) or minus sign **(1)**
[Ecf candidates answers for additional height and distance ie use their distance – 2 × their additional height] 2

(c) Acceleration time graph
Line drawn parallel to time axis extending from t = 0 **(1)**
[Above or below the time axis]
The line drawn parallel to the time axis extends from 0 s to 4 s **(1)**
[If line continues beyond or stops short of 4 s do not give this mark]
Acceleration shown as minus 10 m s^{-2} **(1)**
[This mark is consequent on the second mark being obtained] 3

[8]

24. (a) Account for the force
When the flea pushes (down) on the surface the surface
[accept ground, not earth] pushes back / upwards **(1)**
with an equal (magnitude of) force **(1)**
[A statement of Newton's 3rd law gets no marks – it must be applied] 2

(b) (i) Show acceleration is about 1000 m s^{-2}
Either Selects $v^2 = u^2 + 2as$ **Or** two appropriate equations of motion **(1)**
Correct substitution into the equation **(1)**
[Do not penalise power of ten error. Allow 0.4 mm and 0.9 m s^{-1} substitutions for this mark.]
Answer [in range (1025 – 1060) m s^{-2}, must be given to at least 3 sig fig. No ue] **(1)**

Eg $(0.95 \text{ m s}^{-1})^2 = 2 \times a \times 0.44 (\times 10^{-3})$ m
a = 1026(ms^{-2})

Or
Sets changing Ke = work done (as legs expand) **(1)**
Correct substitution into the equation **(1)**
Answer [1030 m s^{-2}, must be given to at least 3 sig fig. No ue] **(1)**

Eg ΔKe = average F × height
$\frac{1}{2}$ m $(0.95 \text{ m s}^{-1})^2 = \text{m} \times a \times 0.44 \times (10^{-3})$ m
a = 1026 (m s^{-2}) 3

(ii) Resultant force
(Allow ecf)
Answer [4.1×10^{-4} N. 4(.0) $\times 10^{-4}$ N if 1000 m s^{-2} used. Ue.] **(1)**

Eg Force = 4×10^{-7} kg × 1030 m s^{-2} = 4.12×10^{-4} N 1

(c) (i) What constant force opposes upward motion
The weight of / gravitational attraction / gravitational force / gravitational pull / force of gravity / accept pull of earth (on flea) **(1)**
[Not just 'gravity'. Accept bald answers ie 'weight'] 1

(ii) Change in height

Selects $s = (\frac{v+u}{2})t$ **or** uses v = u + at (to find a) then either

$v^2 = u^2 + 2as$ or $s = ut + \frac{1}{2}at^2$ **(1)**

Correct substitution **(1)**
[If two equations are used ‘a’ is negative]
Answer [4.4(2) cm. Do not accept 4.5 cm] **(1)**
[Nb the correct answer can be obtained from omitting ut and using +a – this would get 1 /3]

[Use of $s = ut + \frac{1}{2}at^2$ or $v^2 = u^2 + 2as$ with lal = g and u = 0.95 m s^{-1} will get 1/3 if no attempt is made to find ‘a’. For candidates who use a = 1000 m s^{-2} from (b)(i) give no marks]

Eg $s = (\frac{0 + 0.95 \text{ m s}^{-1}}{2})\, 9.3 \times 10^{-2}$ s
= 0.0442 m

Or

$a = -\frac{0.95 \text{ m s}^{-1}}{0.93 \times 10^{-2} \text{ m}} = -10.2 \text{ m s}^{-2}$

$s = 0.95 \text{ m s}^{-1} \times 9.3 \times 10^{-2} \text{ s} + \frac{1}{2} - 10.2 \text{ m s}^{-2} (9.3 \times 10^{-2} \text{ s})^2$

= 0.0442 m
or $0 = (0.95 \text{ m s}^{-1})^2 + 2 - 10.2 \text{ m s}^{-2}$ s hence s = 0.0442m 3

[10]

25. (a) (i) Explain upward force is about 0.1 N

Correct answer for force to 2 s.f. [(–)0.092 N] [no ue] **(1)**

Explanation that negative means upwards **(1)**

Example of calculation:
W = mg
= 0.0094 kg × 9.81 N kg^{-1}
= –0.092 N 2

(ii) Label balloon diagram ands show that weight is about 0.07 N

Tension + arrow **(1)**
Weight + arrow **(1)**
Weight = 0.068 N **(1)**

(Do not accept ‘gravity’ for ‘weight’) 3

(b) (i) <u>Label 2^{nd} balloon diagram</u>

Weight **(1)**
Air resistance **(1)** 2

(ii) <u>Expression for vertical component</u>

$T \cos 43°$ / upthrust – weight / 0.16 N – 0.068 N / **(1)**
(accept T sin 47°) 1

(iii) <u>Calculate tension in string</u>

Correct expression showing vertical forces on balloon **(1)**

Correct answer (0.13 N) **(1)**

Example of calculation:
$T \cos 43° = 0.16 \text{ N} - 0.068 \text{ N}$
$T \cos 43° = 0.092 \text{ N}$
$T = 0.13 \text{ N}$ 2

(c) <u>Explain change in angle</u>

Air resistance increases **(1)**

Horizontal component of tension increases (while vertical component stays the same) **(1)** 2

[12]

26. (a) <u>Show that E_p lost is about 37 000 J</u>

Recall of $E_p = mgh$ **(1)**

Correct answer to 3 s.f. [37 300 J] [no ue] **(1)**

Example of calculation:
$E_p = mgh$
$E_p = 760 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 5 \text{ m}$
$= 37278 \text{ J}$ 2

(b) (i) <u>Show that E_k of projectile and counterweight is about 26 000 J</u>

Correct calculation of E_p gained by projectile [10 800 J] [no ue] **(1)**

Correct calculation of E_k to 3 s.f. [26 200 J] [no ue] **(1)**

Example of calculation:
E_p gained by projectile $= 55 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 20 \text{ m} = 10\,800 \text{ J}$
$E_k = 37\,000 \text{ J} - 10\,800 \text{ J}$
$= 26\,200 \text{ J}$ 2

(ii) State assumption

All lost gpe → ke of projectile and counterweight
OR Mass of moving arms negligible
OR No loss of energy to /work done against friction/air resistance **(1)** 1

(iii) Explain term 1/2 × 760 kg × (v/4)2

2 points from:

E_k of counterweight
$E_k = ½ mv^2$
Counterweight has speed v/4
Due to lever arm ratio 1:4 **(2)** 2

(c) (i) Calculate time of flight

Use of $s = ut + ½ at^2$ **(1)**

Correct answer [2.1 s]

Example of calculation:
for vertical motion, $s = ut + ½ at^2$
21 m = 0 + ½ × 9.81 m s^{-2} × t^2 **(1)**
$t = \sqrt{(21 \text{ m} \times 2 / 9.81 \text{ m s}^{-2})}$
t = 2.07 s **(1)** 2

(ii) Calculate distance travelled

Recall of $s = vt$ **(1)**

Correct answer [46.6 m] **(1)**

Example of calculation
horizontal motion, $s = vt$
= 22.5 m s^{-1} × 2.07 s
= 46.6 m **(1)** 2

[11]

27. (a) Force arrow diagram:
Weight and upthrust correctly labelled **(1)**
Tension in string shown downwards **(1)** 2

(b) Upthrust on balloon:
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) Airflow diagram:
Diagram showing at least three continuous lines around the balloon **(1)** 1

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

(d) (i) Word equation:
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:
$v = (0.18 - 0.17) / (6\pi \times 1.8 \times 10^{-5} \times 0.15)$
= 202 m s^{-1} 3

(iii) Comment:
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]

28. (a) Displacement and distance?

Displacement has direction distance doesn't or displacement is a vector, distance is a scalar or an explanation in terms of an example. **(1)** 1

[Candidates who describe displacement as "measured from a point" but do not mention direction or equivalent do not get this mark]

(b) (i) Position of train relative to A

300 m **(1)**

West (of) or a description
[Do not accept backwards, behind or negative displacement] **(1)** 2

(ii) <u>Velocity against time graph</u>

Constant velocity shown extending from t = 0, positive / negative **(1)**
[Above mark awarded even if graph does not reach or stop at t = 4 min]

Constant velocity shown beginning at t = 4 min and ending at t =8 min, negative/positive (respectively) **(1)**

Values 2.5 (m s^{-1}) or 3.75 (m s^{-1}) or 3.8 (m s^{-1}) seen
[either calculated or on graph] **(1)**

Both values [allow their values] correctly plotted using a scale **(1)**
[Only give this fourth mark if marking points 1 and 2 are correct.
Also a clear scale must be seen eg 1, 2, 3, –1, –2, –3.
The plot must be accurate to about half a small square.] 4

[7]

29. (a) (i) <u>Speed of spade at impact with soil</u>

Selects correct equation ie v = u + at or 2 appropriate equations **(1)**

Correct substitution into equation **(1)**
[Accept a substitution of –9.81 m s^{-2}, only if it fits **their defined** positive convention]

Answer
[to at least 2 sig. fig., 2.8 m s^{-1}, no unit error. **(1)**
Allow use of g = 10 m s^{-2} giving 2.9 m s^{-1}]
[Check that all working is correct for marks 2 and 3]

Eg v = 9.81 m s^{-2} × 0.29 s
= 2.84 m s^{-1}
[This would get 3 marks even though the equation is not stated]

[Allow 2/3 for reverse argument – gives t = 0.3(05) s with 9.81 m s^{-2} and 0.3 s with 10 m s^{-2}] 3

(ii) Acceleration in soil [Apply ecf]

Use of equation $v^2 = u^2 + 2as$ or use of two appropriate equations **(1)**

[ignore power of 10 error and allow this mark even if they substitute the velocity value as v and not u]

[If acceleration of freefall used for acceleration, award 0/3]

Magnitude of acceleration [78.4 (m s^{-2}), 80.7 (m s^{-2}) or 81(m s^{-2}) if 2.84 m s^{-1} is used; **(1)**
84.1 (m s^{-2}) if 2.9 m s^{-1} is used; 90 (m s^{-2}) if 3 m s^{-1} is used]

[Check that all working is correct for mark 2]

Correct sign [minus] and unit **(1)**

[Only award this mark if there has been correct substitution into equation or equations]

Eg $0 = (2.8 \text{ m s}^{-1})^2 + 2a5 \times 10^{-2}$ m
$a = -78.4 \text{ m s}^{-2}$ 3

(b) Change in impact speed and acceleration in soil

Speed – the same **(1)**

Acceleration – a lower **(1)** 2

[8]

30. (a) How constant measurable force is applied

(i) Newtonmeter/forcemeter (pulled to constant reading) or elastic band (pulled to fixed extension).
[Allow a mass on the end of a string as the force, even if they do not make it clear that the mass being accelerated includes this mass] **(1)** 1
[Do not allow a ramp at a fixed angle]

(ii)

Ticker tape	Light gate/sensor	Motion sensor	Video / strobe
Ticker timer	timer / datalogger / PC	Datalogger /PC	Metre rule / markings on the track

[A **labelled** diagram can get both these marks.] **(1)(1)**
[Do not give first 2 marks for ruler and stopwatch]

Description of distance measured and corresponding time or

any mention of $v = \frac{d}{t}$ **(1)** 3

[Give this mark even if they have not obtained the first two marks]

(b) Additional measurements required for acceleration

Another velocity [accept 'final velocity'] measurement or (zero) velocity at start **(1)**
[Accept mention of double interrupter for first mark]

Either distance **between velocity measurements** / distance to **single velocity measurement** [If zero velocity is given for first marking point] **(1)**

Or time **between velocity measurements** / time **to single velocity measurement from start (1)**

[It must be clear what distance or time they are using to award this mark] 2

(c) How relationship is shown

Divide $\frac{\text{(Applied) Force}}{\text{acceleration}}$ for each pair of measurements or Plot graph of (applied) force v acceleration **(1)**

Ratio should give same value or graph gives straight line **through origin**
[Could obtain these marks from a sketch graph] **(1)**

[A statement "force is proportional to acceleration" would not get these marks] 2

(d) Why effect of friction must be eliminated

(In Newton's law) the force referred to is the resultant force / unbalanced force / accelerating force acting on an object / a description of the resultant force **(1)**

(If friction is not compensated for) the (measured) force would be greater than/not equal to the resultant force (by an amount equal to that needed to overcome friction) or the (measured) force would also have to overcome friction **(1)** 2

[Accept 'friction will reduce the acceleration' for this mark]

[10]

31. (a) Complete statements

(i) ……... tyre/ wheel ……………… road(surface) **(1)**

(ii) ……...road(surface) ……………… tyre/wheel **(1)** 2

(b) Power

(i) Use of power = Fv **(1)**

Answer [4000W]

Eg Power = 400 N × 10 m s^{-1} **(1)**
= 4000 W [or J s^{-1} or N m s^{-1}] 2

(ii) Work done (ecf their value of power)

Answer [1.2×10^6 J] **(1)**

Eg Work done = 4000 W × 5 × 60 s) = 1.2×10^6 J [or N m] 1

(c) Why no gain in E_k

Either
(All the)Work (done)/energy is being transferred [not lost or through] to thermal energy [accept heat] / internal energy (and sound) **(1)**
Overcoming friction (within bearings, axle, gear box but not road surface and tyres) / air resistance / resistive force/ drag **(1)** 2

[The information in the brackets is, of course, not essential for the mark. However, if a candidate refers to friction between the road surface and the tyre do not give this mark]

Or (allow the following)

Driving force is equal to resistive force / friction / air resistance / drag or unbalanced force is zero or forces in equilibrium **(1)**

(Therefore) acceleration is zero (hence no change in speed therefore no change in ke) **(1)** 2

[7]

32. (a) (i) Show that acceleration is about 1.7 m s^{-2}

Use of appropriate equation(s) of motion **(1)**

Correct answer [a = 1.73 m s^{-2}] [no ue] **(1)** 2

Example of calculation:

$s = ½\,at^2$

1.35 m = ½ × a × $(1.25\text{ s})^2$ OR a = 2 × 1.35 m / $(1.25\text{ s})^2$

a = 1.73 m s^{-2}

(ii) Explain constant acceleration

No air resistance **(1)**

Accelerating force on each is constant / Resultant force remains just weight **(1)** 2

(b) Calculate weight

Recall of $W = mg$ **(1)**

Correct answer [179 N] **(1)** 2

Example of calculation:

$W = mg$

$= 105 \text{ kg} \times 1.7 \text{ N kg}^{-1}$

$= 179 \text{ N}$

(c) (i) Time of flight of ball

Recall of trigonometrical function **(1)**

Recall of $v = u + at$ **(1)**

Correct answer [$t = 18.1$ s] **(1)** 3

Example of calculation:

vertical component of velocity $= 45 \text{ m s}^{-1} \times \sin 20°$

$= 15.4 \text{ m s}^{-1}$

$v = u + at$

$15.4 \text{ m s}^{-1} = -15.4 \text{ m s}^{-1} + 1.7 \text{ m s}^{-2} \times t$

$t = 30.8 \text{ m s}^{-1} \div 1.7 \text{ m s}^{-2}$

$t = 18.1 \text{ s}$

(ii) Horizontal distance

Use of trigonometrical function **(1)**

Correct answer [766 m] [ecf] **(1)** 2

Example of calculation:

horizontal component of velocity $= 45 \text{ m s}^{-1} \times \cos 20°$

$= 42.3 \text{ m s}^{-1}$

distance $= 42.3 \text{ m s}^{-1} \times 18.1 \text{ s}$

$= 766 \text{ m}$

(iii) Comment on this distance

[766 m ÷ 1600 m/mile = 0.48 mile] [ecf] – This is only about half a mile (N.B. answer for (c)(ii) required to get this mark) **(1)** 1

[12]

33. (a) (i) Calculate ave speed from D8

Use of equations of motion to find correct answer
[15.2 m s^{-1}][no ue] **(1)** 1

Example of calculation:

v = 7.6 m / 0.5 s

= 15.2 m s^{-1} [No ue]

(ii) Formula for E7

E6 + B7 OR 35.5 + 9.1 OR B4 + B5 + B6 + B7
OR sum(B4:B7) OR 35.3 + 9.1 **(1)** 1

(iii) Use graph to find ave deceleration

line drawn – full width, 0 s to 2 s **(1)**

substitution of values in gradient formula **(1)**

correct answer [5.5 m s^{-2} (± 0.3 m s^{-2})] **(1)** 3

Example of calculation:

gradient = (28 m s^{-1} – 17 m s^{-1}) / 2 s

= 5.5 m s^{-2} (± 0.3 m s^{-2}) [ignore any negative sign]

(b) (i) Calculate average braking force

Recall of $F = ma$ **(1)**

Correct answer [3300 N] [ecf] **(1)** 2

Example of calculation:

$F = ma$

= 600 kg × 5.5 m s^{-2}

= 3300 N

(ii) State origin of force

friction between brake pad and disc **(1)**

[frictional force of road on tyres] 1

(c) (i) Calculation of kinetic energy from F6

Recall of $E_k = ½\, mv^2$ **(1)**

Correct answer [132 kJ] [no ue] **(1)** 2

Example of calculation:

$E_k = ½\, mv^2$

$E_k = ½ \times 600 \text{ kg} \times (21 \text{ m s}^{-1})^2$

= 132 kJ

(ii) Explain gradient = braking force

Change in kinetic energy = work done by braking force **(1)**

work/distance = force **(1)**

OR

gradient = change in kinetic energy / distance **(1)**

= work done by braking force / distance = force **(1)**

(Showing units/dimensions of gradient consistent with force gains 1 mark) 2

[12]

34. How A and B change

Force B
For ticking 'no change' in all 4 boxes **(1)**

Force A
4 ticks right ✓✓✓ **(1)**
3 ticks right ✓✓ **(1)**
2 ticks right ✓ **(1)**

increases	no change	decreases
✓		
	✓	
		✓
	✓	

[4]

35. (a) Path of coin
Curved line that must begin to 'fall' towards the ground immediately **(1)** 1

(b) (i) Show that..

Selects $s = (ut +)\frac{1}{2}at^2$ or selects two relevant equations **(1)**

Substitution of physically correct values into equation or **both (1)** equations.

Answer [0.37 s – 0.38 s] **(1)**

[Allow use of g = 10 m s^{-2}. Must give answer to at least 2 sig. fig., bald answer scores 0. No ue.] 3

eg $0.7 \text{ m} = \frac{1}{2}(9.81 \text{ m s}^{-2})t^2$

(ii) Horizontal distance [ecf their value of t]

Use of $v = \frac{d}{t}$ with correct value of time. [$s = \frac{v+u}{2}t$ is sometimes **(1)** used. In this case v and u must be given as 1.5 m s–1 and t must be correct. Also $s = ut + 0.5at^2$ OK if 'a' is set = 0.]

Answer [0.55 m – 0.60 m] **(1)**

eg $d = 1.5 \text{ (m s}^{-1}) \times 0.38 \text{ (s)}$
$= 0.57 \text{ m}$ 2

(c) A coin of greater mass?

QWOC **(1)**

It will follow the same path [accept 'similar path', do not accept 'same distance'] **(1)**

All objects have the same acceleration of free fall / gravity or acceleration of free fall / gravity is independent of mass / it will take the same time to fall (to the floor) **(1)**

Horizontal motion / velocity is unaffected by any force or (gravitational) force (acting on coin) has no horizontal component or horizontal motion/velocity is the same/constant. **(1)** 4

[10]

36. (a) Meaning of 0.8 s

Reaction time (of cyclist and car driver) **(1)** 1

[Accept descriptions of reaction time eg 'time it takes both to take in that the lights have changed to green'. Accept response time]

(b) (i) Same speed time

Answer [6.8 s –6.9 s] [Accept any value in the range] **(1)**□ 1

(ii) <u>How much further ahead?</u>

Either

For measuring area under car graph at 6.8 s **(1)**

eg = $\frac{6\,\text{s} \times 9\,\text{m}\,\text{s}^{-1}}{2}$ = 27 m [27.5 m if 6.9 s used]

For measuring area under cyclist graph at 6.8 s **(1)**

eg $\frac{2\,\text{s} \times 9\,\text{m}\,\text{s}^{-1}}{2}$ + 4 s × 9 m s^{-1} = 45 m [45.9 m if 6.9 s used]

[For candidates who read the velocity 9 m s^{-1} as 8.5 m s^{-1} but otherwise do their calculation(s) correctly give 2/3]

[Allow one mark to candidates who attempt to measure an appropriate area]

Answer [(45 m – 27 m =) 18 m] **(1)**

Or

For recognising the area enclosed by cyclist and car graphs as the difference in distance travelled **(1)**

Using values from the graph to determine this area **(1)**

Answer [(45 m – 27 m =) 18 m] **(1)**

eg distance = $\frac{1}{2}$ × (6.8 – 2.8) s × 9 m s^{-1}

= 18 m 3

(c) <u>Relationship between average velocities</u>

They are the same **(1)** 1

[6]

37. (a) <u>Comment on assumption</u>

Yes – air resistance negligible OR still close to Earth (ignore upthrust) **or** No – air resistance becomes significant **(1)** 1

(b) <u>Explanation of why formula for cell B6 is appropriate</u>

Recall of $v = u + at$ (accept $\Delta v = a\,\Delta t$ or $\Delta v = at$ for 1st mark) **(1)**

(v is B6), u is zero, a is 9.81 [m s^{-2}] and t is A6 **(1)** 2

(c) (i) <u>Explanation of</u> $\frac{(\text{B6} + \text{B7})}{2}$

it is average speed (for that interval)

or $\frac{(u + v)}{2}$ **(1)** 1

(ii) Why $\frac{(B6+B7)}{2}$ is multiplied by 0.20

because dist = ave speed × time [accept $s = vt$]
and 0.20 is the time **(1)** 1

(d) Formula for D10

= D9 + C10 **(1)** 1

(e) Calculation to check D11

Use of appropriate equation of motion **(1)**

Correct answer [12.557 m] [no ue] **(1)** 2

Example of calculation:

$s = ut + ½ at^2$

$= 0 + ½ \times 9.81 \text{ m s}^{-2} \times (1.6 \text{ s})^2$

= 12.557 m
N.B. use of $v^2 = u^2 + 2as$ gives answer s = 12.563 m

[8]

38. (a) Mark and label W and T

W marked and labelled **(1)**

T marked and labelled **(1)** 2

(b) Calculation of horizontal component of P

Recall of trigonometrical function **(1)**

Correct answer [9974 N] **(1)** 2

Example of calculation:

horizontal component = $P \cos \theta$

= 23600 N × cos 65°

= 9974 N

(c) (i) State magnitude of horizontal component of T
T = 9974 N [ecf] **(1)**□ 1

(ii) Calculate magnitude of T

Use of trigonometrical function **(1)**

Correct answer [13 420 N] [ecf] **(1)** 2

Example of calculation:

horizontal component of $T = T \cos 42° = 9974$ N

$T = 9974$ N ÷ cos 42°

= 13 420 N

(d) Scale drawing

P added **(1)**

resultant correctly drawn **(1)**

magnitude of resultant = 13 400 N (± 400 N) **(1)**

angle = 42° (± 3°) **(1)** 4

(e) Describe one other force

E.g., push from wind **(1)** 1

[12]

39. (a) Complete statement of Newton's Third Law of Motion

....exerts an equal force on (body) A **(1)**

(but) in the opposite direction (to the force that A exerts on B) **(1)** 2

['exerts an equal but opposite force on body A' would get both marks]

(b) Complete the table

1 mark for each of the three columns **(1)** **(1)** **(1)** 3

[Accept from earth for up. Accept towards ground or towards earth for down]

	Earth	Gravitational. [**Not** 'gravity'. **Not** gravitational field strength]	Up(wards) / ↑
	Ground		Down(wards) / ↓

[5]

40. (a) Time to fall

Use of $s = ut + ½ at^2$ **or** use of 2 correct equations of motion **(1)**
or use of mgh = ½ mv^2 and other equation(s)
[allow g = 10 m s^{-2}] 2

Answer to at least 2 sig fig [0.69 s. No ue] **(1)**

Example
2.3 m = 0 + ½ 9.8 m s^{-2} t^2
t = 0.68(5) s [0.67(8) if 10 m s^{-2} used]
[Reverse argument only accept if they have shown that height is 2.4 m]

(b) Time to rise
Select 2 correct equations **(1)**
Substitute physically correct values [not u = 0 or a + value for g] **(1)**
[allow g = 10 m s^{-2} throughout] **(1)** 3
Answer: [$t = 0.38$ s]

Example 1
0 = $u^2 + 2x$ – 9.81 m s^{-2} 0.71 m
0 = 3.73 m s^{-1} + –9.81 m s^{-2} t
t = 0.38 s
[0.376 s if 10 m s^{-2}]

Example 2
0 = u + – 9.81 m s^{-2} t; u = 9.81t
0.71 m = 9.81 $t.t$ + ½ – 9.81 m s^{-2} t^2
t = 0.38 s
[**Note**. The following apparent solution will get 0/3. $s = ut + ½at^2$;
0.71 m = 0 + ½ 9.81 m s^{-2} t^2; t = 0.38 s, unless the candidate makes it clear they are considering the time of fall from the wicket.]

(c) Velocity u
Use of $v \frac{d}{t}$ **(1)**
[d must be 20 m, with any time value from the question eg 0.7 s]

Answer: [18.9 m s^{-1} or 18.2 m s^{-1} if 0.7 s + 0.4 s = 1.1 s is used. **(1)** 2
ecf value for time obtained in (b).]

Example

$$v = \frac{20m}{0.68s + 0.38s}$$

= 18.86 m s^{-1} [18.18 m s^{-1} if 1.1 s used]

(d) Why horizontal velocity would not be constant

Friction/drag/air resistance/inelastic collision at **bounce or impact (1)** / transfer or loss of ke (to thermal and sound) at **bounce or impact** (would continuously reduce the velocity/ kinetic energy). [also allow 'friction between ball and surface when it bounces (will reduce velocity/kinetic energy)']. 1

[Any reference to gravitational force loses this mark. A specific force must be mentioned, eg resistive forces is not enough.]

[8]

41. (i) Work done

Use of work done = force × distance **(1)**
Answer given to at least 3 sig fig. [2396 J, 2393 J if 9.8 m s^{-2} is used, **(1)** 2442 J if g = 10 m s^{-2} is used. No ue.] 2

Work done = 110 kg × 9.81 m s^{-2} × 2.22 m
= 2395.6 J

(ii) Power exerted

Use of power = $\frac{\text{work done}}{\text{time}}$ or power = $F \times v$ **(1)**

Answer: [799 W. 800 W if 2400 J is used and 814 W if 2442 J is used. Ecf value from (i)] **(1)** 2

Power = $\frac{2396\,\text{J}}{3\text{s}}$
= 798.6 W

(iii) Principle of Conservation of Energy

Either
Energy can neither be created nor destroyed **(1) (1)**
OR
Energy cannot be created/destroyed or total energy is not lost/gained **(1)** (merely) transformed from one form to another or in a closed/isolated system. **(1)** 2

[Simple statement 'Energy is conserved' gets no marks]
[Information that is not contradictory ignore. $\Delta Q = \Delta U + \Delta W$, with terms defined acceptable for 1st mark]

(iv) How principle applied to...

Lifting the bar: -
Chemical energy (in the body of the weightlifter) or work done (lifting bar) = (gain in) g.p.e. (of bar) **(1)**
[Reference to k.e. is acceptable]

The bar falling: -
Transfer from g.p.e. to k.e. **(1)**
(and that) g.p.e. lost = k.e. gained **(1)** 3

[‘g.p.e. converted to k.e.’ would get one mark]
[References to sound and thermal energy are OK, but gpe to sound or thermal energy on its own gets no marks]

(v) Speed of bar on reaching the floor
Setting $\frac{1}{2} mv^2 = m g h$ or $\frac{1}{2} mv^2$ = work done or 2400 J **(1)**
[ecf their value]
[Shown as formulae without substitution or as numbers substituted into formulae]
Correct values substituted **(1)**
[allow this mark if the 110 kg omitted – substitution gives v^2 = **(1)**
43.55(6) $m^2 s^{-2}$ or 44.4 $m^2 s^{-2}$ if $g = 10$ m s^{-2} is used]
Answer: [6.6 m s^{-1}. 6.7 m s^{-1} if $g = 10$ m s^{-2} is used.]

½ 110 kg × v^2 = 110 kg × 9.81 m s^{-2} × 2.22 m or = 2400 J / 2396 J
v = 6.6 m s^{-1} [6.66 m s^{-1} if 10 m s^{-2} used] **(1)**

OR
Selects $v^2 = u^2$ + 2as or selects 2 relevant equations **(1)**
Correct substitution into equation **(1)**
Answer [6.6 m s^{-1}] **(1)**

v^2 = 0. + 2 × 9.81 ms^{-2} × 2.22m 3
v = 6.6 m s^{-1}

[12]

42. Calculation of time for ball to travel 30 m

Recall of $v = s/t$ **(1)**

Correct answer [1.2 s] **(1)** 2

Example of calculation:

v = s/t

t = 30 m ÷ 25 m s^{-1}

= 1.2 s

Calculation of westward component of ball's velocity

Recall of $v = u + at$ **(1)**

Correct answer [9.6 m s^{-1}] [ecf] **(1)** 2

Example of calculation:

$v = u + at$

$v = 0 + 8 \text{ m s}^{-2} \times 1.2 \text{ s}$

$= 9.6 \text{ m s}^{-1}$

Calculation of distance ball travels to west

Use of appropriate equation of motion **(1)**

Correct answer [5.76 m] [ecf] **(1)** 2

Example of calculation:

$s = ut + ½ at^2$

$= 0 + ½ \times 8 \text{ m s}^{-2} \times (1.2 \text{ s})^2$

$= 5.76 \text{ m}$

Calculation of final velocity of ball

Use of Pythagoras' theorem or scale drawing with velocity triangle **(1)**

Correct answer for magnitude of velocity [26.8 ms^{-1}, accept in range 26 – 27.5] [allow ecf] **(1)**

Use of trigonometrical equations with velocity triangle **(1)**

Correct answer for direction of velocity [21.0° West or 339.0° ±2°]□**(1)** 4
[allow ecf]

[Allow 3rd and 4th marks for displacement triangle instead of velocity]

Example of calculation:

magnitude of velocity = $\sqrt{((9.6 \text{ m s}^{-1})^2 + (25 \text{ m s}^{-1})^2)}$

$= 26.8 \text{ m s}^{-1}$

angle = $\tan^{-1}(9.6 \text{ m s}^{-1}/25 \text{ m s}^{-1})$

= 21.0° West (or 339.0°)

[10]

43. Show that the average deceleration is about 0.1 m s^{-2}

Use of $v^2 = u^2 + 2as$ **(1)**

Correct answer [0.13 m s^{-2}] to at least 2 sig fig [no u.e.] **(1)** 2
[ignore + or – in answer and reversal of v and u in calculation]
[Bald answer scores 0, reverse calculation 2/3]

Example of calculation:

$v^2 = u^2 + 2as$

$0\ \text{m}^2\ \text{s}^{-2} = (13\ \text{m s}^{-1})^2 + 2 \times a \times 640\ \text{m}$

$a = -(13\ \text{m s}^{-1})^2 \div (2 \times 640\ \text{m})$

$a = -\ 0.13\ \text{m s}^{-2}$ OR deceleration = $0.13\ \text{m s}^{-2}$

Calculation of average resultant force

Recall of $F = ma$ **(1)**

Correct answer [182 N] [allow ecf] **(1)** 2

[Use of $a = -\ 0.1$ m s^{-2} gives answer of 140 N]

Example of calculation:

$F = ma$

$= 1400\ \text{kg} \times 0.13\ \text{m s}^{-2}$

= 182 N

Explanation of graph shape

gradient decreasing / slope of graph becoming less steep**(1)** 1

Using graph for speed after 15 s

Tangent touching at 15 s, not crossing curve**(1)**

Use of $\Delta s/\Delta t$**(1)**

Correct answer calculated using values from curve or tangent**(1)** 3
[range 14.0 m s^{-1} to 17.0 m s^{-1}]

Example of calculation:

Speed = gradient = 800 m / 52 s

= 15.4 m s^{-1}

Calculation of average deceleration

Recall of $a = (v - u) / t$ **(1)**

[Allow use of alternative equation of motion and values from graph or previous parts]

Correct answer [0.97 m s^{-2}] [allow ecf] **(1)** 2

Example of calculation:

$a = (v - u) / t$

$= (15.4 \text{ m s}^{-1} - 30 \text{ m s}^{-1}) \div (15 \text{ s})$

$= (-)0.97 \text{ m s}^{-2}$

Explanation of difference in values of deceleration

Deceleration greater when car at higher speed **(1)**

(because) e.g. more air resistance / greater drag **(1)** 2

[12]

44. (a) Calculation of weight

Use of L × W × H **(1)**

Substitution into density equation with a volume and density **(1)**

Correct answer [49.4 (N)] to at least 3 sig fig. [No ue] **(1)** 3
[Allow 50.4(N) for answer if 10 N/kg used for g.]
[If 5040 g rounded to 5000 g or 5 kg, do not give 3rd mark; if conversion to kg is omitted and then answer fudged, do not give 3rd mark]
[Bald answer scores 0, reverse calculation 2/3]

$80 \text{ cm} \times 50 \text{ cm} \times 1.8 \text{ cm} = 7200 \text{ cm}^3$

$7200 \text{ cm}^3 \times 0.70 \text{ g m}^{-3} = 5040 \text{ g}$

$5040 \text{ g} \times 10^{-3} \times 9.81 \text{ N/kg}$

$= 49.4$ (N)

[May see :
$80 \text{ cm} \times 50 \text{ cm} \times 1.8 \text{ cm} \times 0.7 \text{ g m}^{-3} \times 10^{-3} \times 9.81 \text{ N/kg}$

$= 49.4$(N)]

(b) (i) Horizontal and vertical components

Horizontal component = (83 cos 37 N) = 66.3 N / 66 N **(1)**
Vertical component = (83 sin 37 N) = 49.95 N / 50 N **(1)** 2
[If both calculated wrongly, award 1 mark if the horizontal was identified as 83 cos 37 N and the vertical as 83 sin 37 N]

(ii) Add to diagram

Direction of both components correctly shown on diagram **(1)** 1

(iii) Horizontal force of hinge on table top

66.3 (N) or 66 (N) **and** correct indication of direction [no ue] **(1)** 1
[Some examples of direction: acting from right (to left) / to the left / West / opposite direction to horizontal. May show direction by arrow. Do not accept a minus sign in front of number as direction.]

[7]

45. Expression for E_k and work done / base unit

(a) (i) Kinetic energy = ½ mu^2

Work done = Fd
[must give expressions in terms of the symbols given in the question] **(1)** 1

(ii) Base units for kinetic energy = (kg (m $s^{-1})^2$) = kg m^2 s^{-2} **(1)**
Base units for work done = $kgms^{-2}$ .m = kg m^2 s^{-2} **(1)**
[derivation of kg m^2 s^{-2} essential for 2^{nd} mark to be given] 2
[Ignore persistence of ½] [For 2^{nd} mark ecf mgh for work from (a)(i)]

(b) Show that the braking distance is almost 14 m

[Bald answer scores 0; Reverse calculation max 2/3]

Either

Equating work done and kinetic energy [words or equations] **(1)**

Correct substitution into kinetic energy equation **and** correct substitution **(1)** into work done equation

Correct answer [13.8 (m)] to at least 3 sig fig. [No ue] **(1)**

$0.5 \times m \times (13.4 \text{ m s}^{-1})^2 = m \times 6.5 \text{ m s}^{-2} \times d$

$$\frac{0.5 \times m \times (13.4 \text{ ms}^{-1})^2}{m \times 6.5 \text{ ms}^{-2}} = 13.8 \text{ (m)}$$ 3

[m may be cancelled in equating formulae step and not seen subsequently]

OR

Selecting $v^2 = u^2 + 2as$ OR 2 correct equations of motion **(1)**
Correct magnitudes of values substituted **(1)**
[i.e. 0 = (13.4 m $s^{-1})^2$ + 2((-)6.5 m^{-2})s]
Correct calculation of answer [13.8 (m)] to at least 3 sig fig. [No ue] **(1)**

(c) Why braking distance has more than doubled

QOWC **(1)**

Either
(Because speed is doubled and deceleration is unchanged) time **(1)**
(to be brought to rest) is doubled/increased.
(Since) distance = speed x time [mark consequent on first] or $s = ut + ½ at^2$ **(1)**
the distance is increased by a factor of (about) 4 **(1)** 4

Or
Recognition that (speed)^2 is the key factor **(1)**
Reference to $v^2 = u^2 + 2as$ or rearrangement thereof or kinetic energy ***(1)***
[second mark consequent on first]
(Hence) distance is increased by a factor of (almost) 4 **(1)**

Or
Do calculation using $v^2 = u^2 + 2as$ and use 26.8 m s^{-1} and 6.5 m s^{-2} **(1)**
Some working shown to get answer 55.2 m **(1)**
(Conclusion that) distance is increased by a factor of (almost) 4
[Note : unlikely that QOWC mark would be awarded with this method] **(1)**

Or
Accurate labelled *v-t* graphs for both **(1)**
Explanation involving comparison of areas **(1)**
Distance is increased by a factor of (almost) 4 **(1)**

[In all cases give 4th mark if 4 is not mentioned but candidate shows more than doubled eg “Speed is doubled and the time increased, therefore multiplying these gives more than double.”]

[10]

46. (a) (i) Newton’s First law of Motion

An object will remain (at rest or) uniform/constant velocity/speed/motion in a straight line unless (an external/impressed) force acts upon it / provided resultant force is zero. **(1)** 1

(ii) Everyday situation

Reference to air resistance / friction / drag etc. **(1)** 1

(iii) Equilibrium

The resultant force is zero / no net force /sum of forces is zero / forces are balanced / acceleration is zero **(1)** 1
[Accept moments in place of force]

(b) (i) Identify the other force

Earth **(1)**
Gravitational [consequent on first mark] [Do not credit gravity.] **(1)** 2

(ii) Why normal contact forces are not a Newton's third law pair

Do not act along the same (straight) line / do not act from the same point **(1)**
They act on the same body **(1)**
They act in the same direction / they are not opposite forces **(1)**
They are of different magnitudes **(1)**

max 2

[7]

47. Explain deduction that legs in contact for 0.001 s

Acceleration changes / discontinuity / vertical velocity max / only accelerates during this time [acceleration related] **(1)**

After this upward force ceases / stops when legs no longer pushing leaf [forces related] **(1)** 2

Show that acceleration is about 3000 m s^{-2}

Acceleration = gradient of graph **(1)**

= 2.8 m s^{-1} ÷ 0.0010 s

= 2800 m s^{-2} [No ue] **(1)** 2

Calculation of force exerted by leg muscles

$F = ma$ **(1)**

$= 1.2 \times 10^{-5}$ kg × 2800 m s^{-2}

$= 3.4 \times 10^{-2}$N **(1)** 2

Show that froghopper rises about 0.001 m

Distance = area under graph [or implied by shading etc] **(1)**

= ½ × 2.8 m s^{-1} × 0.001 s

= 0.0014 m [No ue]
(0.0013 to 0.0015 m for square counting) **(1)** 2

Calculation of work done by leg muscles

$W = Fx$ **(1)**

$= 0.034 \text{ N} \times 1.4 \times 10^{-3}\text{m}$ [allow e.c.f.]

$= 4.7 \times 10^{-5}\text{J}$ **(1)** 2

Calculation of power developed by leg muscles

Power $= W \div t$ **(1)**

$= 4.7 \times 10^{-5} \text{ J} \div 0.001 \text{ s}$

$= 0.047$ W **(1)** 2

[12]

48. Show that expected speed is about 35 m s^{-1}

$E_k = \frac{1}{2} mv^2$ and $E_p = mg\Delta h$ **(1)**

$\frac{1}{2}mv^2 = mg\Delta h$ **(1)**

$v = \sqrt{2gh}$

$= \sqrt{(2 \times 9.81 \text{ N kg}^{-1} \times 64 \text{ m})}$

$= 35.4 \text{ ms}^{-1}$ [No ue] **(1)** 3

[For $v^2 = u^2 + 2as$ mark $u = 0$ **(1)**, rest of substitution **1)**, evaluation **(1)**]

Assumption

No resistive force, all gpe → ke, constant acc$^{\underline{n}}$ **(1)** 1

[Do not accept $g = 9.81 \text{ m s}^{-2}$]

Reason for lower speed

Work done against resistive force/frictional forces oppose motion/ some g.p.e. → heat/sound ... **(1)**

reduces maximum kinetic energy / acceleration is reduced/less than 9.8 m s^{-2} **(1)** 2

Calculate efficiency

Efficiency = (actual max k.e. ÷ theoretical max k.e.) × 100%

OR efficiency = (actual max k.e. ÷ initial p.e.) × 100% **(1)**

$= (\frac{1}{2} m \upsilon_{act}^2 \div \frac{1}{2} m \upsilon_{th}^2) \times 100\%$ **OR** $= (\frac{1}{2} m \upsilon_{act}^2) \div (mgh) \times 100\%$

$\frac{(32.5 \text{ m s}^{-1})^2}{(35.4 \text{ m s}^{-1})^2} \times 100\%$ $= \frac{\frac{1}{2}(32.5 \text{ m s}^{-1})^2}{9.8 \times 64} \times 100\%$ **(1)**

= 84.2% **(1)** 3

Reason why speed greater than expected

e.g. motor assisted / initial speed > 0 / run up before drop **(1)** 1

[10]

49. (a) Free body force diagram for magnet

(Electro)magnetic / (force of) repulsion / push **(1)**

Weight / W / mg / pull (of Earth) / gravitational (attractive force) / attraction (of Earth) **(1)** 2

[NOT gravity]

[An additional incorrect force cancels 1 mark awarded]

(b) Newton's third law pairs 6

Force	Body on which corresponding force acts	Direction of the corresponding force	
Contact	(Wooden) stand/base	Downwards / down / ↓	**(1) (1)**
Magnetic	(Magnet) M_1	Upwards / up / ↑	**(1) (1)**
Weight	Earth / Earth's surface	Upwards / up / ↑	**(1) (1)**

[8]

50. (a) Explanation

V_b has a horizontal component equal to V_a **(1)**
V_b has a vertical component **(1)** 2

[V_b has two components of velocity is 1 mark]
[V_b cos 45 = V_a is 2 marks]

(b) Explanation
EITHER
QoWC **(1)**
The average speed / velocity of A is greater (than B) / converse **(1)**
(because) A continually accelerates whereas B slows down / **(1)**
decelerates (initially)
[description of both A and B necessary for this 2nd physics mark]
OR
QoWC **(1)**
V_a = horizontal component of V_b and they travel the same **(1)**
horizontal distance
Vertical component of projectile's motion does not affect **(1)**
horizontal motion 3

[5]

51. (a) Energy change

Both parts correct [NB 1 mark only] **(1)** 1
Gravitational potential (energy) to kinetic / movement (energy) /
work done

(b) Principal of conservation of energy

EITHER **(1) (1)**
Energy can be neither created nor destroyed
OR
Energy cannot be created/destroyed / total energy is not **(1)**
lost/gained
merely transformed from one form to another / in a
closed/isolated system **(1)** 2

(c) Speed of water
Correct substitution into correct formula **(1)**
Correct value with correct unit **(1)** 2
Power = force × velocity
1.7×10^9 (W) = 3.5×10^8 (N) × V
$V = 4.86$ m s^{-1}

–

(d) Explanation

Not all the energy of the falling water is transferred to the output power OR system is not 100% efficient OR water is not brought **(1)** to rest OR friction OR some of the energy is transferred to heat/sound/surroundings. 1

(e) Time
Correct value with correct unit. **(1)** 1

$$\text{Time} = \frac{7 \times 10^6\,(\text{m}^3)}{390\left(\text{m}^3\text{s}^{-1}\right)} = 17\,949\text{ s } (= 299\text{ min})\ (= 5\text{ h})$$

(f) Work done

Correct substitution into correct formula to find mass of water **(1)**

Identifying
"work done = force x distance moved in direction of force" **(1)**

Correct value with correct unit **(1)**

Mass of water = volume × density 3

$= 7 \times 10^6$ (m^3) × 10^3 (kg m^{-3}) (= 6.9×10^9 kg)

Work done = force × distance

Work done = 6.9×10^9 (kg) x 9.81 (ms^{-2}) x 500 (m)

= 3.43×10^{13} J

[10]

52. Show that vertical component of velocity is about 70 m s^{-1} down

Use of $\Delta\xi/\Delta t$ **(1)**

Tangent - touching at 300 s, not crossing curve **(1)**

(65 000 m – 86 500 m) ÷ 290 s

= [–]74.1 m s^{-1} [no ue][accept answers in range 68 m s^{-1} to 79 m s^{-1}] **(1)** 3

Calculation of average vertical acceleration

$a = (v - u)/t$ **(1)**

$= (-38.0 \text{ m s}^{-1} - (-74.1 \text{ m s}^{-1})) \div 100 \text{ s}$ [ecf]

$=$ [+] 0.36 m s^{-2} **(1)**

Upwards **(1)** 3

Calculation the weight of the shuttle

$W = mg$

$= 2.0 \times 10^6 \text{ kg} \times 9.6 \text{ N kg}^{-1}$

$= 1.9 \times 10^7 \text{ N}$ **(1)** 1

Calculation of average upward vertical force

[Resultant] force = ma **(1)**

$= 2.0 \times 10^6 \text{ kg} \times 0.35 \text{ m s}^{-2}$ [ecf]

$= 0.7 \times 10^6 \text{ N}$ **(1)**

Upward force = resultant force + weight [consistent with second part]

$= 2.0 \times 10^7 \text{ N}$ **(1)** 3

[10]

53. Calculate kinetic energy

$E_k = ½\, m\, \upsilon^2$ **(1)**

$E_k = ½ \times 1800 \text{ kg} \times (53 \text{ m s}^{-1})^2$

$= 2.53 \times 10^6 \text{ J}$ **(1)** 2

Show that max height would be about 140 m

$E_p = mg\Delta h$ **(1)**

Initial E_k = final E_p/$½\, m\upsilon^2 = mg\Delta h$/$2.53 \times 10^6 \text{ J} = mg\Delta h$ **(1)**

$\Delta h = 2.53 \times 10^6 \text{ J}/(1800 \text{ kg} \times 9.81 \text{ N kg}^{-1})$

$\Delta h = 143 \text{ m}$ [no ue] **(1)**

OR

$\upsilon^2 = u^2 + 2as$

$0 \text{ m}^2 \text{ s}^{-2} = (53 \text{ m s}^{-1})^2 + 2 \times (-9.81 \text{ m s}^{-2}) \times s$ [subst] **(1)**

$s = (53 \text{ m s}^{-1})^2 \div (2 \times 9.81 \text{ m s}^{-2})$ [rearrangement] **(1)**

$s = 143 \text{ m}$ [no ue] **(1)** 3

Show that energy loss is about 3×10^5 J

E_p = 1800 kg × 9.81 N kg^{-1} × 126 m = 2.22 × 10^6 J **(1)**

$E_k - E_p$ = 2.53 × 10^6 J – 2.22 × 10^6 J

= 3.1 × 10^5 J [no ue] **(1)**

OR

For 143 m

E_p = 1800 kg × 9.81 N kg^{-1} × 143 m = 2.53 × 10^6 J

For 126 m

E_p = 1800 kg × 9.81 N kg^{-1} × 126 m = 2.22 × 10^6 J **(1)**

Energy lost =2.53 × 10^6 J – 2.22 × 10^6 J

= 3.1 × 10^5 J [no ue] **(1)**

OR

Energy lost = 1800 kg × 9.81 N kg^{-1} × (143 m – 126 m) **(1)**
= 3.1 × 10^5 J [no ue] **(1)** 2

<u>Calculation of average resistive force</u>

Work = force × distance **(1)**

Force = work ÷ distance

= 3.1 × 10^5 J ÷ 126 m

= 2500 N **(1)** 2

<u>Calculation of time for climb</u>

$s = ½ (u + v) \times t$ **(1)**

$t = 2s \div (u + v)$

= 2 × 126 m ÷ 53 m s^{-1}

= 4.8 s **(1)**
[Use of g = 9.81 m s^{-2} in equations of motion to get a consistent value of t [$\upsilon = u + at \rightarrow t$ = 5.4 s] → 1 mark]

Assumption: eg assume uniform acceleration/constant resistive force/ constant frictional force **(1)** 3

[12]

54. Maximum velocity

Area = 100 m **(1)**

Attempt to find area of trapezium by correct method **(1)**

$\upsilon = 10 \text{ m s}^{-1}$ **(1)** 3

Sketch graph

Horizontal line parallel to x axis

Some indication that acceleration becomes 0 m s^{-2}

The initial acceleration labelled to be $\upsilon_{max} \div 2$ [initial $a = 5$ (m s^{-2}) **(1)** (ecf)]

$t = 2$ (s) where graph shape changes **(1)** 4

[7]

55. Criticism of statement

Not a Newton third law pair **(1)**

Forces in equilibrium but not for reason stated **(1)**

N3 pairs act upon different bodies **(1)**

N3 pairs same type **(1)**

Line of action different / rotation **(1)** Max 3

Table

Gravitational **(1)**

Earth **(1)**

Upwards **and** downwards [**both** must be correct] **(1)**

Table **(1)** 4

Force	Type of force	Direction of Newton 3rd law 'pair' force	Body 'pair' force acts upon
Weight	Gravitational	Upwards	Earth
Push of table	Electro-magnetic	Downwards	Table

[7]

56. Principal energy transformation

Kinetic energy to internal energy/heat/work done against friction **(1)** 1

Explanation of braking distance

Q_0WC **(1)**

Car is (also) losing gpe **(1)**

Total work done against friction is greater OR more energy to be converted to heat (in the brakes) **(1)**

Since force is same, distance must be greater [consequent] **(1)** 4

[5]

57. Calculation of weight of shuttle

$W = mg$

$= 2 \times 10^6$ kg $\times$ 9.81 N kg^{-1}

$= 1.96 \times 10^7$ N **(1)** 1

Labelling of forces acting on shuttle

Upward force = 3×10^7 N **(1)**

Downward force = 1.96×10^7 N [Allow ecf] **(1)** 2

Show that initial acceleration is about 5 m s^{-2}

$F = ma$ [Stated or implied] **(1)**

$a = (3 \times 10^7 \text{ N} - 1.96 \times 10^7 \text{ N}) \div 2 \times 10^6$ kg [Allow ecf]

$= 5.2$ m s^{-2} [no ue] **(1)** 2

Use of graph to find height of shuttle after 120 s

Use of area [stated or implied e.g. by shading etc] **(1)**

At least to level of ½ vt approximation [44000 m to 63 000 m] **(1)**

Evidence of improved method, e.g. counting squares **(1)**

Answer within range 49 000 m to 53 000 m **(1)** 4

Suggestion and explanation of increased acceleration

Mass decreases [as fuel is burnt] **(1)**

Decrease in mass causes increase in acceleration / a α 1/m **(1)**

OR

Weight decreased because fuel used **(1)**

Resultant force increases **(1)** 2

[Accept Resultant force increased because of decrease in air resistance or in gravitational field strength for **(1)**×]

Reason for reduction in thrust

e.g. to go into orbit/stop going up/danger for craft/crew if acceleration too large/required speed already reached **(1)** 1

[12]

58. Show that initial vertical component of velocity is about 50 m s^{-1}

Identify $v = -u$

OR

Time to top, with $v = 0$, is 5 s in $v = u + at$

OR

$s = 0$ with $t = 10$ s in $s = ut + \frac{1}{2} at^2$ **(1)**

$0 = u + (-9.81 \text{ m s}^{-2} \times 5 \text{ s})$

$u = 49 \text{ m s}^{-1}$ [no ue] **(1)** 2

Calculation of velocity at which arrows left the bow

Vertical component = $v\sin\theta$ [Stated or implied] **(1)**

$v = 49.1 \text{ m s}^{-1} \div \sin 50°$

$= 64.1 \text{ m s}^{-1}$ [Allow ecf] **(1)** 2

Show that range is about 400 m

Horizontal component = $64.1 \text{ m s}^{-1} \times \cos 50°$] [ecf] **(1)**

$= 41.2 \text{ m s}^{-1}$

Horizontal distance = $\upsilon \times t$ [stated or implied] **(1)**

$= 41.2 \text{ m s}^{-1} \times 10 \text{ s}$

= 410 m [no ue] **(1)** 3

Explanation of difference between recorded and calculated ranges

For example: air resistance [has been ignored in calculations]/wind against arrows **(1)**

[air resistance] will cause deceleration / decelerating force [reducing range] **(1)** 2

[9]

59. Table

Type of force	Example	
Gravitational	Weight/attraction between two masses	**(1)**
Electromagnetic	Normal reaction/friction/drag/tension/force between two charges or magnets/ motor effect/ elastic strain forces/contact forces	**(1)**
Nuclear	Strong/Weak/force keeping protons (and/or neutrons) together/beta decay/forces within nucleus	**(1)**

3

Forces

Any three from:

- same type **(1)**
- same magnitude/equal **(1)**
- act on different bodies/exerted by different bodies **(1)**
- opposite direction **(1)**
- same line of action **(1)**
- acts for same time **(1)** Max 3

[6]

60. Deceleration of trolley

Select $\upsilon^2 = u^2 + 2ax$ /both appropriate formulas **(1)**

Correct substitutions **(1)**

0.309 [2 significant figures minimum]**(1)** 3

Frictional force

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

8.7 / 8.6 N [8.4 if 0.3 used] **(1)** 2

Power

Use of $P = F\upsilon$ **(1)**

9.6 / 9.5 W [9.2 if 0.3 used] **(1)** 2

Force

Use of $a = (\upsilon - u)/t$ **(1)**

Add 8.6 /8.7 N to resultant force [8.4 if 0.3 used] **(1)**

42.8 N [42.6 if 0.3 used] [Accept 42.2 N] **(1)** 3

[10]

61. Explanation

Some energy converted to internal energy [or heat or sound] / work done against friction [or air resistance] **(1)** 1

Experiment

Measure υ at the bottom **(1)**

Suitable apparatus, e.g. motion sensor and data logger/light gate(s) and timer or computer **(1)**

Detail of technique, e.g. sensor sends pulses at regular time intervals and time to return is measured/gate measures time for card of known length to pass/tickertape measures length between dots made at regular time intervals **(1)**

Measure mass of trolley with balance **(1)**

Calculate kinetic energy from $m\upsilon^2/2$ **(1)**

Measure vertical drop with ruler **(1)**

Calculate (gravitational) potential energy from mgh **(1)**

Calculate $\frac{\text{ke}}{\text{gpe}} \times 100$ Max 6

[7]

62. Show that average daily capacity provides about 2×10^{13} J

$E_p = mgh$ **(1)**
$= (28 \times 10^6 \text{ m}^3 \times 10^3 \text{ kg m}^{-3}) \times 9.81 \text{ N kg}^{-1} \times 64.5 \text{ m}$

$= 1.8 \times 10^{13}$ J [no up] **(1)** 2

Calculation of efficiency over one year

Efficiency = (useful energy output/total energy input) × 100%
6.1×10^{15} J **(1)**
$\div 365 \times 1.77 \times 10^{13}$ J **(1)**
× 100%

= 94.4 % [Accept fractional answers. Allow use of 2×10^{13} J, which gives 83.6%, or ecf, but check nos.] **(1)** 3

Calculation of average power output over year

$P = W/t$ **(1)**

$= 6.1 \times 10^{15} \text{ J} \div 3.16 \times 10^7 \text{ s}$
$= 1.9 \times 10^8$ W **(1)** 2

Reason for difference from max power output

Any sensible reason, e.g., river flow varies over the year / variations in rainfall [Accept answers related to demand] **(1)** 1

[8]

63. Show that lift is about 14 700 N

Lift = weight = mg

$= 1500 \text{ kg} \times 9.81 \text{ N kg}^{-1}$

= 14 700 N **(1)** 1

Explanation of why vertical component equals weight

No vertical acceleration / resultant vertical force = zero / vertical forces balanced **(1)** 1

Show that horizontal component is about 4500 N

Horizontal component = $F\sin\theta$

OR

= 15 400 N × sin 17°   OR 15 400 N × cos (90° – 17°) **(1)**
= 4503 N   [no up] **(1)** 2

Calculation of forward acceleration

$a = F / m$ **(1)**

= 4503 N ÷ 1500 kg

= 3.0 m s^{-2} **(1)** 2

Calculation of distance travelled after 10 s

$s = ut + ½ at^2$

= 0 + ½ × 3.0 m s^{-2} × (10 s)^2 [e.c.f.] **(1)**

= 150 m **(1)** 2

Explanation of whether likely to be actual distance

Distance likely to be less **(1)**

Air resistance / drag will decrease resultant force / acceleration **(1)** 2

[10]

64. (i) Distance travelled

Attempt to find area under curve/use of suitable equations **(1)**

Distance = 300 m **(1)**

(ii) Averape speed

Use of total distance/20 **(1)**

Average speed = 15 m s^{-1} [e.c.f. distance above] **(1)**

[4]

65. Average deceleration

Select $\upsilon^2 = u^2 + 2ax$, ½ m $\upsilon^2 = Fx$ and $F = ma$ OR equations of motion **(1)**

Correct substitutions of 40 m and 25 m s^{-1} **(1)**

a = 7.8 m s^{-2} [If a = –7.8 m s^{-2} → 2/3] **(1)** 3

Depth of sand and stopping distance

More sand ⇒ shorter stopping distance/stops more quickly/slows down faster **Because** lorry sinks further/ bigger resisting force / bigger friction force **(1)** 1

[4]

66. Resultant force

4 N to the right / 4 N with correct arrow **(1)** 1

Motion of object

(i) Constant velocity / $a = 0$ / constant speed **(1)**

(ii) Accelerates upwards **(1)**

(iii) Slows down **(1)** 3

Student's argument

The forces act on different bodies **(1)**

Therefore cannot cancel out / there is only one force acting on the body [consequent] 2

[6]

67. Vehicle movement

mgh and ½ $m\upsilon^2$ [Both required] / mgh and mgh / ½ $m\upsilon^2$ and ½ $m\upsilon^2$ **(1)** 1

Expression for speed

Kinetic energy gained = gravitational potential energy lost /
$mgh = ½ m\upsilon^2$ **(1)**
$\upsilon = \sqrt{(2gh)}$ **(1)** 2

Assumption

No friction/air resistance/rolling **(1)** 1

Explanation

Yes, because C is lower than A / potential energy is lower at C than at A **(1)**
Yes so it will still have some kinetic energy at C **(1)**
No because:
Frictional forces do act to slow the vehicle **(1)**
even though C is lower than A the vehicle has insufficient kinetic energy to reach C **(1)** 2

[6]

68. Initial speed in *x* direction

Speed= distance ÷ time **(1)**
= 1.2 m/0.2 s
= 6.0 m s^{-1} **(1)** 2

<u>Initial speed in *y* direction</u>

Speed = distance ÷ time
= 1.9 m/0.2 s
= 9.5 m s^{-1} [No u.e.] **(1)** 1

<u>Why answers are estimates</u>

Speed not constant / some deceleration / acceleration ignored / **(1)** 1
speed an average over 2.0 s

<u>Initial velocity</u>

$\upsilon^2 = (6.0\ \text{ms}^{-1})^2 + (9.5\ \text{ms}^{-1})^2$ [e.c.f] **(1)**
$\upsilon = 11.2\ \text{m s}^{-1}$
$\tan\theta = 9.5\ \text{m s}^{-1} \div 6.0\ \text{m s}^{-1}$
$\theta = 58°$ [No u.e.] **(1)** 2

<u>Kinetic energy</u>

k.e. = $\frac{1}{2} m\upsilon^2$ **(1)**

$\frac{1}{2} \times 0.0052\ \text{kg} \times (11.2\ \text{m s}^{-1})^2$
= 0.33 J **(1)** 2

<u>Gravitational potential energy</u>

$E_p = mg\Delta h$ **(1)**
= $0.0052\ \text{kg} \times 9.81\ \text{m s}^{-2} \times 5.3\ \text{m} = 0.27$ J **(1)** 2

<u>Why answers not the same</u>

Horizontal component of motion **(1)**
shuttle still has ke **(1)**
OR
Energy converted to heat/work done against/energy lost because of **(1)**
air resistance **(1)** 2

[12]

69. <u>Weight</u>

750 N **(1)** 1

<u>Mass</u>

W=mg **(1)**
= 750 N ÷ 9.81 m s^{-2}
= 76 kg **(1)** 2

<u>Figure 2 completion</u>

W arrow, labelled 750 N **(1)**
R arrow, labelled 250 N **(1)** 2

[No u.e. in either case]

[Allow 1 mark for downward arrow longer than upward arrow]

<u>Acceleration</u>

F=ma **(1)**

= 750 N – 250 N = 500 N **(1)**

a = 500 N ÷ 76 kg

= 6.6 m s^{-2} **(1)** 3

<u>Description of motion for *t* = 1.3 s to 1.5 s</u>

Constant/steady velocity **(1)**

No acceleration **(1)** 2

<u>Description of motion for *t* = 1.5 s to 2.0 s</u>

Deceleration down/accelerating up **(1)**

Until υ = 0 / to rest / v decreasing **(1)** 2

[12]

70.	<u>Magnitude of resultant force</u>	
	4 cm line S / 1.7 cm line N	1
	8 cm line NE / 8N resolved into two perp. components (5.7E & 1.7N or 5.7N)	1
	Correct construction for vector sum	1
	5.7-6.1N	1
	<u>Name of physical quantities</u>	
	Vectors	1
	<u>Two other examples</u>	
	Any two named vectors other than force (if>2, must all be vectors)	1

[6]

71.	<u>Calculation of average velocity</u>	
	Use of $\upsilon = s/t$	1
	υ = 1.86 m s^{-1} / 1.9 m s^{-1}	1
	<u>Acceleration of trolley</u>	
	Selecting $\upsilon^2 = u^2 + 2as$	1
	Correct substitutions	1
	2.87 m s^{-2} / 2.9 m s^{-2} / 3.0 m s^{-2}	1
	<u>Tension in string</u>	
	Use of $F = ma$	1
	2.73 N / 2.76 N / 2.85 N	1
	Assuming no friction/no other horizontal force/table smooth/light string/inextensible string	1
	<u>Explanation</u>	
	Suspended mass/system is accelerating	1
	Idea of <u>resultant</u> force on the 0.4 kg mass	1

[10]

72. Acceleration of free fall

Advantage:

So time/distance can be measured more precisely/accurately 1
[Allow reaction time less important]

Disadvantage:

Air resistance becomes important [NOT air resistance acting for longer time]/may reach terminal velocity/harder to hit trap door 1

–

Experimental method

Diagram:

Labelled start mechanism (any part) 1
Labelled stop mechanism (any part) 1

Releasing ball starts timer 1
Ball opening trap door/switch stops timer 1

OR

Diagram:

Ticker timer 1
Tape from sphere through timer [at least one labelled] 1

Timer makes dots at known rate 1
Time = number of spaces × time interval between dots 1

OR

Diagram:

Camera 1
Strobe lamp 1

Lamp flashes at known frequency 1
Time = number of spaces between images × time interval between flashes 1

OR

Diagram

Light gate joined to timer 1
Second light gate also joined to timer [one labelled] 1
Ball passing gate starts timer 1
Ball passing second gate stops timer 1

OR

Diagram

Labelled stopwatch -one mark only out of 4 1

OR

Diagram

Motion sensor labelled 1
At top or bottom 1

Produces distance time graph/pulses emitted at known time intervals 1
Time read off from graph 1

OR

Diagram

Video camera 1
At side 1

Frames at known frequency/time interval 1
Time = no. of frames × time interval 1

<u>Statement</u>

Weight = mass × *g* (allow '*W* = mg') 1

g is the same (for all objects) [NOT 'gravity' is constant] 1

[8]

73. <u>Gravitational potential energy</u>

Use of *mgh* 1

Vertical drop per second = (8.4 m) sin (3°) 1

3.9×10^2 J/Js^{-1}/W 1

<u>What happens to this lost gpe</u>

Becomes internal energy/used to do work against friction and/or drag/heat/thermal energy. [mention of KE loses the mark] 1

<u>Estimate of rate at which cyclist does work</u>

Rate of working = 2. × 3.9×10^2 W 1

=7.8×10^2 W 1

[3.9×10^2 W earns 1 out of 2]

[6]

74. Momentum and its unit

Momentum = mass × velocity 1

kg m s^{-1} or N s 1

Momentum of thorium nucleus before the decay

Zero 1

Speed of alpha particle/radium nucleus and directions of travel

Alpha particle because its mass is smaller/lighter 1

So higher speed for the same (magnitude of) momentum
OR N3 argument 1

Opposite directions/along a line 1

[6]

75. Average speed of the car

Speed = s/t [stated or implied] **(1)**

= 15 m/0.7 s [allow 14.5 m to 15.5 m]

= 21.4 m s^{-1} **(1)** 2

–

Deceleration

Identify u = 24.0 m s^{-1} [Can show by correct substitution] **(1)**

$s = ut + \frac{1}{2}at^2$

12.6 m = (24.0 m s^{-1} × 0.7 s) + $\frac{1}{2}$ × a × $(0.7\ s)^2$ + $\frac{1}{2}$ × a × $(0.7\ s)^2$

The rest of the substitution

a = 2(12.6 m – (24.0 m s^{-1} × 0.7 s)) ÷ $(0.7\ s)^2$

Rearrangement

a= (–)17.1 m s^{-2} / deceleration = 17.1 m s^{-2} [No u.e] **(1)** 4

[If using speed limit: identify u **(1)**;
speed limit = 18 m s^{-1} → v = 12 m s^{-1} **(1)**;
substitute in or rearrange $v = u + at$ or $v^2 = u^2 + 2as$ **(1)**,
a = (–)17.1 m s^{-2} **(1)**]

Calculation of braking force

$F = ma$ **(1)**

$= 1400 \text{ kg} \times 17.1 \text{ m s}^{-2}$

$= 2.4 \times 10^4$ N **(1)** 2

[8]

76. Rate of energy transfer

$E_p = mg\Delta h$ **(1)**

For one person: $E_p = 90 \text{ kg} \times 9.81 \text{ m s}^{-2} \times 420 \text{ m} = 370\ 800$ J **(1)**

For 2800 people: $E_p = 2800 \times 370\ 800 \text{ J} = 1.04 \times 10^9$ J]

Rate $= 1.04 \times 10^9 \text{ J} \div 3600$ s

= 288 000 W [No u.e.] **(1)** 3

Total kinetic energy

k.e. = $\frac{1}{2} m\upsilon^2$ **(1)**

$\frac{1}{2} \times 2800 \times 90 \text{ kg} \times (5.0 \text{ ms}^{-1})^2$

= 3 150 000 J ÷ [No u.e.] **(1)** 2

Rate of energy conversion

3 150 000 J ÷ (60 × 60 s) = 875 W [No u.e.] **(1)** 1

Discussion of student's answers

k.e.:

Skiers gain ke, increases total energy used **(1)**

but not significant / 875 W << (364 000 – 288 000) W **(1)**

Heat:

Heat loss indicated **(1)**

Identified mechanism, e.g. friction electrical in motor **(1)** 4

[10]

77. 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

$W = mg = 0.25 \times 9.81 = 2.5$ 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

$\upsilon = F / 6\pi\eta r = 2.5 / 6\pi \times 0.040 \times 1.71 \times 10^{-5} = 1.9 \times 10^{5}$ 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]

78. Gradient

Use a gradient or use of $\upsilon = u + at$ **(1)**

10 (either no unit or m s^{-2}) **(1)**

[A bare answer of 9.8 gets no marks; A bare answer of 10 gets 2 marks]

Significance

It is the acceleration (due to gravity) or close to g **(1)** 3

Ball at point A

It hit the floor/bounces/(idea of collision with floor) **(1)** 1

Calculation of height of window above ground

An area / quote an equation of motion **(1)**

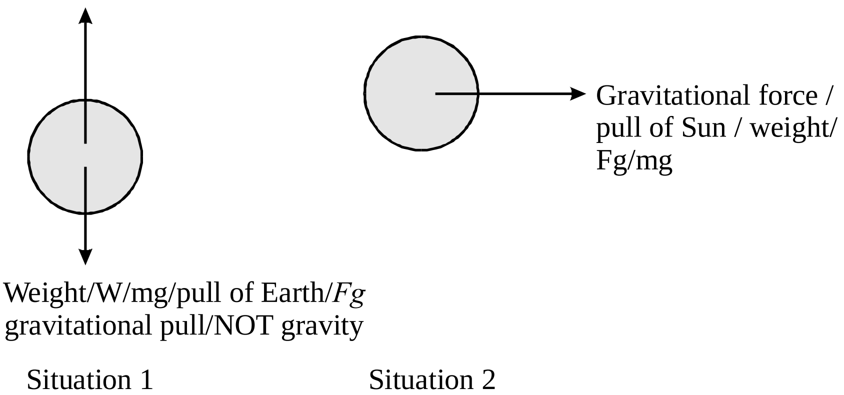
Put in relevant numbers for large triangle / correct substitution
[ecf from first part, or use of 9.8] **(1)**

45 m [accept 44 to 46] **(1)** 3

[7]

79. <u>Free-body force diagrams</u>

Tension/T/pull of string/NOT pull of ceiling
Reaction force from string/Contact force from string **(1)**



[Cancel a mark for every extra force (within each diagram); correct line of action required; penalise "gravity" once only.]

Force	Newton's third law pair, noting its direction and the body on which it acts	
Weight	On Earth......Upwards	**(1)**
Tension	On string......Downwards [N.B. allow ecf from ceiling pull in previous part]	**(1)**
Gravitational force	On Sun......Towards Earth/to the left	**(1)**

[No other ecfs from incorrect forces: "in opposite direction" penalise once only.] 3

[6]

80. <u>Mass approximately 4 kg</u>

Use of volume = $\pi r^2 \times h$ **(1)**

Use of mass = their volume above × density **(1)**

Mass = 3.75 (i.e. ≈ 4) [no u.e.] [Must be calculated to 2 significant figures at least] **(1)** 3

Calculation of change in g.p.e

Use of Δg.p.e = $mg\Delta h$ (ecf from above) **(1)**

39 – 44 J (positive or negative) **(1)** 2

Calculation of average power output

Use of Power = energy/time or use of $P = F\upsilon$ ($\upsilon = 1.8 \times 10^{-6}$ m s^{-1}) **(1)**

Correct conversion of time into seconds (604 800 s) **(1)**

$6.4 - 7.3 \times 10^{-5}$ W [e.c.f. gpe above] **(1)** 3

[Answer in J/day, J/week, J/hour – can get 2 marks, i.e.1st and 3rd marks]

[8]

81. (a) Newton's second law of motion

Rate of change of momentum ∝ (OR =) force/
Force = mass × acceleration / F ∝ (OR =) ma with symbols defined/
$a \propto F$ *and* $a \propto 1/m$ with symbols defined **(1)**

Acceleration or (rate of) change of momentum in direction of force **(1)** 2

Description of demonstration that acceleration is proportional to resultant force

Technique for reducing/compensation for friction **(1)**

e.g. Air track/friction compensated runway/low friction wheels or track/slight slope drawn or mentioned [not if slope used to vary the force] / smooth runway

Correct technique for applying a constant "known" force **(1)**

e.g. Forcemeter/elastics of constant length/slope where $F = mg\sin\theta$ / mass on string and pulley if masses are small or moved from pulley to trolley

Apparatus for measuring acceleration **(1)**

e.g. Ticker timer/ light gate plus double interrupt/ two light gates plus one interrupt/ motion sensor/ strobe camera/ video

Principle behind the measurement **(1)** e.g. gives position at known time intervals or times for known distances

Vary F **(1)**

Graph of a versus F should be a straight line through the origin **(1) Max 5**
OR values of F/a are constant

(b) Explanation of observations

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

Pencil is accelerating/increasing momentum **(1)**

This requires a forward force **(1)**

Back edge of shelf pushes forwards **(1)**

Converse argument for deceleration **(1)**

OR

Pencil travels at constant velocity / constant momentum little acceleration / stays at rest **(1)**

In line with Newton I/due to its inertia/because little or no force on it **(1)**

If car accelerates, it "catches up" with pencil **(1)**

Converse argument for deceleration **(1)** 4

[12]

82. Amount of work done by each of the forces

(Each of the forces does)zero **(1)**

Forces perpendicular to motion [consequent] **(1)** 2

[No marks if imply that work = 0 because forces cancel]

Determination of force F

Use of gradient seen/implied **(1)**

F = 2.7 – 2.9 N **(1)** 2

Graph

Straight line finishing at (1.8, 0) (+ or – 1 small square) **(1)**

Starting at (0, 5) (+ or – 1 small square) **(1)** 2

Calculation of speed

Use of k.e. = ½ $m\upsilon^2$ / use of $F = ma$ and equation of motion **(1)**

υ = 3.5 ms^{-1} (ecf) **(1)** 2

Sketch of graph

Ascending line whose gradient decreases as d increases **(1)** 1

Shape of graph

Force greater at higher speed/gradient is the force/force decreases with distance **(1)** 1

[10]

83. Show that deceleration = 7 m s^{-2}

$a = (\upsilon - u) / t$ **(1)**

a = (0 m s^{-1} – 11.5 m s^{-1})/1.68 s **(1)**

a = 6.85 m s^{-2} [No u.e.] **(1)** 3

Calculation of frictional force

$F = ma$ **(1)**

= 1400 kg × 6.85m s^{-2} [Allow ecf]

= 9590 N **(1)** 2

[F = 9800 N if 7 m s^{-2} used]

[Alternative: Force = kinetic energy ÷ distance **(1)** F = 9590 N **(1)**]

Why driver should not be charged

$\upsilon^2 = u^2 + 2as$

0 $m^2 s^{-2} = u^2 + 2 \times 6.85$ m $s^{-2} \times 20.0$ m **(1)**

$u = \sqrt{2 \times 6.85\,\mathrm{m s^{-2}} \times 20.0\,\mathrm{m}}$

u = 16.6 m s^{-1} **(1)**

16.6 m s^{-1} < 18 m s^{-1}, so not speeding **(1)** 3

[u = 16.7 m s^{-1} if 7 m s^{-2} used]

[OR substitute: 0 m^2 s^{-2} = (18 m s^{-1})^2 + 2 × (– 6.85 m s^{-2}) × s **(1)**

s = 23.6 m **(1)**, 23.6m > 20.0m, so not speeding **(1)**]

Assumption

e.g same deceleration as test car. OR same mass and braking force as test car/F ÷ m same as for test car, OR not wet / icy weather OR speed zero at end of skid/doesn't collide before stopped OR skid starts when brakes applied/stops **(1)** when comes to rest OR same conditions 1

[9]

84. Show that value in cell B3 is correct

Vertical component = υ sin θ OR vertical component G2*sin(F2) **(1)**

Vertical component = 21 m s^{-1} × sin 36° **(1)**

Vertical component = 12.3 m s^{-1} [No ue] **(1)** 3

Suitable formula for B4

υ = u + at OR B4 = B3 – (I2*A4) **(1)** 1

Explanation of constant horizontal velocity

Any 2 from the following: **(1) (1)**

- Horizontal and vertical motion independent
- No air resistance/horizontal force components
- so no acceleration 2

Show that value in cell D7 is correct

Distance = speed × time
OR
D7 = C7*A7
OR
D7 = 17 m s^{-1} × 2s **(1)**
D7 = 34m [No ue] **(1)** 2

Explanation of why flight time of 2.5 s suggested

Vertical component equal in magnitude and opposite in direction to initial vertical component **(1)** 1

Discussion of distance travelled for real discus

Air resistance [will decrease horizontal component of velocity] **(1)**
so it will travel a smaller distance **(1)**
OR
Air flow may produce an upward force [decreasing, vertical acceleration] **(1)**
increasing [the time of flight and therefore] the horizontal distance **(1)**
OR
Discus launched above ground level **(1)**
so it will travel a greater distance **(1)** 2

[11]

85. 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]

86. Deceleration of cars
Acceleration = gradient / suitable eqn. of motion. **(1)**
Correct substitutions [0.9 for t is wrong] **(1)**
6.1 – 6.3 m s^{-2} [-ve value –1] [no ecf] **(1)** 3

Area under velocity-time graph
Distance/displacement **(1)** 1

Shaded area
6.9 – 7.5 **(1)**
m **(1)** 2

[Allow **1** mark for 5.5 – 6.1 cm^2.]

Minimum value of the initial separation
Same as above [ecf] **(1)**
Area is the extra distance car B travels/how much closer they get **(1)** 2

Graph
Both sloping lines continued down to time axis [by eye] **(1)** 1

Explanation
Area between graphs is larger/B travels faster for longer/B still moving when A stops **(1)**
Extra distance B goes is larger/ > ‘7.2’ **(1)**
Initial separation must be greater **(1)** Max 2

[11]

87. Explanation of why kicking a door is more effective
Quality of written communication **(1)** 1
Foot decelerates/ loses momentum **(1)**
This takes place rapidly giving a large force by Newton 2 or equation versions [consequent] **(1)**
Door is providing this force [consequent on mark 1] **(1)**
Door acts on foot; by ‘Newton 3’ foot acts on door’ **(1)** Max 3

[4]

[Allow **1** mark for 5.5 – 6.1 cm^2.]

Minimum value of the initial separation
Same as above [ecf] **(1)**
Area is the extra distance car B travels/how much closer they get **(1)** 2

Graph

Both sloping lines continued down to time axis [by eye] **(1)** 1

Explanation
Area between graphs is larger/B travels faster for longer/B still moving when A stops **(1)**
Extra distance B goes is larger/ > '7.2' **(1)**
Initial separation must be greater **(1)** Max 2

[11]

88. Free-body force diagram
Normal reaction/contact force [or Nor R or push of table] upwards **(1)**
E-M/Magnetic force [or magnetic attraction or pull of magnet] to right **(1)**
Weight [or W or mg or gravitational force or gravitational attraction or pull of Earth] downwards **(1)** 3
[Ignore labelled forces of fiction. or drag] [if unlabelled –1 each force]

Forces
Pull on earth **(1)**
Upwards [consequent] **(1)**

OR

Push/contact force/force on table **(1)**
Downwards [consequent] **(1)**

OR

Force on magnet X **(1)**
To left [consequent] [allow ecf] **(1)** 2

[5]

89. Show that vertical component of velocity is about 14 m s^{-1}

Vertical component = $\upsilon \sin \theta$

OR

Vertical component = 22.5 m s^{-1} × sin 38° **(1)**

= 13.9 m s^{-1} **(1)** 2

Show that time of flight is about 3 s

$s = ut + ½ at^2$

Identify s = 0 (can show by correct substitution) **(1)**

0 = 13.9 m s^{-1} × t – ½ × (9.81 m s^{-2}) × t^2

Manipulation so t on one side only (e.g. 13.9 = 4.9t) **(1)**

t = 2.8 s **(1)**

OR

$\upsilon = u + at$

Time to top assumes $\upsilon = 0$ (can show by correct substitution) **(1)**

$0 = 13.9 \text{ m s}^{-1} - (9.81 \text{ m s}^{-2})t$

$t = 1.4$ s **(1)**

Time of flight = 2 × 1.4 s

$t = 2.8$ s **(1)** 3

<u>Calculation of range</u>

Horizontal component = $22.5 \text{ m s}^{-1} \times \cos 38°$ **(1)**

$= 17.7 \text{ m s}^{-1}$

Horizontal distance = $\upsilon \times t$ [or any speed in the question × time] **(1)**

$= 17.7 \text{ m s}^{-1} \times 2.8$ s

= 49.6 m **(1)** 3

<u>Effect of work done on range</u>

Work done = force × distance **in direction of force (1)**

Any two from:

- assuming force constant or relevant discussion of size of force
- increases distance (moved by force) → more work done
- more work done →more k.e. gained
- more k.e. gained → greater initial speed
- greater initial speed → greater range 3

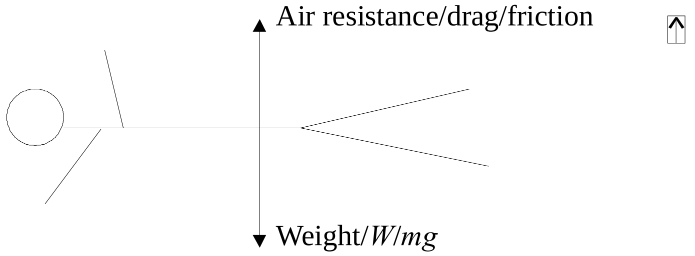
[11]

90. Draw and label forces

Weight, W, mg (not "gravity") **(1)**

Air resistance/drag/friction **(1)**

–1 for each extra force, ignore upthrust, ignore line of action 2



Discussion of forces

(Constant velocity) → zero acceleration / resultant force = zero /forces in equilibrium / sum of forces = 0 / forces balanced **(1)**

Forces equal (and opposite) / weight = drag **(1)** 2

Show that mass is about 70 kg

$m = W/g$

$= 690 \text{ N} \div 9.81 \text{ m s}^{-2}$

$= 70.3$ kg 1

–

Calculation of gravitational potential energy

$\Delta E_{grav} = mg\Delta h$

$= 690 \text{ N} \times 2000 \text{ m}$ [e.c.f.] **(1)**

$= 1.4 \times 10^6$ J **(1)** 2

Comments on suggestion of gravitational potential energy to kinetic energy

Any two from:

- No gain in E_k here
- Air resistance ignored/should be taken into account
- Should be E_{grav} lost = E_k gained + work done against air resistance/drag
- At this stage work done against air resistance = E_{grav} lost 2

[9]

91. Diagram:
Shown and labelled
Ticker timer at top **or** Strobe light **(1)**
Tape from trolley through timer **or** camera [consequent] **(1)**
OR
Motion sensor pointing at trolley **or** video **(1)**
Connection to datalogger/computer or rule [both consequent] **(1)**
OR
Three or more light gates **(1)**
Connection to datalogger/computer [consequent] **(1)**
[**Two** light gates connected to ‘timer’ – max 1]
[Rule **and** stop clock - max 1]

Values for υ and a: 2
0.95 m s^{-1} [2 s.f.] **(1)**
Use of gradient or formula **(1)**
0.79 m s^{-2} [no e.c.f. if u = 0] **(1)**
Distance AB: 3
AB = 'area' under graph, or quote appropriate equation of motion **(1)**
Physically correct substitutions **(1)**
0.86 m [allow 0.9 m] [e.c.f. wrong u or a] **(1)**
Graph: 3
Smooth curve rising from origin, getting steeper **(1)**
Initial gradient non-zero [consequent] **(1)**
(0.70, 0.86) matched (e.c.f. on distance) **(1)** 3

[11]

92. Identification of vector and scalar:

Vector = force, lift, horizontal distance, height, weight **(1)**

Scalar = mass, time, distance **(1)** 2

Calculation of weight:
$W = mg$ OR = 0.1 kg × 9.81 N kg^{-1} **(1)**

[Max 1 mark for g = 10 N kg^{-1}]

= 0.98 N **(1)** 2

Calculation of vertical acceleration:

$s = ut + ½ at^2$

1 m = 0 + ½ × a × (2.5 s)^2

a = 2 m ÷ 6.25 s^2 = 0.32 ms^{-2}

State u = 0 **(1)**

Substitute correct distance **(1)**

a = 0.32 m s^{-2} [no u.e.] **(1)** 3

Calculation of resultant vertical force:

$F = ma$ (stated or implied) **(1)**

= 0.1 kg × 0.32 m s^{-2} [Allow e.c.f.]

= 0.032 N **(1)** 2

Calculation of lift force:

[$F = ma$ mark may be awarded here]

Weight – lift = resultant **(1)**

Lift = 0.98 N – 0.032 N = 0.948 N [Allow e.c.f.]

= 0.95 N [Allow –0.95 N] **(1)** 2

[11]

93. Forces on diagram:

Tension/T in cable on both sides **(1)**

Weight / W / mg / 18 000 N / 18 000 [not "gravity"] **(1)**

[Penalise each wrong force in addition to the 3 but ignore upthrust] 2

Calculation of tension:

Net vertical force = zero

$W = 2T$ **(1)**

× sin 2.5°[allow cos 87.5°] [θ wrong = eop] **(1)**

T = 206 000 N **(1)** 3

–

Show that total k.e. is about 500 000 J:

k.e. = ½ $m\upsilon^2$ **(1)**

= 0.5 × 54 × 1250 kg × (4 m $s^{-1})^2$ **(1)**

= 540 000 J [No u.e.] **(1)** 3

Calculation of time to reach maximum speed:

$P = W/t$

$t = W/P$ = 540 000 J ÷ 500 000 W [Allow e.c.f.] **(1)**

= 1.1 s [Allow 1.0 s from 500 000 J] **(1)** 2

Suggest a reason why time longer:

Friction / air resistance reduces acceleration / resultant force
OR Friction / air resistance reduces **useful** power 1

[11]

94. Calculation of resultant force:

[$a = (\upsilon - u)/t = 16\ \text{m s}^{-1}[(4 \times 60)\ \text{s}]$

$= 0.0666\ \text{m s}^{-2}$

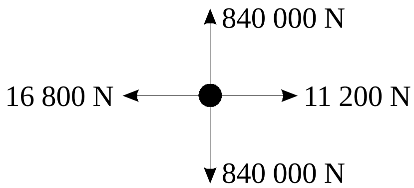
$F = ma = 84\ 000\ \text{kg} \times 0.0666\ \text{m s}^{-2} = 5600\ \text{N}$]

OR

Use of $\dfrac{(\upsilon - u)}{t}$	use of $m\upsilon$	**(1)**	
Use of $F = ma$	use of $\dfrac{m\upsilon}{t}$	**(1)**	
5600 N	5600 N	**(1)**	3

Free-body force diagram:

Diagram [truck can be just a blob] showing:



823 200 – 840 000 N down		**(1)**	
same as down	up	**(1)**	
11 200 N	either way	**(1)**	
correct resultant	to left		
[e.c.f.]			
			4

[Ignore friction. Each extra force –1]

Calculation of average power:

Power = KE gained/time = $\frac{1}{2}mv^2/t$ OR KE = 3.84×10^8 J **(1)**

$= 3.84 \times 10^8\ \text{J}/(4 \times 60)\ \text{s}$ **(1)**

$= 1.60 \times 10^6\ \text{W}$ [OR J s^{-1}] **(1)**

3

Other credit-worthy responses:

$\frac{1}{2} m\upsilon^2$	Fv	$\frac{Fd}{t}$	**(1)**
$\frac{1}{2} \times \frac{3\times10^6 \times 16^2}{240}$	$3 \times 10^6 \times 0.666 \times 8$	$\frac{3\times10^6 \times 0.666 \times 1920}{240}$ [e.c.f. 0.666 and 1920 possible]	**(1)**
1.6×10^6 W	1.6×10^6 W	1.6×10^6 W	**(1)**

3

[10]

95. Completion of table:

Force	Description of force	Body which exerts force	Body the force acts on
A	Gravitational	Earth	Child
B	*(Normal) reaction OR contact OR E/M* **(1)**	*Earth/ground* **(1) for both**	
C	*Gravitational* [Not gravitational weight] **(1)**	*Child* **(1) for both**	*Earth*

4

Why *A* and *B* are equal in magnitude:

Child is at rest/equilibrium OR otherwise child would move/accelerate **(1)**
[NB use of N3 would contradict this]

Why must forces *B* and *D* be equal in magnitude:

Newton's third law OR action + reaction equal and opposite **(1)**
[NB use of N1 or N2 here would contradict this] [Not Newton pair] 2

What child must do to jump and why he moves upwards:

Push down, increasing *D* **(1)**

∴ *B* increases [must be clearly *B* or description of *B*] **(1)**

and is > *A* OR there is a resultant upward force [clearly on child] **(1)**
[Not "movement"] 3

[9]

96. Force:

200 N **(1)** 1

Free body force diagram:

[Unlabelled arrows = 0; ignore point of application of force]
[Double arrows = 0] [Arrows required for marks]

W / weight / 400 N /*mg*/ pull of Earth / gravitational force **(1)**
[Not gravity]

Two tensions OR Two × 300 N OR two × 311 N **(1)**
[Accept *T* for tension OR any label that is not clearly wrong,
e.g. R/W/N 200 N] 2

Applied force:

Attempt to resolve vertically **(1)**

$2T \sin 40 = 400$ **(1)**

[400 ×cos 40 → 306 N(no marks)
400 × sin 40 → 257 N (no marks)
200/cos 40 = 261 N → gets 1 out of 3 (attempted to resolve)]

T = 310 (N) OR 311 (N) [No unit penalty] **(1)** 3

Two reasons why first method is easier:

Force applied is smaller/feels lighter/tension smaller [Not weighs less] **(1)**

They are not pulled sideways/forces only upwards/pulling against each other **(1)**
[Answer must be in terms of forces] 2

Why solution is not sensible:

Because the tension (or description of tension) would be greater **(1)**
OR bigger <u>sideways</u> force 1

[Do not accept bigger force]

[9]

97. Completion of diagram:

Useful work done by motor	$\longrightarrow$	*(Increase)* in gpe OR w.d. against gravity/*mgh* [Not w.d. on car]	**(1)**	1

(i) Useful work done by motor:

Correct substitution in *mgh*, i.e. 3400 (kg) 9.81 (m s^{-2}) × 30 (m) **(1)**

= 1.00 MJ OR M Nm [1.02 MJ] **(1)**

(ii) Power output of motor:

Power = above (J) / 15 (s) **(1)**

= 67 kW [e.c.f.] **(1)** 4

Overall energy conversion occurring as vehicle travels from B to C:

(Gravitational) potential energy OR *w.d. by gravity*	$\longrightarrow$	*Kinetic energy (and g.p.e)*	**(1)**	1

Speed of vehicle at point C:

Δh = 18/(30 – 12) **(1)**

Use of ½ mv^2 = g.p.e. lost **(1)**

[If get height wrong, can only get second mark]

υ = 19 m s^{-1} [18.8 m s^{-1}] 3

How speed at C would be expected to differ from previous answer:

Same speed/no effect [If this is wrong, no marks] **(1)**

GPE and KE both symbol 181 \f " 12µ *m* OR
g same for all masses OR *m*s cancel **(1)** 2

[Not *g* is constant]

[11]

98. 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]

99. Unit for power:

Watt OR W OR J/s OR any correct S.I. equivalent **(1)** 1

Average speed:

500 m /120 s

= 4.2 OR 4.17 m s^{-1} [allow 4.1 or 4.16 or 4 but not 4.0] **(1)** 1

Average resistive force:
[1st mark is for the formula in any arrangement] **(1)**
$F = P/\upsilon$ [accept P = work/t or $P = F \times d/t$]
= 230 W / 4.2 m s^{-1} **(1)**
= 55 N 2

Initial acceleration:

Tangent at t = 0 drawn **(1)**

Acceleration = gradient **(1)**

⇒ value in range 0.50 – 0.85 m s^{-2} **(1)** 3

To travel 500 m:

Distance travelled = area under graph **(1)**

Valid attempt to evaluate appropriate area **(1)**

Answer in range 105 s – 119 s **(1)**
[allow use of s = $\upsilon \times$ t for full marks] 3

Why speed becomes constant:

a = 0 OR $F_{\text{net/total}} = 0$ OR equilibrium/balanced forces **(1)**

for $a = 0$, resistive F = forward F [accept friction or drag for resistive] **(1)**
[do not accept "forces are equal" or "has reached terminal velocity"]

frictional force increases as velocity increases **(1)** Max 2

[12]

100. Speed:

$\upsilon^2 = u^2 + 2as$ (OR $\frac{1}{2} m\upsilon^2 = mgh$)

$\Rightarrow \upsilon^2 = 2 \times 9.81 \times 55$ **(1)**

$\Rightarrow \upsilon = 33\ (32.8)\ \text{m s}^{-1}$ **(1)** 2

Assumption:

No air resistance

OR no friction

OR energy conserved/ no energy loss

OR constant acceleration [not "gravity constant"] **(1)** 1

Value for g:

$s = ut + \frac{1}{2}at^2$**(1)**

$\Rightarrow g = \frac{2s}{t^2}$ OR $\frac{2 \times 30}{2.1^2}$ **(1)**

$=13.6\ \text{s}^{-2}$ 2

Explanation:

Imprecise timing– [not "human error" on its own] **(1)**

t too small $\Rightarrow g$ too large **(1)**

OR

Clock started late/ stopped early OR shuttle already moving **(1)**
[not "air resistance"]
t too small $\Rightarrow g$ too large **(1)** 2

Improvements:

Any two from

Repeat timing, then average **(1)**

Time using video **(1)**

Electronic method e.g. light gates, sensors in context **(1)**

OR other sensible suggestion e.g. time to bottom **(1)** Max 2

Maximum resultant force:

$F = ma$ **(1)**

$= 5000 \times 4.5 \times 9.81$ N

$= 2.2 \times 10^5$ N **(1)** 2

[11]

101. 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 1.0×10^{3} 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]

102. Calculation of work done:

Work = area under graph/average force × distance **(1)**
= $\frac{1}{2}$ × 0.040 m × 22 N **(1)**
= 0.44 J **(1)** 3

[Allow any correct unit, e.g. N m. Penalise unit once only]

[$Fd \rightarrow$ + 0. 88 J gets 1/3]

Calculation of energy:

GPE = 0.024 kg × 9.81 (or 10) m s^{-2} × 0.60 m **(1)**
= 0.14 J **(1)** 2

Comparison:

Some energy transferred to some other form **(1)**

Reason [a mechanism or an alternative destination for the energy], e.g. **(1)**

Friction
Air resistance
Heat transfer to named place [air, frog, surroundings etc]
Internal energy
Vibrational energy of spring
Sound

OR quantitative comparison (0.3 J converted)

[No e.c.f. if gpe > work] 2

[7]

103. Explanation:

Changing direction/with no force goes straight on (along tangent) **(1)**

Acceleration/velocity change/momentum change **(1)** 2

Identification of bodies:

A: Earth [*Not* Earth's gravitational field] **(1)**

B: scales [*Not* Earth/ground] **(1)** 2

Calculation of angular speed:

Angular speed = correct angle ÷ correct time [any correct units] **(1)**

= 4.4×10^{-3} rad min^{-1} / 0.26 rad h^{-1}/ 2πrad day^{-1} etc **(1)** 2

Calculation of resultant force:

Force = $mr\omega^2$ **(1)**

= $55 \text{ kg} \times 6400 \times 10^3 \text{ m} \times (7.3 \times 10^{-5} \text{ rad s}^{-1})^2$ **(1)**

= 1.9 N **(1)** 3

[No e.c.f here unless ω in rad s^{-1}]

Calculation of value of force B:

Force B = 539N – 1.9N **(1)**

= 537 N **(1)** 2

[e.c.f. except where R.F = 0]

Force:

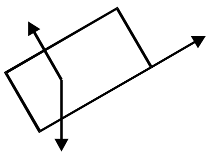
Scales read 537 N (same as B) [allow e.c.f.]

Newton's 3rd law/force student exerts on scales **(1)** 1

[12]

104. Addition of forces to produce a free-body diagram for trolley:

[Unlabelled arrows = 0; ignore point of application of force] **(1)**
R/N/Reaction/push of slope/ normal contact force
[NOT normal]
should be approximately perpendicular to slope]



F/friction/drag/air resistance **(1)** 3

W/weight/mg/pull of Earth/gravitational force
[Not gravity] [Should be vertical by eye]

Evidence that trolley is moving with constant velocity: 1

Trolley travelled equal distances (in same time)

Acceleration of trolley down slope:

0 / no acceleration 1

What value of acceleration indicates about forces acting on trolley:

Forces balance OR $\Sigma F = 0$ OR in equilibrium OR zero resultant 1

[Forces are equal 0/1]

[6]

105. Demonstration that speed is about 7 m s^{-1}

$\upsilon = d/t$ = 130 m / 18 s
(= 7.2 m s^{-1}) **(1)** 1

Calculation of average deceleration:

$\upsilon^2 = u^2 + 2as$ **(1)** 1

$\rightarrow 0 = 7.2^2$ [OR 7^2] + 2 × a × 110 $\rightarrow a$

= 0.24 [OR 0.22] m s^{-2} **(1)** 1

[Ignore signs]

Calculation of average decelerating force if combined mass is 99 kg:

$F = ma$

= 99 × 0.24 (0.22) N **(1)** 1

= 24 (22) N **(1)** 1

Discussion:

Need balanced forces OR forward force = resistive force(s) **(1)** 1

F needed > 24 (22) N **(1)** 1

Max 2

since that value was **average** force **(1)**

[Any 2 points from three]

Energy transferred: 1

3 J **(1)**

[7]

106. Demonstration that initial vertical component is about 7 m s^{-1}:

$\upsilon_{\uparrow} = \upsilon \sin \theta$ = 12.9 × sin 34.5° m s^{-1} **(1)**

= 7.31 m s^{-1} **(1)** 1

Calculation of time:

$t \quad \upsilon_{\uparrow}/g$ = 7.31/9.81 s **(1)**

= 0.745 s **(1)** 2

Comment:

More than twice **(1)**

Because falls further than rises **(1)**

OR

Same time to fall to same level **(1)** 2

OR

Similar reasoning

Calculation of horizontal distance:

$d = \upsilon \times t$ = 12.9 m s^{-1} × cos 34.5° × 1.71 s **(1)**

= 18.2 m **(1)** 2

Demonstration:

K.E. = ½ $m\upsilon^2$ = ½ × 5 × $(12.9)^2$J

(= 416 J) **(1)** 1

Two reasons why figure is low:

Gravitational p.e. gained by shot **(1)**

Kinetic energy and/or gravitational p.e. gained by athlete's body **(1)** **(1)**

[At least ONE of the above needed to gain two marks]

Work against air resistance during acceleration **(1)**

Other sensible point **(1)** Max 2

Suggestion for measuring υ.

Use video + frame analysis OR computer analysis package **(1)**

Further detail,
e.g. υ = distance ÷ time interval OR gradient of svt graph **(1)** 2

[12]

107. What happens when switch moved from A to B:

Ball released/drops

Clock starts 2

Time for ball to fall 1.00 m:

$x = gt^2/2$ [sufficient use of equation of motion]

$t^2 = 2 \times 1.00$ m/9.81 m s^{-2} [correct substitution in <u>all</u> equations]

t = 0.45 s 3

Time for ball to reach ground, with reason:

0.45 s/same as before (e.c.f)

Horizontal and vertical motion independent/same (vertical) height

Same vertical distance/same (or zero) initial velocity

[NOT same force or acceleration] 2

Speed at which ball was fired:

2.00 m/0.45 s (e.c.f)

4.4 m s^{-1} 2

[9]

108. Description of force C which forms a Newton's third law pair with A

Man pulling Earth upwards

with a gravitational force 2

Similarities and differences

Similarities [**any** 3]:

Magnitudes or equal
Kind (or type) of force *or* gravitational forces
Line of action [but **not** same plane, or point, or parallel]
Time interval or duration
Constant [not true in general but true in this instance] Max 3

Differences:

On different bodies [must say "bodies" or equivalent]

Direction [again, it answers this particular question] or opposite 2

Two forces which show whether *or* not man is in equilibrium:

A and B 1

[8]

109. Calculation of total amount of energy released during flight:

1.71×10^5 litres × (38 MJ litre^{-1})

$= 6.5 \times 10^6$ MJ 2

Calculation of input power to engines:

6.5×10^{12}J ÷ (47 × 3600 s) [Allow e.c.f for energy released]

= 38 MW 2

Calculation of aircraft's average speed:

(41 000 km) ÷ (47 h) *or* (41 $\times 10^6$ m)/(47 × 3600 s)

= 870 km h^{-1} *or* 240 m s^{-1}

Multiply *maximum* thrust by average speed and comment on answer:

One engine: (700 kN × 870 km h^{-1}) *or* (700 kN × 240 m s^{-1})

Two engines: (2 × 700 kN × 870 km h^{-1})
or (2 × 700 kN × 240 m s^{-1}) = 340 MW

[Allow any correct unit with corresponding arithmetic, eg kN km h^{-1})

Statement recognising that the product is a power.

Either a comparison of the two powers or a comment on the engine thrusts. 6

[10]

110. Calculation of time bullet takes to reach top of its flight and statement of any assumption made:

– 9.8 m S^{-2} = (0 m s^{-1} – 450 m s^{-1})/t

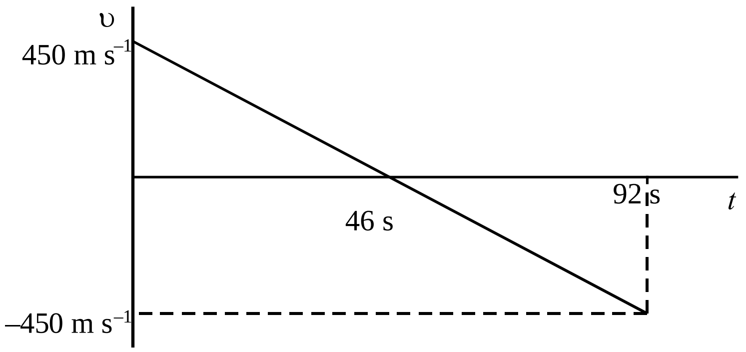
t = 46 s

Assumption: air resistance is negligible, acceleration constant or equivalent 3

Sketch of velocity-time curve for bullet's flight:

Label axes

Show the graph as a straight line inclined to axis
+ 450 m s^{-1} and 46 s shown correctly
– 450 m s^{-1} *or* 92 s for a correctly drawn line



Explanation of shape of graph:

Why the line is straight - acceleration constant
or equivalent or why the velocity changes sign
or why the gradient is negative

Calculate the distance travelled by bullet, using graph:

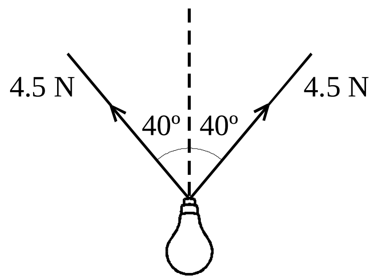
Identification of distance with area between graph and time axis or implied in calculation
20 700 m for g = 9.8 ms^{-2} or alternative answers from different but acceptable "g" values. 7

[Allow e.c.f with wrong time value.]

[10]

111. State the difference between scalar and vector quantities.
Scalar quantities are non-directional (1)
Vector quantities are direction (1)

A lamp is suspended from two wires as shown in the diagram. The tension in each wire is 4.5N.

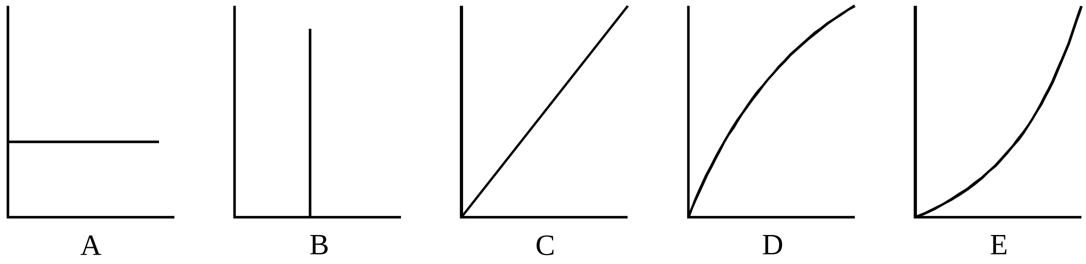


Calculate the magnitude of the resultant force exerted on the lamp by the wires.
4.5 N cos 40° (1)
× 2 (1)
Resultant force = 6.9 N (1)

What is the weight of the lamp? Explain your answer.
6.9 N (1)
Weight = Supporting force or it is in equilibrium (1)

[Total 7 marks]

112. Each of the following graphs can be used to describe the motion of a body falling from rest. (Air resistance may be neglected.)



Which graph shows how the kinetic energy of the body (y-axis) varies with the distance fallen (x-axis)?

Graph **C (1)**

Explain your answer.

Since kinetic energy gained = potential energy lost, (1)

Kinetic energy gained $\propto$ distance fallen (1)

(3 marks)

Which graph shows how the distance fallen (y-axis) varies with the time (x-axis)?

Graph **E (1)**

Explain your answer.

Speed increases with time (1)

So gradient increases with distance (1)

(3 marks)

Which graph shows the relationship between acceleration (y-axis) and distance (x-axis)?

Graph **A (1)**

Explain your answer.

Acceleration is constant (1)

throughout the motion (1)

(3 marks)
[Total 9 marks]

113. An athlete of mass 55 kg runs up a flight of stairs of vertical height 3.6 m in 1.8 s. Calculate the power that this athlete develops in raising his mass.

Power = $\dfrac{(55\,\text{kg})\times(9.81\,\text{N/kg})\times(3.6\,\text{m})}{(1.8\,\text{s})}$

Numerator correct (1)

Denominator correct (1)

Power = 1080 W (1)

(3 marks)

One way of comparing athletes of different sizes is to compare their power-to-weight ratios. Find a unit for the power-to-weight ratio in terms of SI base units.

Units correctly attached to a correct equation (1)

e.g. $\dfrac{\text{power}}{\text{weight}} = \dfrac{\text{N m s}^{-1}}{\text{N}}$ **(1)**

= m s^{-1} (1)

(0) if m s^{-1} is derived wrongly

(2 marks)

Calculate the athlete's power-to-weight ratio.

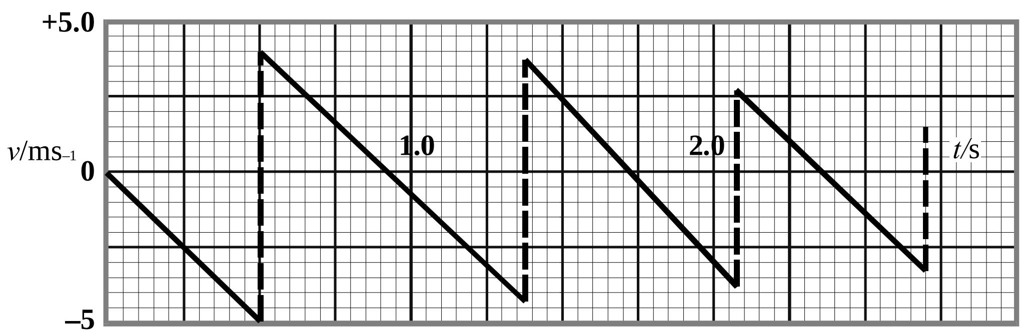
Power to weight ratio = $\dfrac{(1080\,\text{W})}{(55\,\text{kg})\times(9.81\,\text{m s}^{-2})}$ **(1)**

Power-to-weight ratio = 2 [m s^{-1}] (1)

(Unit error not penalised in final part)

(2 marks)
[Total 7 marks]

114. The diagram shows a velocity-time graph for a ball bouncing vertically on a hard surface.



At what instant does the graph show the ball to be in contact with the ground for the third time?

2.05 s $\leq$ t $\leq$ 2.10 s (2)

OR

2.00 $\leq$ t $\leq$ 2.20 s (1)

(2 marks)

The downwards-sloping lines on the graph are straight. Why are they straight?

Acceleration of the ball <u>or</u> force on the ball <u>or</u> gravitational field strength is constant <u>or</u> uniform (2 or 0)

(2 marks)

Calculate the height from which the ball is dropped.

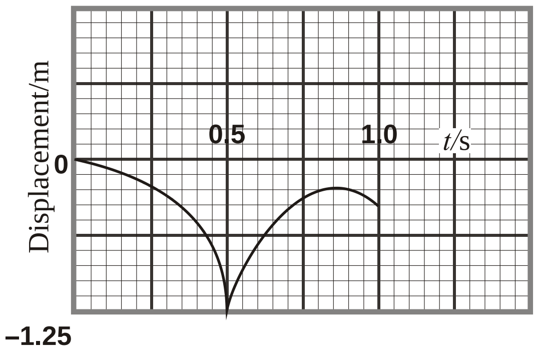
Relevant equation <u>or</u> correct area (1)

Substitution correct (1)

Answer (1.2 m $\leq$ height $\leq$ 1.3 m) (1)

(3 marks)

Sketch a displacement-time curve on the axes below for the first second of the motion.



Displacement scale agreeing with above (1)

First half of curve correct (1)

Second half correct with reduced height (1)

(3 marks)

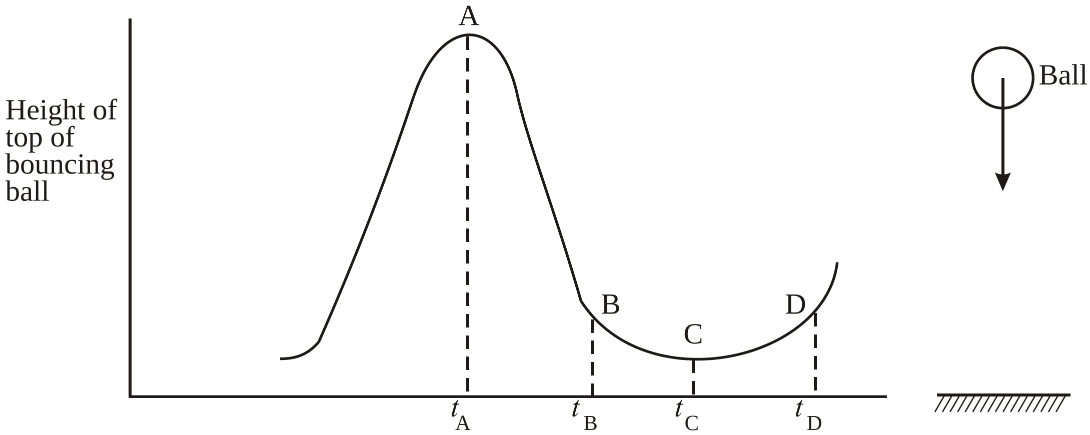
What is the displacement of the ball when it finally comes to rest?

–1.25 m (correct magnitude *and* direction)

(Look at candidate's displacement origin)

(1 mark)
[Total 11 marks]

115. The graph shows how the height above the ground of the top of a soft bouncing ball varies with time.



Describe briefly the principal energy changes which occur between the times

t_A and t_B

The ball loses gravitational potential energy and gains kinetic energy

(2 marks)

t_B and t_C

The kinetic energy is transformed into elastic potential energy when the ball deforms on the ground.

(3 marks)

t_C and t_D

The elastic potential energy is converted back into kinetic energy

(1 mark)
[Total 6 marks]