Question	Answer	Marks
1	C	1
2	A	1
3	Momentum of bullet = mv = 3.0 × 10^{-3} kg × 370 m s^{-1} = 1.11 N s Momentum is conserved, so momentum of rifle = –1.11 N s For rifle, mv = –1.11 N s = 3.2 kg × v so $v = \frac{-1.11\,\text{N s}}{3.2\,\text{kg}}$ = –0.3469 m s^{-1} so speed of recoil = 0.3469 m s^{-1} = 0.35 m s^{-1} (2 s.f.)	1 1 1
4 a	$F = \frac{\Delta p}{\Delta t} = \frac{(4.0\,\text{kg} \times 0.8\,\text{m s}^{-1} - 0)}{0.15\,\text{s}} = \frac{3.2\,\text{kg m s}^{-1}}{0.15\,\text{s}}$ = 21 N (2 s.f.) (One mark for correct method, one for substituting correctly and evaluating the answer. This could also be done by calculating a and using $F = ma$.)	2
4 b	Kinetic energy of each mass before collision = ½mv^2 = 0.5 × 4.0 kg × (0.8 m s^{-1})^2 = 1.28 J Masses are stationary after collision, so all kinetic energy is dissipated (mostly as heat) so energy dissipated = 2 × 1.28 J = 2.6 J (2 s.f.) (One mark for correct method, one for substituting correctly and evaluating the answer.)	2
5 a	kinetic energy gained = potential energy lost ½mv^2 = mgh = 900 kg × 9.8 m s^{-2} × 60 m = 529 200 J $v^2 = \frac{2 \times 529200\,\text{J}}{900\,\text{kg}}$ = 1176 m^2 s^{-2} ⇒ v = √(1176 m^2 s^{-2}) = 34 m s^{-1} (2 s.f.)	1 1 1
5 b	Some of the potential energy will be done as work against frictional forces.	1
6 a	$a = \frac{\Delta v}{\Delta t} = \frac{27\,\text{m s}^{-1}}{5.6\,\text{s}} = 4.821\,\text{m s}^{-2}$ $F = ma$ = 1100 kg × 4.821 m s^{-2} = 5303 N = 5300 N (2 s.f.)	1 1
6 b	$P = Fv$ so mean power = force × mean velocity velocity goes up uniformly from 0 to 27 m s^{-1}, so mean velocity = ½ × 27 m s^{-1} = 13.5 m s^{-1} P = 5303 N × 13.5 m s^{-1} = 71 600 W = 72 000 W (2 s.f.) (Can also use $P = \frac{\text{gain in kinetic energy}}{\text{time}}$ with one mark for method and one for evaluation)	1 1
7 a	For the particle, kinetic energy = $\frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2E_k}{m}}$ $= \sqrt{\frac{2 \times 8.0 \times 10^{-13}}{6.6 \times 10^{-27}}}$ = 1.5... × 10^7 m s^{-1} Momentum is conserved, so $m_1v_1 = m_2v_2 \Rightarrow v_1 = \frac{m_2v_2}{m_1}$ = 2.8... × 10^5 m s^{-1} kinetic energy of nucleus = $\frac{1}{2}mv^2$ = 0.5 × 3.6 × 10^{-25} kg × (2.8... × 10^5 m s^{-1})^2 = 1.5 × 10^{-14} J (2 s.f.)	1 1 1 1
7 b	velocity of particle = 5.5... × 10^7 m s^{-1} (same method as part (a)) velocity of nucleus = 140.2... m s^{-1} kinetic energy of nucleus = 3.5 × 10^{-21} J This is over a million times smaller than the kinetic energy found in part (a) (the emitted particle was significantly lighter and possessed smaller kinetic energy).	1 1 1 1

<table>
<tr><td>8 a</td><td>Reading of 3.4 cm looks like an outlier, so test it by seeing if it is further than 2 × spread of remaining data from the mean of the remaining data.
Mean of remaining data = $\frac{(5.2+5.8+5.7+5.4+5.5)\text{ cm}}{5}$ = 5.52cm Spread of remaining data = ½ × range = $\frac{(5.8-5.2)\text{ cm}}{2}$ = 0.3 cm
$5.52\text{ cm} - 3.4\text{ cm} = 2.12\text{ cm} > 2 \times 0.3\text{ cm} = 0.6\text{ cm}$
so omit the outlier pending further investigation
Round the uncertainty (= spread) to 1 s.f. and round the mean to the same number of decimal places, so depth = 5.5 cm ± 0.3 cm</td><td>1
1
1</td></tr>
<tr><td>8 b</td><td>Point correctly plotted at (12 cm, 5.5 cm)
Uncertainty bars of ± 0.3 cm correctly added
(error-carried forward: allow correct use of own values from part a)</td><td>1
1</td></tr>
<tr><td>8 c</td><td>Reasonable best-fit straight line through all uncertainty bars drawn
Does not go through (0,0) m (so not proportional)</td><td>1
1</td></tr>
<tr><td>8 d</td><td>e.g.<table><tr><th>suggestion</th><th>explanation</th></tr><tr><td>Measured from bottom of rod</td><td>Should have measured from centre to find loss in E_k of rod</td></tr><tr><td>Measured to water level</td><td>Should have measured to half the depth fallen as rod was still moving when it hit the water</td></tr><tr><td>Ignored the effect of water</td><td>Water will have exerted forces upwards on rod and dissipated energy</td></tr></table></td><td>1 mark for each correct suggestion
1 mark for each correct explanation
(4 max)</td></tr>
<tr><td>9 a</td><td>$\Delta(mv)$ = 0.059 kg × 50 m s^{-1} + 0.059 kg × 37 m s^{-1}
= 5.1 kg m s^{-1}
$F = \Delta(mv)/t$
= 1500 N</td><td>1
1
1
1</td></tr>
<tr><td>9 b</td><td>To fall, $s = ½\, gt^2$ where s = 1.2 m
Gives t = 0.49 s
At 37 m s^{-1} this travels 18 m
$18\text{ m} + 3\text{ m} < 23\text{ m}$ so it's in</td><td>1
1
1
1</td></tr>
<tr><td>9 d</td><td>If hit upwards, the vertical component of v will make the ball take longer to hit the ground.
For angles which are not too steep, the horizontal component of v will be enough to take the ball 'out'.
For greater angles, the horizontal component will be too small to take the ball 'out' and it will fall inside the playing area (a 'lob').</td><td>1
1
1</td></tr>
</table>