Question Number		Mark
1 (a)	Use of suitable equation(s) of motion to find distance (1) Height = 7.4 (m) (1) (accept 9.8(1)/6 or 1.635 for acceleration but do not accept g/6 as a substitution if final answer is wrong and looking to award MP1 only) (a reverse argument leading to t = 2.9 s can score both marks) <u>Example of calculation</u> $s = ½ at^2$ s = ½ x (9.81 m s^{-2} / 6) x (3 $s)^2$ s = 7.4 m	**2**
1 (b)(i)	Use of trig function appropriate to calculate vertical component of velocity **Or** 10.1 (m s^{-1}) seen (1) Use of suitable equation(s) of motion to find time (1) t = 12.4 (s) (1) (if v and u not consistent with sign of g max 2 marks. Calculation can be done for total time of 12.3 s with either total displacement =0 or u=-v) <u>Example of calculation</u> u = 18 m s^{-1} x sin 34º = 10.1 m s^{-1} $v = u + at$ 0 = 10.1 m s^{-1} – (9.81 m s^{-2} / 6) x t t = 6.2 s to max height time of flight = 12.4 s	**3**
1 (b) (ii)	Use of trig function appropriate to calculate horizontal component of velocity **Or** 14.9 (m s^{-1}) seen **Or** Use of Pythagoras (1) Use of suitable equation(s) of motion to find distance (1) Distance = 185 (m) (ecf time value from part (i)) (1) <u>Example of calculation</u> v= 18 m s^{-1} × cos 34º = 14.9 m s^{-1} $s = vt$ =14.9 m s^{-1} ×12.4 s s = 185.0 m	**3**

***1 (c**	*lower gravitational field strength*: lower acceleration (1) the idea of an increased time of flight (1) (do not accept slower in place of lower) *lack of atmosphere:* no work done against friction **Or** no slowing/deceleration due to friction (1) (accept air resistance or drag for friction)	**3**
	Total for question	**11**

Question Number	Answer	Mark
2(a)	$mg = ma$ either leading to a = g or a statement that the masses cancel (1) Example of answer $F = ma$ and $W = mg$ $mg = ma$ $a = g$	**1**
2(b)(i)	$s = ½at^2$ **Or** $a = 2s/t^2$ **Or** $s = ut + ½ at^2$ **and** $u = 0$ (1) (allow *g* for *a* and *h* for *s*)	**1**
2(b)(ii)	**Either** Parallax(in measuring *s*) **Or** the ruler was not vertical/perpendicular (1) Giving a larger value for *s* (than the actual value) (1) **Or** The frame rate was incorrect **Or** the idea that the initial velocity of the ball was not zero (1) Giving a lower value for the measured time (1) Examples The ball was dropped before the camera started recording or the ball was dropped before the first frame or the ball was dropped from above the ruler. (Do not accept ball was thrown)	**2**
	Total for Question	**4**

Question Number	Answer	Mark
3(a)(i)	So that it can store/transfer elastic/strain (potential) energy **Or** to produce a (restoring) force on the arm (1) (accept pull for force i.e. 'pull arm up')	**1**
3(a)(ii)	Elastic/strain (potential) energy → E_{grav} +/and E_k (+/and thermal energy) (1)	**1**
***3(b)(i**	(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate) **Either** (the greater the angle) the greater the energy (stored) (1) greater kinetic energy (transferred to projectile/arm) (1) greater (initial) (horizontal) velocity of the projectile (1) $s = ut$ linked to a greater range (1) **Or** the greater the angle the greater the force/stress/tension (1) the greater the acceleration (of the arm/projectile) (1) greater (initial) (horizontal) velocity of the projectile (1) $s = ut$ linked to a greater range (1) (Accept symbols for words)	**4**
3(b)(ii)	Increases acceleration **Or** increases (initial) velocity (of the projectile) (1)	**1**

<table>
<tr><td>3(b)(iii)</td><td>One modification (1)
One reason (1)
(Modification and reason must be linked for both marks to be awarded)

<table>
<tr><th>Modification</th><th>Reason</th></tr>
<tr><td>Double up or increase number of bands</td><td>Would increase the force/tension
Or would increase energy (stored)
Or would increase the work done</td></tr>
<tr><td>Replace with bands that are: stiffer or shorter or wider or have greater k (not smaller)</td><td>Would increase the force/tension
Or would increase energy (stored)
Or would increase the work done</td></tr>
<tr><td>Use a longer arm or raise the device to a greater height</td><td>Greater (vertical) distance to fall</td></tr>
<tr><td>Tilt the model or cross bar</td><td>Projectile launched with an upwards component of velocity or at an angle</td></tr>
</table></td><td>2</td></tr>
<tr><td>3(c)(i)</td><td>Use of $s = ut + ½ at^2$ (1)
t = 0.13 (s) (1)

<u>Example of calculation</u>
0.08 m = ½ × 9.81 m s^{-2} × t^2
t = 0.128 s</td><td>2</td></tr>
<tr><td>3(c)(ii)</td><td>Use of $v = s/t$ to calculate horizontal speed Or see 10.6 (m s^{-1}) (1)
Use of $s = 10.6 \times t$ (1)
s = 1.4 m ecf for time from (i) (1)

(using show that value s = 1.06 m)

<u>Example of calculation</u>
$u_{horizontal} = \frac{1.70\ m}{0\ 16\ s}$ = 10.6 m s^{-1}
s = 10.6 m s^{-1} × 0.13 s
s = 1.38 m</td><td>3</td></tr>
<tr><td></td><td>Total for question</td><td>14</td></tr>
</table>

Question Number	Answer		Mark
*4(a)	**(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate)**		
	Max 5		
	Solid (CO_2) exerts a force on the gas (CO_2)	**(1)**	
	N3 means (gas exerts) a force on the solid/X	**(1)**	
	Force is in opposite direction on the solid/gas	**(1)**	
	There is a resultant/unbalanced force (on the solid)	**(1)**	
	N2/1 means the (solid) accelerates (accept changes velocity/speed)	**(1)**	
	Rapid because mass/friction is small	**(1)**	**5**
	(No mark for a statement of Newton's Laws)		
4(b)	More than one jet	**(1)**	
	Zero/no resultant force **Or** forces balanced/cancel	**(1)**	**2**
	Total for question		**7**

Question Number	Answer	Mark
5(a)(i)	**Laminar flow** – no abrupt change in direction or speed of flow **or** air flows in layers/flowlines/streamlines **or** no mixing of layers **or** layers remain parallel **or** velocity at a (particular) point remains constant **(1)** **Turbulent flow** – mixing of layers **or** contains eddies/vortices **or** abrupt/random changes in speed or direction **(1)**	**2**
5(a)(ii)	Relative speed of upper surface of ball to air is greater (than at lower surface) **Or** The idea that the direction of movement at the top (due to spin) is opposite to/against (direction of) air flow **(1)** (converse arguments acceptable)	**1**
5(b)	Force (by ball) on air upwards **(1)** (Equal and) opposite force (on ball) by air **Or** (Equal and) opposite force acts due to Newton's 3rd law **Or** force of air on ball downwards **(1)**	**2**
5(c)(i)	Use of $v = s/t$ **(1)** Use of $s = 1/2\ at^2$ to find s or use of correct equation**s** that could lead to the final answer. **(1)** Distance = 0.037 (m) **(1)** <u>Example of calculation</u> Time = 2.7 / 31 = 0.087 s s = 1/2 x 9.81 m s^{-2} x $(0.087\ s)^2$ = 0.037 (m)	**3**
5(c)(ii)	(Extra) downwards force (on the ball) **(1)** Greater downwards acceleration **(1)** Greater distance fallen **Or** drops further(in that time) **Or** needs to drop 15 cm, 4 cm drop not enough **(1)**	**3**
	Total for question	**11**

Question Number	Answer	Mark
6(a)	Calculate maximum energy Use of $gpe = mgh$ **(1)** Correct answer (0.28 J) **(1)** *Example of calculation* $gpe = mgh$ $= 0.41 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 0.07 \text{ m}$ $= 0.28 \text{ J}$ [N.B. Bald answer gets 2, but no marks if derived from use of $v^2 = u^2 + 2as$]	**(2)**
6(b)	Resolve this velocity into horizontal and vertical components. Shows a correct, relevant trigonometrical relationship **(1)** Correct answer for horizontal component (12 m s^{-1}) **(1)** Correct answer for vertical component (10 m s^{-1}) **(1)** (max 1 mark total for reversed answers) (apply ue once only) *Example of calculation* $v_h = v \cos\theta$ $= 16 \text{ m s}^{-1} \times \cos 40°$ $= 12.3 \text{ m s}^{-1}$ $v_v = v \sin\theta$ $= 16 \text{ m s}^{-1} \times \sin 40°$ $= 10.3 \text{ m s}^{-1}$	**(3)**
6(c)	Explain another reason why the projectile does not go as far as expected. (QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Max 2 out of three marking points for: A physical cause – e.g. other parts of the machine are moving/the sling stretches/headwind/fired up a slope/the projectile increases in height before release **(1)** Description of **energy** elsewhere than the projectile – e.g. elastic energy in sling/moving parts have ke / projectile has gained gpe before launch [Must refer to energy] **(1)** Stating that less energy has been transferred to the projectile/projectile has a lower speed **(1)**	**(max 2)**
	Total for question	**7**

Question Number	Answer	Mark
7(a)	Show that the resultant force on the rocket is about 4×10^6 N Use of $W = mg$ (1) State or use resultant force = upward force – weight (1) Correct answer to at least 2 s.f. [4.2×10^6 N] (1) [no ue] **Example of calculation** W = mg $W = 3.04 \times 10^6$ kg x 9.81 kg m s^{-2} = 2.98×10^7 N Resultant force = 3.4×10^7 N – 2.98×10^7 N = 4.2×10^6 N	**3**
7(b)	Calculate the initial acceleration. Use of $F = ma$ (1) Correct answer [1.38 m s^{-2}] (1) [ecf] **Example of calculation** $a = F/m$ = 4.2×10^6 N / 3.04×10^6 kg = 1.38 m s^{-2}	**2**
7(c)	Calculate the average acceleration. Use of $v = u + at$ (1) Correct answer [15.9 m s^{-2}] (1) [beware same unit error as part b not penalised] **Example of calculation** $a = (v - u) / t$ = (2390 m s^{-1} – 0) / 150 s = 15.9 m s^{-2}	**2**
7(d)	Suggest a reason for the difference in the values of acceleration calculated. e.g. Mass decreasing / weight decreasing / net upward force increasing / fuel used up / gets lighter / *g* decreasing /air resistance decreasing with altitude (1)	**1**
	Total for question	**8**