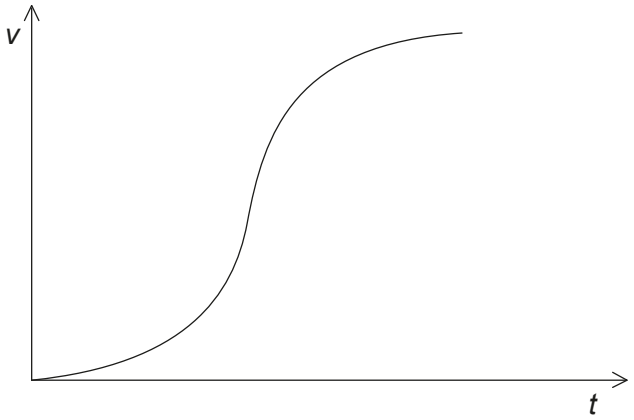
Question			Answers	Notes	Total
1.	a		links 0.84 to Δp ✓ $v = \text{«}\frac{0.84}{5.8\times10^{-2}} = \text{»}\ 14.5\ \text{«m s}^{-1}\text{»}$ ✓	*Award **[2]** for bald correct answer*	**2**
1.	b		use of $\Delta t = \text{«}(28-12)\times10^{-3} = \text{»}\ 16\times10^{-3}\ \text{«s»}$ ✓ $\bar{F} = \text{«}\frac{\Delta p}{\Delta t} = \text{»}\ \frac{0.84}{16\times10^{-3}}$ ***OR*** 53 «N» ✓	*Accept a time interval from 14 to 16 ms* *Allow ECF from incorrect time interval*	**2**
1.	c		$E_k = \frac{1}{2}\times5.8\times10^{-2}\times14.5^2$ ✓ $E_k = W$ ✓ $s = \text{«}\frac{W}{F} = \frac{\frac{1}{2}\times5.8\times10^{-2}\times14.5^2}{53} = \text{»}\ 0.12\ \text{«m»}$ ✓	*Allow ECF from (a) and (b)* *Allow ECF from MP1* *Award **[2]** max for a calculation without reference to work done, eg: average velocity × time*	**3**

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
1.	d		 graph must show increasing speed from an initial of zero all the time ✓ overall correct curvature ✓		2

Question			Answers	Notes	Total
1.	a	i	time taken $\frac{2.0\times10^4}{7}$ **«**$= 2860$ s**»** $= 2900$**«**s**»** ✓	*Must see at least two s.f.*	**1**
1.	a	ii	use of $E = qV$ ***OR*** energy $= 4.3\times10^4\times16$ **«**$= 6.88\times10^5$ J**»** ✓ power $= 241$ **«**W**»** ✓	*Accept 229 W – 241 W depending on the exact value of t used from ai.* *Must see at least three s.f.*	**2**
1.	a	iii	use of power = force x speed ***OR*** force x distance = power x time ✓ 34 **«**N**»** ✓	*Accept 34 N – 36 N.*	**2**
1.	b	i	$66\,g\sin(3°) = 34$ **«**N**»** ✓		**1**
1.	b	ii	total force 34 + 34 = 68 **«**N**»** ✓ 3.5 **«**ms^{-1}**»**✓	*Look for ECF from aiii and bi.* *Accept 3.4 – 3.5 «ms^{-1}».* *Award **[0]** for solutions involving use of KE.*	**2**

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
1.	c		«maximum» distance will decrease ***OWTTE*** ✓ because opposing/resistive force has increased ***OR*** because more energy is transferred to GPE ***OR*** because velocity has decreased ***OR*** increased mass means more work required «to move up the hill» ✓		**2**
1.	d		4 V dropped across battery ***OR*** $R_{circuit} = 1.85\ \Omega$ ✓ so internal resistance $= \frac{4.0}{6.5} = 0.62$ «Ω» ✓		**2**
1.	e	i	$\frac{16}{5} = 3.2$ «V» ✓		**1**
1.	e	ii	***ALTERNATIVE 1:*** $2.5r = 0.62$ ✓ $r = 0.25$ «Ω» ✓ ***ALTERNATIVE 2:*** $\frac{0.62}{5} = 0.124$ «Ω» ✓ $r = 2(0.124) = 0.248$ «Ω» ✓	*Allow ECF from (d).*	**2**

Question			Answers	Notes	Total
1.	a	i	$F = \frac{\Delta mv}{\Delta t}$ / $m\frac{\Delta v}{\Delta t}$ / $\frac{0.058 \times 64.0}{25 \times 10^{-3}}$ ✓ $F = 148$ «N» ≈ 150 «N» ✓		2
1.	a	ii	***ALTERNATIVE 1*** $P = \frac{\frac{1}{2}mv^2}{t}$ / $\frac{\frac{1}{2} \times 0.058 \times 64.0^2}{25 \times 10^{-3}}$ ✓ $P = 4700 / 4800$ «W» ✓ ***ALTERNATIVE 2*** $P =$ average Fv / $148 \times \frac{64.0}{2}$ ✓ $P = 4700 / 4800$ «W» ✓		2

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
1.	b	i	horizontal component of velocity is $64.0 \times \cos 7^\circ = 63.52$ «m s^{-1}» ✓ $t = «\frac{11.9}{63.52} =»$ 0.187 / 0.19 «s» ✓		2
1.	b	ii	***ALTERNATIVE 1*** $u_y = 64 \sin 7 / 7.80$ «m s^{-1}» ✓ decrease in height $= 7.80 \times 0.187 + \frac{1}{2} \times 9.81 \times 0.187^2 / 1.63$ «m» ✓ final height = «2.80 – 1.63» = 1.1 / 1.2 «m» ✓ «higher than net so goes over» ***ALTERNATIVE 2*** vertical distance to fall to net «= 2.80 – 0.91» = 1.89 «m» ✓ time to fall this distance found using «$1.89 = 7.8t + \frac{1}{2} \times 9.81 \times t^2$» $t = 0.21$«s» ✓ 0.21 «s» > 0.187 «s» ✓ «reaches the net before it has fallen far enough so goes over»		3

(continued…)

(Question 1 continued)

1.	**b**	**iii**	***ALTERNATIVE 1*** Initial KE + PE = final KE / $\frac{1}{2}\times 0.058\times 64^2 + 0.058\times 9.81\times 2.80 = \frac{1}{2}\times 0.058\times v^2$ ✓ $v = 64.4$ «$\mathrm{m\,s^{-1}}$» ✓ ***ALTERNATIVE 2*** $v_v = \text{«}\sqrt{7.8^2 + 2\times 9.81\times 2.8}\text{»} = 10.8$ «$\mathrm{m\,s^{-1}}$» ✓ «$v = \sqrt{63.5^2 + 10.8^2}$» $v = 64.4$ «$\mathrm{m\,s^{-1}}$» ✓		**2**
1.	**c**		so horizontal velocity component at lift off for clay is smaller ✓ normal force is the same so vertical component of velocity is the same ✓ so bounce angle on clay is greater ✓		**3**

Question			Answers	Notes	Total
1.	a		change in momentum each second $= 6.6\times10^{-6}\times5.2\times10^{4}$ «$= 3.4\times10^{-1}$ kg m s^{-1}» ✓ acceleration $=$ «$\frac{3.4\times10^{-1}}{740}$ =» 4.6×10^{-4} «m s^{-2}» ✓		**2**
1.	b	i	***ALTERNATIVE 1***: (considering the acceleration of the spacecraft) time for acceleration $= \frac{30}{6.6\times10^{-6}} =$ «4.6×10^{6}» «s» ✓ max speed = «answer to (a) $\times 4.6\times10^{6} =$» 2.1×10^{3} «m s^{-1}» ✓ ***ALTERNATIVE 2***: (considering the conservation of momentum) (momentum of 30 kg of fuel ions = change of momentum of spacecraft) $30\times5.2\times10^{4} = 710\times$ max speed ✓ max speed $= 2.2\times10^{3}$ «m s^{-1}» ✓		**2**
1.	b	ii	problem may be too complicated for exact treatment ✓ to make equations/calculations simpler ✓ when precision of the calculations is not important ✓ some quantities in the problem may not be known exactly ✓		**1 max**

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
1.	**c**	**i**	ions have same (sign of) charge ✓ ions repel each other ✓		**2**
1.	**c**	**ii**	the forces between the ions do not affect the force on the spacecraft. ✓ there is no effect on the acceleration of the spacecraft. ✓		**2**
1.	**d**	**i**	force per unit mass ✓ acting on a small/test/point mass **«**placed at the point in the field**»** ✓		**2**
1.	**d**	**ii**	satellite has a much smaller mass/diameter/size than the planet **«**so approximates to a point mass**»** ✓		**1**

Question			Answers	Notes	Total
3.	a		***ALTERNATIVE 1:*** initial momentum $= mv = \sqrt{2 \times 0.058 \times 0.63}$ **«** $= 0.27\ \text{kg m s}^{-1}$ **»** ***OR*** $mv = 0.058 \times \sqrt{2 \times 9.81 \times 1.1}$ **«** $= 0.27\ \text{kg m s}^{-1}$ **»** ✓ force $=$ **«** $\frac{\text{change in momentum}}{\text{time}} =$ **»** $\frac{0.27}{0.055}$ ✓ 4.9 **«**N**»** ✓ $F - mg = 4.9$ so $F = 5.5$ **«**N**»** ✓ ***ALTERNATIVE 2:*** **«**$E_k = \frac{1}{2}mv^2 = 0.63$ J**»** v = 4.7 m s^{-1} ✓ acceleration $=$ **«** $\frac{\Delta v}{\Delta t} =$ **»** $\frac{4.7}{55x10^{-3}} =$ **«**85 m s^{-2} **»**✓ 4.9 **«**N**»** ✓ $F - mg = 4.9$ so $F = 5.5$ **«**N**»** ✓		**4**

(continued…)

(Question 3 continued)

Question			Answers	Notes	Total
3.	**b**		***ALTERNATIVE 1:*** concrete reduces the stopping time/distance ✓ impulse/change in momentum same so force greater ***OR*** work done same so force greater ✓ ***ALTERNATIVE 2:*** concrete reduces the stopping time ✓ deceleration is greater so force is greater ✓	*Allow reverse argument for grass.*	**2**

Question			Answers	Notes	Total
5.	**a**		0.40 «m s^{-1}» ✓		**1**
5.	**b**		initial energy 24 mJ and final energy 12 mJ ✓ energy is lost/unequal /change in energy is 12 mJ ✓ inelastic collisions occur when energy is lost ✓		**3**
5.	**c**		maximum GPE at extremes, minimum in centre ✓		**1**

Question			Answers	Notes	Total
1.	a		use of conservation of energy ***OR*** $v^2 = u^2 + 2as$ ✓ $v = \text{«}\sqrt{2 \times 60.0 \times 9.81}\text{»} = 34.3\,\text{«ms}^{-1}\text{»}$ ✓		2
1.	b	i	use of impulse $F_{ave} \times \Delta t = \Delta p$ ***OR*** use of $F = ma$ with average acceleration ***OR*** $F = \frac{80.0 \times 34.3}{0.759}$ ✓ 3620 «N» ✓	*Allow ECF from (a).*	2
1.	b	ii	upwards ✓ clearly longer than weight ✓	*For second marking point allow ECF from (b)(i) providing line is upwards.*	2
1.	b	iii	$3620 + 80.0 \times 9.81$ ✓ 4400 «N» ✓	*Allow ECF from (b)(i).*	2

(continued…)

(Question 1 continued)

1.	**c**	**i**	(loss in) gravitational potential energy (of block) into kinetic energy (of block) ✓	*<u>Must</u> see names of energy (gravitational potential energy and kinetic energy) – Allow for reasonable variations of terminology (eg energy of motion for KE).*	**1**
1.	**c**	**ii**	(loss in) gravitational potential and kinetic energy of block into elastic potential energy of rope ✓	*See note for 1(c)(i) for naming convention.* *<u>Must</u> see either the block or the rope (or both) mentioned in connection with the appropriate energies.*	**1**
1.	**d**		k can be determined using $\text{EPE} = \frac{1}{2}kx^2$ ✓ correct statement or equation showing GPE at A = EPE at C ***OR*** (GPE + KE) at B = EPE at C ✓	*Candidate must clearly indicate the energy associated with either position A or B for MP2.*	**2**

(continued…)

(Question 1 continued)

1.	**e**	**i**	$T = 2\pi\sqrt{\frac{80.0}{400}} = 2.81$ **«s»** ✓ $\text{time} = \frac{T}{4} = 0.702$ **«s»** ✓	*Award **[0]** for kinematic solutions that assume a constant acceleration.*	**2**
1.	**e**	**ii**	***ALTERNATIVE 1*** $\omega = \frac{2\pi}{2.81} = 2.24$ **«**rad s^{-1}**»** ✓ $v = 2.24 \times 3.50 = 7.84$ **«**ms^{-1}**»** ✓ ***ALTERNATIVE 2*** $\frac{1}{2}kx^2 = \frac{1}{2}mv^2$ ***OR*** $\frac{1}{2}400 \times 3.5^2 = \frac{1}{2}80v^2$ ✓ $v = 7.84$ **«**ms^{-1}**»** ✓	*Award **[0]** for kinematic solutions that assume a constant acceleration.* *Allow ECF for T from (e)(i).*	**2**

Question			Answers	Notes	Total
1.	a		arrow vertically downwards labelled weight «of sledge and/or girl»/W/mg/gravitational force/F_g/$F_{gravitational}$ ***AND*** arrow perpendicular to the snow slope labelled reaction force/R/normal contact force/N/F_N ✓ friction force/F/f acting up slope «perpendicular to reaction force» ✓	*Do not allow G/g/"gravity".* *Do not award MP1 if a "driving force" is included. Allow components of weight if correctly labelled. Ignore point of application or shape of object.* *Ignore "air resistance".* *Ignore any reference to "push of feet on sledge".* *Do not award MP2 for forces on sledge on horizontal ground* *The arrows should contact the object*	**2**
1.	b		gravitational force/weight from the Earth «downwards» ✓ reaction force from the sledge/snow/ground «upwards» ✓ no vertical acceleration/remains in contact with the ground/does not move vertically as there is no resultant vertical force ✓	*Allow naming of forces as in (a)* *Allow vertical forces are balanced/equal in magnitude/cancel out*	**3**
1.	c		mention of conservation of momentum ***OR*** $5.5 \times 4.2 = (55 + 5.5)$ «v» ✓ 0.38 «m s^{-1}» ✓	*Allow $p = p'$ or other algebraically equivalent statement* *Award **[0]** for answers based on energy*	**2**

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
1.	**d**		same change in momentum/impulse ✓ the time taken «to stop» would be greater «with the snow» ✓ $F = \frac{\Delta p}{\Delta t}$ therefore *F* is smaller «with the snow» ***OR*** force is proportional to rate of change of momentum therefore *F* is smaller «with the snow» ✓	*Allow reverse argument for ice*	**3**
1.	**e**	**i**	«friction force down slope» $= \mu mg\cos(6.5) =$ «5.9N» ✓ «component of weight down slope» $= mg\sin(6.5)$ « $= 6.1$N» ✓ «so $a = \frac{F}{m}$ » acceleration $= \frac{12}{5.5} = 2.2$ «m s^{-2}» ✓	*Ignore negative signs* *Allow use of* $g = 10\,\text{m s}^{-2}$	**3**
1.	**e**	**ii**	correct use of kinematics equation ✓ distance $= 4.4$ ***or*** 4.0 «m» ✓ ***Alternative 2*** KE lost = work done against friction + GPE ✓ distance $= 4.4$ ***or*** 4.0 «m» ✓	*Allow ECF from (e)(i)* *Allow* ***[1 max]*** *for GPE missing leading to 8.2 «m»*	**2**

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
1.	**f**		calculates a maximum value for the frictional force = **«** μR = **»** 7.5 **«**N**»** ✓ sledge will not move as the maximum static friction force is greater than the component of weight down the slope ✓	*Allow correct conclusion from incorrect MP1* *Allow 7.5 > 6.1 so will not move*	**2**