

Mark Scheme

Q1.

Question Number	Answer	Mark
	The correct answer is B A is not the correct answer because gpe should be added not subtracted on the right hand side C is not the correct answer because the total elastic energy is not $F\Delta x$ and gpe should be added not subtracted on the right hand side D is not the correct answer because the total elastic energy is not $F\Delta x$	1

Q2.

Question Number	Answer	Mark
	The only correct answer is B $\left(\frac{Fx}{\cos \theta}\right)$ A is not correct because x is not the distance moved in the direction of the force C is not correct because y is not the distance moved in the direction of the force D is not correct because the distance moved along the slope is $\frac{y}{\sin \theta}$	1

Q3.

Question Number	Answer	Mark
	C is the correct answer A is incorrect because it gives 48% of only the power output. B is incorrect because it gives 52% of the power output. D is incorrect because it gives the total power input.	1

Q4.

Question Number	Answer	Mark
	Either (1) • Use of $\sin \theta = \frac{2.0}{15}$ Or use of $\theta = 7.7^\circ$ (1) • Use of Work done = $F\Delta s$ Or use of $E_{\text{grav}} = mg\Delta h$ (1) • Use of efficiency = $\frac{\text{useful energy output}}{\text{total energy input}} (\times 100 \%)$ (1) • Efficiency = 83 or 84 % so less than 90 % (MP4 dependent on scoring all points MP1& 2 &3) <u>Example of calculation</u> (1) $\sin^{-1}\left(\frac{2.0}{15}\right) = 7.7^\circ$ (1) $W_{50} = 50 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 2.0 \text{ m} \times \frac{2.0}{15} = 130.8 \text{ J}$ (1) $W_8 = 8.0 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 2.0 \text{ m} = 157.0 \text{ J}$ (1) Efficiency = $\frac{130.8 \text{ J}}{157.0 \text{ J}} \times 100 \% = 83 \%$	4
	Total for question	4

Question Number	Acceptable Answer	Additional Guidance	Mark
	Use of $E_k = \frac{1}{2}mv^2$ (1)		4
	Use of $\Delta E_{\text{grav}} = mg\Delta h$ (1)		
	Use of efficiency = $\frac{\text{useful energy output}}{\text{total energy input}}$ (1)		
	Efficiency = 0.28 (1)	Allow efficiency = 28% (must include % symbol) <u>Example calculation</u> $E_k = \frac{1}{2} \times 1800 \text{ kg} \times (14 \text{ m s}^{-1})^2$ $= 176\,000 \text{ J}$ $\Delta E_{\text{grav}} = 1800 \text{ kg} \times 9.81 \text{ N kg}^{-1}$ $\times 0.76 \text{ m} = 13\,400 \text{ J}$ $\text{Efficiency} = \frac{45 \times 10^3 \text{ J}}{176\,000 \text{ J} - 13\,400 \text{ J}} = 0.277$	

Question Number	Answer	Mark
(a)	Use of $E_k = \frac{1}{2} m v^2$ (1) $E_k = 0.54 \text{ J}$ (1) <u>Example of calculation</u> $E_k = 0.5 \times 0.16 \text{ kg} \times (2.6 \text{ m s}^{-1})^2 = 0.541 \text{ J}$	2
(b)	Use of $E_{\text{grav}} = m g \Delta h$ (1) $\Delta h = 0.51 \text{ m}$ (1) (allow ecf from (a)) <u>Example of calculation</u> Decrease in GPE = $0.54 \text{ J} + 0.26 \text{ J} = 0.8 \text{ J}$ $\Delta h = 0.8 \text{ J} / (0.16 \text{ kg} \times 9.81 \text{ m s}^{-2}) = 0.51 \text{ m}$	2
Total for question		4

Question Number	Answer	Mark
(a)	Use of $\Delta E_{\text{grav}} = m g \Delta h$ (1) $\Delta E_{\text{grav}} = 420 \times 10^6 \text{ (J)}$ (1) <u>Example of calculation</u> $\Delta E_{\text{grav}} = 1.7 \times 10^6 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 25 \text{ m} = 4.17 \times 10^8 \text{ J}$	2
(b)	Use $P = W / t$ (1) Use of energy conservation (1) $2.8 \times 10^8 \text{ J}$ (ecf from (a)) (1) <u>Example of calculation</u> $W = 20 \times 10^6 \text{ W} \times 35 \text{ s} = 7.00 \times 10^8 \text{ J}$ $7.00 \times 10^8 \text{ J} - 4.17 \times 10^8 \text{ J} = 2.83 \times 10^8 \text{ J}$	3
Total for question		5

Question Number	Answer	Mark
(a)	Use of $\rho = \frac{m}{V}$	(1)
	Use of trigonometry to calculate Δh	(1)
	Use of $\Delta E_{\text{grav}} = mg\Delta h$	(1)
	Use of $P = \frac{E}{t}$	(1)
	$P = 87.7$ (MW)	(1)
	OR	
	Use of $\rho = \frac{m}{V}$	(1)
	Use of trigonometry to calculate component of g along pipe	(1)
	Use of appropriate suvat equation(s) to determine velocity of water at bottom of pipe and	
	Use of $E_k = \frac{1}{2}mv^2$	(1)
	Use of $P = \frac{E}{t}$	(1)
	$P = 87.7$ (MW)	(1)
	<u>Example calculation</u>	
	$1100 \text{ kg m}^{-3} = \frac{m}{1700 \text{ m}^3}$	
	$m = 1700 \text{ m}^3 \times 1100 \text{ kg m}^{-3} = 1.87 \times 10^6 \text{ kg}$	
	$\Delta h = 350 \text{ m} \times \sin(55^\circ) = 287 \text{ m}$	
	$\Delta E_{\text{grav}} = 1.87 \times 10^6 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 287 \text{ m} = 5.26 \times 10^9 \text{ J}$	
	$P = \frac{5.26 \times 10^9 \text{ J}}{60 \text{ s}} = 87.7 \times 10^6 \text{ W}$	

(b)	Use of efficiency = $\frac{\text{useful power output}}{\text{total power input}}$ (1) Efficiency = 0.27 Or Efficiency = 27% [ecf from (a)] (1) <u>Example calculation</u> Useful power output = $4 \times 87.7 \text{ MW} - 256 \text{ MW}$ $= 350.8 \text{ MW} - 256 \text{ MW}$ $= 94.8 \text{ MW}$ Efficiency = $\frac{94.8}{350.8} = 0.27$	2
	Total for question	7

Question Number	Answer	Mark
(a)	Amount of work from the electric motor is reduced (1) Because there is energy transfer between the counterweight and the lift Or Because counterweight contributes to total work done (on lift cage) Or Because the counterweight reduces the force required from the motor Or Because total work done (on lift cage) is sum of work done by counterweight/gravity and by the motor. (1)	2
(b)	Use of $\Delta W = F\Delta x$ or $\Delta E_{\text{grav}} = mg\Delta h$ (1) Use of conservation of energy (1) Use of $P = W / t$ (1) $P = 12.4$ (kW) (1) Or Calculates resultant force (1) Use of $\Delta W = F\Delta x$ (1) Use of $P = W / t$ (1) $P = 12.4$ (kW) (1) <u>Example of calculation</u> For counterweight $\Delta E_{\text{grav}} = mg\Delta h$ $= 1300 \text{ kg} \times 9.81 \text{ ms}^{-2} \times 40.0 \text{ m} = 5.101 \times 10^5 \text{ J}$ For lift $\Delta E_{\text{grav}} = mg\Delta h$ $= 2250 \text{ kg} \times 9.81 \text{ ms}^{-2} \times 40.0 \text{ m} = 8.829 \times 10^5 \text{ J}$ Energy required $= 8.829 \times 10^5 \text{ J} - 5.101 \times 10^5 \text{ J} = 3.728 \times 10^5 \text{ J}$ $P = 3.728 \times 10^5 \text{ J} \div 30 \text{ s} = 1.243 \times 10^4 \text{ W}$	4
(c)	Use of efficiency = useful power output $\div$ total power input (1) Efficiency = 0.78 (ecf from (b)) (1) <u>Example of calculation</u> Efficiency $= 12.4 \text{ kW} \div (12.4 + 3.6) \text{ kW} = 0.775$	2
	Total for question	8

Question Number	Answer	Mark
(a)	Use $E_K = \frac{1}{2} m v^2$ (1) Use of efficiency = $\frac{\text{useful energy output}}{\text{total energy input}}$ (1) Efficiency = 0.56 Or 56% (1) <u>Example of calculation</u> $E_K = 0.5 \times 1\,560 \text{ kg} \times (13 \text{ m s}^{-1})^2 = 1.32 \times 10^5 \text{ J}$ efficiency = $73.9 \times 10^4 \text{ J} \div 1.32 \times 10^5 \text{ J} = 0.56$	3
(b)(i)	As the velocity increases the drag forces increase. (1)	1
(b)(ii)	At higher speeds more work done against air resistance. (1) So more energy dissipated. (1) So a smaller proportion of energy is available to charge battery. (1) (Hence) the efficiency of the system is lower. (1)	4
Total for question		8

Question Number	Answer	Mark
(a)	Use of $\Delta W = F \Delta x$ [allow any dimensionally correct variation, e.g. involving trig] (1) $\Delta W = 3.2 \times 10^4$ (J) [do not allow if $\cos 4^\circ$ used in MP1, gives 3.217].] (1) Example of calculation $\Delta W = 150 \text{ N} \times 215 \text{ m} = 3.23 \times 10^4 \text{ J}$	2
(b)(i)	Use of correct trigonometry to calculate Δh (1) Or Use of correct trigonometry to calculate component of g along slope, [61.6 (N)] Use of $\Delta E_{\text{grav}} = m g \Delta h$ [$\Delta E_{\text{grav}} = 90 \text{ kg} \times 9.81 \times 215 \text{ m} \times \sin 4.0^\circ$ scores MP1&2] (1) Total work done = work done against gravity + work done against air resistance (1) Work against air resistance = $2.0 \times 10^4 \text{ J}$ (allow ecf from (a)) (1) ["show that" value gives $1.68 \times 10^4 \text{ J}$] Example of calculation $\Delta h = 215 \text{ m} \times \sin 4.0^\circ = 15.0 \text{ m}$ $\Delta E_{\text{grav}} = 90 \text{ kg} \times 9.81 \times 15.0 = 1.32 \times 10^4 \text{ J}$ $W = 3.20 \times 10^4 \text{ J} - 1.32 \times 10^4 \text{ J} = 1.88 \times 10^4 \text{ J}$	4
(b)(ii)	Force of gravity and air resistance are the only significant forces acting (to oppose the motion of the bicycle) (1) Or Frictional forces (in the bearings of the bicycle) are negligible [accept zero, do not accept friction between bicycle and slope/ground] Or Work done against frictional forces (in the bearings of the bicycle) is negligible [accept zero]	1
(c)	No work done against (force of) gravity Or All work done against air resistance Or No backward force due to gravity so resultant force acts (1) Speed increases [MP2 dependent on MP1] (1)	2
Total for question		9

Question Number	Answer	Mark
(a)(i)	The gradient / steepness of the slide varies (1) (So) the acceleration (of the child) varies (1) The equations of motion require a constant acceleration (1)	3
(a)(ii)	Use of $\Delta E_{\text{grav}} = mgh$ (1) Use of $\Delta E_k = \frac{1}{2}mv^2$ (1) $v = 5.8 \text{ m s}^{-1}$ (1) Do not accept use of equations of motion. <u>Example of calculation</u> $\Delta E_{\text{grav}} = 24 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 1.7 \text{ m} = 400 \text{ J}$ $400 \text{ J} = 0.5 \times 24 \text{ kg} \times v^2$ $v = \sqrt{\frac{2 \times 400}{24}} = 5.77 \text{ m s}^{-1}$	3
(b)	$v_X = v_Y$ (1) Maximum 2 from: $\Delta E_{\text{grav}} = \Delta E_k$ and mass is in both equations (1) (Maximum) speed of child = $\sqrt{2g\Delta h}$ (and g is constant) (1) (Maximum) speed does not depend on mass of child Or (Maximum) speed is (only) dependent on Δh (1)	3
	Total for question	9

Question Number	Answer	Mark
(a)	Use of $P = W / t$ and $\Delta W = F \Delta s$ (1) Force = 13.9 (kN) (1) <u>Example of calculation</u> In 1 second $W = 6250$ J and distance travelled = 0.450 m $F = 6250 \text{ W} \div 0.450 \text{ m s}^{-1} = 13.9 \text{ kN}$	2
(b)	Use of $\Delta W = F \Delta s$ (1) Use of $\Delta s = 4.35 / \sin 6.0^\circ$ (1) Total work = 5.8×10^5 J (allow ecf from (a)) (1) <u>Example of calculation</u> $\Delta W = 13.9 \times 10^3 \text{ N} \times 4.35 \text{ m} \div \sin 6.0^\circ = 578 \text{ kJ}$	3
(c)	Use of $\Delta E_{\text{grav}} = m g \Delta h$ (1) Useful work done = 89.6 (kJ) (1) <u>Example of calculation</u> $\Delta E_{\text{grav}} = 2.10 \times 10^3 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 4.35 \text{ m} = 89.6 \text{ kJ}$	2
(d)	Use of $\varepsilon = \text{useful energy output} / \text{total energy input}$ (1) Efficiency = 0.16 (allow ecf from (b) and (c)) (1) <u>Example of calculation</u> $\varepsilon = 89.6 \text{ kJ} \div 578 \text{ kJ} = 0.155$	2
Total for question		9

Question Number	Answer	Mark
(a)	The hammer head is not in free fall Or Person is exerting a force on the hammer (1) <u>Work</u> is done on the hammer head by the person (1) So additional energy is transferred to kinetic energy (MP3 dependent on MP1 or MP2) (1)	3
(b)	Use of $\Delta W = F \Delta s$ (1) Use of $\varepsilon = (\text{useful energy output}) / (\text{total energy input})$ (1) Use of $\Delta E_{\text{grav}} = m g \Delta h$ Or Use of $E_k = \frac{1}{2} m v^2$ and valid <i>suvat</i> method (1) $\Delta h = 1.9 \text{ m}$ Or $F_{\text{req}} = 83 \text{ N}$ Or $E_{\text{req}} = 4.0 \text{ J}$ and $E_{\text{out}} = 2.8 \text{ J}$ (1) Conclusion consistent with student's calculation (1) e.g. The cylinder won't hit the bell because $1.9 \text{ m} < 2.7 \text{ m}$ Or Force needed to hit bell = $83 \text{ N} > 53 \text{ N}$ so cylinder won't hit the bell Or Useful output = 2.8 J but energy needed to hit bell is 4.0 J so cylinder won't hit the bell <u>Example of calculation</u> energy of hammer head = $\Delta W = 58 \text{ N} \times 1.2 \text{ m} = 69.6 \text{ J}$ useful energy output = $0.04 \times 69.6 \text{ J} = 2.78 \text{ J}$ g.p.e. gained = $2.78 \text{ J} = 0.15 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times \Delta h$ $\Delta h = 2.78 \text{ J} \div 1.47 \text{ N} = 1.89 \text{ m}$ $1.9 < 2.7 \therefore \text{no}$	5
(c)	($E_k = \frac{1}{2}mv^2$ so) kinetic energy is proportional to square of velocity Or ($E_k = \frac{1}{2}mv^2$ so) kinetic energy multiplies by four (if v doubles) (1) So cylinder could move through four times the distance (1)	2
Total for question		10