FURTHER MECHANICS / WORK, ENERGY AND POWER

Work-Energy Principle

Mark scheme 10 questions · 97 marks

EXAM BOARDS Edexcel FM1 9FM0/3C · AQA 7367/3M · OCR A Y543 · OCR MEI Mech Minor Y431 OCR MEI Mech Major Y421 · CIE 9231 Paper 3

Questions

Question	Marks by part	Marks	Page
Question 1	(a) 3 (b) 4 (c) 4	11	4
Question 2	(a) 2 (b) 5	7	5
Question 3	(a) 3 (b) 4	7	6
Question 4	(a) 4 (b) 6	10	7
Question 5	(a) 7 (b) 5 (c) 2	14	8
Question 6	(a) 7 (b) 2	9	10
Question 7	(a) 3 (b) 6	9	11
Question 8	(a) 3 (b) 5 (c) 1	9	12
Question 9	(a) 2 (b) 6	8	13
Question 10	(a) 3 (b) 5 (c) 5	13	14
	Total	**97**	

Reading the mark scheme

These rules apply throughout, unless a note says otherwise.

Marks

Every mark is worth one, so **M1 A1** on a row is two marks. Only marks coded ft follow through.

Code	Meaning
M1	Method: a correct method, applied to this question. A slip doesn't cost it if the method is clear. A formula must be used, not just quoted.
dM1	Dependent method: as M1, but only if the method mark before it was earned, unless its note names another.
A1	Accuracy: a correct answer or step. It needs the method mark it follows.
A1ft	As A1, following through from an earlier answer that the note names.
A1 AG	The last mark of a part whose answer is printed in the question: complete working, with no errors.
B1	A correct value, fact or statement. It needs no method mark.
B1ft	As B1, following through from an earlier answer that the note names.
E1	A written explanation, interpretation or conclusion. Concluding a proof by induction needs every earlier mark.

Abbreviations

ft and AG qualify a code in the Marks column. The others appear in the notes. A grey line gives the rule where the name alone doesn't.

ft	follow through Correct work from the student's own earlier wrong value earns the mark.	**AG**	answer given The answer is printed in the question, so every step to it must be shown.
cao	correct answer only No follow-through from an earlier error.	**cso**	correct solution only No error anywhere in the part, not just in its answer.
oe	or equivalent	**awrt**	answers which round to
soi	seen or implied Earned if written, or if later working shows it was used.	**isw**	ignore subsequent working A correct answer, once reached, isn't spoiled by later working.
SC	special case Credit, as the note says, for work outside the main method.	**their**	the student's own earlier value
condone	a slip that doesn't cost the mark	[ ]	working the mark doesn't need
s.f.	significant figures	**d.p.**	decimal places

Reading the scheme

- Each row is a line of working, with the marks it earns beside it. Where a row carries two marks, each note starts with its code.
- [***n***] ends each part with its total.
- A shaded *Alternative* is a second method for the same total. Mark an answer by the method it follows.
- Any other valid method earns the equivalent marks, unless the question names a method or says *hence*.
- A sketch earns one B1 for each feature named below its figure.

Accuracy and answers

- Unless a question says otherwise, give answers to 3 significant figures, and angles in degrees to 1 decimal place. Angles in radians take 3 significant figures.
- A final answer with more figures is accepted if it rounds to the scheme's value; one with fewer is not. An answer spoiled by rounding too early loses its accuracy mark.
- Where a question asks for an exact answer, a decimal loses the final accuracy mark. Otherwise either is accepted.
- Wrong or missing units cost nothing unless the question asks for them.
- An omitted $\mathrm{d}\theta$, $\mathrm{d}x$ or $\mathrm{d}u$ in an integral is not penalised where the variable of integration is clear from the integrand and the limits. It is penalised where it is genuinely ambiguous: a substitution part-way through, two variables in play, or limits in the wrong variable.
- A correct answer with no working earns full marks, unless the question needs the working: show that, prove, hence, a method it names, or an exact answer. A wrong answer with no working earns nothing. Calculator answers are treated the same way.
- A correct answer, once reached, isn't spoiled by later working (isw).

Value of g

- Take $g = 9.8\,\mathrm{m\,s^{-2}}$ unless a question states a value, which is then the only one accepted. Answers that use $g = 9.8$ may be given to 2 or 3 significant figures.
- Where a question doesn't state g, an answer worked with $g = 10$ throughout earns the same marks, keeping any value printed in the question. The worked solutions list the final answers with $g = 10$.

Question	Scheme	Marks	Notes
1(a)	$AB = 3 \Rightarrow \cos\theta = \frac{4}{5}$ $R = 2.5g\cos\theta = 2g$ [= 19.6]	**B1**	$2g$ or 19.6, oe.
	$W = \frac{1}{4} \times$ "$2g$" $\times 3$	**M1**	Multiplies $\frac{1}{4}$ their R, a component of $2.5g$, by their length AB from Pythagoras.
	$W = \frac{3g}{2} = 14.7\,\text{J}$	**A1**	$\frac{3g}{2}$ or 14.7.
		[3]	
1(b)	Gain in $GPE = 2.5g(1.8)$ [= 44.1 J]	**B1**	
	$\frac{1}{2}(2.5)U^2 -$ "14.7" $= 2.5g(1.8)$	**M1 A1ft**	**M1** Forms a work–energy equation from A to B with $\frac{1}{2}(2.5)U^2$, the gain in GPE and their work against friction from (a). Condone sign slips. **A1ft** Correct equation, oe; ft their work against friction from (a).
	$U^2 = 47.04 \Rightarrow U = \frac{14\sqrt{6}}{5} \approx 6.86$	**A1**	awrt 6.86, or $\frac{14\sqrt{6}}{5}$ oe.
		[4]	
1(c)	Loss in $GPE = 2.5g(1.8)$ [= 44.1 J]	**B1**	Or twice their 14.7 for the round trip.
	$2.5g(1.8) -$ "14.7" $= \frac{1}{2}(2.5)v^2$	**M1 A1ft**	**M1** Forms a work–energy equation from B to A with the loss in GPE, $\frac{1}{2}(2.5)v^2$ and their friction work, or from A to A with their U^2 and twice their friction work. Condone sign slips. **A1ft** Correct equation, oe; ft their work against friction from (a).
	$v^2 = 23.52 \Rightarrow v = \frac{14\sqrt{3}}{5} \approx 4.85\,\text{m s}^{-1}$	**A1**	awrt 4.85, or $\frac{14\sqrt{3}}{5}$ oe.
		[4]	
	Total for Question 1	**11**	

Question	Scheme	Marks	Notes
2(a)	$R = mg\cos\alpha$	**M1**	Resolves perpendicular to the roof with R and a component of mg. Condone sin/cos confusion.
	$R = \frac{4mg}{5}$	**A1**	oe, such as $0.8mg$. Not $7.84m$.
		[2]	
2(b)	$s\sin\alpha = 0.6 \Rightarrow s = 1$	**B1**	soi by correct work done by friction.
	$F = 0.25 \times$ "$\frac{4mg}{5}$" $= \frac{mg}{5}$ $\sum W_{\text{other}} = -\frac{mg}{5} \times 1 = -\frac{mg}{5}$	**B1ft**	$0.25\times$ their R $\times 1$, as work done by or against friction. ft their R from (a).
	$KE_0 + GPE_0 + \sum W_{\text{other}} = KE_1 + GPE_1$ $0 + mg(1.5) - \frac{mg}{5} = \frac{1}{2}mv^2 + 0$	**M1 A1ft**	**M1** Forms an energy equation from release to the ground, in one stage or two, with KE, GPE and their friction work. Condone sign slips. **A1ft** Correct equation oe, or a correct pair of stage equations. ft their R from (a).
	$v = \sqrt{\frac{13g}{5}} = 5.05$	**A1**	awrt 5.05, or $\frac{7\sqrt{13}}{5}$.
		[5]	
	Total for Question 2	**7**	

Question	Scheme	Marks	Notes
3(a)	$R = mg\cos\alpha,\ F = \frac{1}{3}R$	**M1**	Uses $F = \frac{1}{3}R$ with R resolved perpendicular to the plane, $mg\cos\alpha$. Condone a slip in finding $\cos\alpha$.
	$\cos\alpha = \frac{24}{25} \Rightarrow F = \frac{1}{3} \times \frac{24}{25}mg = \frac{8}{25}mg$	**A1**	Needs $\cos\alpha = \frac{24}{25}$ or $R = \frac{24}{25}mg$ seen.
	$W = Fd = \frac{8}{25}mg \times d = \frac{8}{25}mgd$	**A1 AG**	Their correct friction multiplied by d, reaching the printed result with no error in the part.
		[3]	
3(b)	$\frac{1}{2}m(\sqrt{gd})^2 - \frac{8}{25}mgd$ $= \frac{1}{2}mv^2 + mgd\sin\alpha$	**M1**	Forms a work–energy equation from A to B with KE at A, GPE gained and work against friction, or compares their s with d. Condone sign slips.
	$\frac{1}{2}mv^2 = -\frac{1}{10}mgd < 0 \Rightarrow$ does not reach B	**A1**	$-\frac{1}{10}mgd$ oe, or $\frac{1}{2}mgd < \frac{3}{5}mgd$, or $\frac{5d}{6} < d$, with the conclusion that it does not reach B.
	$\frac{1}{2}mgd - \frac{8}{25}mgs = \frac{7}{25}mgs \Rightarrow s = \ldots$	**M1**	Forms a work–energy equation from A to rest at distance s, with KE at A, GPE gained and work against friction in terms of s. Condone sign slips.
	$s = \frac{5d}{6}$	**A1**	
		[4]	
	Total for Question 3	**7**	

Question	Scheme	Marks	Notes
4(a)	$h = 39\sin\alpha = 39 \times \frac{5}{13} = 15$	**B1**	
	$\frac{1}{2}m(21)^2 + 0 = \frac{1}{2}mv^2 + mg(\text{“15”})$	**M1 A1**	**M1** Forms an energy equation from A to B with both KE terms and a GPE change mgh using their height. Condone sign slips. **A1** Correct equation, oe; m may be cancelled.
	$v^2 = 147 \Rightarrow v = 7\sqrt{3} \approx 12.1\,\text{m s}^{-1}$	**A1**	$7\sqrt{3}$ or awrt 12.1.
		[4]	
4(b)	$R = mg\cos\alpha = \frac{12mg}{13} \Rightarrow F = \frac{1}{3}R = \frac{4mg}{13}$	**B1**	oe, such as $3.02m$.
	$\frac{1}{2}m(21)^2 - \text{“}\frac{4mg}{13}\text{”} \times 39$ $= \frac{1}{2}mv^2 + 15mg$	**M1**	Forms an energy equation from A to B with both KE terms, the GPE gain and their friction times 39. Condone sign slips. Or earned by comparing their s with 39.
	$\frac{1}{2}mv^2 = -44.1m < 0$, so P does not reach B	**A1**	Correct negative KE, or correct s with $s < 39$, and the conclusion.
	$\frac{1}{2}m(21)^2 - \frac{4mg}{13}s = mg\,s\sin\alpha$	**M1 A1**	**M1** Forms an energy equation from A to rest with initial KE, a GPE gain from $s\sin\alpha$ and their friction times s. Condone sign slips. **A1** Correct equation, oe; m may be cancelled.
	$s = \frac{220.5 \times 13}{9 \times 9.8} = 32.5\,\text{m}$	**A1**	
		[6]	
Total for Question 4		**10**	

Question	Scheme	Marks	Notes
5(a)	$R + 220\sin 15° = 40g\cos 10°$	**M1**	Resolves perpendicular to the slope with the weight component and a component of the tension. Condone sign slips and sin/cos interchange.
	$R = 40g\cos 10° - 220\sin 15° \approx 329.1\,\text{N}$	**A1**	Unevaluated or awrt 329.
	$W_T = 220 \times 5\cos 15°$ $[\approx 1063\,\text{J}]$	**B1**	Unevaluated or awrt 1060.
	$220(5)\cos 15° - 0.25\text{“}R\text{”}(5)$ $= \frac{1}{2}(40)v^2 + 40g(5)\sin 10°$	**M1 A1**	**M1** Forms an energy equation over the 5 m with work by the tension, friction work from their R found by resolving, KE and GPE. Condone sign slips. **A1** Correct equation, oe; need not be simplified.
	$20v^2 = \ldots$ $[310.8] \Rightarrow v \approx 3.94\,\text{m}\,\text{s}^{-1}$	**A1**	
	Resultant force up the slope while the rope pulls, so the speed is greatest when it breaks	**E1**	States that the sledge accelerates, or the resultant force is up the slope, while the rope pulls, so the speed is greatest when it breaks.
		[7]	
5(b)	$R = 40g\cos 10°$	**B1**	
	Work against friction $= 0.25(40g\cos 10°)s$	**B1ft**	0.25 times their R times the distance, oe.
	$\text{“}310.8\text{”} - 0.25\text{“}40g\cos 10°\text{”}s = 40g(\sin 10°)s$	**M1 A1ft**	**M1** Forms an energy equation from the break to rest using their KE from (a), or from the start to rest, with friction work and GPE. Condone sign slips. **A1ft** ft their KE from (a) and their R.
	$s = \ldots$ $[\approx 1.89] \Rightarrow$ total $= 6.89\,\text{m}$	**A1**	Total distance. Not for the further distance alone.
		[5]	
5(c)	Model gives $6.89 > 6.8$, so the model does not support the claim	**E1**	Compares their total from (b) with 6.8 m and states the matching conclusion about the claim.

Question 5 continued

Question	Scheme	Marks	Notes
	Air resistance, ignored by the model, would make the sledge stop sooner: the claim is reasonable	**E1**	Names an effect the model leaves out that would reduce the distance, such as air resistance, and concludes the claim is reasonable. Not for variation in friction or tension alone.
		[2]	
	Total for Question 5	**14**	

Question	Scheme	Marks	Notes
6(a)	$R + 80\sin 20° = 10g\cos 15° \Rightarrow R = \ldots$	**M1**	Resolves perpendicular to the plane with R, a weight component and a tension component. Condone sign slips and sin/cos confusion.
	$R = 67.3$	**A1**	awrt 67.3, or $98\cos 15° - 80\sin 20°$.
	$KE_1 - KE_0 = \frac{1}{2} \times 10 \times (4.5^2 - 1.5^2)$ $[= 90]$	**B1**	Both kinetic energies, 11.25 and 101.25, or their difference.
	Work done by tension $= 80x\cos 20°$	**B1**	
	$KE_0 + GPE_0 + \sum W_{\text{other}} = KE_1 + GPE_1$ $11.25 + 80x\cos 20° - 0.3\text{“}67.3\text{”}x$ $= 101.25 + 98x\sin 15°$	**M1 A1**	**M1** Forms an energy equation with tension work, friction work $0.3\text{“}R\text{”}x$, both KE terms and GPE of the form $10gx\sin\theta$. Condone sign and sin/cos slips. **A1** Correct equation, oe.
	$x = 3.04$	**A1**	awrt 3.04.
		[7]	
6(b)	Include air resistance	**E1**	States a refinement such as air resistance, or another named resistance to motion besides friction.
	It does extra negative work per metre, so $\sum W_{\text{other}}$ is smaller per metre: more distance is needed for the same KE gain, so x increases	**E1**	Argues that the extra resistance does work against the motion over the same KE gain, and concludes x increases. Not for the conclusion alone.
		[2]	
	Total for Question 6	**9**	

Question	Scheme	Marks	Notes
7(a)	$R = mg\cos\theta$	**M1**	Resolves perpendicular to the plane, equating R to a component of the weight. Condone sin/cos confusion.
	$\cos\theta = \frac{12}{13} \Rightarrow R = \frac{12mg}{13}$	**A1**	
	$F = \mu R = \frac{1}{4} \times \frac{12mg}{13} = \frac{3mg}{13}$	**A1 AG**	Uses $F = \mu R$ with correct R, reaching the printed result without error.
		[3]	
7(b)	$\frac{1}{2}m\left(4\sqrt{ag}\right)^2 - \frac{3mg}{13}s = mgs\sin\theta$ $\Rightarrow 8mag - \frac{3mgs}{13} = \frac{5mgs}{13}$	**M1 A1**	**M1** Forms a work–energy equation from O to rest with KE, GPE and the work done by friction. Condone sign slips and sin/cos confusion. **A1** Correct equation, oe.
	$s = 13a$	**A1**	
	$\frac{5mg}{13}$ ("$13a$") $- \frac{3mg}{13}$ ("$13a$") $= \frac{1}{2}mv^2$	**M1 A1ft**	**M1** Forms a work–energy equation ending at O, from rest or over the whole motion, with all nonzero KE, GPE and friction terms. Condone sign slips. **A1ft** Correct equation, ft their distance up the plane.
	$v = 2\sqrt{ag}$	**A1**	oe, such as $\sqrt{4ag}$.
		[6]	
	Total for Question 7	**9**	

Question	Scheme	Marks	Notes
8(a)	$F = \frac{1}{4}R = \frac{1}{4} \times 8g\cos 45°$	**M1**	Uses $F = \frac{1}{4}R$ with R the weight's component perpendicular to the ramp.
	$F = \sqrt{2}g$	**A1**	oe, or awrt 13.9 N.
	$W = Fd = \sqrt{2}gd$	**A1**	$\sqrt{2}gd$ oe, or awrt $1.41gd$. Must be in terms of g and d, not $13.9d$.
		[3]	
8(b)	$KE_1 = \frac{1}{2}(8+2)(2.1)^2 = 22.05$	**B1**	
	A loses $8gd\sin 45° = 4\sqrt{2}gd$; B gains $2gd$	**B1**	Both GPE changes, oe, with any zero levels.
	$KE_0 + GPE_0 + \sum W_{\text{other}} = KE_1 + GPE_1$ $0 +$ "$4\sqrt{2}gd$" $-$ "$\sqrt{2}gd$" $=$ "22.05" $+$ "$2gd$"	**M1 A1ft**	**M1** Forms a work–energy equation, for the system or each block, with both blocks' KE, both GPE changes and their friction work from (a). Condone sign slips. **A1ft** Correct equation oe; ft their friction work from (a).
	$d = \dfrac{22.05}{g(3\sqrt{2}-2)} \approx 1.00$	**A1**	awrt 1.00, or 1.0; not 1 alone.
		[5]	
8(c)	Model the pulley as rough, so friction at the pulley is included	**E1**	Gives one valid refinement, such as a rough or heavy pulley, a rope with mass or that stretches, or the blocks' dimensions. Not for "more accurate" alone.
		[1]	
	Total for Question 8	**9**	

Question	Scheme	Marks	Notes
9(a)	$I = 0.5\big(12 - (-5)\big)$	**M1**	Uses $m(v-u)$ with the two velocities of opposite sign.
	$I = 8.5\,\text{N s}$	**A1**	
		[2]	
9(b)	$\frac{1}{2}(0.5)(12^2) - Rs = (0.5)gs\sin 30°$	**M1 A1**	**M1** Forms an energy equation for the motion up, with KE, GPE and work against resistance over the distance. Condone sign slips and sin/cos confusion. **A1** Correct equation in any distance or height variable, oe.
	$(0.5)gs\sin 30° - Rs = \frac{1}{2}(0.5)(4^2)$	**M1 A1**	**M1** Forms an energy equation for the motion down, or the whole journey, over the same distance, with all relevant nonzero terms. Condone sign slips. **A1** Correct equation, oe, such as $\frac{1}{2}(0.5)(12^2) - \frac{1}{2}(0.5)(4^2) = 2Rs$.
	$0.5gs = 40 \Rightarrow s = \ldots\ [= \frac{80}{g}]$ $36 = (0.25g + R)\text{“}\frac{80}{g}\text{”} \Rightarrow R = \ldots$	**dM1**	Solves their two equations simultaneously, eliminating the distance, to reach $R = \ldots$.
	$R = \frac{g}{5} = 1.96$	**A1**	
		[6]	
Total for Question 9		**8**	

Question	Scheme	Marks	Notes
10(a)	Rise of A: $3\sin\theta = \frac{15}{13}$	**B1**	
	$5g \times 3 - 3g \times$ "$\frac{15}{13}$"	**M1**	Finds the GPE lost by B minus the GPE gained by A, with their rise of A of the form $3\sin\theta$ or $3\cos\theta$.
	$\frac{150g}{13} = \frac{1470}{13} \approx 113\,\text{J}$	**A1**	awrt 113.
		[3]	
10(b)	$\frac{1}{2}(3+5)(4.8)^2 = 92.16$	**B1**	
	$\mu \times \frac{36g}{13} \times 3 = \frac{108g\mu}{13}$	**B1**	oe, such as awrt 81.4μ.
	$0 + 15g - \frac{108g\mu}{13} = 92.16 + \frac{45g}{13}$ or "$\frac{150g}{13}$" $- \frac{108g\mu}{13} = 92.16$	**M1 A1ft**	**M1** Forms an energy equation for the system with the KE of both blocks, both GPE changes or their (a), and friction work. Condone sign slips. **A1ft** Correct equation, ft their potential energy loss from (a).
	$\mu = \frac{1133}{4410} \approx 0.257$	**A1**	awrt 0.257.
		[5]	
10(c)	$\mu \times \frac{36g}{13} \times 0.5 = \frac{18g\mu}{13}$	**B1**	oe, in terms of μ or with a value of μ substituted.
	$3g(0.5+d)\sin\theta = \frac{15g}{13}(0.5+d)$	**B1**	oe, such as $\frac{147}{13}(0.5+d)$.
	$\frac{1}{2}(3)(4.8)^2 - \frac{18g}{13}$"$\mu$" $= \frac{15g}{13}(0.5+d)$	**M1 A1ft**	**M1** Forms an energy equation for A alone after B lands, with the KE of A, GPE gained and friction work. Condone sign slips and slips in distances. **A1ft** Correct equation, ft their μ.
	$d = \frac{16\,523}{7350} \approx 2.25$	**A1**	awrt 2.25.
		[5]	
	Total for Question 10	**13**	