OCR
Oxford Cambridge and RSA

Wednesday 17 May 2017 – Morning

A2 GCE MATHEMATICS (MEI)

4762/01 Mechanics 2

QUESTION PAPER

Candidates answer on the Printed Answer Book.

OCR supplied materials:
- Printed Answer Book 4762/01
- MEI Examination Formulae and Tables (MF2)

Other materials required:
- Scientific or graphical calculator

Duration: 1 hour 30 minutes

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INSTRUCTIONS TO CANDIDATES

These instructions are the same on the Printed Answer Book and the Question Paper.

- The Question Paper will be found inside the Printed Answer Book.
- Write your name, centre number and candidate number in the spaces provided on the Printed Answer Book. Please write clearly and in capital letters.
- **Write your answer to each question in the space provided in the Printed Answer Book**. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the barcodes.
- You are permitted to use a scientific or graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by $g\,\mathrm{m\,s^{-2}}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

INFORMATION FOR CANDIDATES

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- The number of marks is given in brackets **[ ]** at the end of each question or part question on the Question Paper.
- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.
- The total number of marks for this paper is **72**.
- The Printed Answer Book consists of **16** pages. The Question Paper consists of **8** pages. Any blank pages are indicated.

INSTRUCTION TO EXAMS OFFICER/INVIGILATOR

- Do not send this Question Paper for marking; it should be retained in the centre or recycled. Please contact OCR Copyright should you wish to re-use this document.

1 Fig. 1.1 shows the masses and speeds of two small uniform circular discs, A and B, sliding towards one another on a smooth horizontal surface. Each of the discs is moving with its centre on the line shown in the figure; there is a barrier which is perpendicular to this line. The discs collide and separate.

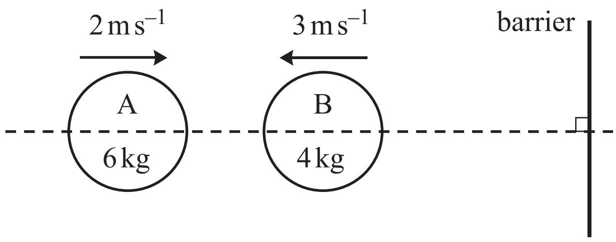

Fig. 1.1

(i) By considering only linear momentum, explain how you know that the direction of motion of each disc must be reversed in the collision. **[2]**

You are now given that the coefficient of restitution is e.

(ii) Show that after the collision A has speed $2e$. Find an expression in terms of e for the speed of B after the collision. **[5]**

(iii) Find an expression in terms of e for the magnitude of the impulse in the collision. **[1]**

Three seconds after its collision with A, disc B has a perfectly elastic direct collision with the barrier shown in Fig. 1.1 and later collides again with A.

(iv) What time will elapse between the two collisions of the discs? **[3]**

In a different situation, B has an oblique impact with a smooth barrier. This barrier is inclined at an angle α to the direction of motion of B. The coefficient of restitution in this collision is $\frac{1}{3}$ and the direction of motion of B is turned through 90° as a result of the collision, as shown in Fig. 1.2.

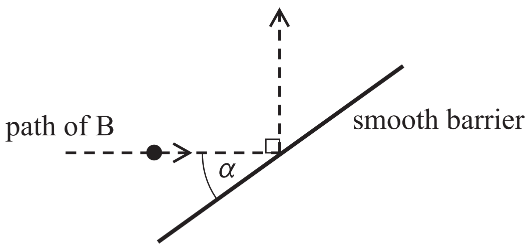

Fig. 1.2

(v) Calculate α, giving your answer in degrees. **[5]**

2 **In this question take $g = 10$.**

Fig. 2 shows a small object Q, of mass 5 kg, which slides in a straight line up a rough ramp. The point D is at the top of the ramp, where the ramp is joined to a horizontal platform. The point C on the ramp is a vertical distance of 2 m below D. CD is inclined at an angle α to the horizontal.

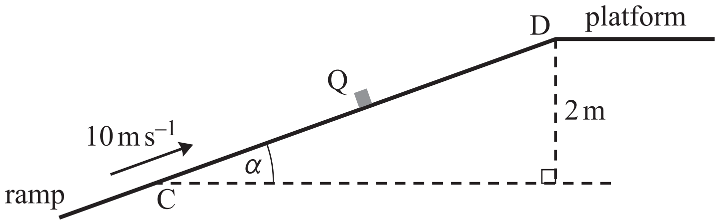

Fig. 2

Q is struck so that it moves up a line of greatest slope of the ramp. Q passes through C with a speed of $10\,\text{m s}^{-1}$ and comes to rest at D.

The motion of Q is first modelled by assuming that the only resistance to its motion is friction with the plane.

(i) Without assuming that the ramp is uniformly rough, calculate the work done by the frictional force as Q travels from C to D. **[3]**

Now assume that the coefficient of friction between the object and the plane has the constant value $\frac{5}{8}$.

(ii) Show that the work done by the frictional force acting on Q as it travels from C to D may be expressed as $\dfrac{125}{2\tan\alpha}$.

Calculate $\tan\alpha$. **[7]**

A new ramp is built that is inclined at an angle greater than α to the horizontal. This also ends at D. Q is now struck so that it moves up a line of greatest slope of the new ramp. As in the previous situation, it passes through a point at a vertical level 2 m below D at a speed of $10\,\text{m s}^{-1}$. The coefficient of friction between Q and the new ramp is the same as that between Q and the old ramp.

(iii) Does Q now come to rest below D or still come to rest at D or is Q still moving at D?
You should explain your answer but you need not produce detailed calculations. **[2]**

Subsequently Q is moving on the horizontal platform and is made to travel in a straight line by a force which has a constant power of 50 W. The resistance to the motion of Q is F N, where F is constant. The velocity and acceleration of Q at time t s are $v\,\text{m s}^{-1}$ and $a\,\text{m s}^{-2}$ in the direction of its motion.

(iv) Write down the equation of motion of Q in terms of F, v and a. **[3]**

(v) Given that Q is travelling at a constant speed of $4\,\text{m s}^{-1}$, calculate F. **[1]**

(vi) Show that a can only be constant if it is zero.

Q changes speed from $U\,\text{m s}^{-1}$ to $V\,\text{m s}^{-1}$ in T s. Explain why it would not be appropriate to calculate the distance travelled in this time as $\frac{1}{2}T(U+V)$. **[3]**

3 (a) Fig. 3.1 shows a framework JKL in a vertical plane. The framework is made from three light rigid rods JK, KL and LJ which are freely pin-jointed to each other at J, K and L. The pin-joint at J is attached to a fixed vertical wall; the pin-joint at L is in contact with a fixed smooth horizontal beam. JK is 5 m, KL is 3 m and LJ is 4 m. Angle KLJ is 90°.

The framework is held in equilibrium with JK horizontal by means of a single applied force of 80 N acting at K parallel to JL. Fig. 3.1 shows this force and the angle α between JL and JK. Fig. 3.1 also shows the horizontal component, X N, of the force on the framework due to J being attached to the wall. Note that the diagram does not show the vertical component of the force acting at J nor the force on the framework at L due to contact with the beam.

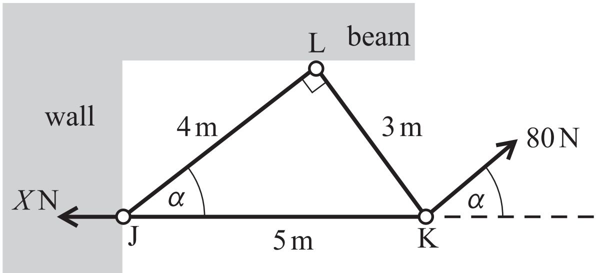

Fig. 3.1

Show that $X = 64$.

By first considering the equilibrium of the pin-joint at K, or otherwise, calculate the forces internal to the rods JK, KL and LJ, stating whether each rod is in tension or thrust (compression). **[8]**

(b) Fig. 3.2 shows a uniform heavy ladder AB, of weight W N, standing on rough horizontal ground and resting on a smooth peg at C. The ladder has length 5 m. C is 3 m above the ground and is a horizontal distance of 1.25 m from A. The ladder is in equilibrium.

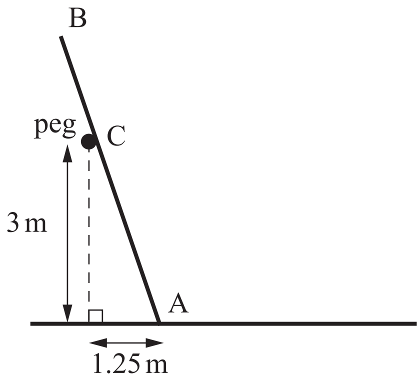

Fig. 3.2

Show that the force exerted on the ladder by the peg at C is $\frac{50W}{169}$.

Calculate the range of possible values of the coefficient of friction between the ladder and the ground. **[12]**

4 **(a)** In this part question, all coordinates refer to the axes shown in Fig. 4.1.

Fig. 4.1 shows a uniform rectangular lamina OABC with OA and OC on the x- and y-coordinate axes. The units of the axes are metres.

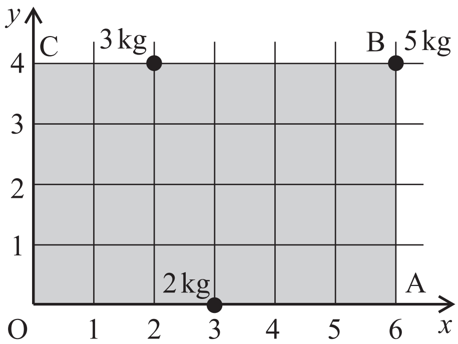

Fig. 4.1

The mass of the lamina is 2 kg and 3 heavy particles are fixed to it. The masses of these particles are 2 kg, 3 kg and 5 kg and they are at points with coordinates (3, 0), (2, 4) and (6, 4), respectively.

(i) Calculate the coordinates of the combined centre of mass of the lamina and the 3 particles. **[3]**

A particle of mass m kg is now fixed to the lamina at a point $(X, 0)$, with $0 < X \leqslant 6$, so that the combined centre of mass of the original 3 particles, the lamina and the mass m kg lies on OB (part of the line with equation $y = \frac{2}{3}x$).

(ii) Establish that $mX = 6$. **[4]**

(b) Fig. 4.2 shows a thin heavy uniform wire ABC bent into the shape of a semi-circle with centre O and radius r. More of the same wire, DE, has its centre at O and lies on the straight line AOC. The distance DE is kr, where $k \geqslant 2$ is a constant. The two wires are joined at A and C to form object P.

You may use without proof the information that the centre of mass of the curved semi-circular section of the wire, ABC, lies on the line OB at a distance $\frac{2r}{\pi}$ from O.

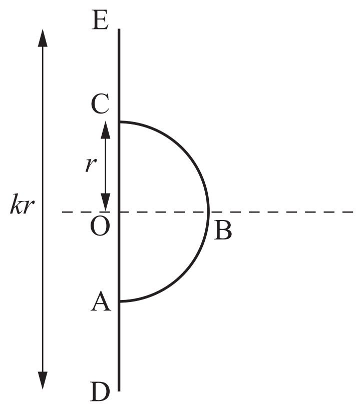

Fig. 4.2

(i) Show that the centre of mass of P lies on OB at a distance $\frac{2r}{\pi + k}$ from O. **[4]**

Two light inelastic strings are attached to P, one at E and the other at B. Both strings are vertical and P is in equilibrium with DE vertical. The tension in the string attached at E is T_E and the tension in the string attached at B is T_B.

(ii) Find the value of k for which $T_E = 2T_B$. **[6]**

END OF QUESTION PAPER

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4762/01 Mechanics 2

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Candidate forename		Candidate surname	

Centre number						Candidate number				

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1 (i)	
1 (ii)	

1 (iii)	
1 (iv)	

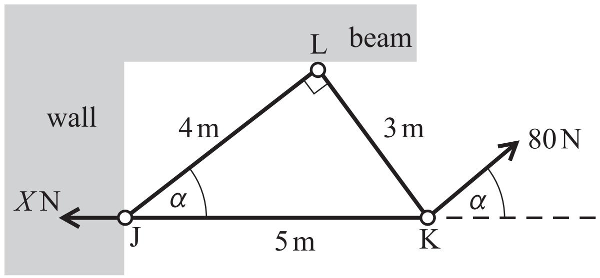
1 (v)

2 (i)	
2 (ii)	
	(answer space continued on next page)

2 (ii)	**(continued)**
2 (iii)	
2 (iv)	

2 (v)	
2 (vi)	

A spare copy of Fig. 3.1 can be found on page 16



3 (a)

(answer space continued on next page)

3 (a)	**(continued)**

3 (b)	
	(answer space continued on next page)

3 (b)	**(continued)**

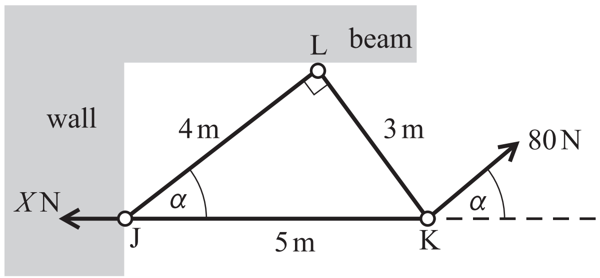
4 (a)(i)	

4 (a)(ii)

4(b)(i)	

4 (b)(ii)

Spare copy of Fig. 3.1



OCR
Oxford Cambridge and RSA

GCE

Mathematics (MEI)

Unit **4762**: Mechanics 2

Advanced GCE

Mark Scheme for June 2017

OCR (Oxford Cambridge and RSA) is a leading UK awarding body, providing a wide range of qualifications to meet the needs of candidates of all ages and abilities. OCR qualifications include AS/A Levels, Diplomas, GCSEs, Cambridge Nationals, Cambridge Technicals, Functional Skills, Key Skills, Entry Level qualifications, NVQs and vocational qualifications in areas such as IT, business, languages, teaching/training, administration and secretarial skills.

It is also responsible for developing new specifications to meet national requirements and the needs of students and teachers. OCR is a not-for-profit organisation; any surplus made is invested back into the establishment to help towards the development of qualifications and support, which keep pace with the changing needs of today's society.

This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

Annotations and abbreviations

Annotation in scoris	Meaning
✓and ✗	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working
M0, M1	Method mark awarded 0, 1
A0, A1	Accuracy mark awarded 0, 1
B0, B1	Independent mark awarded 0, 1
SC	Special case
^	Omission sign
MR	Misread
Highlighting	
Other abbreviations in mark scheme	**Meaning**
E1	Mark for explaining
U1	Mark for correct units
G1	Mark for a correct feature on a graph
M1 dep*	Method mark dependent on a previous mark, indicated by *
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working

Subject-specific Marking Instructions for GCE Mathematics (MEI) Mechanics strand

a Annotations should be used whenever appropriate during your marking.

The A, M and B annotations must be used on your standardisation scripts for responses that are not awarded either 0 or full marks. It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

For subsequent marking you must make it clear how you have arrived at the mark you have awarded.

b An element of professional judgement is required in the marking of any written paper. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct *solutions* leading to correct answers are awarded full marks but work must not be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly.

Correct but unfamiliar or unexpected methods are often signalled by a correct result following an *apparently* incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, award marks according to the spirit of the basic scheme; if you are in any doubt whatsoever (especially if several marks or candidates are involved) you should contact your Team Leader.

c The following types of marks are available.

M
A suitable method has been selected and *applied* in a manner which shows that the method is essentially understood. Method marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, eg by substituting the relevant quantities into the formula. In some cases the nature of the errors allowed for the award of an M mark may be specified.

A
Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

B
Mark for a correct result or statement independent of Method marks.

E
A given result is to be established or a result has to be explained. This usually requires more working or explanation than the establishment of an unknown result.

Unless otherwise indicated, marks once gained cannot subsequently be lost, eg wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

d When a part of a question has two or more ‘method’ steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. (The notation ‘dep *’ is used to indicate that a particular mark is dependent on an earlier, asterisked, mark in the scheme.) Of course, in practice it may happen that when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.

e The abbreviation ft implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only — differences in notation are of course permitted. A (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, exactly what is acceptable will be detailed in the mark scheme rationale. If this is not the case please consult your Team Leader.

Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will often be ‘follow through’. In such cases you must ensure that you refer back to the answer of the previous part question even if this is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

f Unless units are specifically requested, there is no penalty for wrong or missing units as long as the answer is numerically correct and expressed either in SI or in the units of the question. (e.g. lengths will be assumed to be in metres unless in a particular question all the lengths are in km, when this would be assumed to be the unspecified unit.)

We are usually quite flexible about the accuracy to which the final answer is expressed and we do not penalise over-specification.

When a value is given in the paper
Only accept an answer correct to at least as many significant figures as the given value. This rule should be applied to each case.

When a value is not given in the paper
Accept any answer that agrees with the correct value to 2 s.f.

ft should be used so that only one mark is lost for each distinct error made in the accuracy to which working is done or an answer given. Refer cases to your Team Leader where the same type of error (e.g. errors due to premature approximation leading to error) has been made in different questions or parts of questions.

There are some mistakes that might be repeated throughout a paper. If a candidate makes such a mistake, (eg uses a calculator in wrong angle mode) then you will need to check the candidate's script for repetitions of the mistake and consult your Team Leader about what penalty should be given.

There is no penalty for using a wrong value for *g*. E marks will be lost except when results agree to the accuracy required in the question.

g Rules for replaced work

If a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests.

If there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others.

NB Follow these maths-specific instructions rather than those in the assessor handbook.

h For a *genuine* misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate's data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for some units. This is achieved by withholding one A mark in the question.

Marks designated as cao may be awarded as long as there are no other errors. E marks are lost unless, by chance, the given results are established by equivalent working.

'Fresh starts' will not affect an earlier decision about a misread.

Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

i If a graphical calculator is used, some answers may be obtained with little or no working visible. Allow full marks for correct answers (provided, of course, that there is nothing in the wording of the question specifying that analytical methods are required). Where an answer is wrong but there is some evidence of method, allow appropriate method marks. Wrong answers with no supporting method score zero. If in doubt, consult your Team Leader.

j If in any case the scheme operates with considerable unfairness consult your Team Leader.

Question			Answer	Marks	Guidance	
1		(i)	The total LM of 0 is conserved	M1	Both 'LM = 0' and 'conserved' stated or implied in the answer, e.g. $6 \times 2 - 4 \times 3 = 0$ and 'conserved'	
			Cannot both be in same direction (nor in original direction)	A1	Accept "They must be going in opposite directions"	
				[2]		
		(ii)	$\rightarrow$+ve and 'after' velocities $\leftarrow v_A$ and $\rightarrow v_B$			
			PCLM $6 \times 2 + 4 \times -3 = -6v_A + 4v_B$	M1	Use of PCLM. Accept LHS as 0 without comment	
			so $3v_A = 2v_B$	A1	oe	
			NEL $\dfrac{v_B - (-v_A)}{-3-2} = -e$	M1	Use of NEL. Must be attempt at separation/approach (right way up)	
			so $v_B + v_A = 5e$	A1	oe (consistent with PCLM signs)	
			Solving, $v_A = 2e$ and $v_B = 3e$	A1	cao both, speeds not velocities required (v_A is AG)	
				[5]		
		(iii)	**either** Using A: $\leftarrow$ $6(2e + 2) = 12(e + 1)$	B1	cao oe	
			or Using B: $\rightarrow$ $4(3e + 3) = 12(e + 1)$	B1	cao oe	
				[1]		
		(iv)	**either** ▪Speed of B unchanged by impacting barrier; ▪B returns to its original position after 6 s; ▪in this time A has moved 12e; ▪relative speed after 6 s is e.	B1ft B1ft	2 of these 4 statements made or implied, ft speed of B from (ii) all of these 4 statements made or implied, ft speed of B from (ii)	
			Time taken is 6 s + time to catch up (12 s) so 18 s	B1	cao	
			or ▪Speed of B unchanged by impacting barrier; ▪B travels distance 9e to barrier; ▪A is now 15e from barrier ▪relative speed after 6 s is e.	B1ft B1ft	2 of these 4 statements made or implied, ft speed of B from (ii) all of these 4 statements made or implied, ft speed of B from (ii)	
			Time taken is 3 s + time to catch up (15 s) so 18 s	B1	cao	

Question			Answer	Marks	Guidance	
				[3]		
		(v)	Vel of B before impact is v at α to barrier; vel of B after impact is v^1 at β to barrier $\beta = 90 - \alpha$ **either** Use $\tan\beta = e\tan\alpha$ $\tan\beta = \frac{1}{3}\tan\alpha$ **or** $v\cos\alpha = v^1\cos\beta$ and $v^1\sin\beta = \frac{1}{3}v\sin\alpha$ $\tan\beta = \frac{1}{3}\tan\alpha$ **or** $v_x = u_x$ and $v_y = \frac{1}{3}u_y$ $\tan\beta = \frac{v_y}{v_x} = \frac{1}{3}\frac{u_y}{u_x} = \frac{1}{3}\tan\alpha$ **then** so $\frac{1}{\tan\alpha} = \frac{1}{3}\tan\alpha$ so $\tan^2\alpha = 3$ and $\tan\alpha = \sqrt{3}$ (+ve root) and $\alpha = 60°$	B1 M1 A1 M1 A1 M1 A1 A1 A1 **[5]**	Allow any specified value of v May be quoted without proof Award for either statement seen Both statements needed or seen on diagram Any form, in terms of $\tan\alpha$ only cao	

Question			Answer	Marks	Guidance	
2		(i)	$0-\frac{1}{2}\times 5\times 10^2 = -5\times 10\times 2 - \text{WD}$	M1	M1 use of W-E equation with WD, KE and GPE. Allow sign errors	
				A1	Any form. Allow sign error in WD term only	
			So WD = 150. Work done is 150 J	A1 **[3]**	−150 gets 2/3 (Allow 152 from g = 9.8)	
		(ii)	Say Q moves d up ramp and friction is F			
			WD = Fd	M1	used	
			$d=\frac{2}{\sin\alpha}$ so WD = $\frac{2F}{\sin\alpha}$	A1		
			(Since sliding) $F=\mu R$	M1	used	
			Resolving perp to ramp $R=5\times 10\cos\alpha$	B1	$5g\cos\alpha$	
			so $F=50\times\frac{5}{8}\cos\alpha = \frac{125}{4}\cos\alpha$			
			Hence WD is $\frac{2}{\sin\alpha}\times\frac{125}{4}\cos\alpha=\frac{125}{2\tan\alpha}$	A1	AG Properly shown	
			so 150 = $\frac{125}{2\tan\alpha}$	M1	Equate WD to 150. FT(i)	
			and $\tan\alpha=\frac{125}{2\times 150}=\frac{5}{12}$ (0.417 to 3 s. f.)	A1 **[7]**	cao aef NOT implied by 22.6	
		(iii)	**either**			
			Suppose α is greater,			
			$\cos\alpha$ is less so $F=50\times\frac{5}{8}\cos\alpha$ is less			
			also $\sin\alpha$ is greater so $d=\frac{2}{\sin\alpha}$ is less	B1	Award for either F or d stated to be less OR still moving at D	
			Hence Fd = WD is less. GPE the same so Q			

Question			Answer	Marks	Guidance	
			is still moving	B1	Award for both F and d stated to be less AND still moving at D	
			or From (ii) use WD = $\dfrac{125}{2\tan\alpha}$ If α is greater, tanα is greater Hence WD is less. GPE the same so Q is still moving	B1 B1	Award for WD stated to be less OR still moving at D Award for WD stated to be less,with reference to established result, AND still moving at D	
				[2]		
		(iv)	Using N2L $\dfrac{50}{v} - F = 5a$	M1 B1 A1 **[3]**	Use of N2L All terms present ($D - F = 5a$ is sufficient) Use of *Power* = *Driving force* × *speed* Any form	
		(v)	Put a = 0 and v = 4, F = 12.5.	B1 **[1]**		
		(vi)	a and v are the only things in the equation that can change so they are both constant or both vary If $a \neq 0$, v must vary so a must vary. Hence if a is constant it must be zero (giving constant v) *suvat* equations only valid for constant accn	B1 B1 B1 **[3]**	F is constant OR a and v are the only variables Must be convincing	

Question			Answer	Marks	Guidance
3	(a)				In this part, award the best possible mark for marks 3 to 8. M1A1 for a correct resolution and force (even if not the first one given) M1F1 for second resolution and force M1 for third resolution A1 All forces correct and all T/C correct
			$\sin\alpha = 0.6;\ \cos\alpha = 0.8$	B1	Either of these
			Horizontal equilibrium of whole framework: $80\cos\alpha - X = 0$ so $X = 64$	B1	
			Take the internal forces to be +ve in tension		Any convention may be used
			At K↑ $80\sin\alpha + T_{KL}\cos\alpha = 0$	M1	All relevant forces only, resolved if necessary, allow sign errors and cos/sin mix
			so $T_{KL} = -60$ a force in KL of 60 N (C)	A1	
			either At K resolve parallel to JL: $80 - T_{JK}\cos\alpha = 0$	M1	All relevant forces only, resolved if necessary, allow sign errors and cos/sin mix
			or At K→ $80\cos\alpha - T_{KL}\sin\alpha - T_{JK} = 0$	M1	All relevant forces only, resolved if necessary, allow sign errors and cos/sin mix
			so $T_{JK} = 100$ a force in JK of 100 N (T)	F1	FT their value for KL
			either At J→ $T_{JK} + T_{LJ}\cos\alpha - X = 0$	M1	
			so $T_{LJ} = -45$ a force in LJ of 45 N (C)	A1	All values correct and all T/C correct
			or At L→ $T_{KL}\sin\alpha - T_{LJ}\cos\alpha = 0$	M1	
			so $T_{LJ} = -45$ a force in LJ of 45 N (C)	A1	All values correct and all T/C correct
				[8]	

Question			Answer	Marks	Guidance
	(b)		Take: weight of ladder as W N; angle of ladder with horiz as α. Forces: at A, R N ↑, F N ←; at C, S N perp to AB		
			$\tan\alpha = \frac{3}{1.25} = \frac{12}{5}$; $\sin\alpha = \frac{12}{13}$; $\cos\alpha = \frac{5}{13}$	B1	Award for any of these seen. oe for different angle chosen (Award for 67.4)
			ac moments about A $2.5W\cos\alpha - 3.25S = 0$ (3) $S = \frac{50W}{169}$	M1 B1 A1	Moments with all terms present The distance AC is 3.25 (may be implied) Shown: A0 if 67.4 stated with no evidence of 12/5 o.e.
			In equilib; consider vert and horiz cpts ↑ $R + S\cos\alpha - W = 0$ (1) ← $F - S\sin\alpha = 0$ (2)	M1 A1 M1 A1	Award for either. Allow cos/sin mix, allow sign errors oe (R = 0.886W or 1947/2197 W) Second resolution. Allow cos/sin mix, allow sign errors oe (F = 0.273W or 600/2197 W)
			We have $\mu \geq \frac{F}{R}$ Substitute for sinα and cosα and for F and R from (1) and (2). Eliminate S.	M1	Used and attempt to get all in terms of W (Accept '='at this stage)
			so $\mu \geq \dfrac{\frac{50W}{169} \times \frac{12}{13}}{W - \frac{50W}{169} \times \frac{5}{13}}$	F1	Correct ft, dependent on all of previous 3 M marks, all in terms of W
			so $\mu \geq \frac{600W}{(169 \times 13 - 250)W} = \frac{200}{649}$	A1	This value is 0.3081664…: 600/1947

Question			Answer	Marks	Guidance	
			Hence $\mu \geq 0.308$ (3 s. f.)	A1 **[12]**	cao as final answer. Must have > as well as =.	

Question			Answer	Marks	Guidance
4	(a)	(i)	$(2+2+3+5)\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix}=2\begin{pmatrix}3\\2\end{pmatrix}+2\begin{pmatrix}3\\0\end{pmatrix}+3\begin{pmatrix}2\\4\end{pmatrix}+5\begin{pmatrix}6\\4\end{pmatrix}$	M1	Complete method for CoM Using 24 instead of 2 for mass of lamina is NOT a MR: award M1 max. Omitting mass of lamina, M1max. Allow one error
			so $12\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix}=\begin{pmatrix}48\\36\end{pmatrix}$		
			and the CoM is at (4, 3)	A1 A1 **[3]**	One coordinate cao Other coordinate cao
		(ii)	Require		
			$\begin{pmatrix}48\\36\end{pmatrix}+m\begin{pmatrix}X\\0\end{pmatrix}=(12+m)\begin{pmatrix}p\\ \frac{2p}{3}\end{pmatrix}$ for some p	M1	General method for attempt to get new CoM on OB
				B1	Dealing with finding a point on the line OB: using $y=\frac{2}{3}x$ in some way
			Hence $48+mX=(12+m)p$ and $36=(12+m)\frac{2p}{3}$	M1	Consider the components and attempt to eliminate, or equivalent
			Eliminate $(12+m)p$ to get $36=\frac{2}{3}(48+mX)$ so $mX = 6$	A1 **[4]**	Convincingly done (must follow from correct (48, 36))
	(b)	(i)	Let the line density of the wire be λ.		Do not penalise for stating $\lambda = 1$ or assuming this without comment
			$\bar{y}=0$, by considering symmetry	B1	Need a statement including symmetry (or calculation for this coordinate)
			DE has mass $kr\lambda$, CoM at (0, 0). Semi-circle has mass $\pi r\lambda$, CoM at $\left(\frac{2r}{\pi},\ 0\right)$.	B1	Both masses correct (but see above, accept kr and πr)

Question	Answer	Marks	Guidance
	$(kr\lambda + \pi r\lambda)\bar{x} = kr\lambda \times 0 + \pi r\lambda \times \frac{2r}{\pi}$	M1	Method for CoM. Accept 1st term on RHS not present
	so $(k+\pi)\bar{x} = 2r$ and $\bar{x} = \frac{2r}{k+\pi}$	A1	Must be convincing
		[4]	
(ii)	Suppose the weight of *P* is *W* and CoM at G		Condone use of length of wire or of mass instead of weight in correct ratios
	Method A		
	Take c.w moments about G		
	$T_E \times \frac{2r}{\pi+k} - T_B \times \left(r - \frac{2r}{\pi+k}\right) = 0$	M2	Use of moments with all appropriate forces
		A1	A correct moments equation
	Substitute $T_E = 2T_B$ giving	M1	Substitute and attempt elimination
	$\frac{4r}{\pi+k} = r - \frac{2r}{\pi+k}$	A1	o.e.
	so $4r = r(\pi+k) - 2r$		
	so $k = 6 - \pi$ (2.86 to 3 s. f.)	A1	cao
	Method B		
	a.c moments about O: $W \times \frac{2r}{\pi+k} - T_B \times r = 0$	M1 A1	Use of moments with all appropriate forces A correct moments equation. (Allow $\pi r + kr$ as W)
	so $T_B = \frac{2W}{\pi+k}$		
	Using vertical components: $T_B + T_E = W$	M1	Or take moments about a second point, for example B
	so $T_E = W - \frac{2W}{\pi+k}$		

Question			Answer	Marks	Guidance	
			$= \frac{W(\pi + k - 2)}{\pi + k}$			
			$\frac{T_E}{T_B} = 2 = \frac{\frac{W(\pi+k-2)}{\pi+k}}{\frac{2W}{\pi+k}}$	M1	Using their expressions for tensions	
			so $4 = \pi + k - 2$	A1	Some simplification seen	
			so $k = 6 - \pi$ (2.86 to 3 s. f.)	A1	cao	
			Method C			
			$T_E:T_B$ = GB:OG	M2		
			GB = $r - \frac{2r}{\pi + k} = \left(\frac{r(\pi+k-2)}{\pi+k}\right)$	A1		
			$\frac{T_E}{T_B} = 2 = \frac{\frac{W(\pi+k-2)}{\pi+k}}{\frac{2W}{\pi+k}}$	M1	Using their expressions for lengths	
			so $4 = \pi + k - 2$	A1	Some simplification seen	
			so $k = 6 - \pi$ (2.86 to 3 s. f.)	A1	cao	
				[6]		

OCR (Oxford Cambridge and RSA Examinations)
1 Hills Road
Cambridge
CB1 2EU

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4762 Mechanics 2

General Comments:

The standard of the solutions presented by candidates was generally pleasing. Most candidates were able to make a reasonable attempt at most parts of the paper. There was some evidence that candidates felt rushed towards the end of the paper.

Candidates who were able to apply the appropriate mechanical principles to a problem were often hampered by their algebraic skills in being able to simplify and solve equations.

As always, candidates should be encouraged to draw clear and labelled diagrams and these are always appropriate when dealing with forces or velocities. A lot of potentially very good work was marred by sign errors that, perhaps, could have been avoided by having a clear diagram.

Comments on Individual Questions:

Question No. 1

Momentum and Impulse

(i) Most candidates indicated that the momenta of the discs before the collision were equal and opposite, with a sum of zero. Many then simply quoted the result in the question, without any reference to the fact that the total momentum had to be conserved.

(ii) Candidates were now on more familiar territory and they showed that they were able to write down equations using the principle of conservation of linear momentum and Newton's experimental law. A minority of candidates made sign errors in one or other of these equations.

Some candidates ignored the first part of the request, and used the information it conveyed about the speed of A to find the speed of B.

(iii) Candidates often seemed confused about directions and signs in their calculations. Drawing a diagram may have helped candidates avoid errors here.

(iv) Many candidates made a good attempt at this question which tested their ability to decide upon a strategy for solution. A number of different approaches were seen, some using the individual speeds, distances and times for each of the discs and some using relative speeds and distances.

(v) There were some neat and concise correct solutions to this problem. Most candidates were able to state that the angle between the new direction of motion and the barrier was $90° - \alpha$. The next step was to use Newton's experimental law and the principle of conservation of momentum to find the connection between the components of the speeds before and after the collision. This leads to another connection between the angles: $\tan\beta = \frac{1}{3}\tan\alpha$. Some candidates quoted this result without proof, and that was acceptable. The final two marks were awarded for combining these connections between the angles and finding α. A significant minority of candidates were not able to do this convincingly.

Question No. 2

Work, Energy and Power

(i) Most candidates obtained full marks through a correct application of the work-energy equation to this scenario. There were a few sign errors. A minority of candidates did not use the value of *g* as 10, given at the top of the question. They were not penalised in this part of the question.

(ii) Most candidates gained the majority of the marks in this question. A common error was to find the vertical distance travelled as $2\sin\alpha$ instead of $\frac{2}{\sin\alpha}$. Those candidates who insisted on taking the value of *g* as 9.8 were unable to derive the given result, but unfortunately this did not serve as a warning sign that something was wrong.

(iii) Explanations here were very poor. A common misconception was that a steeper slope meant that more work was done, and so the particle would come to rest below D. It was necessary to consider the effects of both reducing the friction, which was proportional to $\cos\alpha$, and the shortening of the ramp, to arrive at the conclusion that the work done by friction was reduced. An alternative approach was to use the result proved (given) in part (ii) to show that less work was done.

(iv) This was usually well-answered.

(v) Again, this was very well-answered.

(vi) The explanations offered by candidates were often lacking the required depth. Most candidates realised that a non-zero acceleration implies a non-constant velocity, but were unable to make any convincing further progress. The key was to use the fact that the force *F* was constant. Almost all candidates gained the final mark for stating that the use of *suvat* equations requires constant acceleration.

Question No. 3

Forces and Equilibrium

Candidates appeared to be confident with the content of this question and there were many very good, well-presented solutions.

(a) Candidates seemed confident when tackling this framework question. Errors were usually sign errors, and usually only occurred when the diagram given in the answer book had not been used to label the internal forces clearly. Some candidates did not realise that some of the external forces had not been given and assumed that there was no external force at L.

(b) There were many good solutions to this question. The given result for the force exerted by the peg on the ladder was usually obtained by writing down a correct moments equation. Some candidates did not realise that they were dealing with a 5, 12, 13 triangle and used inexact values for the trigonometrical ratios. Resolution of the forces on the ladder horizontally and vertically followed by use of $F \le \mu R$ was the most efficient way to find the range of possible values of the coefficient of friction. Some candidates confused themselves by labelling different forces as *F*. There was also a fairly commonly seen belief that the value of the coefficient of friction had to be less than one.

Question No. 4

Centre of mass

(a)(i) This was well-answered by almost all candidates. A minority used the area of the lamina as its mass, rather than its given mass of 2 kg.

(ii) The mechanics required for this part were clearly understood, but the algebra involved created a surprising amount of difficulty for candidates. Having taken moments for the new situation, candidates used the fact that $y = \frac{2}{3}x$ to form an equation in *X*. Those who noted the common factor of $12 + m$ reduced the amount of algebra that was required considerably, and they usually obtained the given result. Those candidates who multiplied everything out usually got lost in their algebra. Some candidates confused *X* and $\bar{x}$ and managed to find values for *m* and *X*.

(b)(i) Most candidates gained at least three of the four marks available in this part. The fourth mark required a statement that the centre of mass was on OB due to symmetry, or a calculation leading to this result.

(ii) This part required the solution of a fairly simple equilibrium problem and there were many routes to the solution, by resolution and/or moments equations. There were a pleasing number of neat and well-crafted solutions. Some candidates did not choose wisely the points about which to take moments, and involved themselves in complicated algebra. Other candidates chose to change the orientation of the shape, and again produced complicated equations. There was some evidence that candidates were running out of time.

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AS GCE / Advanced GCE / AS GCE Double Award / Advanced GCE Double Award

GCE Mathematics (MEI)										
				Max Mark	a	b	c	d	e	u
4751	01	C1 – MEI Introduction to advanced mathematics (AS)	Raw	72	63	58	53	49	45	0
			UMS	100	80	70	60	50	40	0
4752	01	C2 – MEI Concepts for advanced mathematics (AS)	Raw	72	55	49	44	39	34	0
			UMS	100	80	70	60	50	40	0
4753	01	(C3) MEI Methods for Advanced Mathematics with Coursework: Written Paper	Raw	72	54	49	45	41	36	0
4753	02	(C3) MEI Methods for Advanced Mathematics with Coursework: Coursework	Raw	18	15	13	11	9	8	0
4753	82	(C3) MEI Methods for Advanced Mathematics with Coursework: Carried Forward Coursework Mark	Raw	18	15	13	11	9	8	0
			UMS	100	80	70	60	50	40	0
4754	01	C4 – MEI Applications of advanced mathematics (A2)	Raw	90	67	61	55	49	43	0
			UMS	100	80	70	60	50	40	0
4755	01	FP1 – MEI Further concepts for advanced mathematics (AS)	Raw	72	57	52	47	42	38	0
			UMS	100	80	70	60	50	40	0
4756	01	FP2 – MEI Further methods for advanced mathematics (A2)	Raw	72	65	58	52	46	40	0
			UMS	100	80	70	60	50	40	0
4757	01	FP3 – MEI Further applications of advanced mathematics (A2)	Raw	72	64	56	48	41	34	0
			UMS	100	80	70	60	50	40	0
4758	01	(DE) MEI Differential Equations with Coursework: Written Paper	Raw	72	63	56	50	44	37	0
4758	02	(DE) MEI Differential Equations with Coursework: Coursework	Raw	18	15	13	11	9	8	0
4758	82	(DE) MEI Differential Equations with Coursework: Carried Forward Coursework Mark	Raw	18	15	13	11	9	8	0
			UMS	100	80	70	60	50	40	0
4761	01	M1 – MEI Mechanics 1 (AS)	Raw	72	57	49	41	34	27	0
			UMS	100	80	70	60	50	40	0
4762	01	M2 – MEI Mechanics 2 (A2)	Raw	72	56	48	41	34	27	0
			UMS	100	80	70	60	50	40	0
4763	01	M3 – MEI Mechanics 3 (A2)	Raw	72	58	50	43	36	29	0
			UMS	100	80	70	60	50	40	0
4764	01	M4 – MEI Mechanics 4 (A2)	Raw	72	53	45	38	31	24	0
			UMS	100	80	70	60	50	40	0
4766	01	S1 – MEI Statistics 1 (AS)	Raw	72	61	55	49	43	37	0
			UMS	100	80	70	60	50	40	0
4767	01	S2 – MEI Statistics 2 (A2)	Raw	72	56	50	45	40	35	0
			UMS	100	80	70	60	50	40	0
4768	01	S3 – MEI Statistics 3 (A2)	Raw	72	63	57	51	46	41	0
			UMS	100	80	70	60	50	40	0
4769	01	S4 – MEI Statistics 4 (A2)	Raw	72	56	49	42	35	28	0
			UMS	100	80	70	60	50	40	0
4771	01	D1 – MEI Decision mathematics 1 (AS)	Raw	72	52	46	41	36	31	0
			UMS	100	80	70	60	50	40	0
4772	01	D2 – MEI Decision mathematics 2 (A2)	Raw	72	53	48	43	39	35	0
			UMS	100	80	70	60	50	40	0
4773	01	DC – MEI Decision mathematics computation (A2)	Raw	72	46	40	34	29	24	0
			UMS	100	80	70	60	50	40	0
4776	01	(NM) MEI Numerical Methods with Coursework: Written Paper	Raw	72	58	53	48	43	37	0
4776	02	(NM) MEI Numerical Methods with Coursework: Coursework	Raw	18	14	12	10	8	7	0
4776	82	(NM) MEI Numerical Methods with Coursework: Carried Forward Coursework Mark	Raw	18	14	12	10	8	7	0
			UMS	100	80	70	60	50	40	0
4777	01	NC – MEI Numerical computation (A2)	Raw	72	55	48	41	34	27	0

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			UMS	100	80	70	60	50	40	0
4798	01	FPT - Further pure mathematics with technology (A2)	Raw	72	57	49	41	33	26	0
			UMS	100	80	70	60	50	40	0

GCE Statistics (MEI)

				Max Mark	a	b	c	d	e	u
G241	01	Statistics 1 MEI (Z1)	Raw	72	61	55	49	43	37	0
			UMS	100	80	70	60	50	40	0
G242	01	Statistics 2 MEI (Z2)	Raw	72	55	48	41	34	27	0
			UMS	100	80	70	60	50	40	0
G243	01	Statistics 3 MEI (Z3)	Raw	72	56	48	41	34	27	0
			UMS	100	80	70	60	50	40	0

GCE Quantitative Methods (MEI)

				Max Mark	a	b	c	d	e	u
G244	01	Introduction to Quantitative Methods MEI	Raw	72	58	50	43	36	28	0
G244	02	Introduction to Quantitative Methods MEI	Raw	18	14	12	10	8	7	0
			UMS	100	80	70	60	50	40	0
G245	01	Statistics 1 MEI	Raw	72	61	55	49	43	37	0
			UMS	100	80	70	60	50	40	0
G246	01	Decision 1 MEI	Raw	72	52	46	41	36	31	0
			UMS	100	80	70	60	50	40	0

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Level 3 Certificate Mathematics for Engineering

				Max Mark	a*	a	b	c	d	e	u
H860	01	Mathematics for Engineering		This unit has no entries in June 2017							
H860	02	Mathematics for Engineering									

Level 3 Certificate Mathematical Techniques and Applications for Engineers

				Max Mark	a*	a	b	c	d	e	u
H865	01	Component 1	Raw	60	48	42	36	30	24	18	0

Level 3 Certificate Mathematics - Quantitative Reasoning (MEI) (GQ Reform)

				Max Mark	a	b	c	d	e	u
H866	01	Introduction to quantitative reasoning	Raw	72	54	47	40	34	28	0
H866	02	Critical maths	Raw	60*	48	42	36	30	24	0
		*Component 02 is weighted to give marks out of 72	Overall	144	112	97	83	70	57	0

Level 3 Certificate Mathematics - Quantitive Problem Solving (MEI) (GQ Reform)

				Max Mark	a	b	c	d	e	u
H867	01	Introduction to quantitative reasoning	Raw	72	54	47	40	34	28	0
H867	02	Statistical problem solving	Raw	60*	41	36	31	27	23	0
		*Component 02 is weighted to give marks out of 72	Overall	144	103	90	77	66	56	0

Advanced Free Standing Mathematics Qualification (FSMQ)

				Max Mark	a	b	c	d	e	u
6993	01	Additional Mathematics	Raw	100	72	63	55	47	39	0

Intermediate Free Standing Mathematics Qualification (FSMQ)

				Max Mark	a	b	c	d	e	u
6989	01	Foundations of Advanced Mathematics (MEI)	Raw	40	35	30	25	20	16	0