GCE

Further Mathematics A

Y543/01: Mechanics

A Level

Mark Scheme for June 2024

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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.

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MARKING INSTRUCTIONS

PREPARATION FOR MARKING
RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **number of required** standardisation responses.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 40% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. **Annotations**

Annotation	Meaning
✓and✘	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working

Annotation	Meaning
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
BP	Blank Page
Seen	
Highlighting	

Other abbreviations in mark scheme	Meaning
dep*	Mark dependent on a previous mark, indicated by *. The * may be omitted if only one previous M mark
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working
AG	Answer given
awrt	Anything which rounds to
BC	By Calculator
DR	This question included the instruction: In this question you must show detailed reasoning.

5. **Subject Specific Marking Instructions**

a. Annotations must be used during your marking. For a response awarded zero (or full) marks a single appropriate annotation (cross, tick, M0 or ^) is sufficient, but not required.

For responses that are not awarded either 0 or full marks, you must make it clear how you have arrived at the mark you have awarded and all responses must have enough annotation for a reviewer to decide if the mark awarded is correct without having to mark it independently.

It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

Award NR (No Response)
- if there is nothing written at all in the answer space and no attempt elsewhere in the script
- OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
- OR if there is a mark (e.g. a dash, a question mark, a picture) which isn't an attempt at the question.

Note: Award 0 marks only for an attempt that earns no credit (including copying out the question).

If a candidate uses the answer space for one question to answer another, for example using the space for 8(b) to answer 8(a), then give benefit of doubt unless it is ambiguous for which part it is intended.

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 always 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, escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.

If you are in any doubt whatsoever 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, e.g. 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 method mark may usually be implied by a correct answer unless the question includes the DR statement, the command words “Determine” or “Show that”, or some other indication that the method must be given explicitly.

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.

Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. 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, what is acceptable will be detailed in the mark scheme. If this is not the case please, escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.

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. We are usually quite flexible about the accuracy to which the final answer is expressed; over-specification is usually only penalised where the scheme explicitly says so.

- When a value is **given** in the paper only accept an answer correct to at least as many significant figures as the given value.
- When a value is **not given** in the paper accept any answer that agrees with the correct value to **3 s.f.** unless a different level of accuracy has been asked for in the question, or the mark scheme specifies an acceptable range.
  NB for Specification B (MEI) the rubric is not specific about the level of accuracy required, so this statement reads "2 s.f".

Follow through should be used so that only one mark in any question is lost for each distinct accuracy error.
Candidates using a value of 9.80, 9.81 or 10 for g should usually be penalised for any final accuracy marks which do not agree to the value found with 9.8 which is given in the rubric.

g. Rules for replaced work and multiple attempts:
   - If one attempt is clearly indicated as the one to mark, or only one is left uncrossed out, then mark that attempt and ignore the others.
   - If more than one attempt is left not crossed out, then mark the last attempt unless it only repeats part of the first attempt or is substantially less complete.
   - if a candidate crosses out all of their attempts, the assessor should attempt to mark the crossed out answer(s) as above and award marks appropriately.

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 or B mark in the question. Marks designated as cao may be awarded as long as there are no other errors. If a candidate corrects the misread in a later part, do not continue to follow through. Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

i. If a calculator is used, some answers may be obtained with little or no working visible. Allow full marks for correct answers, provided that there is nothing in the wording of the question specifying that analytical methods are required such as the bold "In this question you must show detailed reasoning", or the command words "Show" or "Determine". 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	AO	Guidance	
1	(a)		$\mathbf{p} = m\mathbf{u} = 12.5(-5\mathbf{i} + 12\mathbf{j})$ $p = 12.5\sqrt{((-5)^2 + 12^2)} = 12.5\times13 = 162.5$ awrt 163 ($kgms^{-1}$)	**M1** **A1** **[2]**	1.1 1.1	Using definition of momentum soi e.g. implied by 12.5 x 13 Oe 325/2	
	(b)		$\mathbf{I} = m\mathbf{v} - m\mathbf{u} = 12.5(\mathbf{i} + 4\mathbf{j}) - 12.5(-5\mathbf{i} + 12\mathbf{j})$ $= 75\mathbf{i} - 100\mathbf{j}$ (Ns)	**M1** **A1** **[2]**	1.1 1.1	Using $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$. Could be in column vector form. ISW	Condone $12.5(6\mathbf{i} - 8\mathbf{j})$ oe
	(c)		$-75\mathbf{i} + 100\mathbf{j}$ (Ns)	**B1FT** **[1]**	1.1	FT – their answer to **(b)**. Vector form must be correct (could be column form) No need for units	Condone $12.5(-6\mathbf{i} + 8\mathbf{j})$ oe
	(d)		$I = \sqrt{(75^2 + 100^2)} = 125$ (Ns) $\mathbf{I}.\mathbf{i} = 75 \Rightarrow \cos\theta = 75/125 = 3/5$ θ = awrt -53.1° or -0.927 rad or 307° or 5.36 rad or +53.1° or +0.927 rad or -307° or -5.36 rad	**B1FT** **M1FT** **A1** **[3]**	1.1 1.1 1.1	FT – their answer to **(b)**. Use of dot product, or trig, to obtain a value for sin, cos or tan Positive or negative values are acceptable. Cao. Mark final answer. Must come from correct **I**	 eg $\tan\theta = 100/75$ or $75/100$

Question			Answer	Marks	AO	Guidance	
2	(a)		e.g. Air resistance is ignored or *B* is modelled as a particle or e.g. comment about dimensions – no size or shape gravity is a constant value no need to model spin	**B1** **[1]**	3.3	Allow correct sensible alternatives e.g. elastic limit of the string is not exceeded. Ignore extra comments as long as they are not incorrect e.g. it is a particle (so COM is at it's centre)	Accept: Condone point(-like) mass? Do not accept: B has no mass; assume B doesn't collide with *O;* B is uniform; String is inextensible; Centre of mass is at it's centre
	(b)		Final GPE is $2.5g\times 8.1$ (J) (=198.45) Final EPE is $\frac{20(8.1-1.4)^2}{2\times 1.4}$ (J) (=320.642…) Initial KE is $\frac{1}{2}\times 2.5u^2$ Total final energy = "198.45" + "320.62..." = $\frac{1}{2}\times 2.5u^2$ u = awrt 20.4 (ms^{-1})	**B1** **B1** **M1** **A1** **[4]**	3.4 3.4 3.4 1.1	**DR** For any **one** of these terms correct For any **two** of these terms correct 519.09... Using cons of energy with their EPE, KE and GPE terms of correct form (three terms – implicitly final KE=0) Signs must be correct. Condone *m* seen in energy equation. Do not accept EPE with 1.4 or 8.1 as extension. Positive answer only	**ALT Method** If candidate finds velocity when string is taut and uses this as the initial velocity, will see the energy terms/equation: $\frac{1}{2}2.5(u^2-27.44)$ $=6.7g\times 2.5+\frac{20\times 6.7^2}{2\times 1.4}$

Question			Answer	Marks	AO	Guidance	
3	(a)		D = 90000/25 = 3600 At constant speed, $R = D$ so resistance is 3600 (N)	**M1** **A1** **[2]**	3.3 1.1	Use of $P = Fv$ to find 'driving force' Using fact that a = 0 so the two forces balance. Must indicate they've calculated a different force to D.	

	(b)		$6000a = 60000/10 - \text{“}3600\text{”}$ $a = 2400/6000 = 0.4$ (ms^{-2})	**M1** **A1** **[2]**	3.4 1.1	Using NII with correct number of terms, dimensionally consistent. Correct power of 60000 soi.	
	(c)		$6000g\sin\theta$ $6000g\sin\theta + 90000/40 - 3600 = 0$ $\sin\theta = 9/392$ (0.022959...) $\Rightarrow \theta$ = awrt 1.3° or 0.0230 rads	**DR** **B1** **M1** **A1** **[3]**	1.1 3.4 1.1	**DR** Correct weight component Three terms, condone sign errors and m seen. Do not condone 60000 in place of 90000. Condone 178.7° or 3.12 rads. Note 1dp for 1.3 degrees is good enough (typically 1.32 or 1.31)	

Question			**Answer**	**Marks**	**AO**	**Guidance**	
4	**(a)**		Tangential: $(-)6g\sin 40° = 6a_t$ a_t = (–)6.2993... so tangential acceleration is awrt 6.30 (ms^{-2}) (**tangential)** to the circle and **opposite** to the **direction of motion**	**M1** **A1** **[2]**	3.1b 2.2a	Using NII with a component of the weight. May be implied by $(-)g\sin 40° = a_t$ Accept descriptions like 130 degrees anticlockwise from vertical or 50 degrees to the vertical or 40 degrees from the leftward horizontal. Need to see clear stated **interpretation** of the direction of calculated value.	Condone e.g. “on tangent/tangentially **and** downwards and/or left**”. Condone “perpendicular to the rod** and down”. Do not allow “clockwise tangentially” as implies turning/rotation (not a linear direction). Do not allow e.g. tangent to the rod/radius etc. Do not allow 6.3

	(b)				1.1	**DR**	
			Initial KE = ½×6×12^2 (J)	**B1**		432 J	
			GPE at *A* = 6*g*×2.4(1 – cos40°) (J)	**B1**	1.1	Finding expression for GPE which is consistent with total initial energy. Do not condone missing brackets. If expressions seen with m's then all m's cancelled in energy equation award B1 B1 at that stage. Need to see correct substitution of values into each term.	Could see GPE term split if zero PE not at initial level e.g. – 6*g*×2.4cos40° J if total initial energy given as ½×6×12^2 – 6*g*×2.4 J
			½×6v^2 + 6*g*×2.4(1 – cos40°) = "432"	**M1***	1.1	Setting up CoE equation with inital KE and GPE + final KE at *A*. Correct signs. Do not allow 6g × 2.4 cos 40 only.	
			=> v^2 = 132.99... (=> v = 11.532...)	**A1**	1.1	soi	$v^2 = 144 - 4.8g(1 - cos40°)$ $= 144 - 47.04(1 - cos40°)$
			Radial: $a_r = \frac{v^2}{r} = \frac{"11.532..."^2}{2.4}$	**M1dep**	3.1b	Using correct form for radial acceleration soi. FT their v from energy considerations.	
			= 55.41... so radial acceleration at *A* is awrt 55.4 (ms^{-2}) **towards** *O*	**A1**	1.2	E.g. 50 degrees above negative horizontal If units are stated they must be correct for A mark. Must give a clear magnitude and direction.	**Special case:** If candidates quote $v^2 = u^2 - 2g\Delta h$ without deriving it from energy equation. B marks are not awarded. Correct signs. $v^2 = 12^2 - 2g2.4(1 - \cos(40°))$ gains **M1** with values in And then as main scheme.
				[6]			

	(c)		$T - 6g\cos 40° = 6a_r = 6 \times "55.41 \ldots"$	**M1FT**	1.1	Using NII in the radial direction with a tension, a correct component of the weight and their a_r. (FT from part b) Condone incorrect signs. Do not allow sin/cos interchange.	
			T = 377.53... so (because it is positive) the rod is under a **tension** of awrt 378 (N)	**A1** **[2]**	2.1		
	(d)		$\updownarrow T\cos 40° = 6g$	**M1**	1.1	Balancing vertical forces soi T =76.8 N	If candidates combine and rearrange equations first: e.g. $v^2 = gtan(40) \times 2.4\sin(40)$
			r = 2.4 sin 40°	**B1**	1.1	Radius of horizontal circle soi (r = 1.543)	Gains B1M1M1 once values in.
			$\leftrightarrow T\sin 40° = \frac{6v^2}{2.4\sin 40°}$	**M1**	3.1b	Using NII in the horizontal with a correct form for the centripetal acceleration. Do not condone r=2.4. Condone use of $r = 2.4\cos(40)$ or r = sin(40)	Condone use of $r\omega^2$ in place of $\frac{v^2}{r}$ for method mark. Must find v to gain final mark.
			$\therefore v^2 = 2.4g\sin 40°\tan 40° = 12.685...$ => v = 3.56171... so speed of P is awrt 3.56 (ms^{-1})	**A1** **[4]**	1.1		

	(e)		(If $\theta = 90°$ then the tension in the rod is horizontal because the acceleration must be towards the centre of the circle and so there is) **no component of the tension to balance the weight**. (Thus, there would be an unbalanced force.)	**B1** **[1]**	2.4	They need to reference: **no *vertical* component of tension** and refer to **unbalanced forces** *or e.g* **only *vertical* force acting is weight**	Do not allow mention of air resistance Do not allow 'no tension in the rod can counteract the weight'. Needs to mention 0 component and be clear about vertical. Do not allow mass 'acting' Do not allow calculations that refer to T being undefined.

Question			Answer	Marks	AO	Guidance	
5			Correct use of dimensions using a suitable formula for at least one of the terms in the equation	**M1**		**DR** May not be fully simplified.	Argument could be based around units. eg 1 W = 1 J/s = 1 Nm/s etc until dimensions reached.
			$[P] = [Fv] = MLT^{-2}\ LT^{-1} = ML^2T^{-3}$ (or [WD/t])	**A1**	2.1	Using a suitable relationship involving power and quantities with determinable dimensions to **derive** [P]	
			1st term: $\left[k_1 mv\frac{dv}{dt}\right] = \left[\frac{mv^2}{t}\right]$ $= M\ (LT^{-1})^2\ T^{-1}$ $= ML^2T^{-2}T^{-1} = ML^2T^{-3}$	**A1**	3.4	Condone missing k_1. Derivation must be convincing.	Need to get correctly to the answer
			2nd term: $[k_2mgv] = M\ LT^{-2}\ LT^{-1} = ML^2T^{-3}$	**A1**	2.2a	Condone missing k_2. Derivation must be convincing.	
			3rd term: $[k_3E] = ML^2T^{-3}$ since a rate of energy loss will have the same dimensions as a power	**A1**	3.5a	Condone missing k_3. Can be explained using rate of change of energy or done as [P] above.	
			So, because the **constants are dimensionless** and because **quantities of the same dimensions add to give quantities of that dimension**, LHS and RHS have same dimensions so equation **is** dimensionally consistent.	**A1**	2.2a	Explanation must deal with k's if these are not included in at least one of the above. Argument must include dealing with + (ie different terms) and must reach a clear conclusion. May see the addition in a formula. Do not allow "all the parts have the same dimension so you're able to add the terms" – needs to conclude with dimensions of sum	
				[6]		Condone [] seen around M,L,T	

Question			Answer	Marks	AO	Guidance	
6	(a)					**DR**	If v_A is reversed
			$m\times20 + m\times-10 = mv_A + mv_B$	**M1***	3.3	Attempt at conservation of momentum	$m\times20 + m\times-10 = -mv_A + mv_B$
			$\frac{v_B - v_A}{20 - -10} = e$	**M1***	3.3	Attempt at NEL	$\frac{v_B + v_A}{20 - -10} = e$
			$m\times20 + m\times-10 = mv_A + mv_B$ $\frac{v_B - v_A}{20 - -10} = e$	**A1**	1.1	Both equations correct and consistent $v_B + v_A = 10$ $v_B - v_A = 30e$	Both equations correct and consistent $v_B - v_A = 10$ $v_B + v_A = 30e$
			$2v_B = 10 + 30e$	**M1dep***	1.1	Combining two equations of correct form using simultaneous equations to find v_B	$2v_B = 10 + 30e$
			$v_B = 5 + 15e > 0$ while $u_B = -10 < 0$ *or* $v_B = 5 + 15e$ which is **positive** while original velocity of *B* was **negative** (so the velocity changes sign and hence direction of motion of B is reversed).	**A1** **[5]**	2.2a	Need to see clear comparison of u_b and v_b (may see $0 \le e$)	
	(b)		$\frac{5 + 15e - v_A}{30} = e \Rightarrow v_A = \cdots$	**M1FT**	3.1b	**DR** Using either of their equations from (a) soi to give an expression for v_A consistent with their v_B. May be seen in part a.	$\frac{5 + 15e + v_A}{30} = e \Rightarrow v_A = \cdots$
			$v_A = 5 - 15e$	**A1**	1.1		
			$V_B = -(2/5)e(5 + 15e)$	**B1FT**	1.1	FT their v_B from (a) (Might be positive if candidate redefines positive direction)	
			No collision => $-(2/5)(5 + 15e)e \ge 5 - 15e$	**M1**	2.2a	Correct condition for no further collision for correct v_B and v_a (condone exclusive inequality)	

			$30e^2 + 10e \leq -25 + 75e$ $30e^2 - 65e + 25 \leq 0 \Rightarrow 6e^2 - 13e + 5 \leq 0$ $(3e - 5)(2e - 1) \leq 0$	**M1**	1.1	Reduction to correct 3-term quadratic inequality WWW (condone exclusive inequality, correct direction) and using valid method to find critical values	Could be an equation to find CVs. Could be **BC**
			$\Rightarrow \frac{1}{2} \leq e \leq \frac{5}{3}$	**A1**	1.1	Condone $\frac{1}{2} < e < \frac{5}{3}$	
			So, $\frac{1}{2} \leq e < 1$	**A1** **[7]**	3.2a	Inequalities must be correct	

Question	Answer	Marks	AO	Guidance

7	**(a)**		$R = -kv^2$ so $v = 2$, $R = -24$ => $k = 6$	**B1**	3.3	**DR** Minus sign could be missing throughout here	Or $R = kv^2$ leading to $k = -6$
			$1.5a = 1.5v\frac{dv}{dx} = -6v^2$	**M1**	3.3	Use of NII with correct form for a= $v\frac{dv}{dx}$ and resistance term which must be negative here	Condone incorrect or missing k, or "k" left in.
			$\therefore \frac{1.5v}{1.5v^2}\frac{dv}{dx} = \frac{-6v^2}{1.5v^2}$ $\therefore \frac{1}{v}\frac{dv}{dx} = -4$	**A1** **[3]**	1.1	AG so clear evidence of division must be seen and www. If chain rule used to convert $\frac{dv}{dt} = \frac{dv}{dx} \times \frac{dx}{dt}$ must see clear complete rearrangement.	
	(b)	**(i)**	$\therefore \int \frac{1}{v}dv = \int -4dx = -4x + c$	**M1**	1.1	Separating the variables correctly and integrating one side (condone missing "+ c" or incorrect letter (eg t for x))	Do not condone missing dx's but recovery possible (eg once integration correctly carried out). Could also be a definite integral; ignore limits for this **M1A1**.
			$\ln v = -4x + c$	**A1**	1.1	Correct general solution, any form (condone missing "+ c")	
			$x = 0$, $v = u$ => $c = \ln u$	**M1**	3.4	Using correct initial conditions in a solution to the DE containing one arbitrary constant (or as the lower limits in a definite integral solution with x and v as upper limits)	This could be done after exponentiation: $v = e^{-4x+c} = Ae^{-4x}$ $x = 0,\ v = u \Rightarrow A = u$
			$v = ue^{-4x}$	**A1** **[4]**	1.1	Condone $v = e^{-4x+\ln u}$	

	(b)	**(ii)**	As ($x \to \infty$), ***v* will tend to**, but never reach**, 0**. *and* So the **model** predicts **B will continue to move** when in **reality it will stop.**	**B1** **[1]**	3.5b	Clear reference to the idea that the model predicts that *B* never comes to rest while in real life it does.	Do not condone "unlikely/likely" Do not allow "suggest *v* will never reach 0 which is not realistic" as no reference to v tending to 0.
	(c)	**(i)**	$W = \int_0^X -6v^2 \mathrm{d}x = \int_0^X -6(u\,\mathrm{e}^{-4x})^2 \mathrm{d}x$ $= -6u^2 \int_0^X \mathrm{e}^{-8x}\,\mathrm{d}x = -6u^2 \left[\frac{\mathrm{e}^{-8x}}{-8}\right]_0^X$ $= \frac{6u^2}{8}\left[\mathrm{e}^{-8X} - \mathrm{e}^0\right]$ $= \frac{3u^2}{4}\left(\mathrm{e}^{-8X} - 1\right)$	**M1FT** **M1FT** **A1** **[3]**	3.1b 1.1 1.1	**DR** Correct form for integral and limits for their v and k (may not be numeric). Condone missing dx or missing sign If this is done as an indefinite integral then this mark is awarded when $x = 0$ and WD = 0 and $x = X$ WD = W both used Carrying out the integral for their v of correct form $v = ue^{-cx}$, *c>0* only, and their *k*. *Condone x not X. Condone missing sign.* Can ISW once final expression seen. May not be factorised. Allow 6/8 oe	**ALT method** Changing variable to integrate w.r.t. v, Must see V in limits from next part. $W = \int_0^X -6v^2 dx = \int_u^V -6v^2 \times -\frac{1}{4v}\mathrm{dv}$ **M1FT** $= \int_u^V 1.5v\mathrm{dv} = 1.5\left[\frac{v^2}{2}\right]_u^V$ **M1FT** $= \frac{3}{4}\left(V^2 - u^2\right) = \frac{3}{4}\left(\left(ue^{-4X}\right)^2 - u^2\right)$ $= \frac{3u^2}{4}\left(\mathrm{e}^{-8X} - 1\right)$ **A1**

	(c)	**(ii)**	Since $X > 0$, ($e^{-8X} < 1$ so) $W < 0$ **and** It is negative because work is being done by *B* against the resistance (rather than the resistance actually doing work on *B*.) ie *B* is losing (mechanical) energy	**B1** **[1]**	3.2a	A clear explanation of negative sign from correct expression for W **and** Accept valid alternatives, eg "the particle is doing work against the resistance" or "the particle is losing (mechanical) energy" or "the particle is losing KE to do work against resistance" etc. or "KE is lost"	Do not condone: force and displacement are in opposite directions Do not condone "slowing down" with no comment on energy the resistance does work on B Do not condone "energy is being removed/taken from B" Do not accept "work done against motion" Do not allow additional incorrect statements
	(c)	**(iii)**	Since $V = ue^{-4X}$, $W = \frac{3u^2}{4}\left(\left(e^{-4X}\right)^2 - 1\right) = \frac{3u^2}{4}\left(e^{-4X}\right)^2 - \frac{3u^2}{4}$ $= \frac{3}{4}V^2 - \frac{3}{4}u^2$ $= \frac{1.5}{2}V^2 - \frac{1.5}{2}u^2 = \frac{1}{2}mV^2 - \frac{1}{2}mu^2 = \Delta KE$ ($m = 1.5$) (so the work done is the change in KE. ie KE loss is equal to the energy lost to resistance or work done against resistance)	**M1** **A1** **[2]**	3.4 2.4	Substitute into correct *W* to eliminate *X* and express *W* in terms of *V* and *u*. Need to see **use** of $V = ue^{-4X}$ or $V^2 = u^2e^{-8X}$ Must state WD is ΔKE of *B*. Clear algebraic or stated conclusion. Condone additional mention of total energy. WWW	**SC1** if correct integration wrt v using limit of V seen in part ci) $W = \frac{3}{4}V^2 - \frac{3}{4}u^2 = \frac{1}{2}\times 1.5\left(V^2 - u^2\right)$ $= \Delta KE$ stated in this part. (m=1.5 seen) **SC1** for: $W = -\frac{3u^2}{4}\left(\left(e^{-4X}\right)^2 - 1\right) = -\frac{3u^2}{4}\left(e^{-4X}\right)^2 + \frac{3u^2}{4}$ $= \frac{3}{4}u^2 - \frac{3}{4}V^2$

Question			Answer	Marks	AO	Guidance	
8	(a)		(Because the cone has) **symmetry** (about this axis)	**B1** **[1]**	2.4		
	(b)		$(8m+2m)\bar{x} = \frac{1}{4}h \times 8m + h \times 2m$	**M1**	3.3	Using $\bar{x} = \frac{\sum mx}{\sum m}$ Could see eg $8mg$ rather than $8m$ but must be throughout. May see directly in fraction form. Condone missing $\bar{x}$ or one incorrect distance	**Condone one incorrect distance for the method mark when applying moments throughout pt b.** *Measured from the particle:* $(8m+2m)\bar{x} = \frac{3}{4}h \times 8m$
			$\bar{x} = \frac{4hm}{8m+2m} = \frac{4hm}{10m} = \frac{2}{5}h$	**A1**	1.1		$\bar{x} = \frac{6hm}{10m} = \frac{3}{5}h$
			Moments about centre of base: $10mg \times \frac{2h}{5} = T_V \times h$	**M1***	3.1b	Attempt to balance moments about any point with at least two non-zero terms each comprising the product of a force (or mass) with an appropriate distance.	**M1** for attempt to balance moments about any point About vertex: $10mg \times \frac{3h}{5} = T_A \times h$ *Or* About COM: $T_A \times \frac{2h}{5} = T_V \times \frac{3h}{5}$ If moments taken about eg vertex then could see a second equation eg $T_V + T_A = 10mg$ and two equations solved simultaneously
			$T_V = 4mg$	**A1**	1.1		$T_V = 4mg$

			$4mg = \frac{8mgx}{l}$	**M1dep***	3.4	Use of Hooke's law with their calculated T and lambda substituted. Condone incorrect *x*.	
			$x = \frac{1}{2}l$ $x + l = \frac{3}{2}l = 1.6 + 1.1 = 2.7$	**M1dep***	1.1	Using *x=0.5l* and/or using *x* = 2.7-*l* to find an expression in terms of *l or x only*.	
			l = 1.8 (m)	**A1**	2.2a		
	(b)		Moments taken (centre of base) $8mg\left(\frac{1}{4}h\right) + 2mgh = hT_V$	**M1**	3.3	At least two correct moment terms seen	Moments about vertex **M1** $8mg\left(\frac{3}{4}h\right) = hT_A$
				M1*	1.1	Attempts to balance moments	**A1** $T_A = 6mg$
				A1	3.1b	Correct moments equation	**M1** For finding $T_V + T_A = 10mg$ and combining with simultaneous equations. May also find moments about a second point.
			$T_V = 4mg$	**A1**	1.1		$T_V = 4mg$
			$4mg = \frac{8mgx}{l}$	**M1dep***	3.4	Use of Hooke's law	
			$x = \frac{1}{2}l$ $x + l = \frac{3}{2}l = 1.6 + 1.1 = 2.7$	**M1dep***	1.1	Using *x=0.5l* and/or using *x* = 2.7-*l* to find an expression in terms of *l or x only*.	
			l = 1.8 (m)	**A1**	2.2a		
				[7]			

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