Further Math with Ali Hashir

Hooke's Law

Topical Mark Schemes (CIE 9231)

Mark schemes corresponding to the topical questions booklet for this topic, compiled from official CIE 9231 marking schemes (2015–2025). Question numbers match the questions booklet.

About this resource: I teach CIE A Level Further Mathematics, and over the years I found that there simply weren't many well-organised, topic-wise resources available for this subject – it's a niche A Level with relatively few candidates, so it doesn't get much attention from resource makers. These topical booklets are my attempt to fix that: every past-paper question, sorted by topic, with its official mark scheme alongside it.

Help us improve these documents for future students. If you spot a mistake, email us at **vectorspacepk@gmail.com**.

What kind of mistakes might you find? These booklets are compiled by hand from hundreds of past-paper PDFs. I've checked them as carefully as I can, but I'm only human, and the odd error may have slipped through – so please help me catch what I missed. Things to look out for:

- Spelling or typing mistakes
- Wrong final answers
- A mark scheme that doesn't line up with its question (misaligned pages)
- A mark scheme that belongs to the wrong question entirely
- Pre-2020 questions that are technically out of the current syllabus (the syllabus changed in 2020, but some older questions are still included here for practice)
- Missing, extra, or wrongly-labelled marks (e.g. an M1 or A1 that shouldn't be there, or one that's missing)
- Diagrams or images that are unclear, missing, or don't match the question
- Questions placed under the wrong topic

If you spot any of these (or anything else that looks off), please let me know.

This is **Version 1** of this booklet. As readers point out errors, I'll keep correcting and improving these documents, so I'd recommend checking back on the website from time to time and using the latest version rather than relying on a saved copy.

If you think these documents brought you value, consider following me on social media – it helps more than you'd think.

Contents

Click a question number below to jump straight to its mark scheme. Every box is a live link.

For the best hyperlink experience, open this PDF in a dedicated reader – such as Adobe Acrobat, Apple Preview, or your browser's built-in PDF viewer – rather than a basic in-app or embedded preview, where links sometimes don't work.

Q1

9231/21, 9231/22, 9231/23 • October/November 2015 • Question 3

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Mark scheme.

Find k by equating equilibrium tensions: $mg(a/2)/a = 2mg(3a/2 - ka)/ka$.	**M1A1**
$\frac{1}{2} = 3/k - 2$, so $k = 6/5$ or 1.2.	**A1**
Apply Newton's law at a general point: $m\ddot{x} = -mg(a/2 + x)/a + 2mg(3a/2 - ka - x)/ka$.	**M1A2**
Simplify to standard SHM equation: $\ddot{x} = -8gx/3a$.	**A1**
Period $T = 2\pi\sqrt{3a/8g}$ or $\pi\sqrt{3a/2g}$.	**B1**
Substitute in $v^2 = \omega^2(x_0^2 - x^2)$: $0.7^2 = (8g/3a)\{(0.2a)^2 - (0.05a)^2\}$.	**M1A1**
Solve: $0.49 = (8g/3) \times 0.0375a$, so $a = 0.49$.	**A1**
	Total: 11

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Q2

9231/23 • May/June 2017 • Question 2

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Mark scheme.

Find OM by equating ratios of distances and acceleration: $OL/OM = 3/4$, $OM = 2$ [m]. **(ii)**	**M1,A1**
EITHER: $\omega t_{LM} = \sin^{-1}(OL/2.5) + \sin^{-1}(OM/2.5)$ or $\omega t_{OL} = \sin^{-1}(OL/2.5)$, $\omega(2 - t_{OL}) = \sin^{-1}(OM/2.5)$: so $2\omega = \sin^{-1} 0.6 + \sin^{-1} 0.8$ [$= 0.6435 + 0.9273$]; OR (using $x = a\cos\omega t$, A at 2.5 from O near L): $\omega t_{LM} = \cos^{-1}(-OM/2.5) - \cos^{-1}(OL/2.5)$, so $2\omega = \cos^{-1}(-0.8) - \cos^{-1} 0.6$ [$= 2.498 - 0.927$] or $\pi - \cos^{-1} 0.8 - \cos^{-1} 0.6$.	***M1,A1**
(dep *M1) Simplify to find ω (may be implied by T): $\omega = \pi/4$ or 0.785.	**DM1,A1**
Find period $T = 2\pi/\omega$ (FT on ω): $T = 8$ [s]. **(iii)**	**B1,FT**
Find speed v_L at L: $v_L = \omega\sqrt{(2.5^2 - 1.5^2)} = 2\omega = \pi/2$ or 1.57 [$\mathrm{m\,s^{-1}}$].	**M1,A1**
	Total: 9

Q3

9231/21, 9231/22 • May/June 2018 • Question 2

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Mark scheme.

Use $v^2 = \omega^2(a^2 - x^2)$ at A and B: $v_A^2 = \omega^2(a^2 - 1.6^2)$, $v_B^2 = \omega^2(a^2 - 1.2^2)$	**B1**
Find equation for a from ratio: $\dfrac{9}{16} = \dfrac{a^2 - 1.6^2}{a^2 - 1.2^2}$	**M1 A1**
$7a^2 = 40.96 - 12.96$, $a^2 = 4$, $a = 2$ m (ii)	**A1**
$\omega = \dfrac{\frac{1}{3}\pi}{a} = \dfrac{\pi}{6}$, $T = \dfrac{2\pi}{\omega} = 12$ s (iii)	**M1 A1**
Find time from A to B from $x = a\sin\omega t$ or $a\cos\omega t$ (all terms correct, FT on a, ω)	**M1**
$= \omega^{-1}(0.9273 + 0.6435)$ or $\omega^{-1}(2.498 - 0.9273)$ or $6 - \omega^{-1}(0.6435 + 0.927)$	**A1**
$= 1.771 + 1.229$ or $4.771 - 1.771$ or $6 - 1.229 - 1.771$	**A1**
	Total: 9

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Q4

9231/23 • May/June 2018 • Question 3

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Mark scheme.

Find d by relating accelerations at A and B: $\omega^2(7.5-d) = 2\omega^2(6.5-d)$, $d = 5.5$ (ii)	**M1 A1**
Find ω from period T: $\omega = 2\pi/T = 2$	**B1**
Find amplitude a from max acceleration 10: $a = 10/\omega^2 = 2.5$ m (FT on ω)	**B1**
Find speed v when $OP = 7$, using $v^2 = \omega^2(a^2 - x^2)$, $x = 7 - d = 1.5$	**M1, M1**
$v^2 = 2^2(2.5^2 - 1.5^2) = 16$, $v = 4\ \text{m s}^{-1}$ (iii)	**A1**
Find time from A to B from $x = a\sin\omega t$ or $a\cos\omega t$ (all terms correct, FT on a, ω)	**M1**
$= \frac{1}{2}\sin^{-1}(2/2.5) - \frac{1}{2}\sin^{-1}(1/2.5)$ or $\frac{1}{2}\cos^{-1}(1/2.5) - \frac{1}{2}\cos^{-1}(2/2.5) = \frac{1}{2}(0.9273 - 0.4115)$ or similar (3 d.p., AEF)	**A1**
$= 0.258$ s	**A1**
	Total: 10

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Q5

9231/31, 9231/32 • May/June 2020 • Question 3

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Mark scheme.

$T - mg = m.a.$	**M1**
$T = 5mg.\frac{1}{2}a/a = \frac{5}{2}mg.$	**M1**
$a = \frac{3}{2}g$ (upwards) (AG). **(b)**	**A1**
Gain in KE $= \frac{1}{2}mv^2$; Gain in GPE $= \frac{1}{2}mga.$	**B1**
Loss in EPE $= \frac{1}{2}\frac{5mg.\left(\frac{1}{2}a\right)^2}{a}.$	**B1**
$\frac{1}{2}mv^2 + \frac{1}{2}mga = \frac{1}{2}\frac{5mg.\left(\frac{1}{2}a\right)^2}{a}$ $\left[\Rightarrow \frac{1}{2}mv^2 + \frac{1}{2}mga = \frac{5}{8}mga\right].$	**M1**
$v = \frac{1}{2}\sqrt{ga}.$	**A1**
	Total: 7

Q6

9231/33 • May/June 2020 • Question 7

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Mark scheme.

Collision: $(k+1)mv = mu$ so $v = \dfrac{u}{k+1}$.	**B1**
Loss in KE $= \dfrac{1}{2}m(k+1)\left[v^2 - \dfrac{1}{4}v^2\right]$.	**B1**
Gain in EPE $= \dfrac{1}{2}.\dfrac{4mg}{a}.\left(\dfrac{a}{4}\right)^2$.	**B1**
So, $\dfrac{1}{2}.\dfrac{3}{4}.m(k+1)\dfrac{u^2}{(k+1)^2} = \dfrac{mga}{8}$.	**M1**
Use value of u and solve.	**M1**
$k = 3$. **(b)**	**A1**
$T + F = 4m.\dfrac{9g}{20}$.	**M1**
$4mg.\dfrac{a/4}{a} + F = \dfrac{9mg}{5}$.	**M1**
$\mu R = 4mg/5$ and compare with $R = 4mg$.	**B1**
$\mu = \dfrac{1}{5}$.	**A1**
	Total: 10

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Q7

9231/31, 9231/33 • October/November 2020 • Question 1

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Mark scheme.

Gain in EPE $= \frac{1}{2}.\frac{3mgx^2}{a}$	**B1**
Loss in GPE $= mgx\sin\theta$; equate energies	**M1**
$x = \frac{2}{3}a\sin\theta$ (using forces scores B0M0A0)	**A1**
	Total: 3

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Q8

9231/32 • October/November 2020 • Question 6

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Mark scheme.

$T + mg = m.\frac{7}{3}g$	**M1**
With $T = k.\frac{a/3}{a}$ giving $k = 4mg$ (AG)	**A1**
Let greatest height above Q be $\frac{4}{3}a + x$. Gain in GPE $= mgx$ and loss in KE $= \frac{1}{2}m.2ga$ (the length found may be expressed as total extension or greatest height above Q)	**B1**
Gain in EPE $= \frac{1}{2}.\frac{4mg}{a}\left[\left(x+\frac{a}{3}\right)^2 - \left(\frac{a}{3}\right)^2\right]$ (initial EPE $= \frac{2mga}{9}$)	**B1**
Energy equation, correct number of terms: $\frac{4mg}{2a}\left(x^2 + \frac{2ax}{3} + \frac{a^2}{9} - \frac{a^2}{9}\right) + mgx = mga$	**M1A1**
Simplify to quadratic: $2x^2 + \frac{7ax}{3} - a^2 = 0$	**M1**
$x = \frac{1}{3}a$ so greatest height is $\frac{5}{3}a$	**A1**
	Total: 8

Q9

9231/31, 9231/32 • May/June 2021 • Question 3

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Mark scheme.

Use Hooke's Law: $4mg = \dfrac{kmg(x-a)}{a}$ leading to $k = \dfrac{4a}{x-a}$ (AG, shown convincingly). (b)	**B1**
Gain in KE + gain in EPE = loss in GPE (one correct EPE term seen).	**B1**
$\frac{1}{2} \times 6m \times \frac{ga}{9} + \frac{1}{2}\dfrac{kmg}{a}\left[\left(x+\frac{1}{3}a-a\right)^2-(x-a)^2\right] = 6mg \times \frac{1}{3}a$ (all 3 types of energy included; all terms correct).	**M1 A1**
Simplify and substitute for k from part (a).	**M1**
Obtain linear equation in x and a.	**M1**
$x = \frac{5}{3}a$ $(k = 6)$.	**A1**
	Total: 7

Q10

9231/33 • May/June 2021 • Question 2

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Mark scheme.

EPE correct: $\frac{1}{2} \times \frac{36x^2}{0.8}$ $(= 22.5x^2)$.	**B1**
Energy equation: loss in GPE + loss in KE = gain in EPE: $x\,mg\sin\alpha + \frac{1}{2}m\times 2 = \frac{1}{2} \times \frac{36x^2}{0.8}$ (allow sign errors, allow missing g for M1 only, weight must be resolved).	***M1**
All terms correct.	**A1**
Simplify to 3-term quadratic and attempt to solve: $\left(\frac{6}{5}x + \frac{1}{5} = \frac{9}{4}x^2\right)$ leading to $45x^2 - 24x - 4 = 0$.	**DM1**
$(3x-2)(15x+2) = 0$, $x = \frac{2}{3}$ only.	**A1**
	Total: 5

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Q11

9231/31, 9231/33 • October/November 2021 • Question 3

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Mark scheme.

Loss in EPE $= \frac{1}{2} \times \frac{12mge^2}{a} - \frac{1}{2} \times \frac{12mg}{a} \times \left(e - \frac{a}{3}\right)^2 \left(= \frac{2mg}{3}(6e - a)\right)$ (either term correct).	**B1**
Gain in KE $= \frac{1}{2}mv^2$ and Gain in GPE $= \frac{mga}{3}$.	**B1**
Gain in KE + Gain in GPE = Loss in EPE (KE, GPE and at least one EPE term).	**M1**
$\frac{1}{2}mv^2 + \frac{mga}{3} = \frac{2mg}{3}(6e - a)$ (all terms correct).	**A1**
Simplify to a linear equation in e.	**M1**
$e = \frac{1}{2}a$.	**A1**
	Total: 6

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Q12

9231/31, 9231/32 • May/June 2022 • Question 1

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Mark scheme.

$T\cos\theta = 7.5$, $T\sin\theta = 10$.	**B1**
$T = (7.5^2 + 10^2)^{\frac{1}{2}} = 12.5$ N. (b)	**B1**
Hooke's law: $T = \dfrac{50x}{0.8}$, $x = 0.2$.	**B1**
$(x + 0.8)\sin\theta = 1 \times \dfrac{10}{12.5}$.	**M1**
Vertical distance $= \dfrac{4}{5} = 0.8$.	**A1**
	Total: 5

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Q13

9231/33 • May/June 2022 • Question 2

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Mark scheme.

EPE term correct: $\frac{1}{2} \cdot \frac{\frac{4}{3}mg}{a}x^2$.	**B1**
Work (friction) term correct: $\frac{1}{3}mgx$.	**B1**
Energy equation with 3 terms, allow sign error: Loss in KE = gain in EPE + work done against friction, $\frac{1}{2}mv^2 = \frac{1}{2} \times \frac{\frac{4}{3}mg}{a}x^2 + \frac{1}{3}mgx$.	**M1**
Obtain and attempt to solve a 3-term quadratic equation: $\frac{1}{2} \times \frac{1}{4}ga = \frac{\frac{2}{3}g}{a}x^2 + \frac{1}{3}gx \Rightarrow 16x^2 + 8ax - 3a^2 = 0 \Rightarrow (4x - a)(4x + 3a) = 0$.	**M1**
$x = \frac{1}{4}a$.	**A1**
	Total: 5

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Q14

9231/31, 9231/33 • October/November 2022 • Question 2

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Mark scheme.

EPE terms correct: Loss in KE = Gain in EPE: $\frac{1}{2}mv^2 - \frac{1}{2}m\left(\frac{v}{2}\right)^2 = \frac{1}{2} \times \frac{4mg}{a}\left[\left(\frac{1}{2}a\right)^2 - \left(\frac{1}{4}a\right)^2\right]$ (all 4 terms).	**B1**
All 4 terms and no extras.	**M1**
Simplify: $\frac{3}{4}mv^2 = \frac{4mg}{a} \times \frac{3}{16}a^2$	**M1**
$v^2 = ag$, $v = \sqrt{ag}$ **(b)**	**A1**
Hooke's law: tension $= \frac{4mg}{a} \times \frac{1}{2}a$ $(= 2mg)$	**M1**
Acceleration $= \frac{2mg}{m} = 2g$	**A1**
	Total: 6

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Q15

9231/32 • October/November 2022 • Question 3

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Mark scheme.

In equilibrium, $\frac{\frac{16}{3}Mge}{a} = 4Mg$, $e = \frac{3}{4}a$	**B1**
Energy equation with GPE and KE terms correct and at least one EPE term (dimensionally correct): Loss in GPE = gain in EPE + gain in KE.	**M1**
EPE correct.	**B1**
All correct: $\frac{6Mga}{4} = \frac{1}{2} \cdot \frac{16}{3} \cdot \frac{Mg}{a}\left(a^2 - \left(\frac{3a}{4}\right)^2\right) + \frac{1}{2} \cdot 6Mv^2$	**A1**
Attempt to find v in terms of a and g: $\frac{3Mga}{2} = \frac{8Mg}{3a} \cdot \frac{7}{16}a^2 + 3Mv^2$	**M1**
$\frac{ga}{3} = 3v^2$	**A1**
	Total: 6

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Q16

9231/31, 9231/32 • May/June 2023 • Question 1

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Mark scheme.

Correct EPE term seen: $\frac{3mg}{2a}(2a)^2$.	**B1**
Dimensionally correct energy equation. Must have one KE, one EPE term and at least one GPE. Allow sign errors: $\frac{1}{2}mv^2 + mg \times \left(3a - \frac{3}{4}a\right) = \frac{3mg}{2a}(2a)^2$.	**M1**
$v = \sqrt{\frac{15}{2}ag}$ $[2.74\sqrt{ag}]$ (AEF). (b)	**A1**
$T - mg = mA$ and $T = \frac{3mg}{a} \times 2a$ (N2L and Hooke's law).	**M1**
Acceleration $= 5g$ [upwards] (allow ± 50 or $\pm 5g$).	**A1**
	Total: 5

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Q17

9231/33 • May/June 2023 • Question 2

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Mark scheme.

Kinetic energy = elastic potential energy, 4 terms, dimensionally correct, allow sign errors: $\frac{1}{2}m\left(v^2-\frac{v^2}{4}\right)=\frac{\frac{1}{2}\lambda mg}{a}\left(\left(\frac{2}{3}a\right)^2-\left(\frac{1}{3}a\right)^2\right)$.	**M1**
With v substituted: $\frac{1}{2}m\left(2ag-\frac{1}{2}ag\right)=\frac{\frac{1}{2}\lambda mg}{a}\left(\left(\frac{2}{3}a\right)^2-\left(\frac{1}{3}a\right)^2\right)$.	**A1**
Solve to find value for λ, dependent on energy equation with 3 or 4 terms: $\frac{3}{4}v^2=\lambda g\left(\frac{3}{9}a\right)$.	**M1**
$\lambda=\frac{9}{2}$. [SC B2 for $\lambda=\frac{9}{2}mg$ if given λ not used.]	**A1**
	Total: 4

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Q18

9231/31, 9231/33 • October/November 2023 • Question 4

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Mark scheme.

Energy equation: gain in KE = loss in EPE: $\frac{1}{2}m \times 80ag = \frac{1}{2} \times \frac{5mg}{8a}\left((2L-8a)^2-(4a)^2\right)$ B1 M1 A1		**(a)**
Simplify to quadratic: $4L^2 - 8aL - 20a^2 = 0$	M1	
$L = 10a$	A1	
At P: $2T\cos\theta = m \times$ acceleration	M1	**(b)**
Hooke's law: $T = \frac{5mg}{8a} \times 12a = \frac{15}{2}mg$	M1	
Solve, acceleration $= 12g$	A1	
	Total: 8	

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Q19

9231/32 • October/November 2023 • Question 7

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Mark scheme.

Gain in KE $= \frac{1}{2}m\left(\frac{6}{5}\sqrt{2ag}\right)^2$ and Gain in GPE $= mg \times 3a\sin\theta$	B1	**(a)**
Loss in EPE $= \dfrac{\frac{1}{2}kmg}{a}\left((3a)^2 - a^2\right)$	B1	
Energy equation: $\frac{1}{2}m\left(\frac{6}{5}\sqrt{2ag}\right)^2 + mg \times 3a\sin\theta = \dfrac{\frac{1}{2}kmg}{a}\left((3a)^2 - a^2\right)$	M1A1	
$\frac{36}{25}mg + \frac{12}{5}mg = 4kmg$, so $k = \frac{24}{25}$	A1	
In lower position, tension T in spring $= kmg \times \dfrac{3a}{a} = 3kmg = \dfrac{72}{25}mg$; perpendicular to rod, $T = (F + mg)\cos\theta$	M1	**(b)**
$(F + mg)\cos\theta = \frac{72}{25}mg$, so $F = \frac{19}{5}mg$	A1	
Let tension in rod $= T'$; parallel to rod, $T' = (F + mg)\sin\theta$	M1	**(c)**
$T' = \frac{96}{25}mg$	A1	
		Total: 9

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Q20

9231/31, 9231/32 • May/June 2024 • Question 2

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Mark scheme.

M1: In equilibrium, $2T\cos\theta = mg$.	**(a)**
Hooke's law: $T = \dfrac{\lambda}{2a} \times \left(\dfrac{5a}{2} - 2a\right) = \dfrac{\lambda}{4}$.	**B1**
Equate and use $\cos\theta = \dfrac{3}{5}$: $\lambda = \dfrac{10}{3}mg$.	**A1**
B1: EPE loss $= \dfrac{1}{2}\dfrac{\lambda}{4a}\left(\dfrac{20}{3}a - 4a\right)^2 = \dfrac{80}{27}mga$.	**(b)**
Energy equation: $\dfrac{1}{2}mv^2 + mg\dfrac{8a}{3} = \dfrac{80}{27}mga$ (all 3 terms required, dimensionally correct, their λ).	**M1 A1**
$v = \dfrac{4}{3}\sqrt{\dfrac{ga}{3}}$ (any equivalent form).	**A1**
	Total: 7

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Q21

9231/33 • May/June 2024 • Question 4

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Mark scheme.

Consider A to B: Loss in EPE $= \dfrac{kmg}{2a} \times \left(a^2 - \left(\dfrac{1}{2}a\right)^2\right) = \dfrac{3}{8}kmga$ (accept unsimplified).	**B1**
Energy: $\dfrac{1}{2}mV^2 + \dfrac{mga}{2}\sin\theta = \dfrac{3}{8}kmga$, giving $V^2 = \dfrac{3}{4}ga(k-1)$ (KE, GPE, EPE terms present; must be dimensionally correct; must include $\sin\theta$ or $\cos\theta$ in GPE).	**M1 A1**
Consider A to C: Loss in EPE $= \dfrac{kmg}{2a} \times \left(a^2 - \left(\dfrac{a}{4}\right)^2\right) = \dfrac{15}{32}kmga$ (accept unsimplified).	**B1**
Energy: $\dfrac{1}{2}m\left(\dfrac{1}{2}V\right)^2 + \dfrac{mg\,5a}{4}\sin\theta = \dfrac{15}{32}kmga$, giving $V^2 = \dfrac{15}{4}ag(k-2)$.	**M1**
Alternative third situation B to C: Loss in EPE $= \dfrac{kmg}{2a} \times \left(\left(\dfrac{a}{2}\right)^2 - \left(\dfrac{a}{4}\right)^2\right) = \dfrac{3}{32}kmga$, may be used in combination with either of the first two.	**(B1)**
Energy for B to C: $\dfrac{1}{2}m\left(\dfrac{1}{2}V\right)^2 - \dfrac{1}{2}mV^2 - \dfrac{mg\,3a}{4}\sin\theta = -\dfrac{3}{32}kmga$, giving $V^2 = \dfrac{1}{4}ag(6-k)$.	**(M1)**
Eliminate V^2 from two energy equations to obtain an expression involving only k, a (and possibly $\sin\theta$); at least one energy equation must have scored M1.	**M1**
$k = \dfrac{9}{4}$.	**A1**
	Total: 7

Q22

9231/31, 9231/33 • October/November 2024 • Question 3

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Mark scheme.

(a)

Hooke's law: $T = \dfrac{2mg}{2} \times$ extension and $T = mg$ (equilibrium position).	**M1**
Extension $= 1$ m.	**A1**
EPE loss $= \frac{1}{2} \times \dfrac{2mg}{2} \times (1+d)^2$.	**B1**
Gain in GPE $= mg(2+1+d)$.	**B1**
Equate: $\frac{1}{2}mg(1+d)^2 = mg(3+d)$.	**M1**
$d = \sqrt{5}$. (SC: 3 marks for $\sqrt{5}+1$; SC: 2 marks for $\sqrt{5}+k,\ k \neq 1$.)	**A1**

(b)

Energy equation: $\frac{1}{2}mV^2 + mg(1+d) = \frac{1}{2} \times \dfrac{2mg}{2} \times (1+d)^2$.	**M1**
$V^2 = g(d^2-1)$, $V = \sqrt{40} = 2\sqrt{10}$.	**A1**

Total: 8

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Q23

9231/32 • October/November 2024 • Question 2

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Mark scheme.

Extension when P comes to rest is x, EPE loss $= \frac{1}{2} \times \frac{5mg}{a} \times \left(\left(\frac{a}{2}\right)^2 - x^2\right)$ (both terms seen).	**B1**
Energy: $\frac{1}{2} \times \frac{5mg}{a} \times \left(\left(\frac{a}{2}\right)^2 - x^2\right) = mg\left(\frac{a}{2} - x\right)$ (at least one EPE term and a GPE term, dimensionally correct).	**M1**
Solve: $20x^2 - 8ax - a^2 = 0$ (obtain homogeneous quadratic equation in x and a).	**M1**
$x = -\frac{a}{10}$, so distance of P below O is $\frac{9}{10}a$.	**A1**

Total: 4

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Q24

9231/31, 9231/32 • May/June 2025 • Question 5

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Mark scheme.

At v_{max}, $T = 2g\sin\alpha$ $\left[= \frac{14}{25}g\right]$ (allow $T = mg\sin\alpha$).	**M1**
$\dfrac{14x}{0.5} = \dfrac{14g}{25}$ leading to $x = \frac{1}{5}$ (extension at maximum velocity).	**A1**
EPE at top: $\dfrac{14\times 0.3^2}{2\times 0.5}$ $[= 1.26]$; EPE at bottom: $\dfrac{14\times(\text{their } x)^2}{2\times 0.5}$ $[= 0.56]$. One correct term seen anywhere, FT on their x.	**B1 FT**
Dimensionally correct energy equation including KE, GPE, and at least one EPE term: $2g\sin\alpha(0.8+0.5+\text{their } x)+\dfrac{14\times 0.3^2}{2\times 0.5} = \dfrac{14\times(\text{their } x)^2}{2\times 0.5}+\frac{1}{2}\times 2\times v^2$.	**M1**
Correct equation, FT on their x.	**A1 FT**
$v^2 = 0.91g = 9.1$ leading to $v = 3.02\,\text{m s}^{-1}$.	**A1**
	Total: 6

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Q25

9231/33 • May/June 2025 • Question 2

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Mark scheme.

(a)

Energy equation with all three terms, dimensionally correct: $\frac{mg}{2a}(x-a)^2 = mgx\sin 30 - \frac{11}{30}mgx$.	**M1**
Two terms correct (need not be in equation).	**B1**
Correct energy equation.	**A1**
Simplify to three-term homogeneous quadratic and attempt to solve: $15x^2 - 34ax + 15a^2 = 0$, i.e. $(3x-5a)(5x-3a)=0$.	**M1**
$x = \frac{5}{3}a$ (CAO, reject $x = \frac{3}{5}a$).	**A1**

(b)

$T = \frac{2}{3}mg$.	**B1**
Equation for F (allow sin/cos mix, sign errors): $F = T - mg\sin 30$ $\left[= \frac{2}{3}mg - \frac{1}{2}mg\right]$.	**M1**
$F = \frac{1}{6}mg$.	**A1**

Total: 8

Q26

9231/34 • May/June 2025 • Question 1

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Mark scheme.

Energy equation with two EPE terms and at least one GPE term, dimensionally correct (allow sign errors): $\dfrac{20mg\left(\frac{2}{5}a\right)^2}{2a} + \frac{3}{5}mga = \dfrac{20mgx^2}{2a} + mg(a+x)$.	**M1**
One correct EPE term seen anywhere.	**B1**
Correct energy equation.	**A1**
Simplify to 3-term quadratic in x^2, ax, a^2: $50x^2 + 5ax - 6a^2 = 0$.	**M1**
$x = \frac{3}{10}a$ (single correct answer; reject $x = -\frac{2}{5}a$ if seen).	**A1**

Total: 5

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Q27

9231/31, 9231/33 • October/November 2025 • Question 4

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Mark scheme.

In equilibrium, $\dfrac{5mge}{a} = 5mg$, $e = a$.	**B1**
At least one correct EPE term seen.	**B1**
Dimensionally correct energy equation with one KE term, two EPE terms and at least one GPE term: $\dfrac{5mga^2}{2a} - \dfrac{5mg(x-a)^2}{2a} = mg(e+a-x) + \frac{1}{2}m(\frac{7}{5}ag)$.	**M1**
Fully correct energy equation.	**A1**
Three-term homogeneous quadratic equation in x and a: $25x^2 - 60ax + 27a^2 = 0$.	**M1**
$x = \frac{9}{5}a$ only.	**A1**
	Total: 6

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Q28

9231/34 • October/November 2025 • Question 6

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Mark scheme.

N2L: $T_1 = T_2 + kmg$.	**B1**
Apply Hooke's law to string AP: $T_1 = \dfrac{5mg(22a - BP - 4a)}{4a}$.	**B1**
Apply Hooke's law to string BP: $T_2 = \dfrac{6mg(BP - 8a)}{8a}$.	**B1**
Substitute T_1 and T_2 into N2L and obtain linear expression for BP in terms of a and k.	**M1**
AG, shown convincingly: $BP = \dfrac{57a - 2ak}{4}$. **(b)**	**A1**
At least one correct EPE term.	**B1**
Dimensionally correct energy equation with two EPE terms and at least one GPE term (no KE terms): $\dfrac{6mg(18a - 8a)^2}{2 \times 8a} + 18kmga = \dfrac{5mg(14a - 4a)^2}{2 \times 4a} + 8kmga$.	**M1**
Fully correct energy equation.	**A1**
$k = \frac{5}{2}$.	**A1**
	Total: 9

Q29

9231/32 • October/November 2025 • Question 2

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Mark scheme.

Correct EPE seen OR correct work done by friction seen: EPE $= \frac{2mg}{2a}\left(\frac{1}{3}a\right)^2$; Work done by friction $= \mu mg\left(\frac{1}{3}a\right)$.	**B1**
Equation or inequality involving EPE and work done terms only: $\frac{2mg}{2a}\left(\frac{1}{3}a\right)^2 = \mu mg\left(\frac{1}{3}a\right)$.	**M1**
CWO: $\mu = \frac{1}{3}$. **(b)**	**A1**
Dimensionally correct equation with two EPE terms and one work done term: $\frac{2mg}{2a}\left(\frac{1}{3}a\right)^2 = \frac{2mg}{2a}x^2 + \frac{1}{2}mg\left(\frac{1}{3}a - x\right)$.	**M1**
Correct energy equation (may be unsimplified).	**A1**
CWO: $18x^2 - 9ax + a^2 = 0$, $(6x - a)(3x - a) = 0$, $x = \frac{1}{6}a$ only.	**A1**
	Total: 6

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Written by Ali Hashir.

Questions available in the companion questions booklet.