



Pearson
Edexcel

Mark Scheme (Results)

Summer 2019

Pearson Edexcel GCE
Mechanics (9FM0) Paper 4C

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

| Question Number | Answer | Mark |
|-----------------|---|------------|
| 1 | 1. The only correct answer is A <i>B is not correct because cash in hand is an asset</i> <i>C is not correct because debtors are an asset</i> <i>D is not correct because prepaid expenses are an asset</i> | (4) |

| Question | Scheme | Marks | AOs |
|------------------|---|-------|------|
| 1 | | | |
| | $\updownarrow R \cos \theta = mg$ | M1 | 3.1b |
| | $\leftrightarrow R \sin \theta = mr\omega^2$ | M1 | 3.3 |
| | | A1 | 1.1b |
| | $\tan \theta = \frac{r}{\frac{a}{4}} \quad (\tan \theta = \sqrt{15})$ | B1 | 1.1b |
| | Complete strategy to find ω | M1 | 3.1b |
| | $\tan \theta = \frac{mr\omega^2}{mg} = \frac{4r}{a}, \Rightarrow \omega^2 = \frac{4g}{a}, \omega = 2\sqrt{\frac{g}{a}}$ | A1 | 1.1b |
| | | (6) | |
| | Alternative: | | |
| | $\updownarrow R \cos \theta = mg$ | M1 | 3.1b |
| | $\leftrightarrow R \sin \theta = ma \sin \theta \omega^2$ | M1 | 3.3 |
| | | A1 | 1.1b |
| | $\cos \theta = \frac{1}{4}$ | B1 | 1.1b |
| | Complete strategy to find ω | M1 | 3.1b |
| | $\Rightarrow R = 4mg, 4mg = ma\omega^2 \Rightarrow \omega = 2\sqrt{\frac{g}{a}}$ | A1 | 1.1b |
| | | | |
| (6 marks) | | | |

| Question | Marks | Marking Guidance |
|----------|-------|---|
| 1 | | <p>Check their diagram to see where they have put θ</p> <p>Check the working carefully, particularly the value of r: some errors in the working can lead to a fortuitously correct answer</p> |
| | M1 | Resolve vertically. Must be dimensionally correct. |

| | | |
|--|-----|--|
| | M1 | Resolve horizontally and form equation for circular motion. Must be dimensionally correct. |
| | A1 | Correct pair of equations for their unknowns (any r) |
| | B1 | Correct trig ratio(s) seen or implied. Allow for $r = \frac{\sqrt{15}}{4}a$ |
| | M1 | Complete strategy to form and solve a set of equations with $r \neq a$ to find ω . For solving their 2 equations – not dependent |
| | A1 | Eliminate additional variables to obtain ω . Accept equivalent exact forms. |
| | (6) | |
| | | If R does not act through the centre of the hemisphere then the maximum available is M1M1A0B0M0A0: 2/6 |

| Question | Scheme | Marks | AOs |
|-------------------|---|-------|------|
| 2(a) | Strategy to find v^3 in terms of x | M1 | 3.1a |
| | Differential equation in v and x : $0.4v \frac{dv}{dx} = \frac{k}{v}$ | M1 | 2.1 |
| | $\Rightarrow 0.4v^2 \frac{dv}{dx} = k$, $\frac{0.4}{3}v^3 = kx + C$ | A1 | 1.1b |
| | $x = 3, v = 2 \quad \frac{3 \cdot 2}{3} = 3k + C$ $x = 6, v = 2.5 \quad \frac{25}{12} = 6k + C$ | M1 | 2.1 |
| | $\Rightarrow 3k = \frac{25}{12} - \frac{3 \cdot 2}{3}$, $k = \frac{61}{180}$, $C = \frac{1}{20}$ | A1 | 1.1b |
| | $v^3 = \frac{3}{0.4} \left(\frac{61x}{180} + \frac{1}{20} \right) = \frac{61x+9}{24}$ * | A1* | 2.2a |
| | (6) | | |
| (b) | $\frac{5k}{2v} = \frac{dv}{dt} = \left(\frac{61}{72v} \right)$ | M1 | 2.5 |
| | $\int 2v dv = \int 5k dt \Rightarrow v^2 = 5kt + C'$ ($36v^2 = 61t + C'$) | M1 | 2.1 |
| | $[v^2]_2^{2.5} = [5kt]_0^T$ $(61T = 36(2.5^2 - 2^2))$ | M1 | 1.1b |
| | $T = \frac{180}{61} \left(\frac{9}{20} \right) = \frac{81}{61}$ * | A1* | 2.2a |
| | (4) | | |
| (b) alt | $\frac{dx}{dt} = \sqrt[3]{\frac{61x+9}{24}}$ | M1 | 2.5 |
| | $\int (61x+9)^{\frac{1}{3}} dx = \int \frac{1}{\sqrt[3]{24}} dt$, $\frac{3}{2 \times 61} (61x+9)^{\frac{2}{3}} = \frac{t}{\sqrt[3]{24}} + C''$ | M1 | 2.1 |
| | $T = 2 \times \sqrt[3]{3} \times \frac{3}{2 \times 61} \left(375^{\frac{2}{3}} - 192^{\frac{2}{3}} \right) = \frac{3 \times \sqrt[3]{3}}{61} \left((5\sqrt[3]{3})^2 - (4\sqrt[3]{3})^2 \right)$ | M1 | 1.1b |
| | $T = \frac{9}{61} (25 - 16) = \frac{81}{61}$ * | A1* | 2.2a |
| | | | |
| (10 marks) | | | |

| Question | Marks | Marking Guidance |
|----------------|------------|---|
| 2(a) | M1 | Complete strategy e.g. use of $F = ma$ with appropriate form for a , and use boundary conditions to confirm given result |
| | M1 | Separate variables and integrate. Usual rules for integration. Condone missing C |
| | A1 | Correct integration. Accept equivalent forms. Condone missing C . |
| | M1 | Use boundary conditions to form 2 equations in 2 unknowns and solve for k or C |
| | A1 | Obtain correct values for the constants |
| | A1* | Obtain given answer from correct working |
| | (6) | |
| (b) | M1 | Select correct form for derivative and form a correct differential equation in v and t – follow their k |
| | M1 | Separate and integrate. Condone with no $+C'$ – follow their k |
| | M1 | Evaluate definite integral of the form $pv^2 = qt + C'$ or use limits to find value of constant of integration – follow their k |
| | A1* | Obtain given answer from correct working |
| | (4) | |
| (b) alt | M1 | Select correct form for derivative and form a correct differential equation in x and t |
| | M1 | Separate and integrate. Condone with no $+C''$ |
| | M1 | Evaluate definite integral of the form $pt = q(61x+9)^{\frac{2}{3}} + C''$ or use limits to find value of constant of integration |
| | A1* | Obtain given answer from correct working |
| | | NB: Both parts have given answers, so check very carefully |

| Question | Scheme | Marks | AOs |
|-------------------|--|------------|------|
| 3(a) | Correct strategy | M1 | 3.1a |
| | $8\bar{y} = \frac{1}{2} \int y^2 dx = \frac{1}{2} \int \left\{ \frac{(x-2)^6}{16} + (x-2)^3 + 4 \right\} dx$ | M1 | 2.1 |
| | $= \frac{1}{2} \left[\frac{(x-2)^7}{7 \times 16} + \frac{(x-2)^4}{4} + 4x \right]_0^4$ | A1 | 1.1b |
| | $8\bar{y} = \frac{1}{2} \left[\frac{8}{7} + 4 + 16 + \frac{8}{7} - 4 - 0 \right] = \frac{64}{7}, \quad \bar{y} = \frac{8}{7} \quad *$ | A1* | 2.2a |
| | | (4) | |
| (b) | $8\bar{x} = \int \left(\frac{x(x-2)^3}{4} + 2x \right) dx$ | M1 | 2.1 |
| | $= \left[\frac{x(x-2)^4}{16} - \frac{(x-2)^5}{80} + x^2 \right]_0^4$ | A1 | 1.1b |
| | $= \frac{64}{16} - \frac{32}{80} + 16 - \frac{32}{80} = 19.2$ | M1 | 1.1b |
| | $\bar{x} = 2.4$ | A1 | 1.1b |
| | Complete strategy to find θ | M1 | 3.1a |
| | $\tan \theta = \frac{4 - \bar{x}}{4 - \frac{7}{8}} \left(= \frac{14}{25} \right)$ | A1ft | 3.4 |
| | $\theta = 29.2 \text{ (Accept 29)}$ | A1 | 1.1b |
| | | (7) | |
| (11 marks) | | | |

| Question | Marks | Marking Guidance |
|-------------|-------|--|
| 3(a) | M1 | Complete strategy for \bar{y} : moments equation, use of limits and division by area |
| | M1 | Moments equation to obtain terms of the correct form (with or without limits) The integral must be in terms of x only or y only Allow if area (8) not seen Might see $\int \frac{x^6}{16} - \frac{3x^5}{4} + \frac{15x^4}{4} - 9x^3 + 9x^2 dx$ |

| | | |
|-----|------|--|
| | | Or $\int xydy = \int 2y + y(4(y-2))^{\frac{1}{3}}dy$ |
| | A1 | Correct unsimplified answer (with or without limits) Allow if area (8) not seen ($\int xydy = 12.8$) |
| | A1* | Use moments equation and given area to deduce given answer from correct working |
| | (4) | |
| (b) | | Relevant integral in terms of x only or y only (with or without limits). Allow if area (8) not seen |
| | M1 | Could start with $\int xydx$ or $\int \frac{1}{2}x^2dy$ Might see $\frac{x^4}{4} - \frac{6x^3}{4} + 3x^2 - 2x + 2x$ |
| | A1 | Correct unsimplified form after integration (with or without limits). Allow if area (8) not seen |
| | M1 | Complete process to find \bar{x} following relevant integral |
| | A1 | Correct answer |
| | M1 | Complete strategy to find θ e.g find \bar{x} and then use trig to find appropriate angle |
| | A1ft | Use the model to find a relevant angle. Follow their \bar{x} |
| | A1 | 2 s.f. or better 29.2488... |
| | (7) | |

| Question | Scheme | Marks | AOs |
|-------------------|--|------------|------|
| 4(a) | Total mass = $\int_0^4 (18-3x) dx$ | M1 | 2.1 |
| | $= \left[18x - \frac{3x^2}{2} \right]_0^4$ | A1 | 1.1b |
| | $= 18 \times 4 - \frac{3 \times 16}{2} (= 72 - 24) = 48 \text{ (kg) } *$ | A1* | 1.1b |
| | | (3) | |
| (b) | Taking moments about the base: $\int_0^4 x(18-3x) dx$ | M1 | 3.4 |
| | $= \left[9x^2 - x^3 \right]_0^4 (= 80)$ | A1 | 1.1b |
| | $\Rightarrow 48d = 80$ | M1 | 3.4 |
| | $d = \frac{80}{48} = \frac{5}{3} \text{ (m)}$ | A1 | 1.1b |
| | Complete strategy | M1 | 3.1b |
| | $M(A) : 2T = 4 \cos 45^\circ \times 4g + \frac{5}{3} \cos 45^\circ \times 48g$ | A1ft | 1.1b |
| | $\left(= \frac{96g}{\sqrt{2}} \right)$ | A1ft | 1.1b |
| | $T = 333 \text{ or } 330$ | A1 | 2.2a |
| | (8) | | |
| (c) | Any appropriate comment e.g. the ball has been modelled as a point mass – its centre could be further from A | B1 | 3.5b |
| | | (1) | |
| (12 marks) | | | |

| Question | Marks | Marking Guidance |
|-------------|------------|---|
| 4(a) | M1 | Use integration (usual rules) – do not need to see limits at this stage |
| | A1 | (M1 on open) Correct integration and correct limits seen |
| | A1* | Show sufficient working to justify given answer |
| | (3) | |

| | | |
|------------|--------------|---|
| (b) | M1 | Use the model to find the moment of the pole and the ball about A (usual rules for integration) |
| | A1 | Correct integration |
| | M1 | Use the model to complete the moments equation. Require their 80 and 48 used correctly |
| | A1 | Any equivalent form |
| | M1 | Complete strategy to find the tension – e.g. locate c of m of the pole and use moments. |
| | A1ft A1ft | Moments equation with at most one error. Follow their c of m provided not at centre Correct unsimplified moments equation for their c of m not at centre |
| | A1 | Accept $24\sqrt{2}g$, 333 or 330 ISW |
| | (8) | |
| | | |
| (c) | B1 | <ul style="list-style-type: none"> • The mass of the cable has been ignored – unlikely to be negligible if it can hold a pole this long. • The flagpole will be subject to cross winds • The cable might be extensible • The pole might not be rigid NOT: the wall might be rough / smooth Ignore incorrect statements |
| | (1) | |

| Question | Scheme | | Marks | AOs | |
|-------------------|--|---------------------------|------------------|------|------|
| 5(a) | $\int \pi x^2 y dy = \pi \int \frac{y^5}{4} dy = \pi \left[\frac{y^6}{24} \right]_0^2$ | | M1 | 3.4 | |
| | $= \frac{64\pi}{24} \left(= \frac{8\pi}{3} \right)$ | | A1 | 1.1b | |
| | $\Rightarrow \bar{y} = \left(\text{their } \frac{8\pi}{3} \right) \times \frac{5}{8\pi} \left(= \frac{5}{3} \right)$ | | M1 | 3.1a | |
| | Distance from plane face = $2 - \frac{5}{3} = \frac{1}{3}$ * | | A1* | 2.2a | |
| | | | (4) | | |
| (b) | | Mass ratio | c of m from base | B1 | 1.2 |
| | <i>S</i> | $3 \times \frac{8\pi}{5}$ | $\frac{13}{3}$ | | |
| | cylinder | 16π | 2 | | |
| | <i>M</i> | $(16+4.8)\pi$ | <i>d</i> | | |
| | Moments about diameter of the base: | | | M1 | 2.1 |
| | $\frac{24}{5} \times \frac{13}{3} + 32 = \frac{104}{5} d \left(= \frac{264}{5} \right)$ | | | A1 | 1.1b |
| | $d = \frac{264}{104} \left(= \frac{33}{13} \right) \text{ (cm)}$ | | | A1 | 1.1b |
| | Complete strategy for θ | | | M1 | 3.1a |
| | About to topple: $\tan \theta = \frac{2}{d} \left(= \frac{26}{33} \right)$ | | | A1ft | 3.4 |
| | $\theta = 38.2$ (or 38) | | | A1 | 2.2a |
| | | | | (7) | |
| (11 marks) | | | | | |

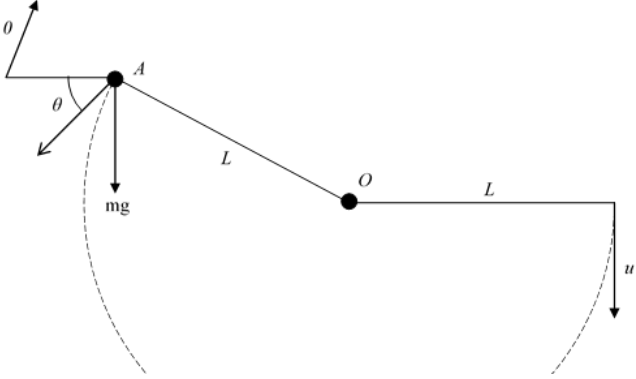
| Question | Marks | Marking Guidance |
|-------------|-------|--|
| 5(a) | M1 | Use the model to find the moment about the base. Usual rules for integration. Correct limits |
| | A1 | Any equivalent form |
| | M1 | Use the model and volume to find \bar{y} : their moments and $\frac{8\pi}{5}$ used correctly |

| | | |
|-----|------|---|
| | A1* | Obtain given answer from correct working |
| | (4) | |
| (b) | B1 | Correct mass ratios seen or implied |
| | M1 | Moments equation. Dimensionally correct. Allow for their mass ratios |
| | A1 | Correct unsimplified equation |
| | A1 | Any equivalent form (2.54 cm) |
| | M1 | Complete strategy to find the position of the centre of mass of the composite body and use trig. to find θ |
| | A1ft | Trig ratio for a relevant angle. Follow their d |
| | A1 | Correct angle (38 or better) (38.2338....) |
| | (7) | |

| Question | Scheme | Marks | AOs |
|-------------|--|----------|--------------|
| 6(a) | Use of Hooke's law seen | B1 | 2.1 |
| | Let x be the displacement from equilibrium, then $T_B - T_A = -0.2\ddot{x}$. | M1 | 3.1a |
| | $\frac{15(2+x)}{1} - \frac{15(1-x)}{0.5} = -0.2\ddot{x}$ | A1 A1 | 1.1b 1.1b |
| | $\Rightarrow \ddot{x} = -225x = -15^2 x$, which is of the form $\ddot{x} = -\omega^2 x$, so SHM * | A1* | 3.2a |
| | | (5) | |
| (b) | $a = 0.5$, $\omega = 15$ or their ω | B1ft | 1.1b |
| | Max speed = $a\omega = 7.5$ (m s ⁻¹) | B1ft | 1.2 |
| | Max acceleration = $a\omega^2 = 112.5$ (m s ⁻²) | B1ft | 1.2 |
| | | (3) | |
| (c) | $x = 0.5\cos 15t \Rightarrow \dot{x} = -7.5\sin 15t$ | B1ft | 2.2a |
| | $ \dot{x} = 7.5\sin 15t = 5 \Rightarrow \sin 15t = \frac{2}{3} \Rightarrow t = \dots$ | M1 | 1.1b |
| | $t = 0.0486\dots$ (s) | A1 | 1.1b |
| | Complete strategy to find the required time | M1 | 3.1a |
| | Speed > 5 for $\frac{2\pi}{15} - 4t = 0.22$ (s) | A1 | 1.1b |
| | | (5) | |

| Question | Marks | Marking Guidance |
|-------------|----------|--|
| 6(a) | B1 | Use of Hooke's law seen at least once (with natural length ≤ 1.5) . |
| | M1 | Form equation of motion involving a difference of 2 tensions. Must be dimensionally correct. Need all terms. Condone incorrect lengths. Condone sign errors. |
| | A1 A1 | Unsimplified equation with at most one error Correct unsimplified equation |
| | A1* | All correct and justification of SHM – comment required |
| | (5) | |
| (b) | B1ft | Correct values seen or implied. a must be correct but follow their ω from (a) |
| | B1ft | Follow their a , ω |

| | | |
|-----|------|---|
| | B1ft | Follow their a, ω |
| | (3) | |
| (c) | B1ft | Use correct equation for speed ($-a\omega\sin\omega t$) Follow their a and ω Allow sin or cos form Can also use correct expression for x combined with use of $v^2 = \omega^2(a^2 - x^2)$ |
| | M1 | Find a relevant time e.g. time taken for 0 m s^{-1} to 5 m s^{-1} |
| | A1 | Seen or implied |
| | M1 | Complete strategy for the required time – e.g. find value for t when $v = 5$ and use symmetry and periodic time |
| | A1 | 2 s.f. or better (0.22428...) |
| | (5) | (13 marks) |

| Question | Scheme | Marks | AOs |
|-------------------|--|-------|------|
| 7(a) | $v = 0 \Rightarrow \frac{v^2}{L} = 0 \Rightarrow$ no acceleration towards O \Rightarrow acceleration is perpendicular to OA | B1 | 2.4 |
| | | (1) | |
| 7(b) |  | | |
| | Conservation of energy | M1 | 2.1 |
| | $0 = \frac{1}{2}mu^2 - mgL\cos\theta \quad \left(0 = \frac{2gL}{3} - 2gL\cos\theta\right)$ | A1 | 1.1b |
| | $\Rightarrow \cos\theta = \frac{1}{3}$ | A1 | 1.1b |
| | Complete strategy to find the angle and acceleration | M1 | 3.1a |
| | Magnitude: $g \sin\theta = \frac{2\sqrt{2}}{3}g$ | A1 | 1.1b |
| | $\theta = 71^\circ$ or better | A1 | 1.1b |
| | | (6) | |
| (c) | Circular motion | M1 | 3.1a |
| | $T - mg = \frac{mv^2}{L}$ | A1 | 1.1b |
| | Energy equation | M1 | 2.1 |
| | $v^2 = \frac{2gL}{3} + 2gL \left(= \frac{8gL}{3}\right)$ | A1 | 1.1b |
| | $T = mg + \frac{8mg}{3} = \frac{11mg}{3}$ | A1 | 2.2a |
| | | (5) | |
| (12 marks) | | | |

| Question | Marks | Marking Guidance |
|-------------|-------|--|
| 7(a) | B1 | Clear explanation using $v = 0$ |
| | (1) | |
| 7(b) | | Check their diagram to see where they have put θ . |
| | M1 | All terms required. Must be dimensionally correct. Condone sign errors. $v = 0$ seen or implied |
| | A1 | Correct unsimplified equation for their θ |
| | A1 | Or equivalent to give trig ratio for relevant angle (taking account of their θ) |
| | M1 | Complete strategy to find our θ or magnitude of acceleration |
| | A1 | Correct magnitude from correct work only. Accept 9.2, 9.24 |
| | A1 | Correct value of θ (1.2 radians or better) from correct work only |
| | (6) | |
| (c) | M1 | Equation for circular motion. Need all terms and dimensionally correct. Condone sign errors. |
| | A1 | Correct unsimplified equation |
| | M1 | Use of conservation of energy. Require all 3 terms and dimensionally correct. |
| | A1 | Correct unsimplified equation |
| | A1 | Correct only |
| | (5) | |

