Pearson

# Mark Scheme (Results)

## January 2017

## Pearson Edexcel International A Level in Mechanics 2 (WME02/01)

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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.

# PEARSON EDEXCEL IAL MATHEMATICS

## General Instructions for Marking

1. The total number of marks for the paper is 75.

2. The Edexcel Mathematics mark schemes use the following types of marks:

'M' marks
These are marks given for a correct method or an attempt at a correct method. In Mechanics they are usually awarded for the application of some mechanical principle to produce an equation.
e.g. resolving in a particular direction, taking moments about a point, applying a suvat equation, applying the conservation of momentum principle etc.
The following criteria are usually applied to the equation.

To earn the M mark, the equation
(i) should have the correct number of terms
(ii) be dimensionally correct i.e. all the terms need to be dimensionally correct
e.g. in a moments equation, every term must be a 'force x distance' term or 'mass x distance', if we allow them to cancel 'g' s.
For a resolution, all terms that need to be resolved (multiplied by sin or cos) must be resolved to earn the M mark.

M marks are sometimes dependent (DM) on previous M marks having been earned.
e.g. when two simultaneous equations have been set up by, for example, resolving in two directions and there is then an M mark for solving the equations to find a particular quantity – this M mark is often dependent on the two previous M marks having been earned.

'A' marks
These are dependent accuracy (or sometimes answer) marks and can only be awarded if the previous M mark has been earned. E.g. M0 A1 is impossible.

'B' marks
These are independent accuracy marks where there is no method (e.g. often given for a comment or for a graph)

A few of the A and B marks may be f.t. – follow through – marks.

3. General Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes.

- bod – benefit of doubt
- ft – follow through
- the symbol $\surd$ will be used for correct ft
- cao – correct answer only
- cso - correct solution only. There must be no errors in this part of the question to obtain this mark
- isw – ignore subsequent working
- awrt – answers which round to
- SC: special case
- oe – or equivalent (and appropriate)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- * The answer is printed on the paper
- ⌐ The second mark is dependent on gaining the first mark

4. All A marks are 'correct answer only' (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.

5. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.

6. If a candidate makes more than one attempt at any question:
   - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
   - If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.

7. Ignore wrong working or incorrect statements following a correct answer.

# General Principles for Mechanics Marking

*(But note that specific mark schemes may sometimes override these general principles)*

- Rules for M marks: correct no. of terms; dimensionally correct; all terms that need resolving (i.e. multiplied by cos or sin) are resolved.
- Omission or extra g in a resolution is an accuracy error not method error.
- Omission of mass from a resolution is a method error.
- Omission of a length from a moments equation is a method error.
- Omission of units or incorrect units is not (usually) counted as an accuracy error.
- DM indicates a dependent method mark i.e. one that can only be awarded if a previous specified method mark has been awarded.
- Any numerical answer which comes from use of g = 9.8 should be given to 2 or 3 SF.
- Use of g = 9.81 should be penalised once per (complete) question.

  N.B. Over-accuracy or under-accuracy of correct answers should only be penalised *once* per complete question. However, premature approximation should be penalised every time it occurs.
- Marks must be entered in the same order as they appear on the mark scheme.

- In all cases, if the candidate clearly labels their working under a particular part of a question i.e. (a) or (b) or (c),…..then that working can only score marks for that part of the question.
- Accept column vectors in all cases.
- Misreads – if a misread does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, bearing in mind that after a misread, the subsequent A marks affected are treated as A ft
- Mechanics Abbreviations

  M(A) Taking moments about A.

  N2L Newton's Second Law (Equation of Motion)

  NEL Newton's Experimental Law (Newton's Law of Impact)

  HL Hooke's Law

  SHM Simple harmonic motion

  PCLM Principle of conservation of linear momentum

  RHS, LHS Right hand side, left hand side.

| Question Number | Scheme | Marks | Notes |
|---|---|---|---|
| **1.(a)** | $F = \dfrac{11760}{10}$ | B1 | Seen or implied |
| | $R = F - 1200g\sin\alpha$ | M1 | Motion up the slope. Allow with $F$.<br>Need all three terms but condone sign errors.<br>Condone trig confusion |
| | $R = \dfrac{11760}{10} - 1200g\dfrac{1}{15}$ | A1 | Correct equation, correctly substituted. |
| | $R = 390$ (392) | A1 | Max 3 s.f. |
| | | (4) | |
| **(b)** | $F = \dfrac{50000}{V}$ | B1 | Seen or implied<br>Could be scored after incorrect work on an energy equation to find $F$ |
| | $F - 1200g\sin\alpha - 700 = 1200$ x 1.5 | M1 | Equation of motion. Must be using 700.<br>Need all four terms but condone sign errors.<br>Condone trig confusion |
| | | A1 | Equation in $V$ or $F$ (and $\alpha$) with at most one error<br>Their $F$ |
| | $\frac{50000}{V} - 1200g\frac{1}{15} - 700 = 1200$ x 1.5 | A1 | Correct equation in $V$ |
| | Solve for $V$ | DM1 | Dependent on previous M |
| | $V = 15$ (15.2) | A1 | Max 3 s.f. |
| | | (6) | |
| | | **10** | |

| Question Number | Scheme | Marks | |
|---|---|---|---|
| **2(a)** | Rectangle + Triangle | B1 | Square - Triangle |
| **(i)** | | | |

| | rectangle | triangle | lamina |
|---|---|---|---|
| Mass ratio | 2 | 1 | 3 |
| From *AB* | $a$ | $\frac{4}{3}a$ | $\overline{y}$ |

| | square | triangle | lamina |
|---|---|---|---|
| Mass ratio | 4 | 1 | 3 |
| From *AB* | $a$ | $\frac{2}{3}a$ | $\overline{y}$ |

2 triangles

| | *DAB* | *DBC* | lamina |
|---|---|---|---|
| Mass ratio | 1 | 2 | 3 |
| From *AB* | $\frac{2a}{3}$ | $\frac{4a}{3}$ | $\overline{y}$ |

| | | | |
|---|---|---|---|
| | $2a + 1.\frac{4}{3}a = 3\overline{y}$ | M1 | Moments about *AB* or a parallel axis. Need all three terms and correct signs $\left(4a - \frac{2}{3}a = 3\overline{y}\right)$ $\left(\frac{2a}{3} + \frac{8a}{3} = 3\overline{y}\right)$ |
| | $\Rightarrow \overline{y} = \frac{10}{9}a$ | A1 | ***Answer Given*** Need some evidence e.g. $\frac{10}{3}a = 3\overline{y}$ |
| **(ii)** | | B1 | |

| | rectangle | triangle | lamina |
|---|---|---|---|
| From *AD* | $\frac{1}{2}a$ | $\frac{4}{3}a$ | $\overline{x}$ |

2nd B1 on epen
Award if seen anywhere in response to part (a).

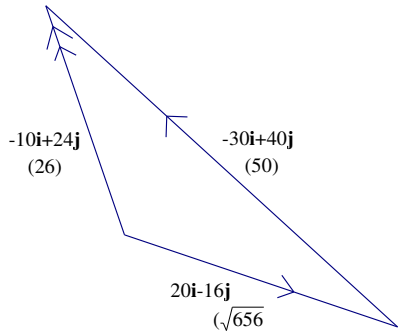
| | square | triangle | lamina |
|---|---|---|---|
| From *AD* | $a$ | $\frac{5}{3}a$ | $\overline{x}$ |

| | *DAB* | *DBC* | lamina |
|---|---|---|---|
| From *AD* | $\frac{a}{3}$ | $a$ | $\overline{x}$ |

| | | | |
|---|---|---|---|
| | $2.\frac{1}{2}a + 1.\frac{4}{3}a = 3\overline{x}$ | M1 | Moments about *AD* or a parallel axis. Need all 3 terms and correct signs. $\left(4a - \frac{5}{3}a = 3\overline{x}\right)$ $\left(\frac{a}{3} + 2a = 3\overline{x}\right)$ |
| | $\Rightarrow \overline{x} = \frac{7}{9}a$ | A1 | Accept $0.778a$ or better |
| | | (6) | |
| **(b)** | $M$(pivot), $kMga = 3Mg\frac{a}{9}$ or<br>$M(A): 3M \times \frac{10a}{9} = (3+k)Ma$ or<br>$M(C): 3M \times \frac{8a}{9} + kM \times 2a = (3+k)Ma$ | M1 | Form equation in $k$<br>Condone $g$ omitted on both sides.<br>Must be using $\frac{10a}{9}$ (i.e. distances along *AD* (from *AB*))<br>If using position vectors they need to pick out the scalar equation. |
| | $kMga = 3Mg\frac{a}{9}$ | A1 | Correct unsimplified equation (with or without $g$) |
| | $k = \frac{1}{3}$ | A1 | Accept equivalent fractions or 0.333 or better |
| | | (3) | |
| | | **9** | |

| Question Number | Scheme | Marks | Notes |
|---|---|---|---|
| **3.** | $v=(2t-3)(t-2)=0$ | M1 | Solve for $v=0$ |
| | $t=\frac{3}{2}$ or $2$ | A1 | Both values |
| | | | The first two marks could be implied by the use of $2$ and $\frac{3}{2}$ as limits in the integration |
| | $\int 2t^2-7t+6\mathrm{d}t$ | M1 | Use of $s=\int v\mathrm{d}t$ |
| | $=\frac{2}{3}t^3-\frac{7}{2}t^2+6t\,(+C)$ | A1 | Correct integration |
| | $s=\int_0^{\frac{3}{2}} v\ \mathrm{d}t-\int_{\frac{3}{2}}^{2} v\ \mathrm{d}t+\int_2^3 v\ \mathrm{d}t$ | M1 | Correct strategy for distance. Accept equivalent e.g. $s=\int_0^3 v\ \mathrm{d}t+2\left\lvert\int_{\frac{3}{2}}^{2} v\ \mathrm{d}t\right\rvert$ |
| | $=\left[\frac{2}{3}t^3-\frac{7}{2}t^2+6t\right]_0^{\frac{3}{2}}$ $-\left[\frac{2}{3}t^3-\frac{7}{2}t^2+6t\right]_{\frac{3}{2}}^{2}$ $+\left[\frac{2}{3}t^3-\frac{7}{2}t^2+6t\right]_2^3$ | | $=\frac{27}{8}+\frac{1}{24}+\frac{7}{6}$ |
| | $=\frac{55}{12}$ | A1 | 4.6 or better from correct working |
| | | **6** | |

**NB Marks changed - 3rd M1 is shown as A1 on epen.**

| Question Number | Scheme | Marks | Notes |
|---|---|---|---|
| **4.(a)** | $(-6\mathbf{i}+8\mathbf{j})=0.2\left[\mathbf{v}-(20\mathbf{i}-16\mathbf{j})\right]$ | M1 | Impulse momentum equation<br>Condone subtraction in wrong order |
| | | A1 | Correctly substituted equation |
| | $\mathbf{v}=(-10\mathbf{i}+24\mathbf{j})$ | A1 | |
| | $\lvert\mathbf{v}\rvert=\sqrt{(-10)^2+24^2}$ | M1 | Correct use of Pythagoras theorem |
| | $=26\ \text{ms}^{-1}$ | A1 | From cwo |
| | | (5) | |
| **(b)** | $\tan\alpha=\frac{16}{20}\quad\tan\beta=\frac{24}{10}$ | M1 | Use trig to find two relevant angles |
| | $\alpha=38.7^o\quad\beta=67.4^o\quad(51.3°,\ 22.6°)$ | A1ft | Both correct - seen or implied<br>Follow their **v**<br>$(0.674$ or $0.897,\ 1.176$ or $0.395$ radians$)$ |
| | | DM1 | Dependent on previous M1<br>Combine correctly to find the required angle<br>e.g. $90°+38.7°+22.6°$ |
| | Angle is $151^o$ or $209^o$ | A1 | Accept $151.3°$ or $208.7°$<br>$(2.635$ or $3.648$ radians$)$ |
| | | (4) | |
| **Alt(b)** |  | | |
| | Correct triangle | M1 | |
| | Cosine rule: $\cos\theta=\dfrac{676+656-2500}{2\times26\times\sqrt{656}}$ | DM1 | Award marks in order on epen |
| | | A1ft | Correct unsimplified. Follow their **v** |
| | $\theta=151°$ | A1 | |
| | | (4) | |
| **Alt(b)** | Correct triangle | M1 | |
| | Scalar product: $\cos\theta=\dfrac{-200-384}{26\times\sqrt{656}}$ | DM1 | Award marks in order on epen |
| | | A1ft | Correct unsimplified. Follow their **v** |
| | $\theta=151°$ | A1 | |
| | | (4) | |
| | | **9** | |

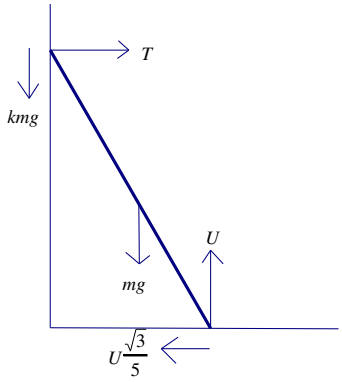
| Question Number | Scheme | Marks | Notes |
|---|---|---|---|
| **5(a)** | CLM: $-2mv + 4.5mv = 2mu_P - 3mu_Q$ | M1 | Need all four terms & dimensionally correct.<br>Condone sign errors. |
| | $\left(2.5v = 2u_P - 3v_Q\right)$ | A1 | Correct unsimplified equation |
| | Impact law: $\dfrac{1.5v + v}{u_P + u_Q} = \dfrac{1}{5}$ | M1 | Must be used right way round.<br>Accept with $e$ not substituted. |
| | $\left(12.5v = u_P + u_Q\right)$ | A1ft | Correct unsimplified equation.<br>Signs consistent with their CLM equation |
| | Solve for $u_P$ and $u_Q$ | DM1 | Dependent on both previous M marks |
| | | A1 | One correct |
| | $u_P = 8v$ and $u_Q = 4.5v$ | A1 | Both correct – from cwo<br>Mark final answer – do not ISW |
| | | (7) | |
| **(b)** | After impact with wall: $1.5ve$ | B1 | |
| | For Q to catch P: $1.5ve > v$ | M1 | Correct inequality for their $1.5ve$ (could be implied by correct answer) |
| | $1 \geq e > \dfrac{2}{3}$ | A1 | Need both ends |
| | | (3) | |
| | | **10** | |

Solutions that have velocity of $P$ and/or $Q$ in wrong direction before or after the collision score max 5/7 in (a).

| Question Number | Scheme | Marks | Notes |
|---|---|---|---|
| **6.** | W.D against $R$: $0.025R$ | B1 | Seen or implied |
| | W.D. against $R$ = KE Loss + PE Loss | M1 | Work-energy equation<br>NB Q asks for work-energy.<br>Need all relevant terms and no extras.<br>Follow their WD<br>Condone 2.5 for 0.025<br>1.5 for 1.525 is M0 - this is equivalent to leaving out a term in the work-energy equation. |
| | $0.025R = \frac{1}{2}\times 0.6\times 22.4^2 + 0.6g\times(1.5+0.025)$ | A1 | At most one error<br>Use of 2.5 for 0.025 is one error |
| | | A1 | Correct unsimplified. Follow their WD |
| | $R = 6380$ N | A1 | Q asks for 3 s.f. - do not accept 6400 |
| | | **5** | |
| | | | Values you might see:<br>KE $= 150.528(\text{J})$<br>Distance to top $= 25.6(\text{m})$<br>Top to ground $= 27.1(\text{m})$<br>Total distance from top $= 27.125(\text{m})$<br>$v^2$ at ground $= 531.16$<br>Change in GPE from top to stop $= 159.495(\text{J})$ |

NB The Q asks for work-energy. Full marks can be scored for a solution which eventually uses work-energy. A candidate who does additional work with *suvat* equations scores no marks until they form a work-energy equation.
NB If working from the max height to the lowest point then the work-energy equation need not show the zero value for KE. Non-zero KE in this instance is M0 for an additional term.

| WD | $h$ | Marks | |
|---|---|---|---|
| $0.025R$ | $1.5+2.5$ | B1M1A1A0A0 | One error 3/5 |
| $0.25R$ | $1.5+0.025$ | B0M1A1A1A0 | One error 3/5 |
| $0.25R$ | $1.5+2.5$ | B0M1A1A0A0 | Two errors 2/5 |

| Question Number | Scheme | Marks | Notes |
|---|---|---|---|
| **7(a)** | $M(A)\quad S.2a\cos 30^\circ = mga\sin 30^\circ$ | M1 | Correct number of terms.<br>Terms must be dimensionally correct<br>Condone trig confusion |
| | | A1 | At most one error<br>Consistent trig confusion is one error |
| | | A1 | Correct unsimplified equation |
| | $S = \dfrac{mg\sqrt{3}}{6}$ | A1<br><br>(4) | Accept exact equivalent<br>Accept $0.289mg$ or better |
| **(b)** | $R = mg\ ;\quad F = S$ | B1 | Resolve vertically and horizontally - must be stated or shown on a diagram. (Used here if seen in (a)) |
| | $\dfrac{mg\sqrt{3}}{6} \le \mu mg$ | M1 | Use of $F \le \mu R$ (not for $F = \mu R$ followed by a fudge of the inequality) |
| | $\dfrac{\sqrt{3}}{6} \le \mu$ | A1<br><br>(3) | ***Answer Given*** CSO |
| **(c)** |  | | |
| | $\updownarrow : U = mg + kmg = mg(1+k)$ | B1 | Or equation in $U$ and $k$ from a second moments equation. |
| | M($A$): $T \times 2a \times \dfrac{\sqrt{3}}{2} = mga \times \dfrac{1}{2} + kmg\,2a \times \dfrac{1}{2}$<br>M($B$): $mg \times \dfrac{a}{2} + \dfrac{U\sqrt{3}}{5} \times \sqrt{3}a = Ua$<br>M($X$): $kmga + mg \times \dfrac{a}{2} = \dfrac{U\sqrt{3}}{5} \times \sqrt{3}a$<br>M(corner): $aU = Ta\sqrt{3} + mg\dfrac{a}{2}$ | M1 | Need all three terms. Condone $\mu = \dfrac{\sqrt{3}}{6}$<br>Terms must be dimensionally correct.<br>Condone trig confusion.<br>Condone sign errors<br><br>($X$ is point of intersection of lines of action of $T$ and $U$) |
| | $\Rightarrow 2T\cos 30° = mg\sin 30° + 2kmg\sin 30°$ | A1 | Correct unsimplified moments equation |
| | $\Rightarrow \dfrac{3}{5}U = \dfrac{1}{2}mg + kmg$ | A1 | Correct equation in $U$ (and $k$)<br>$\mu$ correct if used |
| | $\Rightarrow \dfrac{3}{5}(1+k) = \dfrac{1}{2} + k$ | DM1 | Solve for $k$. Dependent on preceding M |
| | $k = \dfrac{1}{4}$ | A1<br>(6) | |
| | | **13** | |

| Question Number | Scheme | Marks | Notes |
|---|---|---|---|
| **8(a)** | Vertical motion : Use of $v = u + at$ | M1 | Correct equation in $U$, $t$ |
| | $(\uparrow)$: $-U = U - gt$ | A1 | |
| | Horizontal motion: Use of $s = ut$ | M1 | Second equation in $U$ and their $t$<br>e.g. $\frac{U^2}{2g} = U \times \frac{20}{U} - \frac{g}{2}\left(\frac{20}{U}\right)^2$ |
| | $(\rightarrow)$: $3Ut = 120$ | A1ft | Follow their $t$ provided it matches the value of $s$ used. |
| | $\Rightarrow U = 14$ | A1 | ***Answer Given***<br>Need to see supporting evidence e.g. correct linear equation or solution of quadratic in $U^2$ giving $U^2 = 20g$ |
| | | (5) | |
| **(b)** | $v = \sqrt{U^2 + (3U)^2}$ | M1 | Correct use of Pythagoras' theorem and $U = 14$ |
| | $v = 14\sqrt{10} = 44$ or 44.3 m s$^{-1}$ | A1 | Max 3 s.f. |
| | | (2) | |
| **(c)** | $\tan\alpha = \frac{1}{4} \Rightarrow \frac{V}{3U} = \frac{1}{4}$ | M1 | Use angle to find vertical component |
| | $\Rightarrow V = \frac{3}{4}U$ | A1 | $\left(10.5\ \left(\text{m s}^{-1}\right)\right)$ |
| | Use of $v = u + at$ $(\uparrow)$: $\pm\frac{3}{4}U = U - gt$ | M1 | Condone without $\pm$<br>Accept complete alternative routes via suvat. |
| | | A1 | Correct unsimplified (including $\pm$ ) |
| | $t_1 = \frac{U}{4g} = 0.36\text{s}$ , $t_2 = \frac{7U}{4g} = 2.5\text{s}$ | A1 | One value correct<br>Accept $\frac{7}{2g}$ and $\frac{49}{2g}$, but not $\frac{5}{14}$<br>decimals to max 3 s.f. |
| | | A1 | Both values correct<br>Apply accuracy penalty only once |
| | | (6) | |
| | | **13** | |

NB a candidate who misreads horizontal and vertical components gets $t = 4.64\left(\frac{13u}{4g}\right)$ and $t = 3.93\left(\frac{11u}{4g}\right)$.

They can score 11/13. Deduct the first 2 A marks for the misread penalty.

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