Mark Scheme (Results)

Summer 2022

Pearson Edexcel GCE
In Mathematics (9MA0)
Paper 31 Statistics

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications are awarded by Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk. Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk

Summer 2022
Question Paper Log Number P72130A_*
Publications Code 9MA0_31_2206_MS*

- 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.

EDEXCEL GCE MATHEMATICS
General Instructions for Marking

1. The total number of marks for the paper is 50.

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

- **M** marks: method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
- **A** marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
- **B** marks are unconditional accuracy marks (independent of M marks)
- Marks should not be subdivided.

3. 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. 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.

5. Where a candidate has made multiple responses and indicates which response they wish to submit, examiners should mark this response.
   If there are several attempts at a question which have not been crossed out, examiners should mark the final answer which is the answer that is the most complete.

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

7. Mark schemes will firstly show the solution judged to be the most common response expected from candidates. Where appropriate, alternatives answers are provided in the notes. If examiners are not sure if an answer is acceptable, they will check the mark scheme to see if an alternative answer is given for the method used.

Question	Scheme		Marks	AOs
1(a)(i)	$X \sim \text{B}(15, 0.48)$		M1	3.3
	$\text{P}(X = 3) = 0.019668...$ awrt 0.0197		A1	3.4
(ii)	$\left[\text{P}(X \geqslant 5) = 1 \quad \text{P}(X \leqslant 4)\right]$ 0.92013... awrt 0.920		A1	1.1b
			(3)	
(b)	Y is the number of hits	M is the number of misses		
	$Y \sim \text{N}(120, 62.4)$	$M \sim \text{N}(130, 62.4)$	B1	3.3
	$\text{P}(X > 110) \approx \text{P}(Y > 110.5)$ $\left[= \text{P}\left(Z > \frac{110.5 - "120"}{\sqrt{"62.4"}}\right)\right]$	$\text{P}(X > 110) \approx \text{P}(M < 139.5)$ $\left[= \text{P}\left(Z < \frac{139.5 - "130"}{\sqrt{"62.4"}}\right)\right]$	M1	3.4
	= 0.88544…		A1	1.1b
			(3)	
				(6 marks)

Notes:

(a)	**M1**	Writing or using the binomial distribution in (i) or (ii) Allow for sight of B(15, 0.48) or in words: binomial with $n = 15$ and $p = 0.48$ may be implied in (i) or (ii) by one correct answer to 3sf or sight of $\text{P}(X \leqslant 4) = 0.07986…$ i.e. awrt 0.0799. Allow for ${}^{15}C_3 \times 0.48^3 \times 0.52^{12}$ as this is "correct use" Condone B(0.48, 15)
(i)	**A1**	awrt 0.0197
(ii)	**A1**	awrt 0.920 (Allow 0.92)
(b)	**B1**	Setting up a correct Normal model**.** Allow sight of $\text{N}(120, 62.4)$ or $\text{N}(130, 62.4)$ or $\text{N}\left(120, \frac{312}{5}\right)$ or $\text{N}\left(130, \frac{312}{5}\right)$ or may be awarded if used correctly in standardisation or in words: Normal with mean = 120/130 and variance = 62.4 or sd = $\sqrt{62.4}$ condone $\text{N}\left(120, \sqrt{62.4}\right)$ or $\text{N}\left(130, \sqrt{62.4}\right)$ or sd = 62.4 Look out for $\sigma = \frac{\sqrt{1560}}{5}$ or $\frac{2\sqrt{390}}{5}$ or awrt 7.90 (condone 7.9) This may be implied by sight of 0.897 or 0.8854…
	M1	Sight of the continuity correction with a normal distribution **110.5** or 111.5 or 109.5 — **139.5** or 140.5 or 138.5 NB we will also allow **129.5** or 130.5 or 128.5 — NB we will also allow **120.5** or 119.5 or 121.5 Continuity correction may be seen in standardisation NB No continuity correction(CC) gives awrt 0.897 which is M0 unless CC seen
	A1	awrt 0.8854 or awrt 0.885 dependent on sight of >110.5 or <129.5 or < 139.5 or >120.5 Allow $\leqslant$ or $\geqslant$ instead of < or > NB 0.885548… from B(250, 0.48) scores M0A0

Qu	Scheme	Marks	AOs
2(a)	$\left[\mathrm{P}\left(L<7.902\right)=0.025\Rightarrow\right]\dfrac{7.902-8}{x}=-1.96$ oe	M1	3.4
	$\left[x=\right]0.05$*	A1cso*	1.1b
	SC B1(mark as M0A1) for $\dfrac{7.902-8}{0.05}=$ ~~1.96~~ 0.024998		
		(2)	
(b)	$\mathrm{P}\left(7.94\leqslant L\leqslant 8.09\right)=0.8490\ldots$ **awrt 0.849**	B1	1.1b
		(1)	
(c)	$[\mathrm{P}\left(L<7.94\right)=]$ 0.115069...(awrt 0.115) **or** $[\mathrm{P}\left(L>8.09\right)=]$ 0.03593...(awrt 0.036)	B1	1.1b
	$[\mathrm{P}\left(L<7.94\right)=]$ 0.115069...(awrt 0.115) **&** $[\mathrm{P}\left(L>8.09\right)=]$ 0.03593...(awrt 0.036)	B1	1.1b
	Expected income per 500 rods = $\sum\left(\text{Income}\times\text{probability}\times 500\right)$ $\left(500\times\text{"0.849"}\times 0.5\right)+\left(500\times\text{"0.1150..."}\times 0.05\right)+\left(500\times\text{"0.03593..."}\times 0.4\right)$ **or** Expected profit per rod = $\sum\left(\text{Profit}\times\text{probability}\right)$ $0.30\times\text{"0.849"}+-0.15\times\text{"0.1150..."}+0.20\times\text{"0.03593..."}$ **[**= 0.2446..]	M1	3.4
	Expected profit per 500 rods $500\times\sum\left(\text{Profit}\times\text{probability}\right)$ **or** $\sum\left(\text{Income}\times\text{probability}\times 500\right)-500\times 0.2$ $=500\times\text{"0.2446..."}$ **or** $=\text{"222.3"}-500\times 0.2$	M1d	3.1b
	= [£]122.3… **awrt [£]122**	A1	1.1b
		(5)	
(d)	Let $X\sim\mathrm{B}(200,0.015)$	M1	3.3
	$\mathrm{P}(X\leqslant 5)=$ 0.9176… / $\mathrm{P}\left(X\geqslant 6\right)=$ 0.0824	M1	1.1b
	0.9176… / 0.0824	A1	1.1b
	Manufacturer is unlikely to achieve their aim since $\underline{0.9176<0.95}$ / Manufacturer is unlikely to achieve their aim since $\underline{0.0824>0.05}$	A1ft	2.4
		(4)	

Notes: **(12 marks)**

(a)	**M1**	Using the normal distribution to set up equation. Allow σ for x and awrt ± 1.96
	A1*	cso For a correct expression for x followed by 0.05 or 0.05000… No incorrect working seen
(b)	**B1**	awrt 0.849
(c)	**B1**	awrt 0.115 (Implied by awrt 57.5 for number of rods) **or** awrt 0.036 (Implied by awrt 18 for number of rods)
	B1	awrt 0.115 (Implied by awrt 57.5 for number of rods) **and** awrt 0.036 (Implied by awrt 18 for number of rods)
	M1	Correct method to find the total income of 500 rods. Attempt at all 3 with at least two correct and no extras **or** Correct method to find sum of all three profits with at least two of 30, −15 or 20 correct. May work in pence but need to be consistent. Allow awrt 24.5 or 0.245
	M1d	Dep on previous method for finding profit for 500 rods. May work in pence but need to be consistent. Allow $\text{"0.2446..."}\times 500$ or "their income" for 500 rods -500×0.2 (accept 499 or 501)
	A1	All previous marks must be awarded for awrt 122 awrt 12200p **NB** if uses any integer values for numbers of rods then it is A0 other than for 18 for $L>8.09$
(d)	**M1**	Selecting the appropriate model. May be seen or used. Allow B(200,0.985) or Po(3) Condone B(0.015, 200) or B(0.985, 200).
	M1	Writing or using $\mathrm{P}\left(X\leqslant 5\right)$ Do not accept $\mathrm{P}\left(X<6\right)$ unless found $\mathrm{P}\left(X\leqslant 5\right)$ / Writing or using $\mathrm{P}\left(X\geqslant 6\right)$ Do not accept $\mathrm{P}\left(X>5\right)$ unless found $\mathrm{P}\left(X\geqslant 6\right)$
	A1	0.92 (Poisson 0.916…) / 0.08 or better
	A1ft	Need at least one of the method marks to be awarded. Correct conclusion with the comparison (may be in words). Ft "their $p=0.9176\ldots$" as long as $p>0.9$ If "their 0.9176…"< 0.95 must … be unlikely… If "their 0.9176…"> 0.95 they must say … be likely... To ft the alternative then $p<0.1$

Question	Scheme	Marks	AOs
3(a)	tr	B1	1.2
		(1)	
(b)(i)	$\mu = \frac{174.9}{31} = 5.6419\ldots$ awrt 5.64	B1	1.1b
(ii)	$\sigma_r = \sqrt{\frac{3523.283}{31} - \mu^2}$	M1	1.1b
	$= 9.04559\ldots$ awrt 9.05	A1	1.1b
		(3)	
(c)	Leuchars is in the North and Camborne is in the South	M1	2.4
	The mean is smaller for Leuchars than Camborne therefore there is no evidence that Dian's belief is true	A1ft	2.2b
		(2)	
(d)	eg $p = 0.27$ is unlikely to be constant.	B1	2.4
		(1)	
			(7 marks)

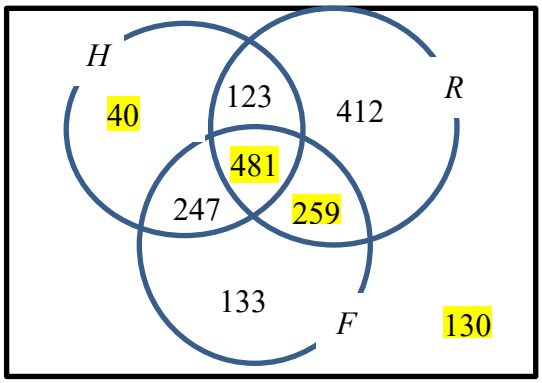
Notes:

(a)	**B1**	Allow Tr or trace or Trace
(b)(i)	**B1**	For a correct mean awrt 5.64
(ii)	**M1**	For a correct expression for sd including the $\sqrt{}$ Ft their mean
	A1	awrt 9.05 (Allow $s = 9.1932\ldots$ awrt 9.19) NB awrt to 9.05 or 9.19 with no working is M1 A1
(c)	**M1**	For stating Leuchars is North of Camborne oe eg Camborne is further south
	A1ft	M1 must be awarded. A correct conclusion **and** correct comment about the means ft their mean in (b) Allow No
	SC	for No **and** there are only 2 places used so there is insufficient data. Mark as M0A1 on epen
(d)	**B1**	A correct reason referring to • independence (needs context as to what is independent) eg consecutive 14 days unlikely to be independent. • probability [of rain] not being constant. • Allow a comment that conveys the idea that the proportion of days with no rain will be different over the year.

Question	Scheme	Marks	AOs
4(a)	$H_0: p = 0.1$ $H_1: p \neq 0.1$	B1	2.5
		(1)	
(b)	Use of $X \sim B(50, 0.1)$ implied by sight of one of awrt 0.0052 or awrt 0.9755 or awrt 0.0245	M1	3.4
	Critical regions $X = 0$ or $X \geqslant 10$	A1	1.1b
	$X = 0$ and $X \geqslant 10$ plus $P(X = 0) =$ awrt 0.0052 and $P(X \geqslant 10) =$ awrt 0.0245	A1	1.1b
	SC: Both CR correct with no probabilities and no distribution seen scores M0A1A0		
		(3)	
(c)	0.0297	B1ft	1.1b
		(1)	
(d)	15 is <u>in the critical region</u> therefore there is evidence to support the **<u>manager</u>**'s belief	B1ft	2.2b
		(1)	
			(6 marks)

Notes

(a)	**B1**	For both hypotheses in terms of p or π. Connected to H_0 and H_1 correctly Condone 10% but not 10
(b)	**M1**	Using correct distribution to find the probability associated with one tail of the CR If the correct distribution is <u>stated</u> (may be seen in part(a)) allow for one tail of the correct CR **or** one of (awrt 0.025 or awrt 0.005 or awrt 0.975) seen connected to a correct probability statement
	A1	Lower CR $X = 0$ / $X < 1$ / $X \leqslant 0$ / [condone eg $P(X = 0)$ labelled as CR] Or Upper CR $X \geqslant 10$ or $X > 9$ [condone $P(X \geqslant 10)$ oe labelled as CR]
	A1	Both CR's correct with the relevant probabilities Allow $\cup$ for "and" and $X > 9$, $X < 1$, $X \leqslant 0$ [**do not allow** $P(X = 0)$ or $P(X \geqslant 10)$ oe] Allow CR in different form eg $(9, \infty)$, $[10, \infty)$
(c)	**B1ft**	awrt 0.0297 or 2.97% or ft for the sum of the probabilities in (b) for "their 2 critical regions" if seen. If none seen it must be awrt 0.0297 **SC M0 in (b) for a one tail test** Allow B1ft for their one tail CR in (b) eg 0.0338 or 0.0245 or 0.0579
(d)	**B1ft**	A correct statement about 15 and "their CR" or sight $P(X \geqslant 15) = 0.0000738...$ and comparison with "their 0.0245" **and** a compatible correct statement in context. eg There is evidence that there has been a change in the **<u>proportion/probability</u>** arriving **<u>late</u>** Condone increase rather than change Do not allow contradicting statements. NB No CR given in (b) then B0

Question	Scheme	Marks	AOs
5(a)	$\frac{365}{1825}$ or $\frac{1}{5}$ or 0.2 oe	B1	1.1b
		(1)	
(b)	$\frac{170}{1825}$ or $\frac{34}{365}$ or awrt 0.093	B1	1.1b
		(1)	
(c)	$90\times0.4+80\times0.05[=40]$ or $90\times0.6+80\times0.95[=130]$ or $740\times0.65[=481]$ or $740\times0.35[=259]$ 	M1 B1 B1 A1	3.1b 1.1b 1.1b 1.1b
		(4)	
(d)	$P(R'\cap F)=\frac{380}{1825}\left[=\frac{76}{365}=0.208...\right]$ oe awrt 0.208	B1	1.1b
		(1)	
(e)	$\left[\frac{133\ +\ "130"}{1825}=\right]\frac{"263"}{1825}$ awrt 0.144	B1ft	1.1b
		(1)	
(f)	$\frac{247+"481"}{247+"481"+123+"40"}$	M1	3.4
	$=\frac{728}{891}$ awrt 0.817	A1	1.1b
		(2)	

Notes: **(10 marks)**

		Look out for answers given in the question. If you see answers in the question and in the answer space those in the answer space take precedence.
(a)	**B1**	Allow equivalent
(b)	**B1**	Allow equivalent
(c)	**M1**	Correct method to find one of the values 40 or 130 or 481or 259 Implied by 40, 481, 259 or130 seen in correct place on diagram
	B1	One of the highlighted correct
	B1	A second value highlighted correct or their $("259"+"\ 481")=740$ or their $("40"+"\ 481")=521$ or their $("40"+"130")=170$
	A1	Fully correct
(d)	**B1**	380/1825oe or awrt 0.208
(e)	**B1ft**	Correct answer or Ft their 130 (> 0) do not allow if blank Allow ft correct to 3 sf.
(f)	**M1**	For a single fraction with the numerator < denominator and *n* is an integer we will award for *n*/ 891 **or** *n*/(sum of their 4 values in *H*, each > 0) or awrt 0.817
	A1	728/891 oe or awrt 0.817

Question	Scheme		Marks	AOs
6(a)	eg As the number of minutes exercise (m) increases the resting heart rate (h) decreases **or** the gradient of the curve is becoming flatter with increasing m: diminishing effect of each additional minute of exercise		B1	2.4
			(1)	
(b)	$H_0 : \rho = 0$ $H_1 : \rho < 0$		B1	2.5
	Critical value – 0.3887 (Allow $\pm$)		M1	1.1b
	There is evidence that the product moment **correlation** is **less than 0/ there is a negative correlation**		A1	2.2b
			(3)	
(c)	$\log_{10} h = 0.05 \log_{10} m + 1.92$	$h = am^k \rightarrow \log_{10} h = \log_{10} am^k$	M1	1.1b
	$\log_{10} h = \log_{10} m^{0.05} + 1.92$ or $\log_{10} h = \log_{10} m^{-0.05} + 1.92$ or $h = 10^{1.92 - 0.05 \log_{10} m}$ oe	$\log_{10} h = \log_{10} a + \log_{10} m^k$ or $\log_{10} a = 1.92$	M1	2.1
	$\log_{10} hm^{0.05} = 1.92$ or $\log_{10}\left(\frac{h}{m^{-0.05}}\right) = 1.92$ or $h = 10^{1.92} \times 10^{-0.05 \log_{10} m}$ oe	$\log_{10} h = \log_{10} a + k \log_{10} m$	M1	1.1b
	$hm^{0.05} = 10^{1.92}$ or $\frac{h}{m^{-0.05}} = 10^{1.92}$ or $h = 10^{1.92} \times 10^{\log_{10} m^{-0.05}}$	$\log_{10} a = 1.92$ and $k = -0.05$	M1	1.1b
	$h = 10^{1.92} m^{-0.05}$ or $h = 83.17...m^{-0.05}$ or a = awrt 83.17 **and** $k = -0.05$		A1	1.1b
			(5)	

Notes: **(9 marks)**

(a)	**B1**	eg Idea as one increases the other decreases (in context). Allow use of m and h eg As m increases h decreases. Do not allow negative correlation with no context or $\rho < 0$ Allow there is a negative correlation/association/relationship/exponential between minutes exercise(m) and resting heart rate (h) oe
(b)	**B1**	Both hypotheses correct in terms of ρ (allow p)
	M1	For the cv of -0.3887 or any cv such that $0.3 < \|cv\| < 0.5$
	A1	Independent of hypotheses. Correct conclusion that implies reject H_0 on basis of seeing – 0.3887 or if they give 0.3887 we must see the comparison $0.3887 < 0.897$ **and** which mentions "pmcc/correlation/relationship" and less than 0/ negative or $\rho < 0$ A contradictory statement scores A0 eg Accept H_0 therefore negative correlation
(c)		**In this part once M0 is scored no more marks can be scored. Condone no base**
	M1	**May be implied by 2nd M1 mark** Method 1: Correct substitution for both x and y Method 2 : Taking the log of both sides
	M1	**May be implied by 3rd M1 mark** Method 1: Correct use of the power log rule **or** making h the subject Method 2 : Correct use of the addition/subtraction log rule
	M1	**This line implies M1M1M1** Method 1: Correct use of the addition/subtraction log rule or eq^n in the form $h = 10^{1.92} \times 10^{-0.05 \log m}$ Method 2: A second correct step for correct use of the power log rule
	M1	**This line implies M1M1M1M1** Method 1: Correct removal of logs or $h = 10^{1.92} \times 10^{\log m^{-0.05}}$ Method 2: Log a (or a) and k correct
	A1	Allow h = awrt $83.2m^{-0.05}$ NB award 5/5 for a = awrt 83.2 and $k = -0.05$ or h = awrt $83.2...m^{-0.05}$ or $h = 10^{1.92} m^{-0.05}$

Pearson Education Limited. Registered company number 872828
with its registered office at 80 Strand, London, WC2R 0RL, United Kingdom

Mark Scheme (Results)

Summer 2022

Pearson Edexcel GCE
In Mathematics (9MA0)
Paper 32 Mechanics

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications are awarded by Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk. Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk

Summer 2022
Question Paper Log Number P72131A*
Publications Code 9MA0_32_2206_MS*

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.

EDEXCEL GCE MATHEMATICS
General Instructions for Marking

1. The total number of marks for the paper is 50.

2. The Edexcel Mathematics mark schemes use the following types of marks:
   - **M** marks: method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
   - **A** marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
   - **B** marks are unconditional accuracy marks (independent of M marks)
   - Marks should not be subdivided.

3. 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
- $\sqsubset$ The second mark is dependent on gaining the first mark

4. 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.

5. Where a candidate has made multiple responses and indicates which response they wish to submit, examiners should mark this response.
   If there are several attempts at a question which have not been crossed out, examiners should mark the final answer which is the answer that is the most complete.
6. Ignore wrong working or incorrect statements following a correct answer.

7. Mark schemes will firstly show the solution judged to be the most common response expected from candidates. Where appropriate, alternatives answers are provided in the notes. If examiners are not sure if an answer is acceptable, they will check the mark scheme to see if an alternative answer is given for the method used.

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	Scheme	Marks	AOs
1(a)	Put $t = 2$ in **v** and use Pythagoras: $\sqrt{12^2 + (-6\sqrt{2})^2}$	M1	3.1a
	$\sqrt{216}, 6\sqrt{6}$ or 15 or better (m s^{-1})	A1	1.1b
		(2)	
1(b)	Differentiate **v** wrt t to obtain **a**	M1	3.4
	$6t\mathbf{i} - 3t^{-\frac{1}{2}}\mathbf{j}$ oe (m s^{-2}) isw	A1	1.1b
		(2)	
1(c)	Integrate **v** wrt t to obtain **r**	M1	3.4
	$\mathbf{r} = t^3\mathbf{i} - 4t^{\frac{3}{2}}\mathbf{j}\ (+\mathbf{C})$	A1	1.1b
	$(\mathbf{i} - 4\mathbf{j}) = 4^3\mathbf{i} - 4\times 4^{\frac{3}{2}}\mathbf{j} + \mathbf{C}$	M1	3.1a
	$(-62\mathbf{i} + 24\mathbf{j})$ (m) isw e.g. if they go on to find the distance.	A1	1.1b
		(4)	
			(8 marks)

Notes: Accept column vectors throughout apart from the answer to (b).

1a	M1	Need square root but -ve sign not required. Allow **i**'s and/or **j**'s to go missing from their **v** at $t = 2$, provided they have applied Pythagoras correctly.
	A1	cao **N.B**. Correct answer with no working can score 2 marks.
1b	M1	Both powers decreasing by 1. Allow a column vector. M0 if **i** or **j** is missing but allow recovery in (b).
	A1	cao. Do not accept a column vector.
1c	M1	Both powers increasing by 1 M0 if **i** or **j** is missing but allow recovery.
	A1	(**r** =) not required
	M1	Putting **r** = $(\mathbf{i} - 4\mathbf{j})$ and $t = 4$ into their displacement **vector** expression which must have **C** (allow *C*) to give an equation in **C** only, seen or implied. Must have attempted to integrate **v** for this mark to be available. **N.B**. **C** does not need to be found and this is a method mark, so allow slips.
	A1	cao

Question	Scheme	Marks	AOs
2(a)(i)	Resolve vertically	M1	3.1b
	F acting UP the plane: **OR** F acting DOWN the plane: $(\uparrow) F\sin\alpha + 68.6\cos\alpha = 5g$ $\quad -F\sin\alpha + 68.6\cos\alpha = 5g$ Other possible equations from which X would need to be eliminated to give an equation in F **only** to earn the M mark are shown below. The equation in F **only** must then be correct to earn the A mark. Possible equations: $(\nwarrow) 68.6 = X\sin\alpha + 5g\cos\alpha$ (leads to $X = 49$ with $g = 9.8$) F acting UP the plane: **OR** F acting DOWN the plane: $(\nearrow) F + X\cos\alpha = 5g\sin\alpha$ $\quad -F + X\cos\alpha = 5g\sin\alpha$ $(\rightarrow) F\cos\alpha + X = 68.6\sin\alpha$ $\quad -F\cos\alpha + X = 68.6\sin\alpha$	A1	1.1b
	9.8 (N) (49/5 is A0) **N.B.** If sin and cos are interchanged in all equations, this leads to an answer of 9.8 in the wrong direction and can only score (a) (i)M1A0A0 (ii) A0	A1	1.1b
		(3)	
2(a)(ii)	Down the plane (Allow down or downwards or an arrow ↙, but must appear as the answer to (a) (ii) not just on the diagram.)	A1	2.2a
		(1)	
2(b)	**N.B.** If they use $R = 68.6$ in this part, the maximum they can score is M1A1M0A0M0A0 If they use $F = 9.8$ or their F from (a) in this part, the maximum they can score is M1A1M0A0M0A0		
	Equation of motion down the plane	M1	2.1
	$5g\sin\alpha - F = 5a$ Allow $(-a)$ instead of a	A1	1.1b
	Resolve perpendicular to the plane	M1	3.1b
	$R = 5g\cos\alpha$	A1	1.1b
	$F = 0.5R$ seen	M1	3.4
	$a = 1.96$ or 2.0 or 2 (m s^{-2}) or $\frac{1}{5}g$	A1	1.1b
		(6)	
			(10 marks)

Notes:		
2a (i)	M1	Complete method to obtain an equation in F **only.** For **each** equation used, correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved.
	A1	Correct equation in F only, trig does **not** need to be substituted
	A1	cao (must be **positive**)
2a (ii)	A1	cao. Note that this mark is **dependen**t on an answer of 9.8 or -9.8 for (a)(i) from a fully correct solution unless they have used $g = 9.81$, in which case the answer will be 9.7 or – 9.7 (2sf) see **SC2** below. **N.B.** Allow this mark, if their answer to (a)(i) is fully correct apart from a small error due to use of inaccurate trig i.e using an angle 36.9^o
		SC 1: If they use μR at any point (with an unknown μ) for F in part (a), can score (a)(i) max M1A1A0 (a) (ii) A1, where they must have obtained $\mu R = 9.8$ or – 9.8, **from correct working**. **SC 2:** **If $g = 9.81$ is used consistently throughout 2(a)**, (leading to $X = 48.9\ldots$and $F = 9.7$ (2sf)) can score max (a)(i) M1A1A0 (a)(ii) A1
2b	M1	Correct no.of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved.
	A1	Correct equation **for their *F***.
	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved. (**N.B.** M0 if $R = 68.6$ (N) is used in this equation)
	A1	Correct equation
	M1	Could be seen on a diagram (**N.B**. M0 if $R = 68.6$ (N) is used)
	A1	Cao. **Must be positive**.

Question	Scheme	Marks	AOs
3(a)	$(4\mathbf{i}-\mathbf{j})+(\lambda\mathbf{i}+\mu\mathbf{j})=(4+\lambda)\mathbf{i}+(-1+\mu)\mathbf{j}$	M1	3.4
	Use **ratios** to obtain an equation in λ and μ *only*	M1	2.1
	$\dfrac{(4+\lambda)}{(-1+\mu)}=\dfrac{3}{1}$ or $\dfrac{\frac{1}{4}(4+\lambda)}{\frac{1}{4}(-1+\mu)}=\dfrac{3}{1}$	A1	1.1b
	$\lambda-3\mu+7=0$ * Allow $0=\lambda-3\mu+7$ but nothing else.	A1*	1.1b
		(4)	
(b)	$\lambda=2 \Rightarrow \mu=3$; Resultant force $=(6\mathbf{i}+2\mathbf{j})$ (N)	M1	3.1a
	$(6\mathbf{i}+2\mathbf{j})=4\mathbf{a}$ **OR** $\lvert(6\mathbf{i}+2\mathbf{j})\rvert=4a$	M1	1.1b
	Use of $\mathbf{r}=\mathbf{u}t+\frac{1}{2}\mathbf{a}t^2$ with **u** = **0**, their **a** and $t=4$: **Or** they may integrate their **a** twice with **u** = **0** and put $t=4$: $\mathbf{r}=\frac{1}{2}\times\frac{(6\mathbf{i}+2\mathbf{j})}{4}4^2=(12\mathbf{i}+4\mathbf{j})$	DM1	2.1
	$\sqrt{12^2+4^2}$	M1	1.1b
	ALTERNATIVE 1 for last two M marks: Use of $s=ut+\frac{1}{2}at^2$, with $u=0$, their a and $t=4$: DM1 $s=\frac{1}{2}\times\sqrt{1.5^2+0.5^2}\times4^2$ Use of Pythagoras to find mag of **a** : $a=\sqrt{1.5^2+0.5^2}$ M1		
	ALTERNATIVE 2 for last two M marks: Use of $s=ut+\frac{1}{2}at^2$, with $u=0$, their a and $t=4$: DM1 $s=\frac{1}{2}\times\left(\frac{\sqrt{6^2+2^2}}{4}\right)\times4^2$ Use of Pythagoras to find $\lvert(6\mathbf{i}+2\mathbf{j})\rvert$: $=\sqrt{6^2+2^2}$ M1		
	$\sqrt{160}$, $2\sqrt{40}$, $4\sqrt{10}$ oe or 13 or better (m)	A1	1.1b
		(5)	
			(9 marks)

Notes: Accept column vectors throughout

3a	M1	Adding the two forces, **i**'s and **j**'s must be collected (or must be a **single** column vector) seen or implied
	M1	Must be using ratios; Ignore an equation e.g. $(4+\lambda)\mathbf{i}+(-1+\mu)\mathbf{j}=3\mathbf{i}+\mathbf{j}$ if they go on to use ratios.

		However, if they write $4+\lambda=3$ and $-1+\mu=1$ then $3(-1+\mu)=3$ so $4+\lambda=3(-1+\mu)$ with no use of a constant, it's M0 They may use the acceleration, with a factor of $\frac{1}{4}$ top and bottom, see alternative **Allow one side of the equation to be inverted**
	A1	Correct equation
	A1*	Given answer correctly obtained. Must see at least one line of working, with the LH fraction 'removed'**.**
3b	M1	Adding $\mathbf{F}_1$ and $\mathbf{F}_2$ to find the resultant force, λ and μ must be substituted **N.B.** M0 if they use $\mu=2$ coming from $-1+\mu=1$ in part (a).
	M1	Use of $\mathbf{F}=4\mathbf{a}$ Or $\lvert\mathbf{F}\rvert=4a$, where **F** is <u>their</u> resultant. (including $3\mathbf{i}+\mathbf{j}$) This is an independent mark, so could be earned, for example, if they have subtracted the forces to find the 'resultant' **N.B.** M0 if only using $\mathbf{F}_1$ or $\mathbf{F}_2$
	DM 1	Dependent on previous M mark for **Either**: use of $\mathbf{r}=\mathbf{u}t+\frac{1}{2}\mathbf{a}t^2$ with **u** = **0**, their **a** and $t=4$ to produce a displacement vector **Or** : integrate twice, with **u** = **0**, their **a** and $t=4$ to produce a displacement Vector **Or**: use of $s=ut+\frac{1}{2}at^2$ with $u=0$, their a and $t=4$ to produce a length
	M1	Use of Pythagoras, with square root, to find the magnitude of their displacement vector, **a** or **F (**M0 if only using $\mathbf{F}_1$ or $\mathbf{F}_2$) depending on which method they have used.
	A1	cao

Question	Scheme	Marks	AOs
4(a)	The horizontal component of T acts to the left and since the **only** other horizontal force is friction, it must act to the right oe	B1	2.4
		(1)	
4(b)	Take moments about A or any other complete method to obtain **an equation in T, M and θ only.** (see possible equations below that they may use)	M1	3.1b
	$T.2a = Mga\cos\theta + 2Mg \times 1.5a\cos\theta$ (A0 if a's missing)	A1	1.1b
	Other possible equations but F and R would need to be eliminated. $(\nwarrow), R\cos\theta + T = F\sin\theta + Mg\cos\theta + 2Mg\cos\theta$ $(\nearrow), R\sin\theta + F\cos\theta = Mg\sin\theta + 2Mg\sin\theta$ $(\rightarrow),\ F = T\sin\theta$ M(B), $R.2a\cos\theta = Mga\cos\theta + 2Mg \times 0.5a\cos\theta + F.2a\sin\theta$ M(G), $Fa\sin\theta + Ta = Ra\cos\theta + 2Mg \times 0.5a\cos\theta$ M(C), $R \times 1.5a\cos\theta = T \times 0.5a + Mg \times 0.5a\cos\theta + F \times 1.5a\sin\theta$		
	$T = 2Mg\cos\theta$ *	A1*	1.1b
		(3)	
4(c)	e.g. Resolve vertically	M1	3.4
	$(\uparrow), R + T\cos\theta = Mg + 2Mg$	A1	1.1b
	$R = \frac{57Mg}{25}$ *	A1*	1.1b
		(3)	
	Other possible equations but F would need to be eliminated. $(\nwarrow), R\cos\theta + T = F\sin\theta + Mg\cos\theta + 2Mg\cos\theta$ $(\nearrow), R\sin\theta + F\cos\theta = Mg\sin\theta + 2Mg\sin\theta$ $(\rightarrow),\ F = T\sin\theta$ M(B), $R.2a\cos\theta = Mga\cos\theta + 2Mg \times 0.5a\cos\theta + F.2a\sin\theta$ M(G), $Fa\sin\theta + Ta = Ra\cos\theta + 2Mg \times 0.5a\cos\theta$ M(C), $R \times 1.5a\cos\theta = T \times 0.5a + Mg \times 0.5a\cos\theta + F \times 1.5a\sin\theta$		
4(d)	Find an equation containing F e.g. Resolve horizontally	M1	3.4
	$(\rightarrow),\ F = T\sin\theta$	A1	1.1b
	Other possible equations		

	$(\nwarrow), R\cos\theta + T = F\sin\theta + Mg\cos\theta + 2Mg\cos\theta$ $(\nearrow), R\sin\theta + F\cos\theta = Mg\sin\theta + 2Mg\sin\theta$ $(\rightarrow),\ F = T\sin\theta$ M(B), $R.2a\cos\theta = Mga\cos\theta + 2Mg\times 0.5a\cos\theta + F.2a\sin\theta$ M(G), $Fa\sin\theta + Ta = Ra\cos\theta + 2Mg\times 0.5a\cos\theta$ M(C), $R\times 1.5a\cos\theta = T\times 0.5a + Mg\times 0.5a\cos\theta + F\times 1.5a\sin\theta$		
	$F = \mu R$ used i.e. both F and R are substituted.	M1	3.1b
	$\mu = \frac{8}{19}$ *	A1*	2.2a
		(4)	
			(11 marks)

Notes:

4a	B1	Any equivalent explanation
4b	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors
	A1	Correct equation, trig does not need to be substituted (Allow: $T.2a = Mga\cos\theta + 3Mga\cos\theta$)
	A1*	Given answer correctly obtained with no wrong working seen. Allow $2Mg\cos\theta = T$ But not $T = 2\cos\theta Mg$
4c	M1	For an equation in R, M, T and θ **only** Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved
	A1	Correct equation, T and trig do not need to be substituted
	A1*	Given answer correctly obtained with no wrong working seen
4d	M1	For any equation with F in it Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved
	A1	Correct equation, trig does not need to be substituted
	M1	Must be used i.e M0 if merely quoting it.
	A1*	Given answer correctly obtained with no wrong working seen

Question	Scheme	Marks	AOs
5(a)	Using horizontal motion	M1	3.3
	Whole Motion **Half way**		
	$U\cos\alpha \times t = 120$ $U\cos\alpha \times t = 60$	A1	1.1b
	Using vertical motion **OR**	M1	3.4
	$U\sin\alpha \times t - \frac{1}{2}gt^2 = 0$ $0 = U\sin\alpha - gt$	A1	1.1b
	Attempt to solve problem by eliminating t	DM1	3.1b
	$U^2\sin\alpha\cos\alpha = 588$ *	A1*	2.2a
		(6)	
	N.B. No credit given if they use the given answer from (b).		
5(b)	Using vertical motion **OR** conservation of energy	M1	3.4
	$0^2 = (U\sin\alpha)^2 - 2g\times 10$ $\frac{1}{2}mU^2 - \frac{1}{2}m(U\cos\alpha)^2 = mg\ \ 10$	A1	1.1b
	ALTERNATIVE 1: If t is time to top: use of $10 = \frac{1}{2}gt^2$ oe ($t = \frac{10}{7}$) to obtain an equation in U and α only M1 $U\sin\alpha = 14$ or $U\cos\alpha = 42$ A1 **ALTERNATIVE 2:** If t is time to top: use of : $10 = U\sin\alpha\ t - \frac{1}{2}gt^2$ with $t = \frac{60}{U\cos\alpha}$ substituted to obtain an equation in U and α only : M1 $10 = U\sin\alpha \times \frac{60}{U\cos\alpha} - \frac{1}{2}g\left(\frac{60}{U\cos\alpha}\right)^2$ A1		
	Attempt to solve problem by eliminating α : e.g. $U\sin\alpha = 14 \Rightarrow U\cos\alpha = 42$, from part (a) or from using $t = \frac{10}{7}$, then square and add to give result **OR:** $U^2\sin^2\alpha = 20g = 196$ and $U^2\sin\alpha\cos\alpha = 588$, divide to give $\tan\alpha = \frac{1}{3}$ then $\sin^2\alpha = \frac{1}{10}$, hence result **OR in ALTERNATIVE 2**: sub for U^2 using part (a), to give $\tan\alpha = \frac{1}{3}$ then $\sin^2\alpha = \frac{1}{10}$, hence result	DM1	3.1b

	N.B. Just stating that $\sin^2\alpha = \frac{1}{10}$, with no working is DM0A0.		
	$U^2 = 1960$ *	A1*	2.2a
	N.B. Verification (i.e. starting with $U^2 = 1960$ and trying to work backwards) is not an acceptable method for this question.		
		(4)	
5(c)	V, since air resistance has to be overcome, or just 'because of <u>air resistance' isw</u>	B1	3.5a
		(1)	
5(d)	e.g. wind effects, more accurate value of g, spin of ball, size of ball, shape of ball, dimensions of ball, not a particle, variable acceleration, surface area of ball, humidity. Allow wind resistance and rotational resistance (Ignore any mention of air resistance or drag)	B1	3.5c
		(1)	
			(12 marks)

Notes:		
5a		**N.B**. Could score 2/6 for any one of the 4 given equations if there is no corresponding second equation or there is an attempt but it's incorrect.
	M1	Complete method to give equation in U, α and t only, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved
	A1	Correct equation
	M1	Complete method to give equation in U, α and t only, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved
	A1	Correct equation
	DM 1	Eliminate t, dependent on first and second M1's
	A1*	Given answer correctly obtained, <u>with no wrong working seen.</u> Allow $588 = U^2 \sin\alpha\cos\alpha$ but nothing else
5b	M1	Complete method to give equation in U and α only with correct no. of terms, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved
	A1	Correct equation
	DM 1	Eliminate α and rearrange, dependent on first M1
	A1*	Given answer correctly obtained with <u>no wrong working seen</u> (**N.B**. If they use a value for α (18.43.°.) they lose the final A1*)
5c	B1	Clear statement isw
5d	B1	B0 if there is an incorrect extra e.g. mass or weight

Pearson Education Limited. Registered company number 872828
with its registered office at 80 Strand, London, WC2R 0RL, United Kingdom