

APOLLO

# Physics

## HL Answers

First assessment 2025

Whole questions arranged by syllabus topic.

Original question and scheme crops preserve source diagrams.

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# Kinematics

13 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q1 | 1 marks

1.       B  

Physics HL | Paper 1A | May 2025 TZ1 | Q2 | 1 marks

2.       B  

Physics HL | Paper 1A | May 2025 TZ1 | Q5 | 1 marks

5.       C  

Physics HL | Paper 1A | May 2025 TZ2 | Q1 | 1 marks

1.       B  

Physics HL | Paper 1A | May 2025 TZ2 | Q2 | 1 marks

2.       C  

Physics HL | Paper 1A | May 2025 TZ2 | Q3 | 1 marks

3.       D  

Physics HL | Paper 1A | May 2025 TZ3 | Q1 | 1 marks

1.       B  

Physics HL | Paper 1A | May 2025 TZ3 | Q2 | 1 marks

2.       C  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q1 | 1 marks

1.       B  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q2 | 1 marks

2.       A  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q1 | 1 marks

1.       A  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q2 | 1 marks

2.       C  

Physics HL | Paper 1A | Specimen 2025 | Q1 | 1 marks

1.       C

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# Forces and momentum

21 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q3 | 1 marks

3.       A  

Physics HL | Paper 1A | May 2025 TZ1 | Q4 | 1 marks

4.       C  

Physics HL | Paper 1A | May 2025 TZ1 | Q6 | 1 marks

6.       A  

Physics HL | Paper 1A | May 2025 TZ2 | Q4 | 1 marks

4.       D  

Physics HL | Paper 1A | May 2025 TZ2 | Q5 | 1 marks

5.       D  

Physics HL | Paper 1A | May 2025 TZ3 | Q3 | 1 marks

3.       C  

Physics HL | Paper 1A | May 2025 TZ3 | Q4 | 1 marks

4.       D  

Physics HL | Paper 1A | May 2025 TZ3 | Q5 | 1 marks

5.       D  

Physics HL | Paper 1A | May 2025 TZ3 | Q6 | 1 marks

6.       D

|    |   |    |                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                       |     |
|----|---|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 1. | a |    | <p><b>ALT 1</b></p> <p>KE before is <math>\frac{1}{2} \times 3.0 \times 6.0^2 = 54 \text{ J} \checkmark</math></p> <p>KE after is <math>\frac{1}{2} \times 3.0 \times 2.0^2 + \frac{1}{2} \times 6.0 \times 4.0^2 = 54 \text{ J} \checkmark</math></p> <p><b>ALT 2</b></p> <p>In elastic collisions relative velocity remains constant in magnitude <math>\checkmark</math></p> <p><math> 6 - 0  =  -2 - 4  \checkmark</math></p>   | Ignore references to conservation of momentum                                                                                                                                                                                         | [2] |
|    | b | i  | <p><math>F = \frac{6.0 \times 4.0}{40 \times 10^{-3}} \text{ OR } F = \frac{3.0 \times (6.0 - (-2.0))}{40 \times 10^{-3}} \checkmark</math></p> <p><math>F = 6.0 \times 10^2 \text{ N} \checkmark</math></p>                                                                                                                                                                                                                        | <p>Allow ECF from a wrong time interval.</p> <p>If the final answer is incorrect, award MP1 for [1max] for any attempt to use rate of change of momentum or mass x acceleration with wrong data values for masses and velocities.</p> | [2] |
|    | b | ii | <p><b>Alternative 1</b></p> <p><math>\Delta E_K = \frac{1}{2} \cdot 6.0 \cdot 4.0^2 \text{ OR } 48 \text{ J} \checkmark</math></p> <p><math>P = \ll \frac{\Delta E_K}{\Delta t} = \gg \frac{48}{40 \times 10^{-3}} = 1200 \text{ W} \checkmark</math></p> <p><b>Alternative 2</b></p> <p><math>\bar{P} = F \frac{u+v}{2} \checkmark</math></p> <p><math>\bar{P} = 600 \times \frac{0+4.0}{2} = 1200 \text{ W} \checkmark</math></p> | <p>Award [2] if 1200 &lt;&lt;W&gt;&gt; is seen as the answer without working</p> <p>Award [1] for 2400 W.</p> <p>Allow ECF from bi) in ALT 2.</p>                                                                                     | [2] |

– 5 –

2225 – 6715M

|  |   |     |                                                                                                                                                             |                    |     |
|--|---|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|-----|
|  | b | iii | <p>KE is <math>\frac{1}{2} \times (3.0 + 6.0) \times 2.0^2 = 18 \text{ J} \checkmark</math></p> <p>PE is <math>54 - 18 = 36 \text{ J} \checkmark</math></p> | Allow ECF from MP1 | [2] |
|--|---|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|-----|

– 6 –

2225 – 6715M

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

|    |   |                                                                                                                               |                                                                                  |   |
|----|---|-------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|---|
| 1. | a | It is a ratio between two forces therefore units cancel out.<br><b>OR</b><br>$\mu = F_f/N$ , therefore units cancel out. ✓    |                                                                                  | 1 |
| 1. | b | uses the static coefficient ✓<br>$F = 0.36 \times 1.2 \times 9.8 = 0.36 \times 11.76$<br><b>OR</b><br>$F = 4.2 \text{ «N»}$ ✓ | Must see full substitution OR answer to 2 (or more) significant figures for MP2. | 2 |

– 5 –

2225 – 6721M

|    |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                       |   |
|----|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|---|
| 1. | c | <b>ALT 1</b><br>$F_f = 0.28 \times 1.2 \times 9.8 = 3.29 \text{ «N»}$ ✓<br>$W \text{ done over } 0.35 \text{ m} = (14 - 3.29) \times 0.35 = 3.75 \text{ «J»}$ ✓<br>$d = \text{«}3.75 \text{ J} / 3.29 \text{ N} \text{»} = \text{«}1.14 \text{ «m»}$ ✓<br><b>ALT 2</b><br>$a = (14 - 0.28 \times 1.2 \times 9.8) / 1.2 = 8.92 \text{ «m s}^{-2}\text{»}$ ✓<br>$v = \sqrt{(2)(8.92)(0.35)} = 2.50 \text{ «m s}^{-1}\text{»}$ ✓<br>$d = \text{«}2.5^2 / (2 \times 0.28 \times 9.8) \text{»} = \text{«}1.14 \text{ «m»}$ ✓ | Allow ECF from MP1.<br>Only award marks from one ALT. | 3 |
| 1. | d | <b>ALT 1</b><br>$\tau \text{ of } F = F \times 0.15$ <b>OR</b> $\tau \text{ of weight} = 1.2 \times 9.8 \times 0.03$ ✓<br>equals both to get $F = 2.4 \text{ «N»}$ ✓<br><b>ALT 2</b><br>$\tau \text{ of } F = F(.162)(\sin 68)$ <b>OR</b> $\tau \text{ of weight} = (1.2)(9.8)(.162/2)(\sin 22)$ ✓<br>equals both to get $F = 2.4 \text{ «N»}$ ✓                                                                                                                                                                        |                                                       | 2 |

|    |   |    |                                                                    |                                                                                                                         |   |
|----|---|----|--------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|---|
| 1. | d | ii | Because «static» friction has a «maximum» value greater than $F$ ✓ | <i>Must see a comparison between <math>F</math> and friction (e.g. frictional force is larger than <math>F</math>).</i> | 1 |
|----|---|----|--------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|---|

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Nov 2025 TZ1 | Q3 | 1 marks

3.       A  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q4 | 1 marks

4.       A  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q3 | 1 marks

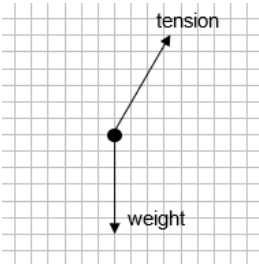
3.       B  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q4 | 1 marks

4.       C  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q5 | 1 marks

5.       B

|    |   |    |                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                         |     |
|----|---|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 2. | a | i  |  <p>Labelled vertical weight / <math>W</math> / <math>mg</math> / <math>F_g</math> and tension / <math>T</math> / <math>F_T</math> in approximately correct direction ✓<br/>With vertical <math>T</math> component equal to weight ✓</p> | Ignore other forces drawn for MP1                                                                                                                                                                                                                                       | [2] |
| 2. | a | ii | $T \sin 30^\circ = ma$<br><b>OR</b><br>$T \cos 30^\circ = mg$ ✓<br>$a = g \tan 30^\circ = 5.66 \approx 5.7 \text{ m s}^{-2}$ ✓                                                                                                                                                                                            | Accept reversed trig functions if $60^\circ$ used.<br>Award [2] for CNA                                                                                                                                                                                                 | [2] |
| 2. | b |    | <p>The ball is in equilibrium / forces are balanced / net force is zero / no acceleration / the vertical weight must be balanced by a vertical tension ✓</p> <p>The angle is zero ✓</p>                                                                                                                                   | For MP2, accept an answer of $10^\circ$ if from the students' answer it can be understood that they interpreted the vertical as the perpendicular line to the ceiling of the truck, so that their answer of $10^\circ$ implies that the string is vertically downwards. | [2] |

– 6 –

8825–6721M

| Question |   | Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Notes                                                                       | Total |
|----------|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|-------|
| 2.       | c | $\mu mg = m \frac{v^2}{R}$ ✓<br>$v = \sqrt{0.6 \times 9.8 \times 75}$ 21 ms <sup>-1</sup> ✓                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Award [2] for a CNA.                                                        | [2]   |
| 2.       | d | <p><b>ALTERNATIVE 1</b></p> <p>KE <math>\frac{1}{2} \times 1400 \times 15^2</math> <b>OR</b> <math>1.6 \times 10^5 \text{ J}</math> ✓</p> <p>Work done by drag force <math>520 \times \pi \times 75</math> <b>OR</b> <math>1.2 \times 10^5 \text{ J}</math> ✓</p> <p>This is less than the KE so the truck will make it ✓</p> <p><b>ALTERNATIVE 2</b></p> <p>Truck decelerates at <math>\frac{520}{1400}</math> <b>OR</b> <math>0.371 \text{ ms}^{-2}</math> ✓</p> <p>Speed at gas station is <math>\sqrt{15^2 - 2 \times 0.371 \times \pi \times 75}</math> <b>OR</b> <math>7.0 \text{ ms}^{-1}</math></p> <p><b>OR</b></p> <p>truck stops after a distance <math>\ll \frac{15^2}{2 \times 0.371} = \gg 303 \text{ m}</math> ✓</p> <p>Speed is not zero</p> <p><b>OR</b></p> <p><math>303 \text{ m} &gt; 75 \pi</math></p> <p><b>OR</b></p> <p><math>303 \text{ m} &gt; 236 \text{ m}</math> ✓</p> | Allow MP3 for a consistent conclusion if any previous calculation is wrong. | [3]   |

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8825–6721M

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Specimen 2025 | Q2 | 1 marks

2.       C  

Physics HL | Paper 1A | Specimen 2025 | Q5 | 1 marks

5.       D  

Physics HL | Paper 1A | Specimen 2025 | Q8 | 1 marks

8.       D

|    |   |  |                                                                                                                                  |                                           |          |
|----|---|--|----------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|----------|
| 1. | a |  | static friction force «between blocks»<br><br><b>AND</b><br><br>directed to the right✓                                           |                                           | <b>1</b> |
| 1. | b |  | $F = 60a$ ✓<br><br>$F_f = 0.6 \times 15 \times 9.8$ «= 88.2N» ✓<br><br>$88.2 = 15 \times \frac{F}{60} \Rightarrow F = 350$ «N» ✓ | Allow use of $a = 0.6g$ leading to 353 N. | <b>3</b> |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

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# Work, energy and power

6 questions

|    |   |     |                                                                                                                                                                                                                                                                                                   |                                                                                                                                                         |     |
|----|---|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 8. | a | i   | Identifies length of cylinder as $v\Delta t$ so volume as $S \times v \times \Delta t$ to show the result ✓                                                                                                                                                                                       |                                                                                                                                                         | [1] |
|    | a | ii  | $\Delta p = \Delta m \times v$ <b>OR</b> $\rho \times S \times v \times \Delta t \times v$ ✓<br>Force is $\frac{\Delta p}{\Delta t} = \frac{\rho \times S \times v \times \Delta t \times v}{\Delta t}$ Hence result ✓                                                                            | Award [1] if solved through $F = ma$ replacing $a = \frac{\Delta v}{\Delta t}$ (therefore not using $v$ as about constant through interval $\Delta t$ ) | [2] |
|    | b | i   | Identifies orbital velocity as $v = \sqrt{\frac{GM}{r}}$ ✓<br>$E_K = \frac{1}{2}mv^2 = \frac{GMm}{2r}$ so $E_T = \frac{GMm}{2r} - \frac{GMm}{r}$ Hence result ✓                                                                                                                                   |                                                                                                                                                         | [2] |
|    | b | ii  | The total energy is reduced <b>OR</b> the satellite gets closer to the surface ✓<br>«From $v = \sqrt{\frac{GM}{r}}$ » the satellite moves faster ✓<br>«From $\rho S v^2$ » the opposing force increases « because $v$ and $\rho$ increase » ✓<br>The satellite burns / crashes / falls to Earth ✓ |                                                                                                                                                         | [4] |
|    | c | i   | $P = \frac{\Delta E}{\Delta t}$ ✓<br>$P = \left\langle \frac{-4.5 \times 10^9}{30 \times 24 \times 3600} \right\rangle = -1.7 \times 10^3 W$ ✓                                                                                                                                                    | Ignore sign                                                                                                                                             | [2] |
|    | c | ii  | Average height 417.5 km ✓<br>$v = \sqrt{\frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(6.38 + 0.4175) \times 10^6}}$ <b>OR</b> $7.7 \times 10^3 m s^{-1}$ ✓                                                                                                                              | Accept $417.5 \pm 0.3$ for MP1                                                                                                                          | [2] |
|    | c | iii | $\Delta T = \frac{Q}{mc}$ ✓<br>$\Delta T = \left\langle \frac{4.5 \times 10^9}{4.2 \times 10^5 \times 500} \right\rangle = 21 K$ <b>OR</b> $21^\circ C$ ✓                                                                                                                                         | Award [2] if 21 is seen as the answer without working                                                                                                   | [2] |

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2225 – 6715M

|  |   |    |                                                                                                                             |                                                                                                                            |     |
|--|---|----|-----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-----|
|  | c | iv | Attempt to use $P = Fv$ ✓<br>$1.7 \times 10^3 W = F \times 7.7 \times 10^3 m s^{-1}$ ✓<br>$F = 0.22 N$ ✓                    | Allow ECF from c) i).<br>Ignore sign.<br>MP3 will vary depending on their values of c) i) and c) ii, between 0.21 and 0.23 | [3] |
|  | d |    | $V = \frac{E}{\text{E density}}$ ✓<br>$V = \left\langle \frac{4.5 \times 10^9}{8.5 \times 10^9} \right\rangle = 0.53 m^3$ ✓ | Award [2] if $0.53 << m^3 >>$ is seen as the answer without working                                                        | [2] |

## Mark-scheme answers

Physics HL | Paper 1A | Nov 2025 TZ1 | Q5 | 1 marks

5.       D  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q6 | 1 marks

6.       D  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q6 | 1 marks

6.       D  

Physics HL | Paper 1A | Specimen 2025 | Q3 | 1 marks

3.       A  

Physics HL | Paper 1A | Specimen 2025 | Q6 | 1 marks

6.       B

APOLLO

# Rigid body mechanics

12 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q7 | 1 marks

7.       B  

Physics HL | Paper 1A | May 2025 TZ1 | Q8 | 1 marks

8.       B  

Physics HL | Paper 1A | May 2025 TZ2 | Q6 | 1 marks

6.       A  

Physics HL | Paper 1A | May 2025 TZ2 | Q7 | 1 marks

7.       D  

Physics HL | Paper 1A | May 2025 TZ2 | Q8 | 1 marks

8.       C  

Physics HL | Paper 1A | May 2025 TZ3 | Q7 | 1 marks

7.       B  

Physics HL | Paper 1A | May 2025 TZ3 | Q8 | 1 marks

8.       A  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q7 | 1 marks

7.       A  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q7 | 1 marks

7.       B

|    |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |  |     |
|----|---|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|-----|
| 6. | a | <p><b>ALTERNATIVE 1</b></p> <p>Energy conservation after heavier block falls a distance <math>h</math> gives</p> $\frac{1}{2} \frac{mr^2}{2} \omega^2 + \frac{1}{2} mv^2 + \frac{1}{2} \times 2mv^2 = 2mgh - mgh \quad \checkmark$ $\omega = \frac{v}{r} \quad \text{so } v^2 = \frac{4gh}{7} \quad \checkmark$ $v^2 = 2ah \Rightarrow \frac{4gh}{7} = 2ah \quad \checkmark$ <p>Hence <math>a = \frac{2g}{7}</math></p> <p><b>ALTERNATIVE 2</b></p> <p>Moment of inertia of system <math>\frac{1}{2}mr^2 + mr^2 + 2mr^2 = \frac{7}{2}mr^2 \quad \checkmark</math></p> <p>Net torque = <math>mgr</math>, so <math>mgr = \frac{7}{2}mr^2 \times \alpha \quad \checkmark</math></p> $\alpha = \frac{a}{r} \quad \checkmark$ <p>Hence <math>a = \frac{2g}{7}</math></p> <p><b>ALTERNATIVE 3</b></p> $2mg - T_1 = 2ma \quad \text{and } T_2 - mg = ma \quad \checkmark$ $(T_1 - T_2)r = \frac{mr^2}{2} \frac{a}{r} \Rightarrow T_1 - T_2 = \frac{ma}{2} \quad \checkmark$ <p>Adding equations of MP1: <math>-\frac{ma}{2} + mg = 3ma \quad \checkmark</math></p> <p>Hence <math>a = \frac{2g}{7}</math></p> |  | [3] |
| 6. | b | No, because there is a non-zero external torque on the system / the system has angular acceleration $\checkmark$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |  | [1] |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Specimen 2025 | Q4 | 1 marks

4.       D  

Physics HL | Paper 1A | Specimen 2025 | Q7 | 1 marks

7.       C

APOLLO

# Galilean and special relativity

10 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q9 | 1 marks

9.       B  

Physics HL | Paper 1A | May 2025 TZ3 | Q9 | 1 marks

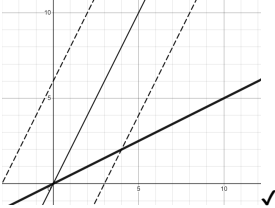
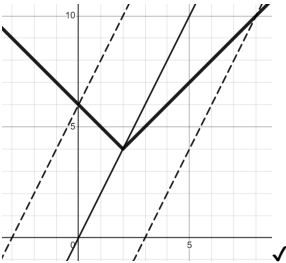
9.       B

|    |   |   |                                                                                                                                                                                        |                                                                                                                                          |     |
|----|---|---|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 6. | a |   | $\gamma = \frac{1}{\sqrt{1-0.60^2}} \text{ OR } \frac{5}{4} \text{ OR } 1.25 \quad \checkmark$ $t = \gamma t' \Rightarrow t' = \frac{4}{5} \times 50 = 40 \text{ yr} \quad \checkmark$ | <p>Award MP1 if seen isolated or within an equation.</p> <p>Award [2] if 40 &lt;&lt;yr&gt;&gt; is seen as the answer without working</p> | [2] |
|    | b | i | <p>45 degree line starting at (30, 50) and ending on Earth's time axis (at A) <math>\checkmark</math></p>                                                                              |                                                                                                                                          | [1] |

|  |   |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                              |     |
|--|---|----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-----|
|  | b | ii | <p><b>Alternative 1</b></p> <p>Line from A parallel to S space axis intersects S time axis at B: <math>ct = 125 \text{ ly} \quad \checkmark</math><br/>             Knowing scale on S time axis gives S time at B of <math>40+40+20 = 100 \text{ yr} \quad \checkmark</math><br/>             Time of travel is <math>100 - 40 = 60 \text{ yr} \quad \checkmark</math></p> <p><b>Alternative 2</b></p> <p>Distance separating P and Earth in S is <math>\frac{30}{\gamma} = 24 \text{ ly} \quad \checkmark</math></p> <p><math>cT = 0.60cT + 24 \quad \checkmark</math></p> <p><math>T = \frac{24}{0.40c} = 60 \text{ yr} \quad \checkmark</math></p> | <p>Accept 55 to 65 years for those using Alt 1</p> <p>MP1 for Alt. 3 can be explicit from graph in (b) i</p> | [3] |
|--|---|----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-----|

|  |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                   |  |
|--|--|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|--|
|  |  | <p><b>Alternative 3</b></p> <p>Travel time for signal for Earth is 30 years so event A has time coordinate <math>50 + 30 = 80</math> yr ✓</p> <p>S time for A is <math>ct' = \gamma(ct - \frac{v}{c}x) = \frac{5}{4} \times 80 = 100</math> ly ✓</p> <p>Time of travel is <math>100 - 40 = 60</math> yr ✓</p> <p><b>Alternative 4</b></p> <p>Calculate time elapsed between signal emitted and signal received as:</p> <p><math>\Delta t = 30</math> ✓</p> <p><math>\Delta x = -30</math> ✓</p> <p>Use of Lorentz transformation to get <math>\Delta t' = 60</math> ✓</p> | <p><i>If candidates use positive <math>\Delta x</math> and a negative velocity, award [2]</i></p> |  |
|--|--|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|--|

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

|    |   |                                                                                                                                                          |  |   |
|----|---|----------------------------------------------------------------------------------------------------------------------------------------------------------|--|---|
| 2. | a | <div> <div>line through origin of gradient 0.5 (by eye)</div>  </div>   |  | 1 |
| 2. | b | <div> <div>two lines of gradient -1 and 1 from E (by eye)</div>  </div> |  | 1 |

|    |   |                                                                                                                                                                                                               |                                                                                                   |   |
|----|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|---|
| 2. | c | <div> <div>«simultaneous for» the passenger ✓</div> <div>because line joining <math>T_B</math> and <math>T_F</math> is parallel to <math>x'</math> axis «so identify the same time coordinate» ✓</div> </div> | <div> <div>Accept equivalent description based on non-simultaneous for the observer.</div> </div> | 2 |
| 2. | d | <div> <div>6 «m» ✓</div> </div>                                                                                                                                                                               |                                                                                                   | 1 |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Nov 2025 TZ1 | Q8 | 1 marks

8.       D  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q9 | 1 marks

9.       D  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q8 | 1 marks

8.       B  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q9 | 1 marks

9.       A  

Physics HL | Paper 1A | Specimen 2025 | Q9 | 1 marks

9.       A

|    |   |    |                                                                                                                                                                                                                                  |                                                                                  |   |
|----|---|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|---|
| 2. | a |    | $\gamma = \frac{1}{\sqrt{1-0.80^2}} = \frac{5}{3} = 1.67 \checkmark$                                                                                                                                                             |                                                                                  | 1 |
| 2. | b | i  | $\llcorner \Delta x' = \gamma(\Delta x - v\Delta t) = \rceil \frac{5}{3} \times 1200 = 2000 \text{ «m»} \checkmark$                                                                                                              | Allow ecf from 1a.<br><br>Allow use of $L = \frac{L_0}{\gamma}$ .                | 1 |
| 2. | b | ii | $\llcorner \Delta t' = \gamma(\Delta t - \frac{v}{c^2}\Delta x) = \rceil \frac{5}{3}(0 - \frac{0.80}{3 \times 10^8} \times 1200) \checkmark$<br><br>$\Delta t' = \llcorner \text{«} 5.3 \text{ «}\mu\text{s}\text{»} \checkmark$ | Allow use of $\Delta t = \gamma\Delta t_0$ .                                     | 2 |
| 2. | c |    | Because $\Delta t' < 0 \checkmark$<br><br>F occurred first $\checkmark$                                                                                                                                                          | 2 <sup>nd</sup> MP only awarded if correct interpretation of 1 <sup>st</sup> MP. | 2 |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

APOLLO

# Thermal energy transfers

11 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q10 | 1 marks

10.       A  

Physics HL | Paper 1A | May 2025 TZ2 | Q9 | 1 marks

9.         C  

Physics HL | Paper 1A | May 2025 TZ3 | Q10 | 1 marks

10.       A  

Physics HL | Paper 1A | May 2025 TZ3 | Q12 | 1 marks

12.       C

|    |   |    |                                                                                                                                                                                                                                                                                                                                |                        |     |
|----|---|----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|-----|
| 2. | a |    | <b>ALT 1</b> (in solids)<br><br>reference to particle/atomic vibrations<br><b>OR</b><br>kinetic energy transferred ✓<br><br>via collisions<br><b>OR</b><br>between adjacent particles/atoms ✓<br><br><b>ALT 2</b> (in metallic conductors)<br><br>reference to motion of electrons ✓<br>that collide with atoms/ions ✓         |                        | [2] |
|    | b |    | $\ll \frac{\Delta Q}{\Delta t} = kA \frac{\Delta T}{\Delta x} = \frac{1.3 \times 18 \times (22 - 13)}{0.25} \gg 8.4 \times 10^2 \quad \checkmark$<br><br>Unit is W / Js <sup>-1</sup> / kgm <sup>2</sup> s <sup>-3</sup> ✓                                                                                                     | Ignore the sign in MP1 | [2] |
|    | c | i  | Identifies gradient as rate of thermal energy transfer<br><b>OR</b><br>temperature difference is decreasing ✓                                                                                                                                                                                                                  |                        | [1] |
|    | c | ii | <b>ALT 1</b><br>$N_0 = \frac{PV}{kT_0}$ and $N = \frac{PV}{kT}$ <b>OR</b> 295 and 279 seen ✓<br><br>$\frac{\Delta N}{N_0} = \frac{\frac{k \times 279}{PV} - \frac{k \times 295}{PV}}{\frac{k \times 295}{PV}} \quad \checkmark$<br>$\ll \frac{\Delta N}{N_0} = \frac{16}{279} = \gg 0.057 \text{ OR } 5.7 \% \quad \checkmark$ |                        | [3] |

- 7 -

2225 – 6715M

|  |   |  |                                                                                                                                                                                                                                                                                                                 |                                                                                                                 |         |
|--|---|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|---------|
|  |   |  | <b>ALT 2</b><br>$NT = \text{constant}$ <b>OR</b> $nT = \text{constant}$ <b>OR</b> 295 <b>AND</b> 279 seen ✓<br><br>$\ll \frac{N_2}{N_1} \text{ OR } \frac{n_2}{n_1} = \gg \frac{295}{279} \text{ seen} \quad \checkmark$<br>5.7 % ✓                                                                             | Award only MP1, [1] max, if work shown in Celsius                                                               |         |
|  | d |  | The heat transfer is irreversible / spontaneous / from hot to cold<br><b>OR</b><br>Heat is removed from the room, so entropy decreases ✓<br>The same heat is deposited at a lower temperature, so outside entropy increase is larger ✓<br>The entropy change of the Universe/isolated system always increases ✓ | For MP1, allow an argument stating that the entropy of the room may have increased due to the increase in mass. | [2 max] |

- 8 -

2225 – 6715M

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

|    |   |    |                                                                                                                                                                                                                                                 |                                                                                                                  |   |
|----|---|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|---|
| 7. | a | i  | Weight and Buoyancy drawn in proper directions (by eye) and correctly identified ✓                                                                                                                                                              | Allow any sensible identification of the forces (e.g. $mg$ for $F_g$ )<br><br>Do not allow "gravity" for weight. | 1 |
| 7. | a | ii | Weight = $\rho_c \cdot A \cdot H \cdot g$<br><br><b>OR</b><br>Buoyancy = $\rho_w \cdot A \cdot D \cdot g$ ✓<br><br>$\rho_c \cdot A \cdot H \cdot g = \rho_w \cdot A \cdot D \cdot g$ ✓<br><br>«algebraic manipulation to show the relationship» |                                                                                                                  | 2 |

– 18 –

2225 – 6721M

|    |   |    |                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                          |       |
|----|---|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------|
| 7. | b |    | When cork is released, upthrust/buoyant force is larger than weight<br><b>OR</b><br>buoyant force is increased when cork submerged. ✓<br><br>«net» force/acceleration is proportional to displacement<br><b>OR</b><br>quotes $a = \omega^2 x$ OR $a \propto x$ ✓<br><br>«net» force/acceleration is in opposite direction of displacement<br><b>OR</b><br>«net» force/acceleration is directed towards equilibrium ✓ |                                                                                          | 2 max |
| 7. | c | i  | solid state volume is less than liquid state<br><b>OR</b><br>molecules/particles/atoms are closer in solids so volume is smaller ✓<br><br>Same mass in smaller volume «so larger density»<br><b>OR</b><br>More mass per unit volume ✓                                                                                                                                                                                |                                                                                          | 2     |
| 7. | c | ii | 4 «°C» ✓                                                                                                                                                                                                                                                                                                                                                                                                             | Allow 3.9 °C - 4.1 °C.<br><br>Accept answer in Kelvin (e.g. 277 K) if proper unit shown. | 1     |

|    |   |    |                                                                                                                                                                                                     |                                                                               |   |
|----|---|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|---|
| 7. | d | i  | $\llcorner (H - 32) / H = 920 / 1030 \text{ so } H = 300 \text{ «m» OR } D = 268 \text{ «m» } \checkmark$<br>$m = 920 \times 300 \times 4200 \text{ OR } 1.16 \times 10^9 \text{ «kg» } \checkmark$ | Must see either full substitution or answer to 3 or more significant figures. | 2 |
| 7. | d | ii | $\frac{1}{40} m_{12} = (\frac{1}{40} m + m)v \checkmark$<br>$v = 0.29 \text{ «m s}^{-1}\text{» } \checkmark$                                                                                        |                                                                               | 2 |
| 7. | e | i  | use of $\Delta T = 6 \text{ «}^\circ\text{C}\text{» } \checkmark$<br><br>$\frac{\Delta Q}{\Delta t A} = \llcorner \frac{2.3 \cdot 6}{0.019} = \gg 730 \text{ «W m}^{-2}\text{» } \checkmark$        |                                                                               | 2 |

|    |   |     |                                                                                                                                                                                                                                                                                                                                                                                                                           |  |       |
|----|---|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|-------|
| 7. | e | ii  | $m = (\rho A)(22) = (1000)(A)(22) = 22000A \text{ AND } \Delta T = 2 \text{ «}^\circ\text{C}\text{» } \checkmark$<br>$Q/A = \llcorner mc\Delta T \gg = (22)(1000)(4200 \cdot 2) = 1.85 \times 10^8 \text{ «J m}^{-2}\text{»}$<br><b>OR</b><br>$Q/A = \llcorner mL \gg = (22)(1000)(330000) = 7.26 \times 10^9 \text{ «J m}^{-2}\text{» } \checkmark$<br><br>$Q/A = 7.4 \times 10^9 \text{ «J m}^{-2}\text{» } \checkmark$ |  | 3     |
| 7. | e | iii | «the thicker the layer the» lower the rate of transfer $\checkmark$                                                                                                                                                                                                                                                                                                                                                       |  | 1     |
| 7. | e | iv  | if solid water were denser than liquid, ice layer would sink<br><b>OR</b><br>water at $4^\circ\text{C}$ sinks to bottom $\checkmark$<br><br>ice layer «would isolate water below ice to» maintain conditions<br>«above freezing » $\checkmark$<br><br>this insulates the lake <b>OR</b> prevents the lake from freezing completely $\checkmark$                                                                           |  | 2 max |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Nov 2025 TZ1 | Q10 | 1 marks

10.       D  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q10 | 1 marks

10.       D  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q11 | 1 marks

11.       D  

Physics HL | Paper 1A | Specimen 2025 | Q13 | 1 marks

13.       A

|    |   |    |                                                                                                                                                                                                                                                                                                                                                            |  |       |
|----|---|----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|-------|
| 8. | a |    | $(0.030 \times 0.7 \times 10^3 \times 5) + (0.030 \times 220 \times 10^3) + (0.030 \times 2.13 \times 10^3)(T - 47)$ $= (0.150 \times 2.13 \times 10^3)(240 - T)$ <p>One heat capacity term correctly substituted ✓</p> <p>latent heat correctly substituted <math>(0.030 \times 220 \times 10^3)</math> ✓</p> <p><math>T = 190^\circ\text{C}</math> ✓</p> |  | 3     |
| 8. | b | i  | <p>Experimental temperature will be lower ✓</p> <p>Heat loss to the environment ✓</p>                                                                                                                                                                                                                                                                      |  | 2     |
| 8. | b | ii | <p>Insulate the container</p> <p><b>OR</b></p> <p>Carry out experiment quicker</p> <p><b>OR</b></p> <p>Use larger volumes of substances ✓</p>                                                                                                                                                                                                              |  | MAX 1 |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

APOLLO

# Greenhouse effect

6 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q11 | 1 marks

11.     D

Physics HL | Paper 1A | May 2025 TZ2 | Q10 | 1 marks

10.     C

Physics HL | Paper 1A | May 2025 TZ3 | Q13 | 1 marks

13.     C

Physics HL | Paper 1A | Nov 2025 TZ1 | Q11 | 1 marks

11.     B

Physics HL | Paper 1A | Nov 2025 TZ1 | Q12 | 1 marks

12.     D

Physics HL | Paper 1A | Nov 2025 TZ3 | Q12 | 1 marks

12.     C

APOLLO

# Gas laws

6 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q12 | 1 marks

12.     C

Physics HL | Paper 1A | May 2025 TZ2 | Q11 | 1 marks

11.     C

Physics HL | Paper 1A | May 2025 TZ2 | Q31 | 1 marks

31.     A

Physics HL | Paper 1A | Nov 2025 TZ1 | Q13 | 1 marks

13.     A

Physics HL | Paper 1A | Nov 2025 TZ3 | Q13 | 1 marks

13.     B

Physics HL | Paper 1A | Specimen 2025 | Q17 | 1 marks

17.     C

APOLLO

# Thermodynamics

15 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q13 | 1 marks

13.       C  

Physics HL | Paper 1A | May 2025 TZ2 | Q12 | 1 marks

12.       D  

Physics HL | Paper 1A | May 2025 TZ3 | Q14 | 1 marks

14.       D  

Physics HL | Paper 1A | May 2025 TZ3 | Q15 | 1 marks

15.       A  

Physics HL | Paper 1A | May 2025 TZ3 | Q16 | 1 marks

16.       C

|    |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                        |   |
|----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---|
| 3. | a | <p><b>ALT 1</b></p> <p>Use of <math>pV = nRT</math> to get <math>T_B = 1200</math> «K»</p> <p><b>AND</b></p> $P_C = \left( \frac{P_A V_A^{\frac{5}{3}}}{V_C^{\frac{5}{3}}} = \frac{(2 \times 10^6)(1 \times 10^{-3})^{\frac{5}{3}}}{(1 \times 10^{-2})^{\frac{5}{3}}} \Rightarrow 43089 \text{ «Pa»} \checkmark \right.$ $T_C = 4.3 \times 10^4 \times 1200 / 2.0 \times 10^5$ <p><b>OR</b></p> $T_C = 258 \text{ «K»} \checkmark$ <p><b>ALT 2</b></p> $P_C = \left( \frac{P_A V_A^{\frac{5}{3}}}{V_C^{\frac{5}{3}}} = \frac{(2 \times 10^6)(1 \times 10^{-3})^{\frac{2}{3}}}{(1 \times 10^{-2})^{\frac{2}{3}}} \Rightarrow 43089 \text{ «Pa»} \checkmark \right.$ <p>Use of <math>p_C V_C = nRT_C = (43089)(1 \times 10^{-2}) = (0.2)(8.31) T_C</math></p> <p><b>OR</b></p> $T_C = 259 \text{ «K»} \checkmark$ | <p><i>Must see full substitution OR answer to 3 (or more) significant figures.</i></p> | 2 |
|----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---|

– 10 –

2225–6721M

|    |   |                                                                                                                                                                                                               |  |       |
|----|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|-------|
| 3. | b | <p>Use of <math>\Delta U = -3/2 n R \Delta T</math> ✓</p> $W = \left( (3/2)(0.2)(8.31)(1200-259) \right) = \left( - \right) 2350 \text{ «J»} \checkmark$                                                      |  | 2     |
| 3. | c | <p>work done by the gas in the isothermal process is larger ✓</p> <p>net work is done by the gas ✓</p> <p>net/total work is positive ✓</p> <p>work done by the gas is greater than work done on the gas ✓</p> |  | 1 max |

– 11 –

2225–6721M

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Nov 2025 TZ1 | Q14 | 1 marks

14.       D  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q15 | 1 marks

15.       A  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q14 | 1 marks

14.       A  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q15 | 1 marks

15.       C  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q16 | 1 marks

16.             C

|    |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                  |     |
|----|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|-----|
| 5. | a | <p><b>ALTERNATIVE 1</b></p> $\Delta U = \frac{3}{2} R n \Delta T = \frac{3}{2} P \Delta V \quad \checkmark$ $Q = \frac{3}{2} P \Delta V + P \Delta V = \frac{5}{2} P \Delta V \quad \checkmark$ $Q = \frac{5}{2} \times 22 \times 10^3 \times (3.2 - 4.5) \times 10^{-2} = -7.15 \times 10^2 \approx -700 \text{ J} \quad \checkmark$ <p><b>ALTERNATIVE 2</b></p> $Q = \frac{3}{2} R n \Delta T + P \Delta V = \frac{3}{2} \frac{P V}{T} \Delta T + P \Delta V \quad \checkmark$ <p>temperature at C: <math>\frac{560 \times 3.2}{4.5} = 398 \text{ K} \quad \checkmark</math></p> $Q = \frac{3}{2} \times \frac{1000}{560} \times (398 - 560) + 22 \times 10^3 \times (3.2 - 4.5) \times 10^{-2} = -7.15 \times 10^2 \text{ J} \quad \checkmark$ | <p><i>Do not penalize absence of minus sign</i></p> <p><i>Allow use of <math>n = 0.21 \text{ mol}</math></i></p> | [3] |
| 5. | b | <p><math>Q_{\text{in}} = \langle \Delta U + W = 0 + 480 \Rightarrow 840 \text{ J} \quad \checkmark</math></p> <p><b>ALTERNATIVE 1</b></p> $\eta = \frac{W}{Q_{\text{in}}} = \frac{Q_{\text{in}} - Q_{\text{out}}}{Q_{\text{in}}} \quad \checkmark$ $\eta = \frac{840 - 715}{840} = 0.149 \approx 0.15 \quad \checkmark$ <p><b>ALTERNATIVE 2</b></p> <p>Net work done <math>(125 \pm 20) \text{ J}</math> by counting squares in loop <math>\checkmark</math></p> $\eta = \frac{125}{840} = 0.15 \pm 0.02 \quad \checkmark$                                                                                                                                                                                                                        | <p>Allow <math>\eta = 0.17</math> if rounded 700 J is used</p> <p>Award [3] for a CNA</p>                        | [3] |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Specimen 2025 | Q10 | 1 marks

10.       D  

Physics HL | Paper 1A | Specimen 2025 | Q11 | 1 marks

11.       A  

Physics HL | Paper 1A | Specimen 2025 | Q12 | 1 marks

12.       D

APOLLO

# Current and circuits

11 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q14 | 1 marks

14.       D  

Physics HL | Paper 1A | May 2025 TZ1 | Q15 | 1 marks

15.       B  

Physics HL | Paper 1A | May 2025 TZ1 | Q16 | 1 marks

16.       C  

Physics HL | Paper 1A | May 2025 TZ2 | Q13 | 1 marks

13.       C  

Physics HL | Paper 1A | May 2025 TZ2 | Q14 | 1 marks

14.       D  

Physics HL | Paper 1A | May 2025 TZ3 | Q17 | 1 marks

17.       A  

Physics HL | Paper 1A | May 2025 TZ3 | Q18 | 1 marks

18.       A  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q16 | 1 marks

16.       D  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q17 | 1 marks

17.       B  

Physics HL | Paper 1A | Specimen 2025 | Q15 | 1 marks

15.       A  

Physics HL | Paper 1A | Specimen 2025 | Q16 | 1 marks

16.       C

APOLLO

# Simple harmonic motion

12 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q17 | 1 marks

17.          B  

Physics HL | Paper 1A | May 2025 TZ1 | Q19 | 1 marks

19.          D  

Physics HL | Paper 1A | May 2025 TZ2 | Q15 | 1 marks

15.          D  

Physics HL | Paper 1A | May 2025 TZ2 | Q16 | 1 marks

16.          B  

Physics HL | Paper 1A | May 2025 TZ2 | Q20 | 1 marks

20.          B  

Physics HL | Paper 1A | May 2025 TZ3 | Q19 | 1 marks

19.          B  

Physics HL | Paper 1A | May 2025 TZ3 | Q20 | 1 marks

20.          C  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q17 | 1 marks

17.          B  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q18 | 1 marks

18.          A  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q19 | 1 marks

19.          A  

Physics HL | Paper 1A | Specimen 2025 | Q19 | 1 marks

19.          C  

Physics HL | Paper 1A | Specimen 2025 | Q21 | 1 marks

21.          B

APOLLO

# Wave model

6 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q18 | 1 marks

18.          B  

Physics HL | Paper 1A | May 2025 TZ2 | Q17 | 1 marks

17.          B  

Physics HL | Paper 1A | May 2025 TZ2 | Q18 | 1 marks

18.          A  

Physics HL | Paper 1A | May 2025 TZ3 | Q21 | 1 marks

21.          C  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q18 | 1 marks

18.          B  

Physics HL | Paper 1A | Specimen 2025 | Q18 | 1 marks

18.          D

APOLLO

# Wave phenomena

18 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q20 | 1 marks

20.          C  

Physics HL | Paper 1A | May 2025 TZ1 | Q21 | 1 marks

21.          C  

Physics HL | Paper 1A | May 2025 TZ1 | Q23 | 1 marks

23.          D  

Physics HL | Paper 1A | May 2025 TZ3 | Q22 | 1 marks

22.          B  

Physics HL | Paper 1A | May 2025 TZ3 | Q23 | 1 marks

23.          B  

Physics HL | Paper 1A | May 2025 TZ3 | Q24 | 1 marks

24.          D

|    |   |     |                                                                                                                                                                                                     |                                                                                                                                                                                                                                                      |     |
|----|---|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 2. | a |     | measure P to be at the centre of the flat edge/side so that incident rays are aimed at P /go through radial lines<br>OR<br>check that the incident angle is $0^\circ$ at every point of incidence ✓ |                                                                                                                                                                                                                                                      | [1] |
| 2  | b | i   | $\theta_r = 49^\circ$ ✓                                                                                                                                                                             | Accept correct answer only                                                                                                                                                                                                                           | [1] |
| 2  | b | ii  | 0.755 ✓                                                                                                                                                                                             | Accept only 0.755. Answer must be quoted to 3 sf.                                                                                                                                                                                                    | [1] |
| 2  | c | i   | use two points from the line that use more than half the line of best fit ✓<br>gradient = 1.5 ✓                                                                                                     | Allow (implicit) use of the origin.<br>Look for $\Delta x \geq 0.3$                                                                                                                                                                                  | [2] |
| 2  | c | ii  | draw max from lower end of lower error bar to upper end of upper error bar ✓                                                                                                                        |                                                                                                                                                                                                                                                      | [1] |
| 2  | c | iii | States gradient gives the value of the refractive index<br>OR<br>$n = 1.5$ ✓<br>$n = 1.5 \pm 0.2$ ✓                                                                                                 | MP1 can be shown as an equation<br>Candidates may calculate the uncertainty by using the gradient of the line found in cii) or finding the average of the max and min lines of best fit.<br>Look for working leading to $0.1 \leq \Delta n \leq 0.2$ | [2] |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

|    |   |    |                                                                                                                                                                                       |                                                                                                                                               |   |
|----|---|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|---|
| 2. | a |    | Measure distance between multiple constructive/maxima fringes ✓<br>Divide this distance by the number of fringes «subtract 1»<br>OR<br>Divide this distance by the number of minima ✓ | <i>Do not accept answers that refer to changing the ruler to other measuring devices</i>                                                      | 2 |
| 2. | b |    | «A smaller d will» increase fringe separation s ✓<br>«Relative» uncertainty in s will decrease ✓                                                                                      | <i>Do not award MP2 without correct MP1 except when applying ECF from MP1</i>                                                                 | 2 |
| 2. | c | i  | $\frac{1}{d}$ ✓                                                                                                                                                                       | Allow $\frac{D}{d}$                                                                                                                           | 1 |
| 2. | c | ii | Uncertainty $\pm 30 \text{ nm}$ ✓<br>Rounding $\lambda = 610 \pm 30 \text{ nm}$ ✓                                                                                                     | <i>MP1 for obtaining uncertainty to any number of s.f.<br/>Allow ECF from MP1 for an answer written to correct s.f.<br/>Award [2] for BCA</i> | 2 |

|    |   |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                  |         |
|----|---|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| 4. | a |    | Light comes from a single source ✓<br>Waves need to have a constant phase difference / in phase ✓<br>«To produce» a fixed/stable/clear/constant pattern «over time»<br><b>OR</b><br>Only coherent light has this property/produces this pattern ✓                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                  | [2 max] |
|    | b | i  | <b>Alternative 1</b><br>$s = \frac{\lambda D}{d} \Rightarrow \phi = \frac{s}{D} = \frac{\lambda}{d}$ ✓<br>$\phi = \frac{720 \times 10^{-9}}{0.12 \times 10^{-3}} = 6.0 \times 10^{-3} \text{ rad}$ ✓<br><b>Alternative 2</b><br>$d \sin \frac{\phi}{2} = \frac{\lambda}{2} \Rightarrow \phi = 2 \sin^{-1} \frac{\lambda}{2d}$ ✓<br>$\phi = 2 \sin^{-1} \frac{720 \times 10^{-9}}{2 \times 0.12 \times 10^{-3}} = 6.0 \times 10^{-3} \text{ rad}$ ✓<br><b>Alternative 3</b><br><<With small angle approximation>> $d \frac{\phi}{2} = \frac{\lambda}{2} \Rightarrow \phi = \frac{\lambda}{d}$ ✓<br>$\phi = \frac{720 \times 10^{-9}}{0.12 \times 10^{-3}} = 6.0 \times 10^{-3} \text{ rad}$ ✓ | Award [2] if $6.0 \times 10^{-3}$ «rad» is seen as the answer without working<br>Do not penalize if answer in degrees (0.34°)<br>Award [1] for an answer of 0.012 or 0.003 «rad» | [2]     |
|    | b | ii | The energy missing at P <sub>1</sub> and P <sub>2</sub> is found at the maxima ✓                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                  | [1]     |
|    | c |    | Waves arrive in phase<br><b>OR</b><br>path difference is zero<br><b>OR</b><br>distance is the same ✓                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                  | [1]     |

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2225 – 6715M

|  |   |  |                                                                                                                                                                                                            |                                                                  |     |
|--|---|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|-----|
|  | d |  | Considers the largest wavelength <b>OR</b> $\theta = 90^\circ$ ✓<br>$d \sin \theta = n\lambda \Rightarrow n = \frac{10^{-3} \sin 90^\circ}{580 \times 10^{-9}} = 2.65$ ✓<br>So the second order/ $n = 2$ ✓ | Award [2] if smallest wavelength used and an answer of $n = 3$ . | [3] |
|--|---|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|-----|

– 12 –

2225 – 6715M

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Nov 2025 TZ1 | Q19 | 1 marks

19.          C  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q20 | 1 marks

20.          C  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q20 | 1 marks

20.          A  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q21 | 1 marks

21.          B  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q22 | 1 marks

22.          C  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q23 | 1 marks

23.          A

|    |   |                                                                                                                                                                                                           |                                                                                                                                           |     |
|----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 7. | a | «All pairs of rays which are symmetrical with respect to the dotted line have»<br>zero phase/path difference ✓<br>so interfere constructively at M ✓                                                      | Award [1] for a generic reference that a<br>path difference of an integer number of<br>wavelengths produces constructive<br>interference. | [2] |
| 7. | b | First diffraction minimum at / value use of $\theta = 0.04 \text{ rad}$ ✓<br>$\theta = \frac{\lambda}{b} \Rightarrow \lambda = b\theta = 1.3 \times 10^{-5} \times 0.04 = 5.2 \times 10^{-7} \text{ m}$ ✓ | Award full marks for a CNA<br><br>Allow ECF from MP1                                                                                      | [2] |

– 12 –

8825 – 6721M

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Specimen 2025 | Q22 | 1 marks

22.        D

Physics HL | Paper 1A | Specimen 2025 | Q23 | 1 marks

23.        D

APOLLO

# Standing waves and resonance

9 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q22 | 1 marks

22.          C  

Physics HL | Paper 1A | May 2025 TZ2 | Q19 | 1 marks

19.          A  

Physics HL | Paper 1A | May 2025 TZ3 | Q25 | 1 marks

25.          B  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q21 | 1 marks

21.          C  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q22 | 1 marks

22.          A  

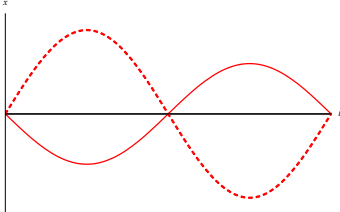
Physics HL | Paper 1A | Nov 2025 TZ3 | Q24 | 1 marks

24.          C

|    |   |     |                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                 |     |
|----|---|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|-----|
| 9. | a | i   | <b>ALTERNATIVE 1</b><br>One mole contains $6.02 \times 10^{23}$ atoms and has mass 63.5 g ✓<br>Mass of one atom is $\frac{63.5 \times 10^{-3}}{6.02 \times 10^{23}} = 1.055 \times 10^{-25} \approx 1.1 \times 10^{-25}$ kg ✓<br><br><b>ALTERNATIVE 2</b><br>The atom has mass 63.5 u ✓<br>I.e. $63.5 \times 1.661 \times 10^{-27} = 1.055 \times 10^{-25} \approx 1.1 \times 10^{-25}$ kg ✓ | Award full marks for a CNA<br><br>Accept similar calculation for a mass of 0.4 kg ( $n = 6.3$ ) | [2] |
| 9. | a | ii  | Volume of copper = $\frac{0.0635}{8940}$ ✓<br><br>$V = \frac{0.0635}{(8940 \times 6.02 \times 10^{23})} = 1.2 \times 10^{-29} \text{ m}^3$ ✓                                                                                                                                                                                                                                                 | Award full marks for a CNA<br><br>Accept similar calculation for a mass of 0.4 kg               | [2] |
| 9. | a | iii | Side of cube $a = \sqrt[3]{1.180 \times 10^{-29}} = 2.277 \times 10^{-10} \approx 2 \times 10^{-10}$ m ✓                                                                                                                                                                                                                                                                                     | Allow ECF from a ii<br><br>Award the mark for the CNA                                           | [1] |
| 9. | b |     | $Q \ll mL = 0.400 \times 206 \times 10^3 = 82.4 \text{ kJ}$ ✓                                                                                                                                                                                                                                                                                                                                |                                                                                                 | [1] |

– 14 –

8825–6721M

| Question |   |     | Answers                                                                                                                                                                                                                                                                                      | Notes                                                                    | Total |
|----------|---|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|-------|
| 9.       | c |     | Internal energy is greater in the liquid phase ✓<br>in liquid the intermolecular potential energy is greater / the separation is greater / energy has been added ✓<br>kinetic energy is unchanged / temperature is the same / internal energy is the sum of kinetic and potential energies ✓ |                                                                          | [3]   |
| 9.       | d | i   | wave «created by the hammer» is reflected / two «identical» waves in opposite directions ✓<br>the right and left waves superpose / add up / interfere ✓                                                                                                                                      | Accept reference to constructive and destructive interference in MP2     | [2]   |
| 9.       | d | ii  | Antinodes at both ends, a node in the middle ✓                                                                                                                                                                                                                                               | Accept only one wave or wave and envelope, either solid or broken lines. | [1]   |
| 9.       | d | iii | Opposite line i.e. phase difference of $\pi$ ✓<br>Smaller amplitude, ✓<br>                                                                                                                                | Labelling not necessary<br><br>MP2 only scores if MP1 scores             | [2]   |
| 9.       | e | i   | The standing wave is longitudinal/sand moves horizontally / sand is pushed/vibrates<br><b>OR</b><br>there are nodes and antinodes ✓<br>« sand moves» away from antinodes/ to nodes ✓                                                                                                         |                                                                          | [2]   |

| Question |   |    | Answers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Notes                                                              | Total |
|----------|---|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|-------|
| 9.       | e | ii | <p><b>ALTERNATIVE 1</b></p> <p>Wavelength in air is <math>2d</math> (<math>= 3.6\text{ cm}</math>) ✓</p> <p>Frequency of wave in copper is the same as that in the air in the tube ✓</p> $\frac{v_{\text{Cu}}}{2L} = \frac{v_{\text{air}}}{2d} \text{ ✓}$ $v_{\text{Cu}} = \frac{L}{d} \times v_{\text{air}} = \frac{34}{1.8} \times 330 = 6.2 \times 10^3 \text{ m s}^{-1} \text{ ✓}$ <p><b>ALTERNATIVE 2</b></p> <p>Wavelength in air is <math>2d</math> (<math>= 3.6\text{ cm}</math>) ✓</p> $f = \frac{330}{3.6 \times 10^{-2}} = 9.167 \times 10^3 \text{ Hz} \text{ ✓}$ $\lambda_{\text{Cu}} = 68 \text{ cm} \text{ ✓}$ $v_{\text{Cu}} = 9167 \times 0.68 = 6.2 \times 10^3 \text{ m s}^{-1} \text{ ✓}$ | <p>Award [4] for a CNA</p> <p>Allow ECF from wrong wavelengths</p> | [4]   |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Specimen 2025 | Q20 | 1 marks

20.      C

|    |   |                                                                                                                                                                                               |                                                                                  |   |
|----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|---|
| 3. | a | standing waves form «in the oven» by superposition / constructive interference✓<br>energy transfer is greatest at the antinodes «of the standing wave pattern»✓                               |                                                                                  | 2 |
| 3. | b | $\lambda = 12.2\text{cm}$ ✓<br><br>$f\text{«}=\frac{c}{\lambda}\text{»} = \frac{3.0\times10^8}{1.22\times10^{-1}}$ ✓<br><br>$f = 2.46\text{GHz}$ ✓ correct answer only including power of ten | Allow $\lambda \pm 2\text{ mm}$ .<br><br>Condone power of ten error in MP2 only. | 3 |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

APOLLO

# Doppler effect

3 questions

|    |   |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                    |       |
|----|---|----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------|
| 4. | a |    | <p>sound waves are longitudinal <b>OR</b> light waves are transverse ✓</p> <p>sound waves cannot travel through vacuum <b>OR</b> light waves travel can travel through vacuum ✓</p> <p>sound waves are propagated due to pressure changes <b>OR</b> light waves are propagated due to electric or magnetic field changes ✓</p> <p>speed of sound not the same between inertial reference frames <b>OR</b> speed of light same in all inertial reference frames ✓</p> <p>Speed of sound is «generally» slower <b>OR</b> speed of light is «generally» faster. ✓</p> |                                                                                    | 2 max |
| 4. | b | i  | <p>Wavelength = 0.68 «m» ✓</p> <p>Period = 0.002 «s» ✓</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Accept 0.67 – 0.70 m for wavelength.                                               | 2     |
| 4. | b | ii | <p><math>v = \lambda/T = 0.68 / 0.002 = \gg 340 \text{ «m s}^{-1}\text{»} \checkmark</math></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <p>Allow ECF from 4bi</p> <p>Allow <math>v = 335 - 350 \text{ m s}^{-1}</math></p> | 1     |

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2225 – 6721M

|    |   |     |                                                                                                                                                                                                                                                                                                 |  |   |
|----|---|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---|
| 4. | c | i   | <p>«apparent» change in the frequency/wavelength/pitch✓<br/>caused by a compression/stretching of wavefronts « due to relative motion»<br/><b>OR</b><br/>meets wavefronts more of less frequently ✓</p>                                                                                         |  | 2 |
| 4. | c | ii  | <p><math>440 \cdot \frac{340 + v}{340} = 540 \cdot \frac{340 - v}{340} \checkmark</math><br/>so <math>v = 34.7 \text{ «m s}^{-1}\text{»} \checkmark</math></p>                                                                                                                                  |  | 2 |
| 4. | c | iii | <p>Use of <math>\frac{v}{c} = \frac{\Delta\lambda}{\lambda} = \frac{(659 \times 10^{-9}) - (656.1 \times 10^{-9})}{(656.1 \times 10^{-9})} \checkmark</math></p> <p><math>v = 1.33 \times 10^6 \text{ «m s}^{-1}\text{»}</math><br/><b>OR</b><br/><math>0.00442 \text{ c} \checkmark</math></p> |  | 2 |

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2225 – 6721M

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Nov 2025 TZ1 | Q23 | 1 marks

23.        B

Physics HL | Paper 1A | Nov 2025 TZ3 | Q25 | 1 marks

25.        D

APOLLO

# Gravitational fields

16 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q24 | 1 marks

24.          B  

Physics HL | Paper 1A | May 2025 TZ1 | Q25 | 1 marks

25.          A  

Physics HL | Paper 1A | May 2025 TZ2 | Q21 | 1 marks

21.          A  

Physics HL | Paper 1A | May 2025 TZ3 | Q26 | 1 marks

26.          B  

Physics HL | Paper 1A | May 2025 TZ3 | Q27 | 1 marks

27.          A  

Physics HL | Paper 1A | May 2025 TZ3 | Q28 | 1 marks

28.          D  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q24 | 1 marks

24.          C  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q25 | 1 marks

25.          A  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q26 | 1 marks

26.          A  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q27 | 1 marks

27.          C  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q28 | 1 marks

28.          C  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q29 | 1 marks

29.          B  

Physics HL | Paper 1A | Specimen 2025 | Q25 | 1 marks

25.          D

## Mark-scheme answers

Physics HL | Paper 1A | Specimen 2025 | Q28 | 1 marks

28.          D  

Physics HL | Paper 1A | Specimen 2025 | Q30 | 1 marks

30.          C

|    |   |    |                                                                                                                                                                                                                                                                                                    |                         |   |
|----|---|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|---|
| 4. | a |    | arrow normal to the orbit towards the Earth ✓                                                                                                                                                                                                                                                      |                         | 1 |
| 4. | b | i  | <p>use of <math>v_{\text{orbital}} = \frac{2\pi r}{T}</math> AND either <math>v_{\text{orbital}} = \sqrt{\frac{GM}{r}}</math> or <math>\frac{mv_{\text{orbital}}^2}{r} = \frac{GMm}{r^2}</math> correctly manipulated ✓</p> <p>«to yield <math>T^2 = \left(\frac{4\pi^2}{GM}\right)r^3</math>»</p> | Allow use of $\omega$ . | 1 |
| 4. | b | ii | <p><math>r = \sqrt[3]{\frac{GMT^2}{4\pi^2}} = \sqrt[3]{\frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times (5620)^2}{4\pi^2}}</math> ✓</p> <p><math>= 6.83 \times 10^6</math> «m»</p> <p>height = «<math>6.83 \times 10^6 - 6.37 \times 10^6 \Rightarrow 4.6 \times 10^5</math> «m» ✓</p> |                         | 2 |
| 4. | c |    | <p>Total energy is reduced ✓</p> <p>hence decrease in orbital radius leads to increase in kinetic energy ✓</p> <p>decrease in potential energy must be larger than increase in kinetic energy for total energy to decrease ✓</p>                                                                   | Allow ECF from b ii.    | 3 |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

APOLLO

# Electric and magnetic fields

23 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q26 | 1 marks

26.          A  

Physics HL | Paper 1A | May 2025 TZ1 | Q27 | 1 marks

27.          D  

Physics HL | Paper 1A | May 2025 TZ1 | Q28 | 1 marks

28.          A  

Physics HL | Paper 1A | May 2025 TZ1 | Q29 | 1 marks

29.          C  

Physics HL | Paper 1A | May 2025 TZ1 | Q30 | 1 marks

30.          B  

Physics HL | Paper 1A | May 2025 TZ2 | Q22 | 1 marks

22.          B  

Physics HL | Paper 1A | May 2025 TZ2 | Q23 | 1 marks

23.          C  

Physics HL | Paper 1A | May 2025 TZ2 | Q24 | 1 marks

24.          B  

Physics HL | Paper 1A | May 2025 TZ2 | Q27 | 1 marks

27.          A  

Physics HL | Paper 1A | May 2025 TZ3 | Q29 | 1 marks

29.          D  

Physics HL | Paper 1A | May 2025 TZ3 | Q30 | 1 marks

30.          B  

Physics HL | Paper 1A | May 2025 TZ3 | Q31 | 1 marks

31.          C

|    |   |  |                                                                                                                                                                                                                                  |                                                                                                                                            |         |
|----|---|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|---------|
| 3. | a |  | $r$ ✓<br>because it gives the most uniform field in space between coils/across the magnet<br>OR<br>$2r$ gives a lower magnitude of the field OR<br>$0.5r$ gives a greater magnitude of the field but not uniform across magnet ✓ |                                                                                                                                            | [2]     |
| 3  | b |  | $B_H$ will be perpendicular to $B_{coils}$ ✓<br>the deflection of the magnet will allow for the determination of $B_H$ ✓<br>gives the maximum possible deflection of the magnet ✓                                                | MP2 can be given for use of deflection to measure $B_H$ .                                                                                  | [2] max |
| 3  | c |  | $\tan 24^\circ = B_H/B_{coils}$ ✓<br>$B_H = \llcorner 7.5 \times 10^{-5} \text{ T} \times \tan 24^\circ \Rightarrow 3.3 \times 10^{-5} \text{ T} \llcorner$ ✓                                                                    | Watch for ECF from a).<br>For MP2:<br>for $2r$ , $B_H = 1.3 \times 10^{-5} \text{ T}$<br>for $0.5r$ , $B_H = 4.5 \times 10^{-5} \text{ T}$ | [2]     |

## Mark-scheme answers

Physics HL | Paper 1A | Nov 2025 TZ1 | Q26 | 1 marks

26.          D  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q27 | 1 marks

27.          B  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q30 | 1 marks

30.          D  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q31 | 1 marks

31.          C  

Physics HL | Paper 1A | Specimen 2025 | Q24 | 1 marks

24.          A  

Physics HL | Paper 1A | Specimen 2025 | Q26 | 1 marks

26.          B  

Physics HL | Paper 1A | Specimen 2025 | Q27 | 1 marks

27.          B  

Physics HL | Paper 1A | Specimen 2025 | Q31 | 1 marks

31.          C  

Physics HL | Paper 1A | Specimen 2025 | Q32 | 1 marks

32.          A

|    |   |    |                                                                                                                                                                                                                                                                   |  |   |
|----|---|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---|
| 9. | a | i  | equally spaced arrows «by eye» all pointing down ✓<br>edge effects also shown with arrows ✓                                                                                                                                                                       |  | 2 |
| 9. | a | ii | $E = \frac{V}{d} = \frac{960}{8.0 \times 10^{-3}} \checkmark$<br>$E = 1.2 \times 10^5 \text{ «NC}^{-1}\text{»} \checkmark$                                                                                                                                        |  | 2 |
| 9. | b |    | friction transfers electron(s) to or from drop<br><b>AND</b><br>through collisions/ interaction with air molecules in the tube OR through collisions/interaction with wall of tube ✓                                                                              |  | 1 |
| 9. | c | i  | weight of oil drop is $\rho_o g V \checkmark$<br>$\frac{F_b}{W} = \frac{\rho_a g V}{\rho_o g V} = \frac{\rho_a}{\rho_o} \checkmark$<br>$\frac{F_b}{W} = \frac{1}{730} \Rightarrow 1.4 \times 10^{-3}$<br><b>OR</b><br>Ratio of $F_b$ to $W$ is much less than 1 ✓ |  | 3 |

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SPEC/4/PHYSI/HP2/ENG/TZ0/XX/M

|    |   |     |                                                                                                                                                                                            |                                          |   |
|----|---|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|---|
| 9. | c | ii  | Weight vertically down <b>AND</b> electric force vertically up ✓<br>Of equal length «by eye» ✓                                                                                             |                                          | 2 |
| 9. | c | iii | Mass of drop is $\rho_o V \checkmark$<br>$qE = (\rho_o V)g \checkmark$<br>«hence answer»                                                                                                   | MP1 must be shown implicitly for credit. | 2 |
| 9. | c | iv  | Negative ✓                                                                                                                                                                                 |                                          | 1 |
| 9. | d | i   | Net force is zero ✓<br>Acceleration of the oil drop is zero ✓<br><b>OR</b><br>For terminal velocity drag must equal weight ✓<br>weight = $\rho_o g V$ and drag = $6\pi\eta r v \checkmark$ |                                          | 2 |

|    |   |     |                                                                                                                                                                                                                          |                                |   |
|----|---|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|---|
| 9. | d | ii  | $q = \frac{6\pi\eta rV}{E} \checkmark$ $q = \frac{6\pi \times 1.60 \times 10^{-5} \times 1.36 \times 10^{-6} \times 1.40 \times 10^{-4}}{1.2 \times 10^5} \checkmark$ $q = 4.79 \times 10^{-19} \text{ «C» } \checkmark$ | Answer must be shown to 3+ sf. | 3 |
| 9. | d | iii | charge is quantized $\checkmark$<br>so, the charges must be 1e and 2e $\checkmark$                                                                                                                                       |                                | 2 |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

APOLLO

# Motion in electromagnetic fields

8 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ2 | Q25 | 1 marks

25.          A  

Physics HL | Paper 1A | May 2025 TZ2 | Q26 | 1 marks

26.          A

|    |   |     |                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                   |     |
|----|---|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|-----|
| 3. | a |     | $E = \llcorner \frac{120}{8.0 \times 10^{-2}} = \gg 1.5 \times 10^3 \text{ NC}^{-1} \text{ OR } V\text{m}^{-1} \checkmark$                                                                                                                                                                                                                                           |                                                                                                                   | [1] |
|    | b | i   | $F = \llcorner eE = \gg 3.2 \times 10^{-19} \times 1.5 \times 10^3 \text{ OR } 4.8 \times 10^{-16} \text{ N} \checkmark$<br>$a = \llcorner \frac{F}{m} = \gg \frac{4.8 \times 10^{-16}}{4 \times 1.67 \times 10^{-27}} \text{ OR } 7.2 \times 10^{10} \text{ ms}^{-2} \checkmark$                                                                                    | Allow ECF from a).<br><br>Award [1] if they use a charge of e and a mass of 2u obtaining the right result.        | [2] |
|    | b | ii  | <b>ALT 1</b><br>$t = \sqrt{\frac{2s}{a}} \checkmark$<br>$t = \llcorner \sqrt{\frac{2 \times 8.0 \times 10^{-2}}{7.2 \times 10^{10}}} = \gg 1.5 \times 10^{-6} \text{ s} \checkmark$<br><br><b>ALT 2</b><br>$v = \sqrt{2as} \llcorner = 1.06 \times 10^5 \text{ ms}^{-1} \gg \checkmark$<br>$t = \llcorner \frac{v}{a} = \gg 1.5 \times 10^{-6} \text{ s} \checkmark$ | Award [2] if $1.5 \times 10^{-6} \text{ s}$ is seen as the answer without working.                                | [2] |
|    | b | iii | 240 eV $\checkmark$                                                                                                                                                                                                                                                                                                                                                  | Accept $3.8 \times 10^{-17} \text{ J}$                                                                            | [1] |
|    | c |     | $F_m = F_e \text{ OR } qvB = qE \text{ OR } B = F_e / qv \checkmark$<br>$B = \llcorner \frac{E}{v} = \frac{1.5 \times 10^3}{5.0 \times 10^5} = \gg 3.0 \times 10^{-3} \text{ T} \checkmark$                                                                                                                                                                          | Award [2] if $3.0 \times 10^{-3} \text{ T}$ is seen as the answer without working.<br>Allow ECF from a) and b) i) | [2] |

– 9 –

2225–6715M

|  |   |  |                                            |  |     |
|--|---|--|--------------------------------------------|--|-----|
|  |   |  |                                            |  |     |
|  | d |  | Horizontal / undeflected path $\checkmark$ |  | [1] |

– 10 –

2225–6715M

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Nov 2025 TZ1 | Q28 | 1 marks

28.          C  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q29 | 1 marks

29.          B  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q32 | 1 marks

32.          B

|    |   |    |                                                                                                                                                        |                                                                 |     |
|----|---|----|--------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|-----|
| 3. | a |    | $\ll 8.99 \times 10^9 \times \left( \frac{9Q}{0.30^2} + \frac{Q}{0.06^2} \right) = 3.26 \times 10^7 \text{ so } \gg Q = 9.6 \times 10^{-6} \checkmark$ |                                                                 | [2] |
|    |   |    | C $\checkmark$                                                                                                                                         |                                                                 |     |
| 3. | b | i  | $qvB = m \frac{v^2}{R} \checkmark$ Hence answer                                                                                                        |                                                                 | [1] |
| 3. | b | ii | Force is perpendicular to the velocity / F acts as centripetal / F does no work / F only changes direction of velocity $\checkmark$                    | <i>Do not accept reference to centripetal acceleration only</i> | [1] |
| 3. | c |    | loss of energy / speed reduced $\checkmark$<br>so radius decreases $\checkmark$                                                                        | <i>MP2 scores only if MP1 is scored.</i>                        | [2] |

– 8 –

8825–6721M

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

|    |   |     |                                                                                                                                                                                                                                                                                                                        |                                    |   |
|----|---|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|---|
| 1. | a | i   | 0.02 «kV» ✓                                                                                                                                                                                                                                                                                                            |                                    | 1 |
| 1. | a | ii  | by measuring the time for many bounces ✓<br>and dividing the result by the number of bounces ✓                                                                                                                                                                                                                         |                                    | 2 |
| 1. | a | iii | it is not possible to draw a straight line through all the error bars ✓                                                                                                                                                                                                                                                |                                    | 1 |
| 1. | a | iv  | $T = 0.5 \text{ s}$ ✓<br>« $\frac{0.1}{0.5} \Rightarrow 0.2$ » ✓                                                                                                                                                                                                                                                       |                                    | 2 |
| 1. | b | i   | a best-fit line drawn through the entire range of the data ✓<br>large triangle greater than half a line or two data points on the line greater than half a line apart ✓<br><br>correct read offs consistent with the line, eg $\frac{1.6 - 0}{0.40 - 0} = 4.0$ ✓                                                       | Accept answer in the range 3.8–4.2 | 3 |
| 1. | b | ii  | kV s ✓                                                                                                                                                                                                                                                                                                                 |                                    | 1 |
| 1. | b | iii | the angle between the string and the vertical should be very small «for any position of the ball» ✓<br>so that the tension in the string is «almost» balanced by the ball's weight<br><b>OR</b><br>restoring force from the string / horizontal component of tension negligibly small «compared with electric force» ✓ | OWTTE                              | 2 |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

APOLLO

# Induction

10 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q31 | 1 marks

31.          D  

Physics HL | Paper 1A | May 2025 TZ2 | Q28 | 1 marks

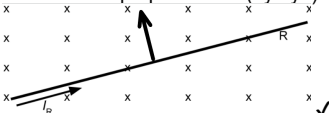
28.          B  

Physics HL | Paper 1A | May 2025 TZ2 | Q29 | 1 marks

29.          A  

Physics HL | Paper 1A | May 2025 TZ2 | Q30 | 1 marks

30.          D

|    |   |    |                                                                                                                                      |                                                                                                                                  |   |
|----|---|----|--------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|---|
| 8. | a | i  | Use of $F = BIL$ <b>OR</b> $F/L = BI$ ✓<br>$= 1.0 \text{ «N m}^{-1}\text{»}$ ✓                                                       |                                                                                                                                  | 2 |
| 8. | a | ii | Arrow drawn perpendicular (by eye) as shown.<br>    | Arrow can be drawn anywhere along the wire.                                                                                      | 1 |
| 8. | b | i  | $\frac{F}{L} = \frac{\mu_0 I_R I_Z}{2\pi r}$<br><b>AND</b><br>$\frac{F}{L} = B_R I_Z$ ✓<br>Combine to give the result ✓              | <b>Must</b> see subscripts on both $I$ and $B$ for full marks. Award [1 max] for correct derivations with incomplete subscripts. | 2 |
| 8. | b | ii | $\text{kg m s}^{-2} \text{ A}^{-2}$ ✓                                                                                                | Allow fractional answers such as:<br>$\frac{\text{kg m}}{\text{s}^2 \text{ A}^2}$                                                | 1 |
| 8. | c | i  | the magnetic field produced by the wire/ $I_R$ is constant. ✓<br>therefore the «magnetic» flux/field through the coil is constant. ✓ |                                                                                                                                  | 2 |

– 22 –

2225 – 6721M

|    |   |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |   |
|----|---|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---|
| 8. | c | ii  | $\Delta B = \frac{\mu_0}{2\pi} \left( \frac{10-2}{0.1} \right)$ <b>OR</b> $2 \times 10^{-5} - 4 \times 10^{-6} = 1.6 \times 10^{-5} \text{ «T»}$ ✓<br><br>$\Delta \phi = A \Delta B = (\pi)(0.02^2)((2 \times 10^{-5}) - (4 \times 10^{-6})) = 2.5 \times 10^{-8} - 5.03 \times 10^{-9}$<br>$= 2.01 \times 10^{-8} \text{ «Wb»}$ ✓<br><br>$\varepsilon = \frac{n \Delta \phi}{\Delta t} = \frac{(20)(2.01 \times 10^{-8})}{0.5} = 8.0 \times 10^{-7} \text{ «V»}$ ✓ |  | 3 |
| 8. | c | iii | Anticlockwise/counterclockwise/CCW ✓<br><br>magnetic field from the wire is «increasing» into the page <b>OR</b> induced field must be out of the page ✓                                                                                                                                                                                                                                                                                                            |  | 2 |
| 8. | d |     | sine graph with half the period, i.e. one large square/5 small squares (by eye) ✓<br>and twice the amplitude, i.e. four small squares (by eye) ✓                                                                                                                                                                                                                                                                                                                    |  | 2 |

|    |   |    |                                                                                                                                                                                                                                                                                                                                                                                                                        |  |   |
|----|---|----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---|
| 8. | e | i  | <p>use of <math>qvB = mv^2/r</math></p> <p><b>OR</b></p> $r = \frac{mv}{qB} \quad \checkmark$ $1.6 \times 10^{-19} \times 4.0 \times 10^{-6} = \frac{9.1 \times 10^{-31} \times 9 \times 10^5}{r}$ <p><b>OR</b></p> $r = \frac{(9.1 \times 10^{-31})(9 \times 10^5)}{[(1.6 \times 10^{-19})(4 \times 10^{-6})]} \quad \checkmark$ <p><math>r = 1.28</math> <b>OR</b> <math>1.3 \text{ «m»} \quad \checkmark</math></p> |  | 3 |
| 8. | e | ii | <p>Force/Field decreases as electron moves away from the wire <math>\checkmark</math></p> <p>Hence radius increases. <math>\checkmark</math></p>                                                                                                                                                                                                                                                                       |  | 2 |

## Mark-scheme answers

Physics HL | Paper 1A | Nov 2025 TZ1 | Q30 | 1 marks

30.        A

Physics HL | Paper 1A | Nov 2025 TZ1 | Q31 | 1 marks

31.        C

|    |   |    |                                                                                                                                                                                                                                                                                                                                                                                                                             |  |     |
|----|---|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|-----|
| 8. | a |    | The flux is increasing / there is an induced emf/current ✓<br>The induced current will be counter-clockwise / current is induced in a direction that creates a force that opposes the change ✓<br>A magnetic force to the left / opposing will act on the rod ✓<br>(bringing it to rest)                                                                                                                                    |  | [3] |
| 8. | b | i  | «The current in the circuit will be clockwise so there will be a magnetic force accelerating the rod that then» moves to the right ✓                                                                                                                                                                                                                                                                                        |  | [1] |
| 8. | b | ii | <b>ALTERNATIVE 1</b><br>Since the induced emf $BLv$ opposing the cell's emf is proportional to speed ✓<br>It will eventually equal the emf of the cell resulting in zero current and hence zero net force on the rod ✓<br><br><b>ALTERNATIVE 2</b><br>«As in 8a, » there is a counter-clockwise induced current / a force to the left ✓<br>This current / force increases with $v$ until resultant current/ force is zero ✓ |  | [2] |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Specimen 2025 | Q29 | 1 marks

29.          B

|    |   |                                                                                                                                                                                                                                                                                         |  |   |
|----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---|
| 5. | a | ring B cuts an increasing number of magnetic field lines<br><br><b>OR</b><br>magnetic field from current in A increases at the position of B ✓                                                                                                                                          |  | 1 |
| 5. | b | counterclockwise ✓                                                                                                                                                                                                                                                                      |  | 1 |
| 5. | c | the rate of change of «magnetic» flux in B increases<br><br><b>OR</b><br>The gradient of the graph is increasing with time ✓<br>Faraday's law states that the induced emf in B will «therefore» increase ✓<br>so induced current will increase because resistance of ring is constant ✓ |  | 3 |
| 5. | d | the current induced in B gives rise to a magnetic field opposing that of A<br><br><b>OR</b><br>there will be a magnetic force opposing the motion ✓<br>work must be done to move B in the opposite direction to this force ✓                                                            |  | 2 |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

APOLLO

# Structure of the atom

11 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q32 | 1 marks

32.        A

Physics HL | Paper 1A | May 2025 TZ1 | Q33 | 1 marks

33.        C

Physics HL | Paper 1A | May 2025 TZ2 | Q33 | 1 marks

33.        C

Physics HL | Paper 1A | May 2025 TZ3 | Q33 | 1 marks

33.        D

|    |   |     |                                                                                                                                                                                                                                                                                                                                 |                                                                         |       |
|----|---|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-------|
| 5. | a | i   | 86 ✓                                                                                                                                                                                                                                                                                                                            |                                                                         | 1     |
| 5. | a | ii  | <b>ALT 1</b><br>mass defect = $226.02540 - 222.01757 - 4.00260 = 0.00523$ «u» ✓<br>$0.00523 \times 931.5 = 4.87$ «MeV» ✓<br><b>ALT 2</b><br>initial energy = $(226.02540)(931.5) = 210542.66$ «MeV»<br><b>OR</b><br>final energy = $(222.01757 + 4.00260)(931.5) = 210537.79$ «MeV» ✓<br>$210542.66 - 210537.79 = 4.87$ «MeV» ✓ | Must see full substitution or answer to at least 2 significant figures. | 2     |
| 5. | a | iii | $p_{\alpha} = p_{Rn}$ ✓<br>«Use of $KE = p^2/2m$ to get $KE_{\alpha}/KE_{Rn} = 222/4$ so»<br>$KE_{\alpha} = 222/226$ OR $0.982$ ✓                                                                                                                                                                                               |                                                                         | 2     |
| 5. | b | i   | «a few» alpha particles bounce back from the foil ✓<br>«most» alpha particles pass through «undeflected» ✓<br>«some» alpha particles were scattered/deviated from their path ✓                                                                                                                                                  |                                                                         | 2 max |
| 5. | b | ii  | «nucleus is» small <b>AND</b> dense ✓<br>«nucleus is» positively charged<br><b>OR</b>                                                                                                                                                                                                                                           |                                                                         | 2     |

– 14 –

2225–6721M

|    |   |     |                                                                                                                                                                                                                                                                                                                                                                                   |  |   |
|----|---|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---|
|    |   |     | a nucleus «is postulated» ✓                                                                                                                                                                                                                                                                                                                                                       |  |   |
| 5. | b | iii | $E = (4.8 \times 10^6)(1.6 \times 10^{-19}) = 7.68 \times 10^{-13}$ «J» ✓<br>$q_{Au} = (79)(1.6 \times 10^{-19}) = 1.264 \times 10^{-17}$ «C»<br><b>OR</b><br>$q_{\alpha} = (2)(1.6 \times 10^{-19}) = 3.2 \times 10^{-19}$ «C» ✓<br>$\frac{(8.99 \times 10^9)(1.26 \times 10^{-17})(3.2 \times 10^{-19})}{(7.68 \times 10^{-13})} =$ $d = \text{« » } 4.7 \times 10^{-14}$ «m» ✓ |  | 3 |
| 5. | b | iv  | Use of $\frac{\text{radius of Au nucleus}}{\text{radius of Al nucleus}} = \frac{A_{Au}^{1/3}}{A_{Al}^{1/3}}$ ✓<br>$197^{1/3}/27^{1/3} = 1.9$ ✓                                                                                                                                                                                                                                    |  | 2 |

– 15 –

2225–6721M

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Nov 2025 TZ1 | Q32 | 1 marks

32.          C  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q33 | 1 marks

33.          B  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q34 | 1 marks

34.          D  

Physics HL | Paper 1A | Specimen 2025 | Q34 | 1 marks

34.          A  

Physics HL | Paper 1A | Specimen 2025 | Q38 | 1 marks

38.          B  

Physics HL | Paper 1A | Specimen 2025 | Q40 | 1 marks

40.          B

APOLLO

# Quantum physics

19 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q34 | 1 marks

34.          A  

Physics HL | Paper 1A | May 2025 TZ1 | Q35 | 1 marks

35.          A  

Physics HL | Paper 1A | May 2025 TZ2 | Q32 | 1 marks

32.          D  

Physics HL | Paper 1A | May 2025 TZ2 | Q34 | 1 marks

34.          B  

Physics HL | Paper 1A | May 2025 TZ2 | Q35 | 1 marks

35.          B  

Physics HL | Paper 1A | May 2025 TZ3 | Q32 | 1 marks

32.          C  

Physics HL | Paper 1A | May 2025 TZ3 | Q34 | 1 marks

34.          B

|    |   |     |                                                                                                                                                                                                                         |                                                                                                                           |     |
|----|---|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|-----|
| 5. | a |     | Compton scattering provides evidence for «the energy and » the momentum of the photon / refers to the collision between photon and electron ✓<br>The photoelectric effect provides evidence for the energy of photons ✓ |                                                                                                                           | [2] |
|    | b |     | The photon loses energy / transfers energy to the electron ✓<br>$E = \frac{hc}{\lambda}$ / lower energy implies longer wavelength ✓                                                                                     |                                                                                                                           | [2] |
|    | c | i   | $E = \frac{hc}{\lambda} = \frac{1.24 \times 10^{-6}}{7.47 \times 10^{-12}} \text{ OR } 0.166 \text{ MeV}$ ✓                                                                                                             |                                                                                                                           | [1] |
|    | c | ii  | $E = \langle 0.194 - 0.166 = \rangle 0.028 \text{ MeV}$ ✓                                                                                                                                                               | Accept 0.024 from the value given as show that.<br>Allow ECF from c) i)<br>Accept $4.5 \times 10^{-15} \text{ J}$ .       | [1] |
|    | c | iii | $7.47 \times 10^{-12} - 6.40 \times 10^{-12} = 2.43 \times 10^{-12} (1 - \cos \theta)$ ✓<br>« $\cos \theta = 0.5597$ so » $\theta = 56.0^\circ$ ✓                                                                       | Accept angle in radians (0.98 « rad »).<br>Award [2] if $56^\circ$ or 0.98 « rad » are seen as the answer without working | [2] |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

|    |   |                                                                                                                                                                                 |                                                                                              |   |
|----|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|---|
| 6. | a | <p>reads <math>\lambda = 5.0 \times 10^{-7}</math> «m» ✓</p> <p><math>\Phi = \frac{hc}{\lambda} = \frac{1.24 \times 10^{-6}}{5 \times 10^{-7}}</math> <b>OR</b> 2.48 «eV» ✓</p> | <p><i>Must see full substitution or answer to 3 or more significant figures for MP2.</i></p> | 2 |
|----|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|---|

– 16 –

2225–6721M

|    |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |  |       |
|----|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|-------|
| 6. | b | <p><b>ALT 1</b></p> <p>«hf <b>OR</b> <math>hc/\lambda = (1.24 \times 10^{-6})/(4.0 \times 10^{-7}) = 3.1</math> «V» ✓</p> <p>«3.1 - 2.5 =» 0.6 «V» ✓</p> <p><b>ALT 2</b></p> <p><math>\frac{(6.63 \times 10^{-34})(3 \times 10^8)}{(4 \times 10^{-7})} - (4 \times 10^{-19}) = 9.73 \times 10^{-20}</math> «J» ✓</p> <p>«<math>(9.73 \times 10^{-20})/(1.6 \times 10^{-19})</math>» = 0.6 «V» ✓</p>                                                                                       |  | 2     |
| 6. | c | <p>Particle nature suggests photons have energy related to frequency/wavelength ✓</p> <p>Intensity does not change photon energy</p> <p><b>OR</b></p> <p>Intensity not related to E necessary to release electron. ✓</p> <p>One photon of sufficient energy is necessary to release an electron</p> <p><b>OR</b></p> <p>photon must have sufficient energy to release electron. ✓</p> <p>If light is a wave, higher intensity should provide energy with time to eject an electron. ✓</p> |  | 2 max |

– 17 –

2225–6721M

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Nov 2025 TZ1 | Q33 | 1 marks

33.        A

Physics HL | Paper 1A | Nov 2025 TZ1 | Q34 | 1 marks

34.        B

Physics HL | Paper 1A | Nov 2025 TZ1 | Q35 | 1 marks

35.        D

Physics HL | Paper 1A | Nov 2025 TZ1 | Q36 | 1 marks

36.        C

Physics HL | Paper 1A | Nov 2025 TZ3 | Q35 | 1 marks

35.        D

Physics HL | Paper 1A | Nov 2025 TZ3 | Q36 | 1 marks

36.        D

|    |   |  |                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                    |     |
|----|---|--|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 1. | a |  | 3 ✓                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                    | [1] |
| 1. | b |  | <p>Chooses 3-&gt;2 transition ✓</p> $\lambda = \frac{hc}{\Delta E} \quad \checkmark$ $\lambda = \frac{1.24 \times 10^{-6}}{1.89} \Rightarrow 6.56 \times 10^{-7} \text{ m}$ <p><b>OR</b></p> $\lambda = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{1.89 \times 1.6 \times 10^{-19}} \Rightarrow 6.58 \times 10^{-7} \text{ m} \quad \checkmark$ | <p><i>Ignore sign.</i><br/> <i>Award [3] for CNA (correct numerical answer)</i><br/> <i>Allow ECF from MP1 if they choose an incorrect transition</i><br/> <i>Do not penalize 657 nm</i><br/>                     Award [1] max if they calculate a wavelength using a single energy level instead of a <math>\Delta E</math>.</p> | [3] |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

|     |   |    |                                                                                                                                                                                                                                                                                                                                            |                                                                                           |     |
|-----|---|----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-----|
| 10. | a |    | Reference to an experimental evidence e.g. Compton or photoelectric effect ✓<br><br>Brief reference to the transfer of momentum and/or energy of a photon in the example given e.g. photon scatters from an electron transferring momentum and/or energy or photon strikes «and ejects» an electron transferring momentum and/or energy. ✓ | Accept any correct reference to the experiment quoted even if only about energy transfer. | [2] |
| 10. | b | i  | Energy incident per second/power is $N \frac{hc}{\lambda}$ ✓<br>Intensity is power per area ✓<br>so $I = \frac{N hc}{A \lambda}$                                                                                                                                                                                                           | Allow [1] if student consistently uses energy instead of power.                           | [2] |
| 10. | b | ii | Use of photon momentum $\frac{h}{\lambda}$ ✓<br>Force is rate of change of total momentum $N \frac{2h}{\lambda}$ ✓<br>Pressure is force per unit area $\frac{N 2h}{A \lambda}$ and substitution $\frac{N h}{A \lambda} = \frac{I}{c}$ to get result ✓                                                                                      |                                                                                           | [3] |

– 17 –

8825 – 6721M

| Question |   |     | Answers                                                                                                                                                                                                                                                                                                                  | Notes                                                                                        | Total |
|----------|---|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|-------|
| 10.      | c | i   | $F = \langle PA \Rightarrow \frac{2 \times 420}{3 \times 10^8} \times 1600$ OR $4.48 \times 10^{-3} N$ ✓<br><br>$a = \langle \frac{F}{m} \Rightarrow \frac{2 \times 420 \times 1600}{3 \times 10^8 \times 1400}$ OR $3.2 \times 10^{-6} ms^{-2}$ ✓                                                                       |                                                                                              | [2]   |
| 10.      | c | ii  | $s = \frac{1}{2} at^2 \Rightarrow t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 6.1 \times 10^{11}}{3.2 \times 10^{-6}}}$ ✓<br>$t = 6.175 \times 10^8 s = 19.6 \approx 20$ years ✓                                                                                                                                      | Award full marks for a correct answer in seconds or years.<br><br>Award full marks for a CNA | [2]   |
| 10.      | c | iii | The intensity of light on the sail will not remain constant/the force due to the Sun/Earth/Jupiter/other planets is ignored/sail may not be flat/light may be incident at an angle/part of the radiation may be absorbed/any other reasonable statement ✓                                                                |                                                                                              | [1]   |
| 10.      | d | i   | Any position along the dotted line between the spacecraft and the centre of the ellipse ✓                                                                                                                                                                                                                                |                                                                                              | [1]   |
| 10.      | d | ii  | Jupiter is at a focus of the ellipse ✓<br><br>Speed is a maximum, potential energy is a minimum hence the spacecraft is closest to Jupiter<br>OR<br>The angular momentum $mvr$ of the spacecraft is conserved and since speed is maximum the spacecraft is closest to Jupiter<br>OR<br>reference to Kepler' second law ✓ | Accept not at the centre for MP1                                                             | [2]   |

| Question |   |    | Answers                                                                                                                                                                                                                                                               | Notes              | Total |
|----------|---|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|-------|
| 10.      | e | i  | $\omega^2 r = G \frac{M}{r^2} \quad \text{OR} \quad \frac{GM}{r} = \frac{2\pi r}{T} \quad \checkmark$ $M = \rho \frac{4\pi r^3}{3} \quad \checkmark$ <p>Manipulation to show the result e.g.</p> $T^2 = \frac{4\pi^2}{G\rho \frac{4\pi r^3}{3}} r^3 \quad \checkmark$ |                    | [3]   |
| 10.      | e | ii | $\rho = \frac{3\pi}{GT^2} = \frac{3\pi}{6.67 \times 10^{-11} \times (2.9 \times 60 \times 60)^2} \quad \checkmark$ $\rho = 1.3 \times 10^3 \text{ kg m}^{-3} \quad \checkmark$                                                                                        | Allow ECF from MP1 | [2]   |

## Mark-scheme answers

Physics HL | Paper 1A | Specimen 2025 | Q35 | 1 marks

35.        D

Physics HL | Paper 1A | Specimen 2025 | Q39 | 1 marks

39.        B

APOLLO

# Radioactive decay

9 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q36 | 1 marks

36.          A  

Physics HL | Paper 1A | May 2025 TZ1 | Q37 | 1 marks

37.          A  

Physics HL | Paper 1A | May 2025 TZ2 | Q37 | 1 marks

37.          A  

Physics HL | Paper 1A | May 2025 TZ2 | Q38 | 1 marks

38.          C  

Physics HL | Paper 1A | May 2025 TZ3 | Q35 | 1 marks

35.          C  

Physics HL | Paper 1A | May 2025 TZ3 | Q36 | 1 marks

36.          D  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q37 | 1 marks

37.          B

|    |   |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                            |     |
|----|---|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 4. | a | i   | 600 «counts per hr» ✓                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                            | [1] |
| 4. | a | ii  | <b>ALTERNATIVE 1</b><br>Subtract their background rate to 3000 to get the initial count rate<br>e.g. initial count rate 2400 counts per h ✓<br>Attempt to read t for $\frac{1}{2}$ , $\frac{1}{4}$ or $\frac{1}{8}$ this initial count rate plus their background rate ✓<br>Half-life is 10 h ✓<br><br><b>ALTERNATIVE 2</b><br>Use of decay equation with $A_0 = 3000$ (their ai) and one point correctly read from graph ✓<br>calculate decay constant ✓<br>Use $half\ life = \frac{\ln 2}{\lambda}$ to get $T_{1/2} = 10\ h$ ✓ | Allow ECF from a i)<br><br>Allow ECF from MP1, i.e. max [2] for answer of about 14 h if background rate not used<br><br>Accept 9 to 11 hours for MP3                                                       | [3] |
| 4. | a | iii | The BE «per nucleon» is greater for $^{204}_{82}\text{Pb}$ ✓<br>Because $^{204}_{82}\text{Pb}$ is more stable/tightly bound than $^{204}_{83}\text{Bi}$ ✓                                                                                                                                                                                                                                                                                                                                                                        | Award [1] if they recognize Pb as more stable but conclude incorrectly.                                                                                                                                    | [2] |
| 4. | a | iv  | The alpha particles would be absorbed / have low penetration / short range / ✓                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                            | [1] |
| 4. | b |     | $\Delta m = 203.932254 - (203.928034 + 0.000549) = 3.671 \times 10^{-3}\ \text{u}$ ✓<br>$Q = 3.671 \times 10^{-3} \times 931.5 \approx 3.42\ \text{MeV}$ ✓                                                                                                                                                                                                                                                                                                                                                                       | Allow ECF from MP1<br>Award [1] if electron mass is neglected and $Q = 3.93\ \text{MeV}$ or $6.30 \times 10^{-13}\ \text{J}$<br>Award [2] for a CNA<br>Accept final answer in J ( $5.48 \times 10^{-13}$ ) | [2] |

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8825–6721M

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

|    |   |                                                                                                                                                                                                                                                                                                                          |       |   |
|----|---|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---|
| 6. | a | ${}_{95}^{241}\text{Am} \checkmark$<br>${}_{93}^{237}\text{Np} + {}_2^4\alpha \checkmark$                                                                                                                                                                                                                                |       | 2 |
| 6. | b | Alpha particles only travel a few cm in air / penetration of alpha particles is poor (and will not escape the chamber) $\checkmark$                                                                                                                                                                                      | OWTTE | 1 |
| 6. | c | Half-life = $\frac{\ln 2}{5.08 \times 10^{-11}} \approx 10^{10} \text{ s} \checkmark$<br>Idea that this is much longer than lifetime of other components $\checkmark$<br>Reasoned comparison by conversion to reasonable unit eg $\approx 430 \text{ year} \checkmark$                                                   |       | 3 |
| 6. | d | Each alpha gives rise to $\frac{5.5 \times 10^6}{15} = 3.67 \times 10^5 \text{ ion pairs} \checkmark$<br>So $\frac{3.67 \times 10^5 \times 42000}{3} = 5.13 \times 10^9 \text{ ion pairs per second} \checkmark$<br>current = $1.6 \times 10^{-19} \times 5.13 \times 10^9 = 0.82 \times 10^{-9} \text{ «A»} \checkmark$ |       | 3 |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

APOLLO

# Fission

8 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q38 | 1 marks

38.          D  

Physics HL | Paper 1A | May 2025 TZ1 | Q39 | 1 marks

39.          C  

Physics HL | Paper 1A | May 2025 TZ2 | Q39 | 1 marks

39.          D  

Physics HL | Paper 1A | May 2025 TZ3 | Q37 | 1 marks

37.          A  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q38 | 1 marks

38.          B  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q37 | 1 marks

37.          C  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q38 | 1 marks

38.          D  

Physics HL | Paper 1A | Specimen 2025 | Q36 | 1 marks

36.          C

APOLLO

# Fusion and stars

16 questions

## Mark-scheme answers

Physics HL | Paper 1A | May 2025 TZ1 | Q40 | 1 marks

40.          D  

Physics HL | Paper 1A | May 2025 TZ2 | Q40 | 1 marks

40.          B  

Physics HL | Paper 1A | May 2025 TZ3 | Q11 | 1 marks

11.          A  

Physics HL | Paper 1A | May 2025 TZ3 | Q38 | 1 marks

38.          A  

Physics HL | Paper 1A | May 2025 TZ3 | Q39 | 1 marks

39.          D  

Physics HL | Paper 1A | May 2025 TZ3 | Q40 | 1 marks

40.          A

|    |   |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                               |     |
|----|---|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 7. | a | i  | Mention of core temperature <b>and</b> density ✓<br>Core temperature implies high kinetic energy/high speed<br><b>OR</b><br>needed to overcome repulsion/e.m. force ✓<br>Density needed to increase frequency/number/probability of collisions ✓                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Ignore reference to mass.<br>Do not award MP1 if radius and/or surface temperature are mentioned.                                                                                                             | [3] |
|    | a | ii | <<Inwards>> gravitational force/pressure/ ✓<br><br><<Outwards>> thermal/gas/radiation pressure/force ✓                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                               | [2] |
|    | b |    | $\Delta m = 2M_{H1} - (M_{H2} + m_e) =$<br>$2 \times 1.007276 - 2.013550 - 0.000549 \checkmark$<br>$= 4.53 \times 10^{-4} \text{ u}$<br>$Q = 4.53 \times 10^{-4} \times 931.5 = 0.422 \approx 0.42 \text{ MeV} \checkmark$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Accept $6.8 \times 10^{-14} \text{ J}$ as final answer.<br>Award [1] for final answer of 0.93 MeV, if positron ignored.<br>Award [1] for final answer of $1.5 \times 10^{-13} \text{ J}$ if positron ignored. | [2] |
|    | c | i  | Hydrogen mass to be lost<br>$0.1 \times 1.5 \times 10^{30} \text{ OR } 1.5 \times 10^{29} \text{ kg} \checkmark$<br>Number of reactions per second $\frac{3.8 \times 10^{26}}{4.3 \times 10^{-12}} \text{ OR } 8.8 \times 10^{37} \text{ s}^{-1}$<br><br><b>OR</b><br>Time for one reaction $\frac{4.3 \times 10^{-12}}{3.8 \times 10^{26}} \text{ OR } 1.1 \times 10^{-38} \text{ s}$<br><br><b>OR</b><br>Total mass (4H or He-4) in each reaction is $4 \times 1.67 \times 10^{-27} \text{ kg} \checkmark$<br><br>$T = \frac{0.1 \times 1.5 \times 10^{30}}{8.8 \times 10^{37} \times 4 \times 1.67 \times 10^{-27}} \text{ OR } 2.5 \times 10^{17} \text{ s OR } 8.1 \times 10^9 \text{ a} \checkmark$ | Award MP1 if seen isolated or in a calculation.<br>Award MP2 if 4 x mass of H seen isolated or in calculation.<br>Allow ECF from MP2 if they use H instead of 4H as the mass in each reaction.                | [3] |

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2225 – 6715M

|  |   |     |                                                                                                                                                                                                                                                                                                                                  |                                                 |         |
|--|---|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|---------|
|  | c | ii  | The luminosity/power output has remained constant ✓                                                                                                                                                                                                                                                                              | Accept rate of fusion or similar.               | [1]     |
|  | c | iii | $8.1 \times 10^8 \text{ years} = 2.5 \times 10^{17} \text{ seconds}$<br><b>OR</b><br>Energy produced while on the main sequence $= L \times t \checkmark$<br>Mass loss $= \frac{3.8 \times 10^{26} \times 2.55 \times 10^{17}}{c^2} = 1.1 \times 10^{27} \text{ kg} \checkmark$                                                  |                                                 | [2]     |
|  | d |     | $\lambda = \frac{2.9 \times 10^{-3}}{T} \checkmark$<br>$\lambda = 5.0 \times 10^{-7} \text{ m} \checkmark$                                                                                                                                                                                                                       |                                                 | [2]     |
|  | e | i   | P is approaching ✓<br>wavelength decrease ✓<br>mention of Doppler/blueshift ✓                                                                                                                                                                                                                                                    |                                                 | [2 max] |
|  | e | ii  | $\frac{\Delta \lambda}{\lambda_0} = \frac{v}{c} \text{ AND } v = \frac{2\pi R}{T} \checkmark$<br>$T = \lambda_0 \frac{2\pi R}{c \Delta \lambda} \checkmark$<br>$T = 656.2797 \times \frac{2\pi \times 7.0 \times 10^8}{3 \times 10^8 \times 4.4 \times 10^{-3}} = 2.19 \times 10^6 \text{ s} \approx 25 \text{ days} \checkmark$ | Do not penalize the use of observed wavelength. | [3]     |

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2225 – 6715M

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|

## Mark-scheme answers

Physics HL | Paper 1A | Nov 2025 TZ1 | Q39 | 1 marks

39.          D  

Physics HL | Paper 1A | Nov 2025 TZ1 | Q40 | 1 marks

40.          C  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q39 | 1 marks

39.          A  

Physics HL | Paper 1A | Nov 2025 TZ3 | Q40 | 1 marks

40.          B

|    |   |  |                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                              |     |
|----|---|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|-----|
| 2. | a |  | $1.63 \times 10^9 \checkmark$<br>and $3.84 \checkmark$                                                                                                                                                                                                                                                                                                                                                            | If they use more or fewer than 3 SF, max [1].                                                | [2] |
| 2. | b |  | manipulates SB law using logs $\checkmark$<br>relates 4 from SB to 3.99 in the equation of line of best fit as the same $\checkmark$                                                                                                                                                                                                                                                                              |                                                                                              | [2] |
| 2. | c |  | $10^{-6.15} = \sigma 4\pi \checkmark$<br>$\sigma = 5.63 \times 10^{-8} \checkmark$                                                                                                                                                                                                                                                                                                                                | Award [1] for use of data point to solve for $\sigma$ .<br>Do not award NCA without working. | [2] |
| 2. | d |  | <b>ALTERNATIVE 1</b><br>the linear graph suggests that SB applies to stars $\checkmark$<br><br><b>ALTERNATIVE 2</b><br>the « accurate » calculation of $\sigma$ from the data suggests that SB applies to stars $\checkmark$<br><br><b>ALTERNATIVE 3</b><br>« if 2c has a value of $\sigma$ that is not accurate » the calculation of the $\sigma$ from the data suggests SB does not apply to stars $\checkmark$ |                                                                                              | [1] |
| 2. | e |  | Use a wider range of temperatures $\checkmark$                                                                                                                                                                                                                                                                                                                                                                    | OWTTE                                                                                        | [1] |

## Mark-scheme answers

Physics HL | Paper 1A | Specimen 2025 | Q14 | 1 marks

14.       B  

Physics HL | Paper 1A | Specimen 2025 | Q33 | 1 marks

33.       B  

Physics HL | Paper 1A | Specimen 2025 | Q37 | 1 marks

37.       A

|    |   |                                                                                                                                                                                         |                                                                         |   |
|----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|---|
| 7. | a | <div> <div>correct substitution into <math>\lambda_{\text{max}} = \frac{2.9 \times 10^{-3}}{T}</math> OR 9350 K ✓</div> </div>                                                          |                                                                         | 1 |
| 7. | b | <div> <div>Attempted use of <math>L = 4\pi bd^2</math> ✓</div> <div>use of <math>r = \sqrt{\frac{L}{4\pi\sigma T^4}}</math> ✓</div> <div><math>r = 1.4 \text{ Gm}</math> ✓</div> </div> | <div> <div>Accept a range of values between 1.3 to 1.5 Gm</div> </div>  | 3 |
| 7. | c | <div> <div>Shows <math>r \approx 2R_{\odot}</math> ✓</div> <div>Correct position on diagram</div> <div> </div> </div>                                                                   | <div> <div>[use of 9000 K gives <math>2.2R_{\odot}</math>]</div> </div> | 2 |

| Question | Answers | Notes | Total |
|----------|---------|-------|-------|
|----------|---------|-------|-------|