

# A-LEVEL PHYSICS A

PHYA2 – mechanics, materials and waves  
Mark scheme

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Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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**COMPONENT NAME:** Unit 2 – Mechanics, materials and waves

**COMPONENT NUMBER:** PHYA2

Question	Part	Sub Part	Marking Guidance	Mark	Comments
1	a		$8300 \times 9.81$ OR $= 81423 \checkmark$ $(8300 \times 9.81 \sin 25)$ $= 3.4 \times 10^4$ (N) $\checkmark$ (34 411 N) ecf from first line unless g not used  m sin 25 gets zero	2	Penalize use of $g=10$ <u>here only</u> (35 077 N) Allow 9.8 in any question  <b>Correct answer only, gets both marks for all two mark questions</b>
1	b	i	$(E_k = \frac{1}{2}mv^2)$ $= \frac{1}{2} \times 8300 \times 56^2 \checkmark$ $= 1.3 \times 10^7$ (J) $\checkmark$ (13 014 400) allow use of 8300 only	2	In general: Penalise transcription errors and rounding errors in answers

1	b	ii	$mgh = KE$ (13 014 400) <span style="float: right;">for <math>mgh</math> allow GPE or <math>E_p</math></span> OR 13 014 400 / 81 423 ✓ $h = 160$ (m) ✓ (159.8) ecf 1bi	2		Allow use of suvat approach
1	c	i	(work done) by friction \ drag \ air resistance \ resistive forces ✓ (Energy converted) to internal \ thermal energy ✓	2		Allow 'heat'
1	c	ii	$0.87 \times (8300 \times 9.81 \times 140 = 9\,917\,000)$ OR $v = \sqrt{\left[\frac{2 \times (9\,917\,000)}{8300}\right]}$ ✓ $= 49$ (= 48.88 ms <sup>-1</sup> ) ✓	2		87% of energy for 140m or 160m only for first mark. Use of 160 (52.26) and/or incorrect or no % (52.4) gets max 1 provided working is shown. <b>Do not credit suvat approaches here.</b>
			Total	10		

2	a	i	Use of $(s = \frac{1}{2}gt^2)$ OR $t^2 = 2s/g$ ✓ $t = \sqrt{\frac{2 \times 1.2}{9.81}}$ ✓ $= 0.49$ (0.4946 s) ✓ allow 0.5 do not allow 0.50	3		Some working required for full marks. Correct answer only gets 2
2	a	ii	$(s = vt)$ $= 8.5 \times 0.4946$ ✓ ecf ai $= 4.2$ m ✓ (4.20) ecf from ai	2		
2	b	i	$(s = \frac{1}{2}(u + v)t)$ $t = \frac{2s}{u(+v)}$ or correct sub into equation above ✓ $= \frac{2 \times 0.35}{8.5} = 8.2 \times 10^{-2}$ (s) ✓ (0.0824) allow 0.08 but not 0.080 or 0.1	2		Allow alternative correct approaches
2	b ii		$a = (v-u) / t$ OR correct substitution OR $a = 103$ ✓ $(= -8.5) / 8.24 \times 10^{-2} = 103.2)$  $(F = ma =) 75 \times (103.2)$ ✓ ecf from bi for incorrect acceleration due to arithmetic error only, not a physics error (e.g. do not allow $a = 8.5$ . Use of $g$ gets zero for the question.  $= 7700$ N ✓ (7741) ecf (see above)	3		Or from loss of KE Some working required for full marks. Correct answer only gets 2
				Total	10	

3	a	i	$m = W/g$ $(3.4 \times 10^4 / 9.81 =) 3500$ (3466 kg) ✓	1		Allow use of $g=10$
3	a	ii	(moment = $34\,000 \times 5.0$ ) = $1.7 \times 10^5$ ✓ (Nm) <b>Nm</b> ✓ do not allow NM \ nM etc	2		allow in words
3	a	iii	$170\,000 = T \times \underline{12}$ OR $T = 170\,000 / \underline{12}$ ✓ ecf aii $= 1.4(167) \times 10^4$ ✓ (N)	2		
3	a	iv	(Component of T perpendicular to lever) = $T \cos 24$ OR $14\,167 \times 0.9135$ OR $12942$ (N) ✓ ecf aiii allow $2.5 \cos 24 \times T$  $(12942) \times 2.5 = F \times 8.0$ OR $F = ((12942) \times 2.5) / 8.0$ ✓ ecf for incorrect component of T or T on its own $F = 4000$ (N) ✓ (4044) ecf ecf for incorrect component of T or T on its own allow 4100 for use of 14 200 (4054)	3		Some working required for full marks. Correct answer only gets 2. Failure to find component of T is max 2 (4400 N)
			total	8		

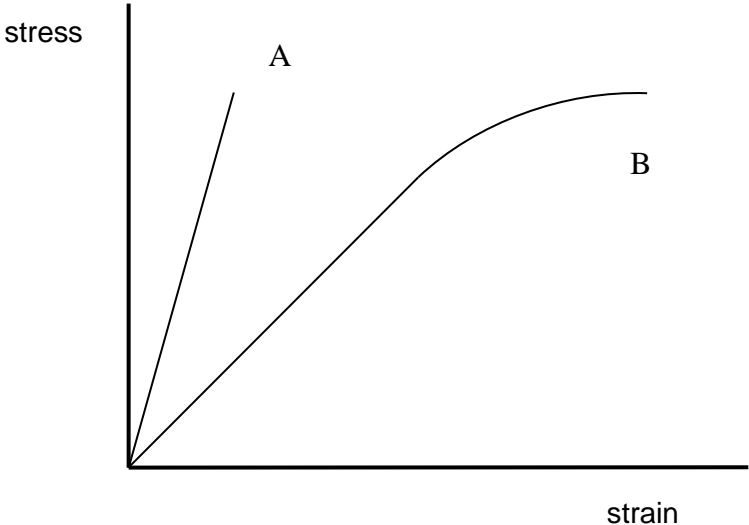
4	a 5/6	Good/excellent	<p><b>The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.</b></p> <p>The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.</p> <p><b>High Level (Good to excellent): 5 or 6 marks</b></p> <p>The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.</p> <p>Mentions <b>5</b> of the following:</p> <ul style="list-style-type: none"> <li>• Diagram (not necessarily labelled) showing a workable arrangement of suitable apparatus</li> <li>• measure <u>diameter</u> of wires</li> <li>• use a micrometer (for the diameter)*</li> <li>• apply range of loads or masses</li> <li>• measure original length</li> <li>• measure or calculate extension</li> <li>• (metre) rule (or equivalent) for the original length or extended length or extension*</li> <li>• Calculation of the weight of the mass \ use 'weights' in newtons</li> </ul> <p>And <b>2</b> of the following:</p> <ul style="list-style-type: none"> <li>• Measure diameter in several places</li> <li>• At least 7 different loads*</li> <li>• Repeat measurements for the same wire (or measure whilst unloading)</li> </ul>	5/6		
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			<ul style="list-style-type: none"> <li>• Use of a <u>travelling microscope</u> or Searle's apparatus \ pointer <u>touching</u> scale \ set square (for parallax reduction) \ Vernier scale (not Vernier calipers) *</li> <li>• Monitor diameter change during experiment</li> </ul> <p>*These points may appear in a clear diagram</p>			
	3/4	Moderate	<p><b>Intermediate Level (Modest to adequate): 3 or 4 marks</b>                  The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.</p> <p>Mentions <b>4</b> points in total from the following 2 lists:</p> <ul style="list-style-type: none"> <li>• Diagram (not necessarily labelled) showing a workable arrangement of suitable apparatus</li> <li>• measure <u>diameter</u> of wires (must be stated)</li> <li>• use a micrometer (for the diameter)*</li> <li>• apply range of loads or masses</li> <li>• measure original length</li> <li>• measure or calculate extension</li> <li>• (metre) rule (or equivalent) for the original length or extended length or extension*</li> <li>• Calculation of the weight of the mass \ use 'weights' in newtons</li> </ul> <p>Accuracy</p> <ul style="list-style-type: none"> <li>• Measure diameter in several places</li> <li>• At least 7 different loads*</li> <li>• Repeat measurements for the same wire (or measure whilst unloading)</li> <li>• Use of a <u>travelling microscope</u> or Searle's apparatus \ pointer</li> </ul>	3/4		



			<p>touching scale \ set square(for parallax reduction) \ Vernier scale (not Vernier calipers)*</p> <ul style="list-style-type: none"> <li>• Monitor diameter change during experiment</li> </ul> <p>*These points may appear in a clear and suitably labelled diagram</p> <p>A <b>four mark answer</b> will have good QWC <b>OR</b> will exceed the specification above and will have at least one of the 5 points from the Accuracy list.</p>			
	1/2	Limited	<p><b>Low Level (Poor to limited): 1 or 2 marks</b></p> <p>The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.</p> <p><b>Two</b> valid points from the list</p> <p>For two marks, at least <b>3</b> points are required</p>	1/2		
			<p>Marking points:</p> <ul style="list-style-type: none"> <li>• Diagram (not necessarily labelled) showing a workable arrangement of suitable apparatus</li> <li>• measure <u>diameter</u> of wires</li> <li>• use a micrometer (for the diameter)*</li> <li>• apply range of loads or masses</li> <li>• measure original length</li> <li>• measure or calculate extension</li> </ul>		<b>6 marks</b>	

			<ul style="list-style-type: none"> <li>• (metre) rule (or equivalent) for the original length or extended length or extension*</li> <li>• Calculation of the weight of the mass \ use 'weights' in newtons</li>   <li>• Measure diameter in several places</li> <li>• At least 7 different loads*</li> <li>• Repeat measurements for the same wire (or measure whilst unloading)</li> <li>• Use of a <u>travelling microscope</u> or Searle's apparatus \ pointer touching scale \ set square(for parallax reduction) \ Vernier scale (not Vernier calipers) *</li> <li>• Monitor diameter change during experiment</li> </ul>			
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4	b	i	<p><u>brittle</u> ✓ allow misspellings                  allow:                  brittle, brittleness,</p>	1		
4	b	ii	<div style="text-align: center;">  </div> <p><u>For stress- strain:</u>                  Straight line labelled 'A' with greater gradient than other line and starting close to origin ✓ allow small curve in correct direction at end of line.                  Line labelled 'B' with significant curve and decreasing gradient which may then undulate ✓  <b>(forgive one label to be missing)</b></p>	3		<p>Allow full credit if strain plotted against stress correctly</p> <p>Allow reasonable free hand straight line.</p> <p>Tolerance for curve of A: no more than 10% of the total change in strain for their line.</p>

			<p>Both of the above AND axes labelled, y, 'stress' or symbol or F/A, and x, '<u>strain</u> or symbol or <math>\Delta L / L</math>' ✓ (disallow if incorrect units are included but forgive 'PA' etc) (Assume stress-strain if no labels are give – max 2)</p> <p><u>For strain – stress:</u> Straight line labelled 'A' with lesser gradient than other line ✓ allow small curve in correct direction at end of line. Line labelled 'B' with significant curve and increasing gradient which may then undulate ✓ (allow one label to be missing)</p> <p>Both of the above AND axes labelled, x, 'stress' or symbol or F/A , and y, '<u>strain</u> or symbol or <math>\Delta L / L</math>' ✓ (disallow if incorrect units are included)</p>			<p>Line B must have a curved portion of 20% or more. It must have an initial straight section</p> <p>A correct force-extension graph gets max 2</p>
4	c	i	<p>(strain = <math>\Delta L / L</math>) strain = <math>0.24/100</math> (= 0.0024) OR correct calculation of extension (0.0036) ✓</p> <p>( stress = <math>E \times</math> strain ) stress = <math>2.80 \times 10^{11}</math> ) x 0.0024 ✓ <b>ecf from first mark</b> = <math>6.7 \times 10^8</math> (Pa) ✓ ecf from first mark</p>	3		<p>Some working required for full marks. Correct answer only gets 2</p>
4	c	ii	<p>( <math>A = \pi(D/2)^2</math> )</p>	3		<p>Some working required for full</p>

		$\pi(1.4 \times 10^{-3} / 2)^2$ OR $= 1.539 \times 10^{-6} \text{ (m}^2\text{)} \checkmark$ ignore incorrect powers of ten  $F = E \times A \times \Delta L / L$ OR $= 280 \text{ (} \times 10^9 \text{)} \times 1.539 \text{ (} \times 10^{-6} \text{)} \times 0.0024$ ecf 4ci (incorrect extension or strain)  OR A x their stress from 4ci $\checkmark$ ecf 4ci for strain and ecf for incorrect area in 4cii but do not accept use of diameter or radius as the area  $= 1\,000 \checkmark$ (1034.46 N)			marks. Correct answer only gets 2  Use of diameter or radius for area gets zero for the question
			total	16	

5	a	i	$\sin 60 = 1.47 \sin \theta$ <b>OR</b> $\sin \theta = \sin 60 / 1.47$ ✓ $(\sin^{-1} 0.5891) = 36$ (°) ✓ (36.0955°) (allow 36.2)	2		Allow 36.0
5	a	ii	$\sin \theta_c = 1.33/1.47$ OR $\sin \theta_c = 0.9(048)$ ✓ $(\sin^{-1} 0.9048) = 65$ (°) ✓ (64.79)	2		Allow 64 for use of 0.9 and 66 for use of 0.91
5	a	iii	Answer consistent with previous answers, e.g. If $a_{ii} > a_i$ : Ray refracts at the boundary AND goes to the right of the normal ✓ Angle of refraction > angle of incidence ✓ <b>this mark depends on the first</b>  If $a_{ii} < a_i$ : TIR ✓ Angle of reflection = angle of incidence ✓  Ignore the path of the ray beyond water/glass boundary	2		Approx. equal angles (continuation of the line must touch 'Figure 4' label)
5	b		For Reason or Explanation:  The angle of refraction should be > angle of incidence when <u>entering the water</u> ✓ water has a lower refractive index than glass \ light is faster in water than in glass ✓  TIR could not happen \ there is no critical angle, when ray travels from	4		Allow 'ray doesn't bend towards normal' (at glass/water)  Allow <u>optical</u>

			water to oil ✓ TIR only occurs when ray travels from higher to lower refractive index \ water has a lower refractive index than oil ✓			density  Boundary in question must be clearly implied
				total	10	

6	a		<p>One of:                      (spectral) analysis of light from stars                      (analyse) composition of stars                      Chemical analysis                      Measuring red shift \ rotation of stars ✓</p> <p>Insufficient answers:                      'observe spectra', 'spectroscopy', 'view absorption \emission spectrum',                      'compare spectra', 'look at light from stars'.</p>	1		<p>Allow : measuring wavelength or frequency from a <u>named source</u> of light.</p> <p>Allow any other legitimate application that specifies the source of light. E.g. absorbtion\emission spectra in stars, 'observe spectra of materials'</p>
6	b	i	<p>first order beam                      first order spectrum                      first order image                      ✓</p>	1		<p>Allow 'n=1', '1', 'one', 1<sup>st</sup></p>
6	b	ii	<p>The light at A will appear white (and at B there will be a spectrum)                      OR greater intensity at A ✓</p>	1		
6	c		<p>( <math>d = 1 / (\text{lines per mm} \times 10^3)</math>  <math>= 6.757 \times 10^{-7} \text{ (m)}</math> OR <math>6.757 \times 10^{-4} \text{ (mm)}</math> ✓</p>	3		<p>Some working required for full marks. Correct</p>



		<p> <math>(n\lambda = d \sin \theta)</math>  <math>= 6.757 \times 10^{-7} \times \sin 51.0</math> ✓ ecf <b>only</b> for :                 <ul style="list-style-type: none"> <li>incorrect power of ten in otherwise correct calculation of d</li> <li>use of <math>d = 1480, 1.48, 14.8</math> (etc)</li> <li>from incorrect order in 6bii</li> </ul> </p> <p> <math>= 5.25 \times 10^{-7}</math> (m) ✓ ecf <b>only</b> for :                 <ul style="list-style-type: none"> <li>incorrect power of ten in otherwise correct d</li> <li>from incorrect order in 6bii</li> </ul> </p>		<p>answer only gets 2</p> <p>Power of 10 error in d gets max 2. For use of d in mm, answer = <math>5.25 \times 10^{-4}</math> gets max 2</p> <p>n =2 gets max 2 unless ecf from 6bii</p> <p>use of <math>d = 1480</math> yields wavelength of 1150m</p>
6	d	<p> <math>n = d (\sin 90) / \lambda</math> OR <math>n = 6.757 \times 10^{-7} / 5.25 \times 10^{-7}</math> ✓ ecf both numbers from 6c                 </p> <p> <math>= 1.29</math> so <u>no more</u> beams observed ✓ or answer consistent with their working                 </p> <p><b>OR</b></p> <p> <math>2 = d (\sin \theta) / \lambda</math> OR <math>\sin \theta = 2 \times 5.25 \times 10^{-7} / 6.757 \times 10^{-7}</math> ✓ ecf both numbers from 6c                 </p> <p> <math>\sin \theta = 1.55</math> (so not possible to calculate angle) so <u>no more</u> beams ✓                 </p>	2	<p>Accept 1.28, 1.3</p> <p>Second line gets both marks</p> <p>Conclusion consistent with working</p>

			OR $\sin^{-1}(2 \times (\text{their } \lambda / \text{their } d))$ ✓ (not possible to calculate) so <u>no more</u> beams ✓ ecf			
			total		8	
7	a		number of (complete) <u>waves</u> (passing a point) <u>in 1 second</u> OR number of waves / time (for the waves to pass a point) OR (complete number of) oscillations \ vibrations <u>per second</u> OR 1/T with T defined as time for 1 (complete) oscillation ✓	1		Allow: Cycles Allow: unit time
7	b		<p><u>For two marks:</u>                  Oscillation of particles \ medium \ material etc, but not oscillation of wave                  is parallel to \ in same direction as                  the direction wave (travels) ✓✓</p> <p><u>For one mark:</u>                  Particles\material\medium <u>move(s)</u> \ disturbance \ displacement                  Parallel to \ in same direction as                  the direction wave travels                  OR                  (oscillations) parallel to direction of wave travel ✓</p> <p>The one mark answer with:                  Mention of <u>compressions</u> and <u>rarefactions</u></p>	2		Allow Vibration Allow direction of energy transfer \ wave propagation

			OR (Longitudinal waves) cannot be polarised Gets <b>two</b> marks ✓			
7	c		$(f = 1540 / 0.50 \times 10^{-3})$ $= 3\,100\,000 \text{ (Hz)}$ ✓ (3 080 000) <b>2sf</b> ✓	2		
7	d		No more than two points from either list (max 3): <u>Description</u> <ul style="list-style-type: none"> <li>• Mention of nodes <u>and</u> antinodes</li> <li>• Particles not moving at a node</li> <li>• Maximum displacement at antinode</li> <li>• Particles either side of node in antiphase / between two nodes in phase</li> <li>• Variation of amplitude between nodes</li> </ul> <u>Explanation</u> <ul style="list-style-type: none"> <li>• A stationary wave (forms)</li> <li>• two waves are of <u>equal frequency</u> or wavelength (and amplitude in the same medium)</li> <li>• reflected and transmitted waves \ waves travelling in opposite directions, pass through each other</li> <li>• superpose / interfere occurs</li> <li>• constructive interference at antinodes</li> <li>• destructive interference at nodes</li> </ul>	3		Allow 'standing wave'

			✓✓✓			
				total		8
				Total on paper		70