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General Certificate of Education (A-level)
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Physics A PHYA2

(Specification 2450)

Unit 2: Mechanics, materials and waves

Final

Mark Scheme

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Question	Part	Sub Part	Marking Guidance	Mark	Comments
1	a	i	1000(N) AND 6000(N) seen **OR** $F = \sqrt{(1000)^2 + (6000)^2}$ ✓ allow incorrect values seen = **6083** (N) (= 6100) ✓ More than 2 sf seen	2	Independent marks Allow full credit for appropriate scale drawing Ignore rounding errors in 3rd sig fig.
1	a	ii	tanΘ = 1000/ 6000 or correct use of sin or cos ✓ Θ = 9.5 (9.46°) ✓ Allow range 9.4 – 10.4	2	Use of cos yields 10.4 Allow use of 6100 Some working required for 2 marks. Max 1 mark for correct calculation of vertical angle (range 79.6 – 80.6) some working must be seen
1	a	iii	($m = W/g$ =) 6500 / 9.81 (= 662.6 kg) ✓ ($a = F/m$ = 6083 / 662.6) = 9.2 (ms^{-2}) ✓ (9.180)	2	Use of weight rather than mass gets zero Correct answer on its own gets 2 marks Penalise use of g=10 in this question part only (max 1)
1	b	i	= 6500 × 600 ✓ (662.6 x 9.81 x 600) = 3 900 000 ✓ (J)	2	Look out for *W* x *g* x *h* which gives 39000000 (gets zero) Correct answer on its own gets 2 marks **Do not allow use of 1/2mv^2 (= 39 000)**

1	b	ii	(E= Pt =) 320 000 × 55 (= 17 600 k J) **OR** P= 1(b)(i) / 55 (7.09x10^4) ✓ 3.9 / 17.6 OR 70.9 / 320 OR = 0.22(16) ✓ ecf from first line conversion to a percentage (= 22 %) ✓	3	Some valid working required for 3 marks Look out for physics error: Power/time (320/55) then use of inverted efficiency equation yielding correct answer Do not allow percentages >= 100% for third mark

2	a	i	($s = \frac{1}{2}gt^2$) $1.5 = \frac{1}{2}9.81t^2$ OR $t = \sqrt{\frac{2s}{g}}$ OR $t = \sqrt{\frac{2\times1.5}{9.81}}$ ✓ (= 0.553) = 0.55 (s) ✓	2	Allow g=10 (0.5477) 0.6 gets 2 marks only if working shown. 0.6 on its own gets 1 mark.

2	a	ii	($s = v\,t$ = 430 × 0.553 = 237.8 =) 240 (m) ✓ ecf a(i)	1	

2	b		their vertical motion is independent of their horizontal motion **OR** <u>downward</u> /<u>vertical</u> acceleration is the same for both **OR** acceleration <u>due to gravity</u> is the same for both **OR** <u>vertical</u> speed/velocity is the same for both ✓ (bullets A and B will be in the air) for the same time ✓ (Horizontal acceleration is zero and thus horizontal) distance is proportional to <u>horizontal</u> speed **OR** *s* = *ut* where *u* is the <u>horizontal</u> velocity ✓	3	Allow 'time is constant' Don't allow 'similar' 'velocity smaller so distance smaller' is not sufficient

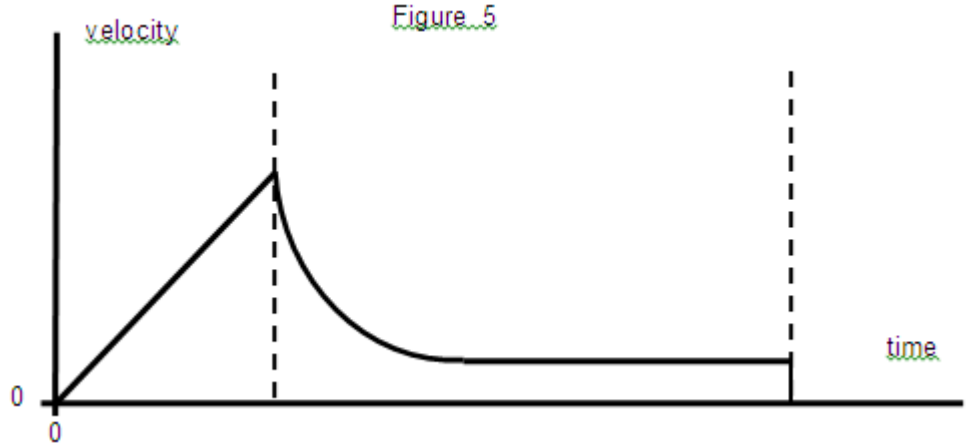
3	a		vol = $\frac{4}{3}\pi 0.011^3$ = (5.5753) 5.6×10^{-6} (m^3)✓ ($m = \rho V$) (= 8100 × 5.575×10^{-6} =) 0.045 (kg) ✓ ecf from first part **candidate's mass x g** (W = 0.045160 × 9.81 = 0.44302 = 0.44 N) ✓ **any 2sf** ✓	4	Allow use of g = 10 0.36kg , 3.5N from use of diameter rather than radius (max 3 from 4)

3	b	i	**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** 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. Mentions **all** of the following: • velocity (or speed) increases and then becomes constant (terminal velocity) • acceleration reduces to zero • forces become equal / balanced • weight (allow 'gravity') and drag/friction correctly identified	5-6	

3	b	i	**For 6 marks: In addition to the above, two of the following:** • drag force increases with speed • (weight /downward force initially) greater than drag/friction etc • resultant force causes acceleration • Resultant force = W – drag • acceleration = gradient • acceleration is maximum (9.81) at the beginning **Intermediate Level (Modest to adequate): 3 or 4 marks** 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. Mentions the **two** following points: • velocity (or speed) increases **OR** velocity (or speed) becomes constant / terminal velocity reached • acceleration decreases **OR** acceleration becomes zero **AND** for 3 marks: mentions **one** more valid point from the 4 above or from the 7 below: for 4 marks: at least two additional points with at least one from the 'Forces' list	3-4	

			• acceleration = gradient • acceleration is maximum (9.81) at the beginning **Forces** • <u>weight</u> greater than drag (before terminal velocity) • there is a resultant force downwards (before terminal velocity) • forces become equal/ balanced / drag = weight • drag force increases with speed. • Resultant force = W – drag **Low Level (Poor to limited): 1 or 2 marks** 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. **One** valid point from list below For two marks: **Two** valid points **The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.** Mention of the points below may influence the mark given within each category: • velocity increases • velocity becomes constant (terminal velocity) • acceleration is maximum (9.81) at the beginning • acceleration decreases (to zero) • <u>weight</u> greater than drag (before terminal velocity)	1-2	Poor QWC may result in award of the lower mark within a band. **Max 3 for mention of deceleration or increasing acceleration** Several serious misconceptions may reduce a 2 mark answer to 1

			• there is a resultant force downwards (before terminal velocity) • forces become equal/ balanced / drag = weight • drag force increases with speed. • resultant force = W – drag • acceleration = gradient valid point explaining why rapid decrease in velocity occurs when ball hits bottom of container. E.g. resultant upward force (decelerates the ball)		

3	b	ii	Figure 5  straight line with positive gradient from origin to first dotted line ✓ descending line (curved or straight but non-vertical) starting from a point on first dotted line (must not have negative velocity at any point) and the line may then become horizontal ✓ <u>curved</u> line descending from first dotted line which is a continuation of the initial line (the gradient must be decreasing initially (a curve) and the line may then become horizontal **AND** extending up to second dotted line (with positive non-zero velocity) **AND** no **incorrect** continuation of line beyond second time line ✓ **OR** straight line with positive gradient from origin to first dotted line ✓ straight line with positive gradient from origin to first dotted line **AND** ascending <u>curved</u> line with positive gradient decreasing, starting from a point on first dotted line (continuation of first line) ✓ extending up to second dotted line **AND** no **incorrect** continuation of line beyond second time line ✓	3	3rd mark: Allow lines that become straight with a constant negative gradient after a curve. Vertical line at the end is not necessary. End of line must be between start of 'e' in 'time' and end of 'w' in 'when'. Allow correct lines beyond the second time line: continuous zero velocity or falling below x axis and rising back to x axis (bouncing) but not reaching a higher speed than descent

4	a		Force proportional to extension ✓ up to the limit of proportionality (accept elastic limit) ✓ dependent upon award of first mark	2	Symbols must be defined Accept word equation allow '$F=k\Delta L$ (or $F \propto \Delta L$) up to the limit of proportionality' **for the second mark only** allow stress ∝ strain up to the limit of proportionality' **for the second mark only**

4	b		Gradient clearly attempted / use of $k=F/\Delta L$✓ correct values used to calculate gradient with appropriate 2sf answer given (1100 or 1200) OR <u>1154 ± 6</u> seen AND <u>load used >= 15</u> ✓ (= 1100 or 1200 (2sf)) **Nm^{-1}** / N/m (newtons per metre) ✓ (not n/m, n/M, N/M)	3	k = 30/0.026 = 1154 or 31/0.027 = 1148 1100 or 1200 with no other working gets 1 out of 2 Do not allow 32/0.0280 or 33/0.0290 (point A) for second mark. 32/0.028 is outside tolerance. 32/0.0277 is just inside.

4	c		any area calculated or link energy with area / use of $1/2F\Delta L$ ✓ 35 whole squares, 16 part gives 43 ± 1.0 **OR** equivalent correct method to find whole area ✓ 0.025 Nm per (1cm) square x candidates number of squares and correctly evaluated OR (= 1.075) = 1.1 (J) (1.05 to 1.10 if not rounded) ✓	3	(or 0.001 Nm for little squares)

4	d		permanent deformation / permanent extension ✓	1	Allow: 'doesn't return to original length'; correct reference to 'yield' e.g. allow **'extension beyond the yield point'** do not accept: 'does not obey Hooke's law' or 'ceases to obey Hooke's law',

4	e		any line from B to a point on the x axis from 0.005 to 0.020 ✓ straight line from B to x axis (and no further) that reaches x axis for 0.010<=ΔL<= 0.014 ✓	2	

4	f		work done by spring < work done by the load	1	Accept 'less work' or 'it is less' (we assume they are referring to the work done by spring)

5	a		$n_1 > n_2$ ✓ (incident) angle > critical angle (allow θ_c not 'c') **OR** critical angle must be exceeded ✓	2	Allow correct reference to 'optical density' Allow $n_A > n_B$ Do not allow: 'angle **passes** the critical angle'

5	b		($n_s = \frac{c}{c_s}$) ($c_A = \frac{c}{n_A}$ =) $\frac{3.00\times10^8}{1.80}$ ✓ (= 1.667×10^8) = 1.67×10^8 (ms^{-1}) ✓	2	For second mark, don't allow 1.6×10^8 Allow 1.66×10^8 or 1.70×10^8 Allow $1.\dot{6}$ x 10^8

5	c		$\sin 72 = 1.80 \sin\theta$ ✓ ($\sin\theta = \frac{\sin 72}{1.80}$ = $\frac{0.9510565}{1.8}$ = 0.52836) θ = 31.895 = 31.9 correct answer >= 2sf seen ✓	2	Correct answer on its own gets both marks Do not allow 31 for second mark Allow 31.8 - 32

5	d		$1.80 \sin\theta_c = 1.40$ **OR** $\sin\theta_c = \frac{1.40}{1.80}$ θ_c = 51.058 = 51.1 ° ✓ (accept 51) **OR** = 0.778 ✓	2	Correct answer on its own gets both marks Don't accept 50 by itself

5	e	i	22 + their 5(c) (22+31.9 = 53.9) ✓ 53.9 > (51.1) critical angle ✓ **OR** 5c + 22 **<** their 5d (θ_c) ✓ ecf from (c) and (d) angle less than critical angle ✓	2	If 5c+22 **>** 5d then TIR expected If 5c+22 **<** 5d then REFRACTION expected Allow max 1 for 'TIR because angle > critical angle' only if their 5d >5c +22

5	e	ii	TIR angle correct ✓ ecf from e(i) for refraction answer	1	Tolerance: horizontal line from normal on the right/ horizontal line from top of lower arrow. If 5ei not answered then ecf 5(d). If 5ei and 5d not answered then ecf 5c

6	a	i	$\pi/2$ (radians) or 90 (degrees) ✓	1	No path differences Penalise contradictions No fractions of a cycle

6	a	ii	$3\pi/2$ (rad) or 270 (degrees) ✓	1	No path differences Penalise contradictions No fractions of a cycle

6	b		(oscillation or motion) perpendicular to direction of wave (travel /velocity/energy transfer) ✓ (oscillates from equilibrium to maximum positive displacement, back to equilibrium, then to max negative displacement) and back to equilibrium /starting position /rest position ✓	2	do not allow 'up and down' for first mark allow 'up and down', or 'down then up', 'side to side', 'rise and fall' in place of oscillates Allow 'rest position', 'starting position' ,'middle', 'centre line' ref to nodes/antinodes not allowed for 2nd mark

6	c		(the wave is) transverse **OR** not longitudinal✓ only transverse can be polarised **OR** longitudinal waves cannot be polarised **OR** oscillations are in one plane ✓	2	accept it is an S wave or secondary wave

6	d	i	number of waves/complete cycles/wavelengths (passing a point/produced) per second ✓	1	or 'unit time' **allow: (number of) oscillations/vibrations/cycles per second** allow $f=1/T$ only if T is correctly defined do not allow references to f=c/λ

6	d	ii	($v = f/\lambda$ $\lambda = v/f$ =) $4.5 \times 10^3 / 6.0$ ✓ = 750 (m) ✓	2	correct answer only gets 2 marks

7	a		single frequency (or wavelength or <u>photon</u> energy) ✓	1	not single colour accept '<u>very</u> narrow band of frequencies'

7	b		subsidiary maxima (centre of) peaks further away from centre ✓ subsidiary maxima peaks further away from centre **AND** central maximum twice width of subsidiaries **AND** symmetrical ✓	2	For second mark: One square tolerance horizontally. One whole subsid max seen on either side. Central higher than subsid and subsid same height +/- 2 squares. Minima on the x axis +/- 1 square. Must see 1 whole subsidiary for second mark

7	c		ONE FROM: • don't shine towards a person • avoid (accidental) reflections • wear laser safety goggles • 'laser on' warning light outside room • Stand behind laser • other sensible suggestion ✓ • eye / skin damage could occur ✓	2	allow green goggles for red laser, 'high intensity goggles', etc. not 'goggles', 'sunglasses'

7	d		3 from 4 ✓✓✓ • central white (fringe) • each/every/all subsidiary maxima are composed of a spectrum (clearly stated or implied) • each/every/all subsidiary maxima are composed of a spectrum (clearly stated or implied) **AND** (subsidiary maxima) have violet (allow blue) nearest central maximum **OR** red furthest from center • Fringe spacing less / maxima are wider / dark fringes are smaller (or not present)	3	allow 'white in middle' For second mark do not allow 'there are colours' or 'there is a spectrum' on their own Allow 'rainbow pattern' instead of spectrum but not 'a rainbow' If they get the first, the second and third are easier to award Allow full credit for annotated sketch