A-LEVEL

Physics

PHYA4 – Fields and Further Mechanics
Mark scheme

2450
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Version/Stage: 1.1 Final

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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Section A

1	**D**	14	**C**
2	**A**	15	**A**
3	**A**	16	**C**
4	**D**	17	**C**
5	**D**	18	**D**
6	**B**	19	**B**
7	**C**	20	**A**
8	**B**	21	**B**
9	**A**	22	**A**
10	**B**	23	**C**
11	**A**	24	**B**
12	**C**	25	**D**
13	**D**		

Question	Answers	Additional Comments/Guidance	Mark	ID details
1(a)	*Forced vibrations*: repeated upwards and downwards movement ✓ vibrations at frequency of support rod ✓ amplitude is small at high frequency **or** large at low frequency ✓ correct reference to phase difference between displacements of driving and forced vibrations ✓ *Resonance*: frequency of support rod **or** driver is equal to natural frequency of (mass-spring) system ✓ large (or maximum) amplitude vibrations of mass ✓ maximum energy transfer (rate) (from support rod to mass-spring system) ✓ correct reference to phase difference between displacements of driving and driven vibrations at resonance ✓	Acceptable references to phase differences: *Forced vibrations* – when frequency of driver » frequency of driven, displacements are out of phase by (almost) π radians or 180° (**or** ½ a period) **or** when frequency of driver « frequency of driven, displacements are (almost) in phase. [Accept either] [Condone >, < for », «] *Resonance* – displacement of driver leads on displacement of driven by $\pi/2$ radians or 90° **or** ¼ of a period (or driven lags on driver by $\pi/2$ radians or 90° **or** ¼ of a period) [Condone phase difference is $\pi/2$ radians or 90°]	max 4	
1(b)(i)	cone oscillates without ring *(ticked)*	Only one box to be ticked.	1	
1(b)(ii)	damping is caused by air resistance ✓ area is the same whether loaded or not loaded ✓ loaded cone has more kinetic energy **or** potential energy **or** momentum (at same amplitude) ✓ smaller <u>proportion</u> (or <u>fraction</u>) of (condone less) energy removed per oscillation from loaded cone (or vice versa) ✓ inertia of loaded cone is greater ✓	Award marks for correct physics even when answer to 1(b)(i) is incorrect.	max 3	
Total			8	

Question	Answers	Additional Comments/Guidance	Mark	ID details
2(a)	force between two (point) charges is proportional to product of charges ✓ inversely proportional to square of distance between the charges ✓	Mention of force is essential, otherwise no marks. Condone "proportional to charges". Do not allow "square of radius" when radius is undefined. Award full credit for equation with all terms defined.	2	
2(b)	*V* is inversely proportional to *r* [**or** $V \propto (-)1/r$] ✓ (*V* has negative values) because charge is negative [**or** because force is attractive on + charge placed near it **or** because electric potential is + for + charge and – for – charge] ✓ potential is defined to be zero at infinity ✓	Allow $V \times r$ = constant for 1st mark	max 2	
2(c)(i)	$Q\left(=4\pi\varepsilon_0 rV\right)=4\pi\varepsilon_0 \times 0.125\times 2000$ (for example, using any pair of values from graph) ✓ = 28 (27.8) (± 1) (nC) ✓	**or** gradient = $Q/4\pi\varepsilon_0$ = 2000/8 ✓ (gives *Q* = 28 (27.8) ±1 (nC) ✓	2	
2(c)(ii)	at *r* = 0.20m *V* = –1250V and at *r* = 0.50m *V* = –500V so pd ΔV = –500 – (–1250) = 750 (V) ✓ work done ΔW (= $Q\Delta V$) = $60 \times 10^{-9} \times 750$ = $4.5(0) \times 10^{-5}$ (J) (45 μJ) ✓ (final answer could be between 3.9 and 5.1×10^{-5})	Allow tolerance of ± 50V on graph readings. [Alternative for 1st mark: $\Delta V = \dfrac{27.8\times10^{-9}}{4\pi\varepsilon_0}\times\left(\dfrac{1}{0.2}-\dfrac{1}{0.5}\right)$ (**or** similar substitution using 60 nC instead of 27.8 nC: use of 60 nC gives ΔV = 1620V)]	2	
2(c)(iii)	$E\left(=\dfrac{Q}{4\pi\varepsilon_0 r^2}\right)=\dfrac{27.8\times10^{-9}}{4\pi\varepsilon_0\times0.40^2}$ ✓ = 1600 (1560) (V m^{-1}) ✓ [or deduce $E=\dfrac{V}{r}$ by combining $E=\dfrac{Q}{4\pi\varepsilon_0 r^2}$ with $V=\dfrac{Q}{4\pi\varepsilon_0 r}$ ✓ from graph $E=\dfrac{625\pm50}{0.40}$ = 1600 (1560 ± 130) (V m^{-1}) ✓]	Use of *Q* = 30 nC gives 1690 (V m^{-1}). Allow ecf from *Q* value in (c)(i). If *Q* = 60 nC is used here, no marks to be awarded.	2	
Total			10	

Question	Answers	Additional Comments/Guidance	Mark	ID details
3(a)(i)	determine area under the graph [**or** determine area between line and time axis] ✓		1	
3(a)(ii) *as seen*	line starts at very low current (within bottom half of first square) ✓ **either** line continuing as (almost) horizontal straight line to end ✓✓ **or** very slight exponential decay curve ✓ which does not meet time axis ✓ **OR** suitable verbal comment that shows appreciation of difficulty of representing this line on the scales involved ✓✓✓	*Use this scheme for answers which treat the information in the question literally.*	3	
3(a)(ii) *as intended*	line starts at half of original initial current ✓ slower discharging exponential (ie. smaller initial gradient) than the original curve ✓ correct line that intersects the original curve (**or** meets it at the end) ✓	*Use this scheme for answers which assume that both resistance values should be in Ω or kΩ.* ½ initial current to be marked within ±2mm of expected value.	3	
3(b)(i)	energy stored (= ½ CV^2) = ½ × 0.12 × 9.0^2 ✓ (= 4.86 (J)) 4.86 = 3.5 Δh ✓ gives Δh = (1.39) = 1.4 (m) ✓ to 2SF only ✓	SF mark is independent. Students who make a PE in the 1st mark may still be awarded the remaining marks: treat as ECF.	4	
3(b)(ii)	energy is lost through heating of wires **or** heating the motor (as capacitor discharges) ✓ energy is lost in overcoming frictional forces in the motor (or in other rotating parts) ✓ [**or** any other well-expressed sensible reason that is valid eg. capacitor will not drive motor when voltage becomes low ✓]	Allow heating of circuit **or** I^2R heating. Location of energy loss (wires, or motor, etc) should be indicated in each correct answer. Don't allow losses due to sound, air resistance or resistance (rather than heating of) wires.	max 2	
Total			10	

Question	Answers	Additional Comments/Guidance	Mark	ID details
4(a)(i)	meter deflects then returns to zero ✓ current produces (magnetic) field/flux ✓ change in field/flux through Q induces emf ✓ induced emf causes current in Q (and meter) ✓	Deflection to right (condone left) then zero is equivalent to 1st mark. Accept momentary deflection for 1st point. "change in field/flux induces current in Q" is just ✓ from the last two marking points.	max 3	
4(a)(ii)	meter deflects in opposite direction (or to left, or ecf) ✓ field/flux through P is reduced ✓ induces emf/current in opposite direction ✓	Ignore references to magnitude of deflection.	max 2	
4(b)(i)	flux linkage $(= n\Phi = nBA) = 40 \times 0.42 \times 3.6 \times 10^{-3}$ $= 6.0(5) \times 10^{-2}$ ✓ Wb turns ✓	Unit mark is independent. Allow 6×10^{-2} Accept 60 mWb turns if this unit is made clear. Unit: allow Wb	2	
4(b)(ii)	change in flux linkage = $\Delta(n\Phi) = 6.05 \times 10^{-2}$ (Wb turns) ✓ induced emf $\left(= \frac{\Delta(n\Phi)}{\Delta t}\right) = \frac{6.05 \times 10^{-2}}{0.50} = 0.12(1)$ (V) ✓	Essential to appreciate that 6.05×10^{-2} is *change in* flux linkage for 1st mark. Otherwise mark to max 1.	2	
Total			9	

Question	Answers	Additional Comments/Guidance	Mark	ID details
5(a)(i)	$\omega\left(=\frac{v}{r}\right)=\frac{8.6}{1.5}$ (= 5.73 rad s^{-1}) ✓ $\theta(=\omega t)$ = 5.73 × 0.40 = 2.3 (2.29) (rad) ✓ = $\frac{2.29}{2\pi}\times 360$ = 130 (131) (degrees) ✓ [**or** $s((=vt)$ = 8.6 × 0.40 (= 3.44 m) ✓ $\theta=\frac{3.44}{2\pi\times 1.5}\times 360$ ✓ = 130 (131) (degrees) ✓]	Award full marks for any solution which arrives at the correct answer by valid physics.	3	
5(a)(ii)	tension $F\left(=m\omega^2 r\right)$ = 0.25 × 5.73^2 × 1.5 ✓ = 12(.3) (N) ✓ [**or** $F\left(=\frac{mv^2}{r}\right)=\frac{0.25\times 8.6^2}{1.5}$ ✓ = 12(.3) (N) ✓]	Estimate because rope is not horizontal.	2	
5(b)	maximum $\omega\left(=\sqrt{\frac{F}{mr}}\right)=\sqrt{\frac{60}{0.25\times 1.5}}$ (= 12.6) (rad s^{-1}) ✓ maximum $f\left(=\frac{\omega}{2\pi}\right)=\frac{12.6}{2\pi}$ = 2.01 (rev s^{-1}) ✓ [**or** maximum $v=\sqrt{\frac{Fr}{m}}=\sqrt{\frac{60\times 1.5}{0.25}}$ (= 19.0) (m s^{-1}) ✓ maximum $f\left(=\frac{v}{2\pi r}\right)=\frac{19.0}{2\pi\times 1.5}$ = 2.01 (rev s^{-1}) ✓]	Allow 2 (rev s^{-1}) for 2nd mark. Ignore any units given in final answer.	2	

5(c)	**The student's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The student'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. *The student appreciates that the velocity of the ball is not constant and that this implies that it is accelerating. There is a comprehensive and logical account of how Newton's laws apply to the ball's circular motion: how the first law indicates that an inward force must be acting, the second law shows that this force must cause an acceleration towards the centre and (if referred to) the third law shows that an equal outward force must act on the point of support at the centre. The student also understands that the rope is not horizontal and states that the weight of the ball is supported by the vertical component of the tension.* **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. *The student appreciates that the velocity of the ball is not constant. The answer indicates how at least one of Newton's laws applies to the circular motion. The student's understanding of how the weight of the ball is supported is more superficial, the student possibly failing to appreciate that the rope would not be horizontal and omitting any reference to components of the tension.*	A **high level** answer must give a reasonable explanation of the application of at least two of Newton's laws, and an appreciation of why the rope will not be horizontal. An **intermediate level** answer must show a reasonable understanding of how at least one of Newton's laws applies to the swinging ball. A **low level** answer must show familiarity with at least one of Newton's laws, but may not show good understanding of how it applies to this situation. References to the effects of air resistance, and/or the need to keep supplying energy to the system would increase the value of an answer.	max 6	

5(c)	**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. *The student has a much weaker knowledge of how Newton's laws apply, but shows some understanding of at least one of them in this situation. The answer coveys little understanding of how the ball is supported vertically.* **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.** • *First law*: ball does not travel in a straight line, so a force must be acting on it • although ball has constant speed its velocity is not constant because its direction changes constantly • because its velocity is changing it is accelerating • *Second law*: the force on the ball causes the ball to accelerate (or changes the momentum of it) in the direction of the force • the acceleration (or change in momentum) is in the same direction as the force • the force is centripetal: it acts towards the centre of the circle • *Third law*: the ball must pull on the central point of support with a force that is equal and opposite to the force pulling on the ball from the centre • the force acting on the point of support acts outwards • *Support of ball*: the ball is supported because the rope is not horizontal • there is equilibrium (or no resultant force) in the vertical direction • the weight of the ball, *mg*, is supported by the vertical component of the tension, $F \cos \theta$, where θ is the angle between the rope and the vertical and *F* is the tension • the horizontal component of the tension, $F \sin \theta$, provides the centripetal force $m\, \omega^2\, r$ **Credit may be given for any of these points which are described by reference to an appropriate labelled diagram.**	A reference to Newton's 3rd law is not essential in an answer considered to be a high level response. 6 marks may be awarded when there is no reference to the 3rd law.	max 6	

Total			13	