Advanced Level Physics – May 2016 – Paper 2

Mark schemes are prepared by the Examination Board and considered, together with the relevant questions. 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 Examination Board.

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.

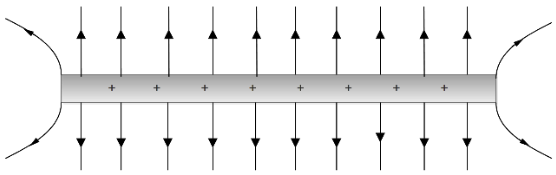
Section A

Question	Part	Subpart		Mark	Additional Guidelines
1.					
	a)		Temperature is a property which tells whether two systems are in thermal equilibrium or not. Systems which are in thermal equilibrium have the same temperature. The total energy of the particles of a body is its internal energy. Heat is energy transfer which occurs between bodies due to their different temperatures.	2 2 2	
	b)	i.	It demands skill and time; Useless for measuring changing temperatures	2 2	
		ii.	$T = \frac{P}{P_{tr}} \times 273.16 = \frac{1.10}{0.42} \times 273.16$ $T = 715.42$ K	2 1	
				13	

Question	Part	Subpart		Mark	Additional Guidelines
2.					
	a)	i.	$H_{gained} = mc\Delta\theta$ $H_{gained} = 0.30 \times 4200 \times (56 - 20)$ $H_{gained} = 45360\ \text{J}$	 1 1	
		ii.	$H_{lost} = mc\Delta\theta$ $H_{lost} = 0.02 \times 4200 \times (100 - 56)$ $H_{lost} = 3696\ \text{J}$	 1 1	
		iii.	$ml + H_{lost} = H_{gained}$ $0.02 \times l + 3696 = 45360$ $\rightarrow l = 2.08 \times 10^6 \text{J kg}^{-1}$	 2 1	
	b)		Thick polystyrene is <u>a good thermal insulator</u> so that the <u>heat losses during mixing can be neglected.</u> The <u>mass of the cup is much smaller than the mass of water</u> in it so that the heat transfer to it may be neglected.	2 2	
				11	

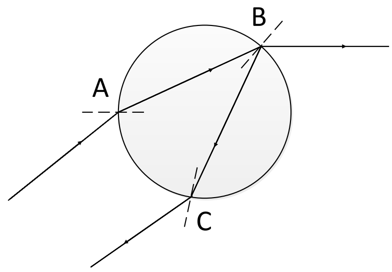
Question	Part	Subpart		Mark	Additional Guidelines
3.					
	a)		$PV = \frac{1}{3}N_A m < c^2 >$ $P = \frac{1}{3} \times \frac{N_A m}{V} \times < c^2 >$ $P = \frac{1}{3} \times \frac{M}{V} \times < c^2 >$ $P = \frac{1}{3}\rho < c^2 >$	 1 1 1	
	b)	i.	$slope\ of\ graph = \frac{1}{3} < c^2 >$ $slope\ of\ graph = \frac{2.6 \times 10^5}{3} = \frac{1}{3} < c^2 >$ $\sqrt{< c^2 >} = \sqrt{2.6 \times 10^5} = 509.9\ \text{m s}^{-1}$	2 2 1	
		ii.	$PV = RT$ $V = \frac{M}{\rho} \rightarrow \frac{PM}{\rho} = RT$ $\frac{P}{\rho} = \frac{RT}{M} \rightarrow \frac{2.6 \times 10^5}{3} = \frac{8.31 \times T}{0.032}$ $T = 333.73\ \text{K}$	 1 1 1	
				11	

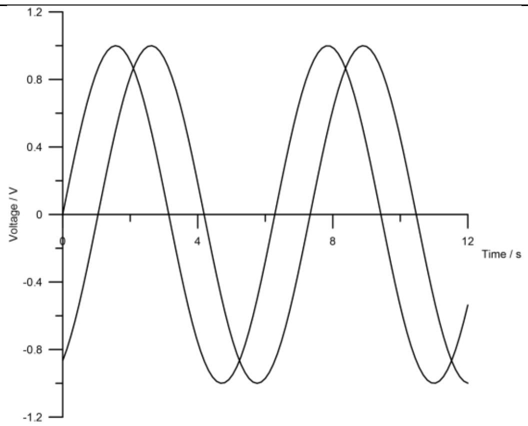
Question	Part	Subpart		Mark	Additional Guidelines
4.					
	a)		$X_c = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 500 \times 5 \times 10^{-6}} = 63.67\ \Omega$ $I = \frac{V}{X_c} = \frac{10}{63.67} = 0.16\ \text{A}$	2 2	
	b)		As the voltage across the capacitor increases, a <u>charging current</u> flows through the connecting wires. As the voltage decreases, the <u>capacitor discharges</u> through the connecting wires.	2 2	
	c)		If the frequency increases, X_c becomes smaller. $I \propto \frac{1}{X_c} \rightarrow I$ increases	1 2	
	d)		$X_L = 2\pi f L \rightarrow X_L$ increases with increasing frequency f. X_L increases $\rightarrow I$ decreases.	1 2	
				14	

Question	Part	Subpart			Additional Guidelines
5.					
	a)			3	
	b)		The <u>charge on the plate is stationary</u> so that there is <u>no potential difference</u> between points on the plate.	2 1	
	c)			3	
	d)	i.	The electric field strength does not change. Or From $Q = CV$ and $E = \frac{V}{d}$ $E = \frac{Q}{Cd} = \frac{Q}{\varepsilon_0 \varepsilon_r A} \rightarrow E\ is\ independent\ of\ d$	3	
		ii.	The potential difference between the plates decreases. Or $V = \frac{Qd}{\varepsilon_0 \varepsilon_r A} \rightarrow V\ decreases\ with\ decreasing\ d$	3	
				15	

Question	Part	Subpart			Additional Guidelines
6.					
	a)		The number of wavelengths up to P is <u>equal</u> to the number of wavelengths up to R. The <u>difference in distance</u> travelled by the two wave trains in reaching the detector is DR - DP.	1 1	
	b)		The intensity increases as the path difference approaches $\lambda/2$. Maximum intensity is observed when DR-DP is equal to $\lambda/2$. The intensity falls to a minimum when the path difference is equal to λ. The pattern is repeated as the source rises above the horizon.	1 1 2 1	
	c)		$DR\sin 5 = 150 \rightarrow DR = \frac{150}{\sin 5} = 1721\text{ m}$ $DP = DR\sin 80 = 1695\text{ m}$ $DR - DP = 1721.06 - 1694.91 = 26\text{ m}$ $\lambda = \frac{c}{f} = \frac{3\times 10^8}{23\times 10^6} = 13\text{ m}$ $Path\ difference = 2\lambda$ Since on reflection at the sea surface there is π phase change, there will be a minimum at the detector D.	1 1 1 1 1 1	
				13	

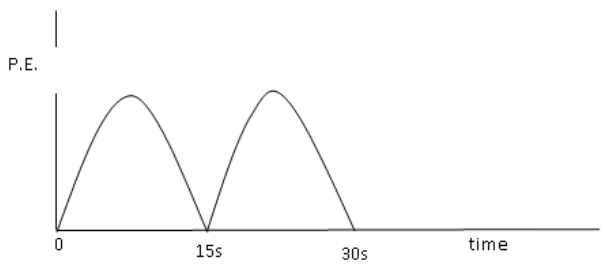
Question	Part	Subpart			Additional Guidelines
7.					
	a)	i.	$n_1\sin\theta_1 = n_2\sin\theta_2$ $1.50\sin 20 = 1\sin r$ $r = 30.87°$	 2 1	
		ii.	$n = \frac{1}{\sin c}$ $1.50 = \frac{1}{\sin c}$ $c = 41.81°$	 2 1	
		iii.	White light will be dispersed at the point of incidence. That part of the spectrum from red to green will be refracted into the air bubble. From green to violet will be totally internally reflected at the point of incidence.	1 1 1	

	b)	i.		3	Only ray passing through A and B is expected.
		ii.	Green light travelling in air will be refracted towards the normal at A. At B, light is travelling from a dense to a rarer medium. Since it cannot be totally internally reflected at B (unless it is the case where there is grazing incidence at A), the light ray emerges from B bending in a direction away from the normal. Partial reflection can take place at B. In this case, the partially reflected ray hits at C and emerges from the water droplet.	1 1 1 1	Additional drawing of the light ray from B to C is expected.
				16	

Question	Part	Subpart			Additional Guidelines
8.					
	a)	i.	Only a changing magnetic field can induce an e.m.f. in a conductor.	2	
		ii.	A copper coin because the resistivity of copper is less than that of lead.	1	Accept resistance.
	b)	i.	 When two signals are <u>out of step</u> we say that there is a phase difference between them.	2 1	
		ii.	The shape, size, and material.	1	
				7	

Section B

Question	Part	Subpart			Additional Guidelines
9.					
	a)	i.	A heat engine is a mechanical device which, working in a cycle, converts heat energy into mechanical energy.	1	
		ii.	Chemical energy in the candle is converted into heat energy. Part of the heat energy is converted into work by the expansion of boiling water into steam as it drives the water out of the tube.	1 2	
		iii.	In a heat engine working in a cycle, it is impossible to convert all the heat transfer from a hot reservoir into work.	2	
		iv.	$\frac{\Delta Q_{hot}}{T_{hot}} = \frac{\Delta Q_{cold}}{T_{cold}}$ $W = \Delta Q_{hot} - \Delta Q_{cold}$ $\eta = \frac{W}{\Delta Q_{hot}} = \frac{\Delta Q_{hot} - \Delta Q_{cold}}{\Delta Q_{hot}} = 1 - \frac{\Delta Q_{cold}}{\Delta Q_{hot}}$ $\eta = 1 - \frac{T_{cold}}{T_{hot}}$	1 1 2	
		v.	$\eta = 1 - \frac{20 + 273.16}{100 + 273.16}$ $\eta = 0.21$	2 1	
	b)	i.	AB; CA	1 1	
		ii.	CA; BC	1 1	
		iii.	There is no change in U, because the system has returned to its original state.	1 1	
	c)	i.	$Work\ done\ in\ 1\ second = 0.15 \times 10^{-3} \times \frac{540}{120}$ $= 6.75 \times 10^{-4}\text{J}$ $Heat\ energy\ supplied\ by\ 0.75\ g\ of\ wax\ in\ 10\ min$ $= 0.75 \times 3200 = 2400\ J$ $Heat\ energy\ supplied\ by\ wax\ in\ 1\ second = \frac{2400}{600}$ $= 4\ \text{J}$ $\eta = \frac{W}{\Delta Q_{hot}} = \frac{6.75 \times 10^{-4}}{4} \times 100$ $\eta = 1.69 \times 10^{-2}\ \%$	1 1 1 1 1	
		ii.	A very low efficiency of no practical purpose.	1	
				25	

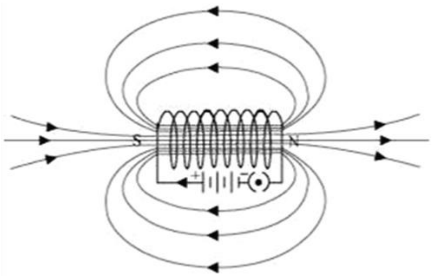
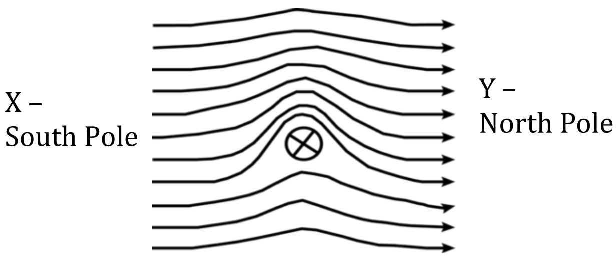
Question	Part	Subpart			Additional Guidelines
10.					
	a)		If a body moves so that its acceleration is proportional to its displacement from a fixed point and directed towards that point, then the body is said to perform simple harmonic motion. Period is the time taken by one oscillation. Amplitude is the maximum displacement from the centre of oscillation.	2 1 1	
	b)	i.	$Amplitude \; = \; 4.5\ m;$ $Period \; = \; 30\ s;$ $v_{max} = \omega A = \frac{2\pi}{T} A = \frac{2\pi}{30} \times 4.5$ $v_{max} = 0.94 \text{ m s}^{-1}$	1 1 2 1	
		ii.	$a = -\omega^2 x = \frac{4\pi^2}{T^2} A$ $a = 0.20 \text{ m s}^{-2}$	2 1	
		iii.	$E_{total} = KE_{max} = \frac{1}{2} m v_{max}^2 = \frac{1}{2} \times 75 \times 0.94^2$ $E_{total} = 33.14 \text{ J}$	2 1	
	c)	i.	The work that must be done in moving away from the centre of oscillation against the Earth' gravitational field.	2	
		ii.		2	
		iii.	$PE = 0 \text{ J at } t = 0, 15, 30 \text{ s}$	2	
	d)		When the skateboarder is close to the ends of the oscillation, his weight acts as the restoring force. However, the component of the weight along the tangent to the half pipe does not obey the conditions for s.h.m. There is no restoring force acting on the skateboarder when he is situated in the middle portion of the half pipe.	1 1 2	
				25	

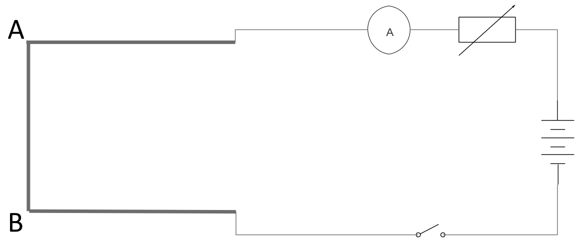
Question	Part	Subpart			Additional Guidelines
11.					
	a)	i.	$I = \frac{P}{A}$ $I = 1370 \text{ W m}^{-2}$ $A = 4\pi \times (1.50 \times 10^{11})^2 = 2.83 \times 10^{23} \text{ m}^2$ $P = IA = 3.88 \times 10^{26} \text{ W}$	2 2	
		ii.	$F = \frac{M_E v_E^2}{R_E}$ $F = \frac{M_E}{R_E}\left(\frac{2\pi R_E}{T}\right)^2$ $F = \frac{4\pi^2 M_E R_E}{T^2}$	1 2 1	
		iii.	$F = \frac{GM_S M_E}{R_E^2} = \frac{4\pi^2 M_E R_E}{T^2}$ $\rightarrow M_S = \frac{4\pi^2 R_E^3}{GT^2}$	2 1	
		iv.	$M_S = \frac{4\pi^2 R_E^3}{GT^2} = \frac{4\pi^2 (1.50 \times 10^{11})^3}{6.67 \times 10^{-11} \times (3.2 \times 10^7)^2}$ $M_S = 1.95 \times 10^{30} \text{ kg}$ Mass-to-light ratio $= \frac{1.95 \times 10^{30}}{3.88 \times 10^{26}} = 5025.77 \text{ kg W}^{-1}$	1 1 1	
	b)	i.	When a light source travels away from an observer, its wavelength is observed to increase in length. The wavelength is said to move towards the red end of the spectrum. The change in wavelength is proportional to the component of the velocity of the source along the line from observer to source. Measurement of the change in wavelength gives this component of the velocity.	1 1 1	(Accept "increases with velocity")
		ii.	rms velocity = the square root of (the sum of the squares of the separate velocities divided by the number of velocities observed) Or $rms\ \ velocity\ = \sqrt{\frac{n_1 v_1^2\ +\ n_2 v_2^2\ +\ \ldots\ldots}{n_1 +\ n_2 + \ldots\ldots\ldots}}$ Where n_1 is the number of stars with velocity v_1, n_2 is the number of stars with velocity v_2 .....)	1 1 1	
		iii.	$M_C = \frac{< v^2 > R}{0.4\ G} = \frac{2.3 \times 10^{12} \times 4.6 \times 10^{22}}{0.4 \times 6.67 \times 10^{-11}}$ $= 3.97 \times 10^{45} \text{ kg}$ Mass-to-Light Ratio$= \frac{3.97 \times 10^{45}}{3.5 \times 10^{39}} = 1.13 \times 10^6 \text{ kg W}^{-1}$	3 1	

		iv.	The cluster may contain a large proportion of matter which does not emit light.	1	
				25	

Question	Part	Subpart			Additional Guidelines
12.					
	a)	i.	Out of the paper.	1	
		ii.	$F = Bev = \frac{mv^2}{r} \rightarrow v = \frac{Ber}{m}$ $v = \frac{2\pi r}{T} \rightarrow T = \frac{2\pi r}{v}$ $T = \frac{2\pi rm}{Ber} = \frac{2\pi m}{Be}$	2 2 2	
		iii.	The period remains constant. T is independent of r. The period is halved. T is inversely proportional to B.	2 2	
		iv.	$v = \frac{Ber}{m}$ The flux density must be doubled to keep the radius at its previous value.	1 1	
		v.	The electric force acting on a charged particle moving in an electric field <u>can do work on</u> the particle because, in general, <u>the force has a component acting along the direction of the field.</u> A charged particle moving in a magnetic field has a force acting on it which is <u>always perpendicular to the direction of motion</u> of the particle. The force <u>can do no work</u> on the particle.	2 2	
	b)	i.	Plate X is negative. The magnetic force is towards plate Y. (Left hand rule) The protons with high velocities move towards Y because the magnetic force is proportional to the velocity. The protons with lower velocities move towards X because the electric force on them is greater than the magnetic force.	1 1 1 1	
		ii.	$F_{electric} = Ee$ $F_{magnetic} = Bev$ $F_{electric} = F_{magnetic} \rightarrow Ee = Bev$ $v = \frac{E}{B}$	 1 1	
		iii.	$v = \frac{E}{B}$		

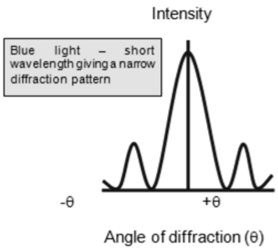
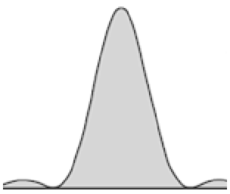
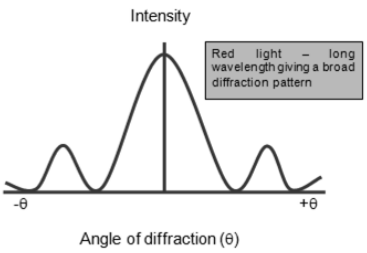
			so that either <u>the strength of the electric field is increased</u>, or the <u>flux density of the magnetic field is decreased.</u>	1 1	
				25	

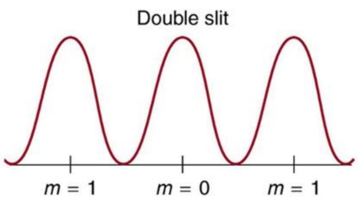
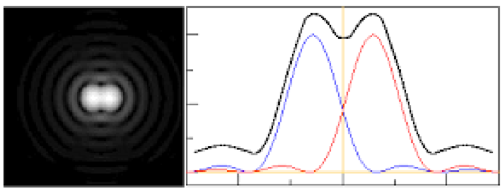
Question	Part	Subpart			Additional Guidelines
13.					
	a)	i.		4	
		ii.	X is a South magnetic pole Y is a North magnetic pole	1 1	
	b)	i.	Inside the solenoid, the magnetic field lines point from South to North.  Strong field above wire, weak field below Correct directions Correct Shape	2 2	
		ii.	The current in the conductor flows from A to B. The magnetic fields of the solenoid near the conductor and the field due to current <u>reinforce one another above the conductor.</u> The <u>conductor moves from where the field is strong to where it is weaker</u>. (OR:The flux behaves like elastic strings pushing the wire downwards)	2 2	

		iii.			
			Circuit diagram including frame, rheostat, ammeter, current source, switch.	3	
			Measure length, l of side AB.	1	
			Balancing frame with $I_2 = 0$ A, by loading or unloading side CD;	1	
			Pass current through AB.	1	
			Load CD using mass m	1	
			Adjust current I_2 till frame is horizontal as shown on vertical scale close to CD.	1	
			Repeat for other values of the current I_2	1	
			Plot a graph of m against I_2. Slope of straight line $= \frac{Bl}{g}$ where B is the flux density at the position of side AB.	2	
				25	

Question	Part	Subpart			Additional Guidelines
14.					
	a)	i.	$V = V_0 e^{-\frac{t}{RC}}$	2	
		ii.	$\ln V = -\frac{t}{RC} + \ln V_0$	2	
	b)	i.	Voltage V_0 is noted. The resistance value R is noted. The wooden block passes over switch S. The voltmeter reading V is obtained. The procedure is repeated for other values of R.	1 1 1 1 1	
		ii.	A graph of $\ln V$ against $1/R$ gives a straight line of slope $-t/C$ because $\ln V = -\frac{t}{RC} + \ln V_0$	2 1	
	c)	i.	Discharging time is the time it takes the wooden block to pass over the switch. $t = \frac{s}{v} = \frac{0.5}{10} = 0.05\ s$	1 2	

		ii.	$RC = 2 \times 0.05 = 0.10\ s$ $5000 \times C = 0.10 \rightarrow C = \frac{0.1}{5000} = 20 \times 10^{-6}\ F$ $C = 20\ \mu F$	1 2 1	
		iii.	If RC is too large, the difference between V and V_o will be too small to measure accurately.	2 1	
		iv.	In the very short time interval between the changeover of the switch, we are assuming that there is no discharge of the capacitor through the voltmeter.	1 2	
				25	

Question	Part	Subpart			Additional Guidelines
15.					
	a)	i.	A band of maximum light intensity is at the centre of a pattern. There are dark and bright thinner bands on each side of the central band. The intensity of the bright bands decreases away from the centre of the pattern.  The central bright band becomes much wider and the intensity fainter. The number of minima on each side decreases. 	1 1 1 1 2 1	
		ii.	The width of the central band is proportional to the wavelength so that the width of the central band increases. 	1	

	b)		A series of bright and dark fringes (Young's) is observed, replacing the wide band of the single slit diffraction pattern. A graph of intensity along the field of view is shown below:  Interferences fringes will not be observed. The field will be uniformly illuminated.	1 2 1 1	
	c)		When the aperture is wide, two well-separated, narrow, diffraction patterns will be observed. As the aperture becomes smaller, the two patterns become wider and start to overlap. When the aperture is small enough, the two diffraction patterns merge into one another until they are indistinguishable. 	1 2 2 2	
	d)		$\theta = \frac{1.22\lambda}{D}$ $\frac{3}{4500} = \frac{1.22 \times 600 \times 10^{-9}}{diameter}$ Diameter = 1.1 mm	3 2	
				25	