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PHYSICS **9702/42**

Paper 4 A Level Structured Questions **February/March 2024**

MARK SCHEME

Maximum Mark: 100

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

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Abbreviations

/	Alternative and acceptable answers for the same marking point.
( )	Bracketed content indicates words which do not need to be explicitly seen to gain credit but which indicate the **context** for an answer. The context does not need to be seen but if a context is given that is incorrect then the mark should not be awarded.
___	Underlined content must be present in answer to award the mark. This means either the exact word or another word that has the same technical meaning.

Mark categories

B marks	These are independent marks, which do not depend on other marks. For a **B** mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer.
M marks	These are method marks upon which **A** marks later depend. For an **M** mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer. If a candidate is not awarded an **M** mark, then the later **A** mark cannot be awarded either.
C marks	These are compensatory marks which can be awarded even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known them. For example, if an equation carries a **C** mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C** mark is awarded. If a correct answer is given to a numerical question, all of the preceding **C** marks are awarded automatically. It is only necessary to consider each of the **C** marks in turn when the numerical answer is not correct.
A marks	These are answer marks. They may depend on an **M** mark or allow a **C** mark to be awarded by implication.

Question	Answer	Marks
1(a)	(gravitational) potential is zero at infinity (gravitational force between two masses is attractive so)	B1
	either work is done on a mass to move it away from another mass **or** work is done on a mass to move it to infinity	B1
1(b)(i)	M = (–) gradient / G	C1
	e.g. $M = (1.76 \times 10^{8}) / (3.0 \times 10^{-8} \times 6.67 \times 10^{-11}) = 8.8 \times 10^{25}$ kg	A1
1(b)(ii)	**either** $GMm / r^2 = mr\omega^2$ **and** $\omega = 2\pi / T$ **or** $GMm / r^2 = mv^2 / r$ **and** $v = 2\pi r / T$ **or** $GMm / r^2 = 4\pi^2 mr / T^2$	C1
	$R^3 = 6.67 \times 10^{-11} \times 8.8 \times 10^{25} \times (0.72 \times 24 \times 60 \times 60)^2 / 4\pi^2$	C1
	$R = 8.3 \times 10^{7}$ m	A1
1(b)(iii)	$\Delta E = (GMm / r) - ½mv^2$ kinetic energy = $(½ \times 1200 \times 8400^2)$	C1
	potential energy = $(–)[(6.67 \times 10^{-11} \times 8.8 \times 10^{25} \times 1200) / (8.3 \times 10^{7})]$	C1
	$\Delta E = [(6.67 \times 10^{-11} \times 8.8 \times 10^{25} \times 1200) / (8.3 \times 10^{7})] - (½ \times 1200 \times 8400^2)$ $= 4.3 \times 10^{10}$ J	A1

Question	Answer	Marks
2(a)	total kinetic energy associated with random motion of molecules	**M1**
	plus total potential energy (of molecules) but potential energy is zero	**A1**
2(b)(i)	$W = p\Delta V$	**C1**
	$= 1.01 \times 10^5 \times 5.20 \times 10^{-5}$ $= (+)5.25$ J	**A1**
2(b)(ii)	$V \propto T$ *or* V / T = constant	**C1**
	$1.24 / (273 + 20) = (1.24 + 0.520) / T$ $T = 416$ K	**A1**
2(b)(iii)	$c = Q / m\Delta T$	**C1**
	$= 960 / (0.016 \times (416 - 293))$ $= 490$ J kg^{-1} K^{-1}	**A1**
2(c)	no change in volume so no work is done (by the gas)	**B1**
	(same temperature change so) same change in internal energy	**B1**
	less thermal energy needs to be supplied so *c* is less	**B1**

Question	Answer	Marks
3(a)	$E = ½\, m\omega^2 x_0^2$	**C1**
	$2.2 \times 10^{-4} = ½ \times 24 \times 10^{-3} \times (14 \times 10^{-3} / 4)^2 \times \omega^2$	**C1**
	$\omega = 39$ rad s^{-1}	**A1**

Question	Answer	Marks
3(b)(i)	use of acceleration = 9.81 m s^{-2}	C1
	x_0 = 9.81 / 39^2	
	= 6.4 × 10^{-3} m	A1
3(b)(ii)	at top of oscillation	B1
	any one point from: where the downward acceleration first exceeds free-fall acceleration where the greatest downwards acceleration occurs where the resultant force is the maximum downwards where the contact force is a minimum	B1

Question	Answer	Marks
4(a)	combined capacitance of parallel capacitors = 30 (μF)	C1
	total capacitance = $(1 / 45 + 1 / 30)^{-1}$ = 18 μF	A1
4(b)	$E = ½CV^2$	C1
	ΔE = ½ × 45 × 10^{-6} (9.6^2 – 8.0^2) = 6.3 × 10^{-4} J	A1
4(c)(i)	gaps in circuit closed and correct symbol for capacitor shown in parallel with load resistor	B1
4(c)(ii)	two correct pairs of values of t and V read off from within same discharge cycle, e.g. (5.0, 4.0) and (13.0, 3.2)	C1
	correct substitution of values of V, V_0 and Δt into $V = V_0 \exp(-\Delta t / \tau)$ e.g. 3.2 = 4.0 exp (–8.0 / τ)	C1
	τ = 36 ms	A1

Question	Answer	Marks
4(d)(i)	8.0 W	**A1**
4(d)(ii)	4.0 W	**A1**

Question	Answer	Marks
5(a)	*any 2 points from*: • (angular) displacement • velocity • momentum • (centripetal) acceleration • (resultant) force	**B2**
5(b)(i)	$Bqv = mv^2 / r$	**M1**
	$v = 2\pi r / T$	**M1**
	completion of algebra leading to $B = 2\pi m / qT$	**A1**
5(b)(ii)	$B = (2\pi \times 4 \times 1.66 \times 10^{-27}) / (2 \times 1.60 \times 10^{-19} \times 2.5 \times 10^{-6})$	**C1**
	= 0.052 T	**A1**
5(b)(iii)	**either** the same because T is independent of r **or** the same because B, q and m are unchanged **or** the same because both radius and speed have doubled	**B1**
5(b)(iv)	$qE = Bqv$	**C1**
	$E = Bv = 0.052 \times 1.1 \times 10^6$ $= 5.7 \times 10^4$ N C^{-1}	**A1**

Question	Answer	Marks
6(a)(i)	non-zero horizontal straight line from X to Y	**B1**
6(a)(ii)	constant flux density (inside coil)	**B1**
	either (magnetic) flux linkage proportional to flux density **or** $\Phi = BAN$ and B, A and N are all constant	**B1**
6(a)(iii)	$\Phi = BAN$	**C1**
	$= 0.080 \times 0.71 \times 10^{-4} \times 64$ $= 3.6 \times 10^{-4}$ Wb	**A1**
6(a)(iv)	*sketch showing*: *E* is zero from time 0 to time *t* and non-zero after time *t*	**B1**
	E has constant non-zero magnitude between time *t* and time 4*t*	**B1**
	E has non-zero value of one sign between time *t* and time 2*t*, and non-zero value of the opposite sign between time 2*t* and time 4*t*	**B1**
6(b)	current in spring creates a magnetic field around the spring	**B1**
	either (magnetic) fields around adjacent turns interact to cause a force to be exerted (between the turns) **or** current in one turn interacts with (magnetic) field due to adjacent turns to cause force to be exerted (between the turns)	**B1**
	(magnetic force) is attractive so distance (between turns) decreases	**B1**

Question	Answer	Marks
7(a)	$p = E / c$	C1
	$= (3.11 \times 10^{-19}) / (3.00 \times 10^{8})$ $= 1.04 \times 10^{-27}$ N s	A1
7(b)(i)	$E = hf$ and $c = f\lambda$ so energy of one photon = hc / λ $350 \times 10^{-3} = N \times (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (640 \times 10^{-9})$	C1
	$N = 1.1 \times 10^{18}$	A1
7(b)(ii)	F = (change in) momentum / time	M1
	Clear use of $p = E / c$ and $t = E / P$ to complete the algebra and arrive at the final equation: e.g. $F = [E / c] / [E / P] = P / c$	A1
7(c)(i)	maximum wavelength (of electromagnetic radiation) that causes electrons to be emitted (from surface of metal)	B1
7(c)(ii)	work function = $2.26 \times 1.60 \times 10^{-19}$ (J) $E = hc / \lambda$ so $(2.26 \times 1.60 \times 10^{-19}) = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / \lambda_0$	C1
	$\lambda_0 = 5.50 \times 10^{-7}$ m	A1

Question	Answer	Marks
8(a)	(minimum) energy required to separate the nucleons (of a nucleus)	M1
	to infinity	A1
8(b)(i)	4	A1

Question	Answer	Marks
8(b)(ii)	energy = (142 × 8.37) + (90 × 8.72) – (235 × 7.59)	**C1**
	= 190 MeV	**A1**
8(b)(iii)	**either** it has too many neutrons (for the number of protons) **or** its neutron to proton ratio is too high	**B1**
8(b)(iv)	(when t = 6.0 s), N / N_0 = 1 / 32	**C1**
	either (1 / 32) = exp (– ln2 × 6.0 / $t_{½}$)	**C1**
	$t_{½}$ = 1.2 s	**A1**
	or 32 / 2^n = 1 so n = 5 (half-lives)	**(C1)**
	$t_{1/2}$ = 6.0 / 5 = 1.2 s	**(A1)**

Question	Answer	Marks
9(a)(i)	$eV = hc / \lambda$	**C1**
	λ = (6.63 × $10^{–34}$ × 3.00 × 10^8) / (84 × 10^3 × 1.60 × $10^{–19}$) = 1.5 × $10^{–11}$ m	**A1**
9(a)(ii)	**either** (some) kinetic energy (of electrons) is converted to thermal energy at target **or** some X-rays are absorbed by the target so its temperature increases	**B1**
	(tungsten) has higher melting point so does not melt quickly / easily	**B1**

Question	Answer	Marks
9(b)	$I = I_0 \exp(-\mu t)$	**C1**
	$0.13 = [\exp(-3.0x)] \times [\exp(-0.22x)]$ $= \exp(-3.22x)$	**C1**
	x = 0.63 cm	**A1**
9(c)(i)	product of density and speed	**M1**
	speed of ultrasound in medium	**A1**
9(c)(ii)	$I_R / I_0 = (7.8 - 1.7)^2 / (7.8 + 1.7)^2$ $= 0.41$ fraction transmitted = 1.00 – 0.41 = 0.59	**C1**
	percentage transmitted = **59%**	**A1**
9(c)(iii)	more than one <u>boundary</u> so more reflections	**B1**
	some ultrasound is attenuated in matter	**B1**

Question	Answer	Marks
10(a)(i)	$L = 4\pi\sigma r^2 T^4$ $3.85 \times 10^{26} = 4\pi \times 5.67 \times 10^{-8} \times r^2 \times 5780^4$	**C1**
	$r = 6.96 \times 10^8$ m	**A1**

Question	Answer	Marks
10(a)(ii)	$F = L / 4\pi d^2$ $= (3.85 \times 10^{26}) / (4\pi \times (1.50 \times 10^{11})^2)$	C1
	$= 1.36 \times 10^3\ \text{W m}^{-2}$	A1
10(a)(iii)	line of same shape showing peak intensity at greater wavelength	B1
	line of same shape showing lower peak intensity	B1
10(b)(i)	5 lines in same pattern shifted to longer wavelengths	B1
10(b)(ii)	$\Delta\lambda / \lambda = v / c$ $\Delta\lambda = (21400 / 300000) \times 656$ $= 46.8$ nm	C1
	wavelength $= 656 + 46.8$ $= 703$ nm	A1
10(b)(iii)	(peak) wavelength too high so temperature too low	B1