Markscheme

May 2024

Physics

Higher level

Paper 2

20 pages

Subject Details: Physics HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer ALL questions. Maximum total = [90 marks].

1. Each row in the "Question" column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the "Total" column.

3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by "max" written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.

5. An alternative wording is indicated in the "Answers" column by a slash (/). Either wording can be accepted.

6. An alternative answer is indicated in the "Answers" column by "***OR***" between the alternatives. Either answer can be accepted.

7. Words in angled brackets **« »** in the "Answers" column are not necessary to gain the mark.

8. Words that are <u>underlined</u> are essential for the mark.

9. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

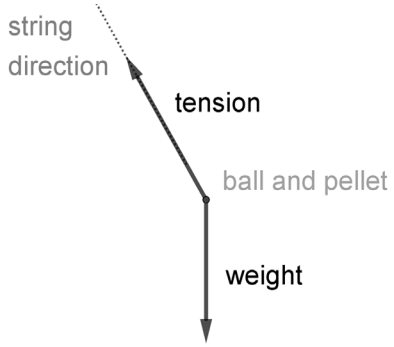
10. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the "Notes" column.

11. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

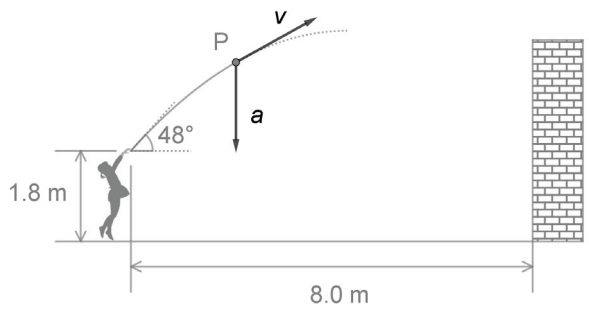
12. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. "Allow ECF" will be displayed in the "Notes" column.

13. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

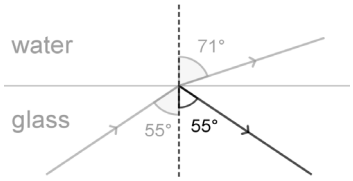
14. Allow reasonable substitutions where in common usage, *eg* ^{c} for rad.

Question			Answers	Notes	Total
1.	a		$(2.0)(160) = (250 + 2.0)v$ ✓ $v = «\frac{(2.0)(160)}{250 + 2.0} = »1.3$ «m s^{-1}» ✓	*Award [1 max] for 1.28 m/s (mass of pellet neglected)* *Award [2] for BCA*	**2**
1.	b		« Work is done by contact forces» to /penetrate/deform/squash/change shape of the ball / the interaction causes deformation of the ball. «this requires energy transfer» from kinetic to other forms e.g. PE of deformation/heat/internal ✓	*Allow 'embedded'.* ***Do not** allow 'inelastic collision'* ***MP2** requires at least one other appropriate energy form to be mentioned having been transferred from KE. NOT 'sound energy'*	**2**
1.	c		arrow along the string direction line labelled tension / *T* ✓ arrow downwards of approximately correct length labelled weight / *W* / *mg* ✓  	*Allow F_T or T for tension in **MP1*** *Allow F_g, F_W, mg, or W for Weight in **MP2*** *Do **not** allow "gravity" for weight in **MP2*** *Do **not** allow F_c for tension in **MP1*** *Ignore any additional forces."*	**2**
1.	d		$\frac{1}{2}mv^2 = mgh \Rightarrow h = \frac{v^2}{2g}$ ✓		**2**

			Accept working from $u^2 = -2as$, equivalent to $v^2 = -2gh$ $h = «\frac{1.270^2}{2 \times 9.8} =» 8.2 \times 10^{-2}$ «m» ✓	*Award [2] for BCA*	

Question			Answers	Notes	Total
2.	**a**	**i**	arrow tangent to the path in the correct direction ✓	*If the line when produced backwards goes below the curve – no mark.* *Arrows not beginning at P score [0]*	**1**
2.	**a**	**ii**	arrow vertically downwards ✓  		**1**
2.	**b**	**i**	horizontal velocity $v_x = \frac{8.0}{1.3}$«$= 6.2$ m s^{-1}» ✓ «$\frac{v_x}{v} = \cos 48° \Rightarrow$»$v = \frac{8.0}{1.3\cos 48°} = 9.2$ «m s^{-1}» ✓		**2**
2.	**b**	**ii**	initial vertical velocity $v_y = 9.2\sin 48°$«$= 6.8$ m s^{-1}» ✓ $h = 1.8 + (9.2\sin 48° \times 1.3) - \frac{1}{2} \times 9.8 \times 1.3^2$ ✓ 2.4 «m» ✓	*Award [2 max] for h=0.6m - candidates have not taken the initial height of 1.8m into account.* *Award [2 max] for h=19m* *Award [3] for BCA*	**3**

Question			Answers	Notes	Total
3.	a		uses any **two** pairs of points to show that *pV* = constant ***OR*** a statement that any 2 pairs of values of pV « from graph » always = 12 ✓ because pV does not change, air behaves ideally ✓	*Look for 1x12, 4x3 or any combination leading to 12J for MP1* *DO NOT award MP1 or 2 for 'the graph shows that pV is constant', or similar with no numerical support*	**2**
3.	b		Use of pV=nRT. ✓ 321K (320.89) « K » ✓	*Look for substitution: 1x12, 4x3 or any combination leading to pV =12J* *Award [2] for BCA*	**2**
3.	c		«absolute» temperature is proportional to/related to the KE of the molecules. ✓ pressure is related to the «average» rate of momentum transfer due to the collisions of the molecules with the container ***OR*** average force molecules exert per unit area. ***OR*** pressure is the result of molecular force on /collisions with the container walls. ✓ Higher pressure is the result of higher KE of molecules « in constant random motion » or vice versa ✓	*OK to use atoms/molecules/particles*	**2 max**

Question			Answers	Notes	Total
4.	**a**		$v_{water} = 2.0 \times 10^8 \times \frac{\sin 71°}{\sin 55°}$ ✓ 2.3×10^8 «m s^{-1}» ✓ Any answer to 2 s.f. ✓	*Use of Snell's Law for MP1* *Award [3] for BCA*	**3**
4.	**b**		speed increases ***AND*** frequency unchanged ✓ «from $\lambda = \frac{c}{f}$ » the wavelength increases ✓		**2**
4.	**c**	**i**	ray at a correct angle by eye to the normal ✓ 		**1**
4.	**c**	**ii**	parallel to the «water-glass» boundary ✓	*Allow 'horizontal'*	**1**
4.	**d**		refractive index of glass $= «\frac{3.0 \times 10^8}{2.0 \times 10^8} =» 1.5$ ***OR*** speed of light in air $= 3.0 \times 10^8$ «m s^{-1}» ✓ $\sin\theta_c = \frac{1}{1.5} \Rightarrow \theta_c = 42°$ ✓		**3**

			the angle of incidence is greater than c or θ_c so no light emerges ✓	*Must see a reason for MP3: 'no light emerges' alone is not enough.*	
Question			**Answers**	**Notes**	**Total**
5.	**a**		ALT 1 total resistance $= \frac{3.00}{59.0 \times 10^{-3}} = 50.85$ «Ω» ✓ $r =$ «50.85 – 50.0 =»0.85 «Ω» ✓ ALT 2 $r = \frac{\varepsilon}{I} - R = \frac{3}{0.059} - 50$ ✓ $= 0.85$ « Ω » ✓	*Award [2] for BCA*	**2**
5.	**b**	**i**	external/total/effective/resistance decreases ✓ « $I = \frac{\varepsilon}{R_{ext} + r}$ » the current «in the ammeter» increases ✓		**2**
5.	**b**	**ii**	***Alternative 1*** terminal pd $= \varepsilon - Ir$ ✓ I increases hence terminal pd decreases ✓ ***Alternative 2*** Since lost volts/pd used in the battery=Ir, this increases with greater I. ✓ Hence smaller pd available for external circuit. ✓		**2**

5.	**c**		Use of $\rho = \frac{RA}{l}$ ✓ $k = \text{«}\frac{4.9 \times 10^{-7}}{3.1 \times 10^{-8}} \text{=»} 16$ ✓ $\Omega\ m^{-1}$ ✓	*MP1 is for use of the equation* *MP2 is for calculation* *MP3 is for unit (Ω/m, or Ωm^{-1})* *Award [3] for BCA*	**3**

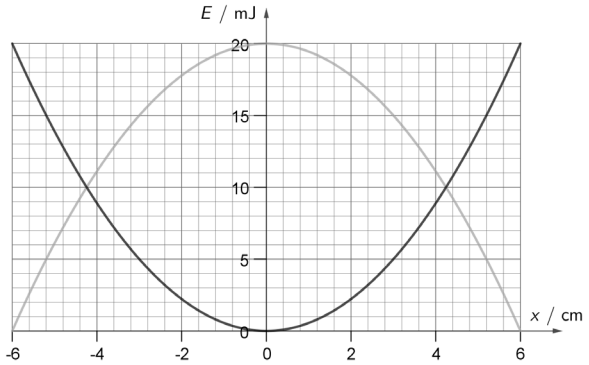
Question			Answers	Notes	Total
6.	a		time for activity/number of « parent » nuclei in the sample to decrease to ½ of the initial value ✓	*Allow 'number of radioactive particles'* *DO NOT allow 'nuclide'*	1
6.	b		ALT 1 «activity reduces to 1/8 after» 3 half-lives ✓ $T_{1/2} = «\frac{37.0}{3} =»12.3$ «years» ✓ ALT 2 $A=A_0 e^{-\lambda t}$ to find $\lambda, = 0.056\ (y^{-1})$ ✓ $\text{half life } =\ll \frac{\ln 2}{\lambda} = \frac{\ln 2}{0.056} =\gg 12.3 \ll \text{y} \gg$ ✓		2
6.	c		alpha particle / α / ^4_2He ✓		1
6.	d	i	$4 \times 7.074 - 2 \times 1.112 - 3 \times 2.827$ ✓ 17.6 «MeV» ✓	*MP1: Any one of the following calculations:* *4x7.074* *2x1.112* *3x2.827* *MP2: correct arithmetic, leading to 17.6 MeV*	2

				Calculation shown or answer to at least 3 sf for MP2	
6.	**d**	**ii**	mass of reactants $\approx 5 \times 1.661 \times 10^{-27} = 8.3 \times 10^{-27}$ «kg» ✓ energy from 1 kg of fuel $= \frac{17.6 \times 10^{6} \times 1.6 \times 10^{-19}}{8.3 \times 10^{-27}} = 3.4 \times 10^{14}$ «J» ✓	*Award [2] for BCA*	**2**
6.	**d**	**iii**	for the same mass of fuel fusion releases much more energy, with quantitative detail e.g. $\frac{10^{14}}{10^{7}} = 10^{7}$ ***OR*** $10^{14} \gg 10^{7}$ ✓	*Look for their answer in dii >>10^{7}*	**1**

Question			Answers	Notes	Total
7.	a		More « long wave » surface radiation / radiation from Earth is absorbed by GHG/the atmosphere ✓ increased intensity/more radiation (re)directed back to Earth/ I_2 increased ✓	*Not 'heat'*	**2**
7.	b		$I_1 = «240 + 150 =» 390$ «W m^{-2}» ✓ $T = \sqrt[4]{\frac{390}{5.67 \times 10^{-8}}} = 288$ «K» ✓	*Award [2] for BCA*	**2**

Question			Answers	Notes	Total
8.	a		correct algebraic manipulation involving $V_g = -\frac{GM}{r}$ ***AND*** $g = \frac{GM}{r^2}$ ✓	*e.g.* $-\frac{GM}{r^2} \times r = -\frac{GM}{r}$ ***OR*** $-\frac{GM}{r} = \left(\frac{GM}{r^2}\right) r$	**1**
8.	b	i	$V_g = -4.0 \times 10^7$ «J kg^{-1}» ✓ $g = \text{«}-\frac{V_g}{r} = \frac{4.0 \times 10^7}{1.0 \times 10^7} =$» 4.0 «m s^{-2}» ✓	*Using the tangent to the graph is acceptable* *Award [2] for BCA*	**2**
8.	b	ii	$F = \text{«}750 \times 4.0\text{»} = 3000$ «N» ✓	*750 x (value in 8bi) for ECF*	**1**
8.	c	i	change in the orbital radius is very small compared with the original radius / new radius is approximately the same as the original radius ✓ « Since g=-V_g/r, » very small change in r means a very small change in g / (Δ(V_g/r) is almost zero ✓		**2**
8.	c	ii	**ALTERNATIVE 1** $\Delta E_p = \text{«}mg\Delta r =\text{»} 750 \times 4.0 \times 2.0 \times 10^3$ ***OR*** 6.0×10^6 «J» ✓ $\Delta E_k = -\frac{1}{2}\Delta E_p$ ***OR*** $\Delta E = \frac{1}{2}\Delta E_p$ ✓ $\Delta E = 3.0 \times 10^6$ «J» ✓ **ALTERNATIVE 2** mass of Earth $= \frac{4.0 \times 10^7 \times 1.0 \times 10^7}{6.67 \times 10^{-11}} = 6.0 \times 10^{24}$ «kg» ✓	*Award [3] for BCA*	**3**

			$\Delta E = \frac{1}{2} \times 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 750 \left(\frac{1}{1.0 \times 10^{7}} - \frac{1}{1.0 \times 10^{7} + 2.0 \times 10^{3}} \right)$ ✓ $\Delta E = 3.0 \times 10^{6}$ «J» ✓		

Question			Answers	Notes	Total
9.	**a**		6 «cm» ✓		**1**
9.	**b**		parabolic graph passing through (0, 0) and (±6, 20) ✓  	*A good quality parabola optimally passing through (4.2,10) by eye scores [1]*	**1**
9.	**c**		« $E_K = E_P$ » 2 points per half oscillation « on the graph » ✓ « every position is reached twice during an oscillation so $E_K = E_P$ » four times ✓	*Reference to 2 times for MP1 and 4 times for MP2.* *This can be seen as a 'walk through' of the four places per oscillation where KE=PE, for MP1 and MP2*	**2**
9.	**d**	**i**	Use of $E_T = \frac{1}{2}m\omega^2 A^2$ ***OR*** $20\times10^{-3} = \frac{1}{2}\times0.15\times\omega^2\times0.060^2$ ✓	*Answer should be to 2sf or better.* *Other pathways possible e.g;* $E = \frac{1}{2}kA^2, so\ k = \frac{2E}{A^2}$ *(MP1)* $from\ which.\ T = 2\pi\sqrt{\frac{m}{k}}$ *k=11.11 (MP2). and T=0.73 (MP3)*	**3**

			$\omega = 8.6$ «rad s^{-1}» ✓ $T = «\frac{2\pi}{\omega} =» 0.73$ «s» ✓		
9.	**d**	**ii**	**ALTERNATIVE 1** $a_{max} = 8.6^2 \times 0.060$ ***OR*** $\left(\frac{2\pi}{0.73}\right)^2 \times 0.060 «= 4.44 \text{ m s}^{-2}»$ ✓ $F_{max} = 0.15 \times 4.44 = 0.67$ «N» ✓ **ALTERNATIVE 2** $k = 8.6^2 \times 0.15$ ***OR*** $\left(\frac{2\pi}{0.73}\right)^2 \times 0.15 «= 11.1 \text{ N m}^{-1}»$ ✓ $F_{max} = 11.1 \times 0.060 = 0.67$ «N» ✓	*MP1 find a or k* *MP2 F=ma/F=kx* *Award [2] for BCA*	**2**

Question			Answers	Notes	Total
10.	**a**	**i**	$\varepsilon = 3.9 \times 10^{-3} \times 2.3 \times 10^{3} = 9.0$ «V» ✓		**1**
10.	**a**	**ii**	**ALTERNATIVE 1** the sum of the pd's across R and C is constant/equal to the emf of the cell ✓ the pd across the capacitor increases «during charging» so the pd across the resistor decreases «hence, the current decreases» ✓ **ALTERNATIVE 2** As C is charging, current decreases « with time » ✓ because R and C are in series, « I through R decreases with time » ✓	*ALT 1 is about pd, ALT 2 is about current and charge.* *Accept answers from **one** ALT only.*	**2**
10.	**b**		an arrow drawn upwards near the resistor ✓		**1**
10.	**c**		use of $\frac{1}{2}CV^2$ to calculate the initial ***OR*** final energy in the capacitor ✓ $\frac{1}{2} \times 1.0 \times 10^{-3}\left(8.0^2 - 2.2^2\right)$ ✓ 3.0×10^{-2} «J» ✓	*Award [1 max] for ΔV = 5.8 V leading to E = 1.7 x 10^{-2} J* *Award [3] for BCA*	**3**
10.	**d**		Capacitor stores charge, releasing it when the current falls, reducing fluctuations across R ✓ the current is smoother/the variation of the current is reduced ✓ when pd across R increases, the capacitor is being charged ✓	*Main ideas to look for:* *-smoothing* *-storage and release of charge* *A diagram showing smoothing is acceptable*	**3 max**

			when pd decreases/between charging cycles, the charge is released through R✓ the diodes prevent the capacitor from discharging through the ac source ✓	*e.g,* 	

Question			Answers	Notes	Total
11.	a		photon energy is proportional to frequency ✓ «when $f < f_0$,» photon energy is less than the work function/energy needed to release an electron «from the surface» ✓	*Need to see 'is proportional to', not 'is related to'. Reference to E=hf is satisfactory for MP1*	**2**
11.	b	i	electrons are repelled from/do not « have enough KE to » reach the collecting plate /attracted back to the photosurface ✓ maximum KE of an electron is less than the work/energy needed to transfer it to the collecting plate ✓ Stopping potential /reverse pd opposes electron flow/reduces I « to zero » to the photocathode. ✓		**2**
11.	b	ii	***ALTERNATIVE 1*** electrons are attracted to the collecting plate ✓ Every electron emitted from the surface reaches the collecting plate ✓ ***ALTERNATIVE 2*** there is a maximum number of photoelectrons that can be emitted per second ✓ this number is limited by the intensity of incident radiation «not the applied voltage» ✓	*Select responses from one ALT only*	**2**
11.	c	i	$hf = \text{«}\frac{hc}{\lambda} = \frac{1.24\times10^{-6}}{430\times10^{-9}} = \text{»}2.9 \text{ «eV»}$ ✓		**1**
11.	c	ii	$E_K = 0.9$ «eV» ✓ $\Phi = \text{«}hf - E_K = \text{»}2.0$ «eV» ✓	*Look for 2.9-0.9 = 2.0eV* *Award [2] for BCA*	**2**