Markscheme

November 2024

Physics

Standard level

Paper 2

Subject Details: Physics SL Paper 2 Markscheme

Candidates are required to answer **all** questions. Maximum total = **50 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*". Either answer can be accepted.

7. An alternative markscheme is indicated in the "Answers" column under heading ***ALTERNATIVE 1*** *etc*. Either alternative can be accepted.

8. Words inside chevrons **« »** in the "Answers" column are not necessary to gain the mark.

9. Words that are underlined are essential for the mark.

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

11. 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.

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

13. 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. "ECF acceptable" will be displayed in the "Notes" column.

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

Question			Answers	Notes	Total
1	a	i	$mg \times 0.15 = \dfrac{1}{2}mv^2$ ✓ $v = \sqrt{2 \times 9.81 \times 0.15}\ OR\ 1.72 \ll ms^{-1} \gg$ ✓	*Award MP1 for recognition that KE of car at P is GPE lost.* *Do not award MP1 for answers based on suvat equations. MP2 can still be awarded for a correct answer.*	2
	a	ii	$N + mg = \dfrac{mv^2}{r}$ ✓ $N = 0.12 \times (\dfrac{1.72^2}{0.15} - 9.81)$ ✓ $N = 1.2$ **«N»** ✓	*Allow 1.1 or 1.2 depending on g and rounding of v.* *Award [0] for answers based on N = W.*	3
	a	iii	**ALTERNATIVE 1** the normal force is greater than zero ✓ **ALTERNATIVE 2** $min i mum\ speed\ at\ P = \sqrt{9.81 \times 0.15} = 1.2 \ll m\,s^{-1} \gg$ **AND** actual speed is greater ✓	*Do not accept a statement of the value of N e.g. N = 1.2 <<N>>.*	1

b	**i**	**ALTERNATIVE 1** $mg \times 0.45 = \frac{1}{2}mv^2$ ✓ $v = \ll \sqrt{2 \times 9.81 \times 0.45} \gg = 3.0 \ll m\,s^{-1} \gg$ ✓ **ALTERNATIVE 2** $0.12 \times v = (0.12 + 0.18) \times 1.2$ ✓ $v = 3.0$ «ms^{-1}» ✓		*Do not award BCA.* *For ALT1 award MP1 for recognition that KE of car at P is GPE lost.* *For ALT1 do not award MP1 for answers based on suvat equations. MP2 can still be awarded for a correct answer.*	**2**
b	**ii**	**ALTERNATIVE 1** rate of change of momentum is the net force ✓ $Fd = \frac{1}{2}(m_1 + m_2)u^2$ ✓ $F = «\frac{0.30 \times 1.2^2}{2 \times 0.20} =»1.08 \approx 1.1$ «N» ✓ **ALTERNATIVE 2** rate of change of momentum is the net force ✓ $a = «\frac{u^2}{2d} = \frac{1.2^2}{2 \times 0.20} =»3.6$ «ms^{-2}» ✓ $F = «ma = 0.30 \times 3.6 =»1.08 \approx 1.1 \ll N \gg$ ✓ **ALTERNATIVE 3** $t = \frac{2 \times 0.2}{1.2}$ OR $0.333 \ll s \gg$ ✓ $\Delta p = (0.18 + 0.12) \times 1.2$ OR $0.36 \ll Ns \gg$ ✓ $F \ll = \frac{\Delta p}{\Delta t} = \frac{0.36}{0.333} = \gg 1.1 \ll N \gg$ ✓		*Do not award BCA.* *MP1 can be awarded if an equation stated implies that force is rate of change of momentum or the final answer is clearly a force.*	**3**
b	**iii**	$\mu = «\frac{F}{(m_1 + m_2)g} =» \frac{1.08}{0.30 \times 9.81}$ ✓ $\mu = 0.367 \approx 0.37$ ✓		*Allow ECF from (bii).*	**2**

	Question		Answers	Notes	Total
2	**a**		momentum of molecules/particles changes at each collision with container/walls ✓ so container/walls exert forces on molecules/particles✓ <<by N3>> molecules/particles exert a force on container/walls✓	*Award [1 max] for using 'gas' instead of 'molecules/particles'.*	**Max 2**
	b		<<An ideal gas>> has point particles/elastic collisions/no forces between molecules/zero intermolecular PE/cannot change phase/obeys the ideal gas equation for all P & T✓	*Accept opposite statements for real gas.*	**1**
	c		***ALTERNATIVE 1*** pressure due to gas in left container $3.0\times10^4\times\dfrac{0.20}{0.30}=2.0\times10^4$ **«Pa»** ✓ pressure due to gas in right container $9.0\times10^4\times\dfrac{0.10}{0.30}=3.0\times10^4$ **«Pa»** ✓ adding gives $P=5.0\times10^4$ **«Pa»** ✓ ***ALTERNATIVE 2*** number of moles <<in a container is>> $\dfrac{3.0\times10^4\times0.20}{RT}$ **OR** $\dfrac{9.0\times10^4\times0.10}{RT}$ ✓ $P\times0.30=(\dfrac{3.0\times10^4\times0.20}{RT}+\dfrac{9.0\times10^4\times0.10}{RT})RT$ ✓		**3**

$P = 5.0 \times 10^4 \ll \text{Pa} \gg$ ✓

ALTERNATIVE 3
Use of $P_1 V_1 + P_2 V_2 = P(V_1 + V_2)$ ✓

$3.0 \times 10^4 \times 0.2 + 9.0 \times 10^4 \times 0.1 = P(0.2 + 0.1)$　✓

$P = 5.0 \times 10^4 \ll Pa \gg$　✓

	Question		Answers	Notes	Total
3	**a**	**i**	the displacement/oscillation is at right angles/perpendicular to the direction of energy transfer/propagation✓	*Accept vibration/movement of particles for oscillation.*	**1**
	a	**ii**	P and Q are performing SHM ✓ <<in SHM>> acceleration is proportional to displacement so P✓ acceleration is a maximum at P **AND** zero/minimum at Q ✓	*MP2 can be expressed as an equation.*	**Max 2**
	a	**iii**	wavelength is 1.20 «m»✓ $T = \ll \frac{\lambda}{c} = \frac{1.20}{62} = 1.936 \times 10^{-2} \gg 1.9 \times 10^{-2} \ll s \gg$✓	*For MP2 the final answer must be to 2 s.f.* *Allow ECF from MP1 provided the answer is to 2 s.f.*	**2**
	a	**iv**	distance travelled is 4 × 0.04 **OR** 0.16 «m»✓ $v = \ll \dfrac{0.16}{1.936 \times 10^{-2}} = \gg 8.3 \text{«m s}^{-1}\text{»}$ ✓	*Allow ECF from (aiii).* *Allow 8.3 or 8.4 <<m s⁻¹ >>*	**2**

| | b | | | *Accept either the solid or dashed line alone, or 2 solid lines.* | 1 |
| | c | | SHM helps understand wave motion
OR
Real/complex systems resemble SHM for small oscillations
OR
Complex oscillations can be modelled as a combination of SHM / reference to Fourier analysis
OR
If friction is small, SHM can be a good approximation to the real system / small damping ✓ | | 1 |

	Question		Answers	Notes	Total
4	a		X has a greater resistance ✓ The current is the same ***AND*** power is RI^2 ✓		2
	b		Y has greater power✓ voltage is the same ***AND*** power is $\dfrac{V^2}{R}$	*Allow ECF from (a)*	2

			OR voltage is the same, X has a smaller current **AND** power is *IV* ✓	*For MP2 allow a correct argument provided V is constant **AND** a correct expression for power is included.*	
	c	**i**	$R = « \dfrac{8.0}{0.050} = »160 «\Omega»$ ✓		**1**
	c	**ii**	<<trial and error to find voltages that add to 12 «V» for same current>> current is 0.050 «A» ✓ and voltage for Z is 4.0 «V»✓ power = <<IV=>> 0.2 «W»✓	*Award ECF for MP3 if the current chosen for Z matches the V for Z from the graph.*	**3**

	Question		Answers	Notes	Total
5	**a**	**i**	«minimum» energy required to «completely» separate the nucleons of a nucleus **OR** energy released when nucleus is assembled from the nucleons✓	*Accept protons and neutrons for nucleons.*	**1**
	a	**ii**	Use of $Binding\ energy = mass\ of\ separate\ nucleons - mass\ of\ nucleus$ $«1105 = 54 \times 938 + 77 \times 940 - Mc^2»$ ✓ $M = 122$ «$GeV\,c^{-2}$» ✓	***Do not*** *allow BCA.* *Award ECF from using binding energy with incorrect sign.* *An answer that doesn't include binding energy scores [0].*	**2**
	b	**i**	<<nuclei with the>> same number of protons✓ different number of neutrons✓		

b	**ii**	binding energy per nucleon is a measure of stability so $^{131}_{54}\mathrm{Xe}$ has the greater binding energy per nucleon✓	*Correct mention of stability required to award the mark.* *Allow opposite comment for Xe 133.*	**1**
b	**iii**	protons have 2 u quarks **OR** neutrons have one u quark✓ $N =<< 2 \times 54 + 1 \times 77 =>> 185$ ✓	*For MP1 accept e.g proton uud.*	**2**
c		accept range 5.2 days to 5.4 days✓		**1**

	Question		Answers	Notes	Total
6	**a**		kinetic energy of wind to rotational/kinetic/mechanical energy of turbine/generator✓ rotational/kinetic/mechanical energy of turbine/generator to electrical energy✓		**2**
	b		wind stops at blades/air is incompressible/air is not turbulent/wind is normal to rotors/Betz limit ignored✓	*Do not allow answers that state that the quantities in the formula are constant.* *Do not credit answers discussing friction or energy losses to the surroundings.*	**1**
	c		$P = \dfrac{1}{2} \times 1.2 \times \pi \times 2.5^2 \times (6.8^3 - 2.6^3)$ ✓ $P = 3500$ W✓	*Do not award BCA. Calculations must be checked.* *Award [1 max] for 3704 W. (Not subtracting the wind after the blades).* *Award [0] for use of $(6.8 - 2.6)^3$.* *Unit required for MP2.*	**2**