Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2016

Physics

Higher level

Paper 2

19 pages

Subject Details: Physics HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer ALL questions. Maximum total = [95 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.

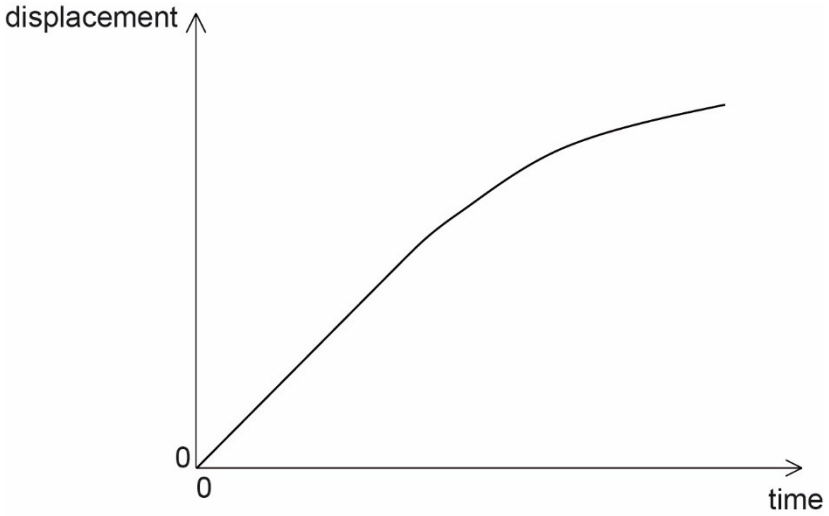
6. An alternative answer is indicated in the "Answers" column by "***OR***" between the alternatives. Either answer can be accepted.

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.

Question			Answers	Notes	Total
1	a	i	«$E_{el} =$» $\frac{1}{2}mv^2 + mgh$ ***OR*** «$E_{el} =$» $E_P + E_K$ ✓ «$E_{el} =$» $\frac{1}{2}\times 55\times 0.90^2 + 55\times 9.8\times 1.2$ ***OR*** 669 J ✓ «$E_{el} = 669 \approx 670$ J»	*Award **[1 max]** for use of $g = 10$ N kg $^{-1}$, gives 682 J.*	**2**
	a	ii	$\frac{1}{2}\times 55\times v^2 = 670$ J ✓ $v =$ «$\sqrt{\frac{2\times 670}{55}} =$» 4.9 m s^{-1} ✓	*If 682 J used, answer is 5.0 m s^{-1}.*	**2**
	b	i	no force/friction on the block, hence constant motion/velocity/speed ✓		**1**
	b	ii	force acts on block ***OR*** gravity/component of weight pulls down slope ✓ velocity/speed decreases ***OR*** it is slowing down ***OR*** it decelerates ✓	*Do not allow a bald statement of "N2" or "F = ma" for MP1.* *Treat references to energy as neutral.*	**2**

Question			Answers	Notes	Total
1	c		straight line through origin for at least one-third of the total length of time axis **covered by candidate line** ✓ followed by curve with decreasing positive gradient ✓  	*Ignore any attempt to include motion before A.* *Gradient of curve must always be less than that of straight line.*	**2**
	d		$F = \text{«}\frac{\Delta p}{\Delta t} \text{=»} \frac{55 \times 4.9}{0.42}$ ✓ $F = 642 \approx 640$ N ✓	*Allow ECF from (a)(ii).*	**2**
	e		«energy supplied by motor =»$120 \times 6.8 \times 1.5$ ***or*** 1224 J ***OR*** «power supplied by motor =»120×6.8 ***or*** 816 W ✓ e = 0.55 ***or*** 0.547 ***or*** 55% ***or*** 54.7% ✓	*Allow ECF from earlier results.*	**2**

Question			Answers	Notes	Total
1	f		«energy dissipated in friction =» $0.03 \times 55 \times 9.8 \times 2.0$ «= 32.3» ✓ hence use result to show that block cannot reach C ✓ ***FOR EXAMPLE*** total energy at C is $670 - 32.3 - 646.8 = -9.1\,\text{J}$ ✓ negative value of energy means cannot reach C ✓	*Allow ECF from (a)(ii).* *Allow calculation of deceleration ($a = -0.29\ \text{m s}^{-2}$) using coefficient of dynamic friction. Hence KE available at B = 628 J.*	**2**

2	a		two arrows each along the line connecting the planet to its star ***AND*** directed towards each star ✓ arrow lines straight and of equal length ✓	*Do not allow kinked, fuzzy curved lines.*	**2**
	b		$g = \text{«}\frac{GM}{r^2} = \frac{6.67 \times 10^{-11} \times 2.0 \times 10^{30}}{\left(6.0 \times 10^{11}\right)^2}\text{»}$ ***OR*** $3.7 \times 10^{-4}\,\text{N kg}^{-1}$ ✓ $g_{\text{net}} = \text{«}2g\cos\theta = 2 \times 3.7 \times 10^{-4} \times \frac{\sqrt{6.0^2 - 3.4^2}}{6.0} \text{=»} 6.1 \times 10^{-4}\,\text{N kg}^{-1}$ ✓ directed vertically down «page» ***OR*** towards midpoint between two stars ***OR*** south ✓	*Allow rounding errors.*	**3**

Question			Answers	Notes	Total
3	a		use of $m \times c \times \theta$ with correct substitution for either original water ***or*** water from melted ice ✓ energy available to melt ice = «8820 – 1260 =» 7560 J ✓ equates 7560 to mL ✓ 3.02×10^5 J kg^{-1} ✓ ***FOR EXAMPLE*** $0.35 \times 4200 \times (18 - 12)$ ***OR*** $0.025 \times 4200 \times 12$ ✓ 7560 J ✓ $L = \frac{7560}{0.025}$ ✓ 3.02×10^5 J kg^{-1} ✓	*Award **[3 max]** if energy to warm melted ice as water is ignored (350 kJ kg^{-1}).* *Allow ECF in MP3.*	**4**
	b	**i**	no change in temperature/no effect, the energies exchanged are the same ✓		**1**
	b	**ii**	the time will be less/ice melts faster, because surface area is greater ***or*** crushed ice has more contact with water ✓		**1**

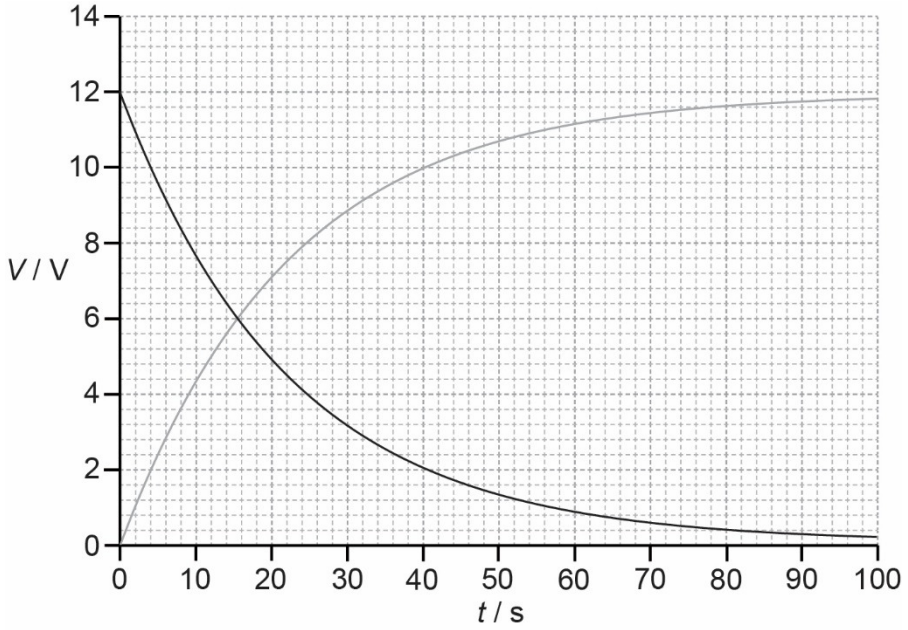
Question			Answers	Notes	Total
4	a		a wave where the displacement of particles/oscillations of particles/movement of particles/vibrations of particles is parallel to the direction of energy transfer/wave travel/wave movement ✓	*Do not allow "direction of wave".*	**1**
	b	i	***ALTERNATIVE 1*** «distance travelled by wave =» 0.30 m ✓ $v = \text{«}\frac{\text{distance}}{\text{time}} \text{=»} 340\ \text{m s}^{-1}$ ✓ ***ALTERNATIVE 2*** evaluates $T = \frac{0.882\times10^{-3}\times1.6}{0.3} \text{«=} 4.7\,\text{ms»}$ to give $f = 210$ ***or*** 212 Hz ✓ uses $\lambda = 1.6$ m with $v = f\lambda$ to give 340 m s^{-1} ✓		**2**
	b	ii	***ALTERNATIVE 1*** $\lambda = 1.60$ m ✓ $\omega = \text{«}2\pi f = 2\pi\frac{v}{\lambda} \text{=»} 2\pi\times\frac{340}{1.60} = 1.3\times10^{3}$ ***or*** 1.34×10^{3} rad s^{-1} ✓ ***ALTERNATIVE 2*** «0.882 ms is $\frac{0.3}{1.6}$ of cycle so whole cycle is» $\frac{2\pi\times3}{16\times0.882\times10^{-3}}$ ✓ 1.35×10^{3} rad s^{-1} ✓	*Allow ECF from (b)(i).*	**2**

Question			Answers	Notes	Total
4	c	i	the displacement of the particle decreases ***OR*** «on the graph» displacement is going in a negative direction ***OR*** on the graph the particle goes down ***OR*** on the graph displacement moves towards equilibrium/0 ✓ to the left ✓	*Do not allow "moving downwards".*	**2**
	c	ii	$y = -1.5$ mm ✓ $v = 2\pi \times 212 \times \sqrt{\left(4.0\times10^{-3}\right)^2 - \left(1.5\times10^{-3}\right)^2}$ ✓ «$v = 4.939 \approx 4.9 \text{ms}^{-1}$»	*Allow ECF from (b)(ii).* *Do not allow* $\frac{4.3\text{mm}}{0.882\text{ms}} = 4.87\text{m s}^{-1}$.	**2**
	d	i	the superposition/interference of two oppositely moving/reflected «identical travelling» waves ✓		**1**
	d	ii	the allowed wavelengths in the tube are $\lambda = \frac{4L}{n} = \frac{4.80}{n}$, $n = 1, 3, 5, \ldots$ ***OR*** diagram showing $\frac{3}{4}$ of a standing wavelength in the tube ✓ $1.6 = \frac{4.80}{n} \Rightarrow n = 3$ ***OR*** justification that $\frac{3}{4} \times 1.6 = 1.2$ m ✓	*Allow diagram showing* $\frac{3}{4}$ *of a wavelength for MP1.*	**2**

Question			Answers	Notes	Total
5	a		speed to reach infinity/zero gravitational field ***OR*** speed to escape gravitational pull/effect of planet's gravity ✓	*Do not allow reference to leaving/escaping an orbit.* *Do not allow "escaping the atmosphere".*	**1**
	b		«kinetic energy at take off» = $\frac{9}{16}\times\frac{GMm}{R}$ ✓ kinetic energy at take off + «gravitational» potential energy = «gravitational» potential energy at maximum height ***OR*** $\frac{9}{16}\times\frac{GMm}{R}-\frac{GMm}{R}=-\frac{GMm}{r}$ ✓ solves for r and subtracts R from answer = $\frac{9R}{7}$ ✓	*Award **[0]** for work that assumes constant g.*	**3**
	c		energy reduces/lost ✓ radius decreases✓ speed increases✓	*Do not allow "kinetic energy reduces" for MP1.*	**3**

Question			Answers	Notes	Total
6	a		***ALTERNATIVE 1*** correct application of Kirchhoff to at least one loop ✓ E = «4.0 × 2.0 =» 8.0 V ✓ ***FOR EXAMPLE*** $12 = 2.0I_1 + 4.0I_2$ for top loop with loop anticlockwise ✓ «but $I_2 = I_1$ as $I_3 = 0$» «E =» 8.0 V ✓ ***ALTERNATIVE 2*** «recognition that situation is simple potential divider arrangement» pd across 4 Ω resistor $= \frac{12 \times 4}{(2+4)}$ ✓ = 8 V ✓	*Award **[0]** for any answer that begins with the treatment as parallel resistors.*	**2**

Question			Answers	Notes	Total
6	b	i	***ALTERNATIVE 1*** equating electric to magnetic force $qE = qvB$ ✓ substituting $E = \frac{V}{L}$ ✓ «to get given result» ***ALTERNATIVE 2*** $V = \frac{\text{work done}}{Q}$ ***AND*** work done = force × distance ✓ work done $= qv = Bqv \times L$ ✓ «to get given result»		**2**
	b	**ii**	some mark indicating lower surface of conductor ***OR*** indication that ***positive*** charge accumulates at top of conductor ✓	*Do not allow negative or positive at top **and** bottom.*	**1**

Question			Answers	Notes	Total
7	a		 general shape starting at 12 V ✓ crosses at 6 V ✓	*Line must not touch time axis for MP2.* *Allow tolerance of one square in 12 V (start) and 6 V (crossing).*	**2**

Question			Answers	Notes	Total
7	b	i	the time for the voltage/charge/current «in circuit» to drop to $\frac{1}{e}$ ***or*** 37 % of its initial value «as the capacitor discharges» ***OR*** time for voltage/charge/current «in circuit» to increase to $\left(1-\frac{1}{e}\right)$ ***or*** 63 % of its final value «as the capacitor charges» ✓		**1**
	b	ii	$R = «\frac{22}{4.5\times10^{-6}} =» \ 4.9\times10^{6}\,\Omega$ ✓		**1**
	c	i	no change ***OR*** «remains at» 12 V ✓		**1**
	c	ii	increases ***OR*** doubles ✓	*Allow "doubles" in the light of (d).*	**1**
	d	i	recognises that new capacitance is 9.0 μF ✓ $E = «\frac{1}{2}CV^2 = \frac{1}{2}\times9.0\times10^{-6}\times12^2» \ = 0.65$ mJ ***or*** 6.5×10^{-4} J ✓	*Allow 11.8 V (value on graph at t = 100 s).*	**2**
	d	ii	energy goes into the resistor/surroundings ***OR*** «energy transferred» into thermal/internal energy form ✓	*Do not accept "dissipated" without location or form.* *Do not allow "heat".*	**1**

Question			Answers	Notes	Total
8	a		«lepton number on» LHS = 0 and «lepton number on» RHS $= 0 + 1 - 1$ ***OR*** quarks have no/0/zero lepton number and the lepton number for electron and the antineutrino cancel ✓		**1**
	b	i	energy released when a nucleus forms from constituent nucleons ***OR*** minimum energy needed/work done to break a nucleus up into its constituent nucleons ✓	*Do not allow reference to "atom".* *Award **[0]** for "energy to assemble nucleus".* *Do not allow "particles", "constituents" or "components" for "nucleons".*	**1**
	b	ii	«energy/mass difference =» 8.450 – 8.398 «= 0.052 MeV» ✓ $Q = 1.7$ ***or*** 1.66 ***or*** 1.664 MeV ***OR*** 2.66×10^{-13} J ✓		**2**
	c		quark theory is simpler ***OR*** Occam's razor example ***OR*** simple model explains complex observations ✓ quotes experiment that led to quark theory, eg deep inelastic scattering ***or*** electron scattering ✓ model incorporates strong/weak interactions/forces between protons and neutrons ✓ model incorporates conservation rules ✓ model explains differences between neutrons and protons ***OR*** explains decay of neutron to proton ✓		**3 max**

Question			Answers	Notes	Total
9	a		$I = \frac{\sigma A T^4}{4\pi d^2}$ ✓ $= \frac{5.67\times10^{-8}\times\left(7.0\times10^{8}\right)^2\times5800^4}{\left(1.5\times10^{11}\right)^2}$ ***OR*** $\frac{5.67\times10^{-8}\times4\pi\times\left(7.0\times10^{8}\right)^2\times5800^4}{4\pi\times\left(1.5\times10^{11}\right)^2}$ ✓ $I = 1397\,\text{W m}^{-2}$ ✓	*In this question we must see 4SF to award MP3.* *Allow candidate to add radius of Sun to Earth–Sun distance. Yields 1386 W m^{-2}.*	**2 max**
	b		«transmitted intensity =» 0.70×1400 «= 980 W m^{-2}» ✓ $\frac{\pi R^2}{4\pi R^2}\times 980\ \text{W m}^{-2}$ ✓ $245\,\text{W m}^{-2}$		**2**
	c		$5.67\times10^{-8}\times T^4 = 245$ ✓ $T = 256\,\text{K}$ ✓		**2**
	d		the emitted radiation is in the infrared/IR/long wavelength/low frequency region ✓ «greenhouse» gases in the atmosphere absorb «infrared» radiation ✓ radiated in all directions «including back down to Earth» warming the Earth ✓	*Do not allow "traps the heat".* *Must see clear implication somewhere in response that gases are in the atmosphere for MP2.* *Must see sense that Earth temperature is raised for MP3.*	**2 max**

Question			Answers	Notes	Total
10	a		constructive interference ✓ amplitude/amount of light from 4 slits is 4 × amplitude «from one slit» ✓ intensity is proportional to amplitude^2 ***OR*** shows $4^2 = 16$ in context of intensity ✓		**3**
	b	i	«diffraction minimum at» $\theta = 0.43\,\text{rad}$ ✓ $\lambda = \text{«}b\theta = 1.0\times10^{-6}\times0.43 =\text{»}\ 4.3\times10^{-7}\,\text{m}$ ✓	*Accept θ in range 0.41 to 0.45 rad.* *Allow $\lambda = b\sin\theta$ but do not allow $n\lambda = d\sin\theta$.* *Award **[1 max]** for solution using factor of 1.22.* *Award **[0]** if use of $s = \frac{\lambda D}{d}$ seen.*	**2**
	b	ii	«first secondary maximum at» $\theta = 0.125\,\text{rad}$ ✓ $d = \frac{1\times\text{value from (b)(i)}}{\sin 0.125} = 3.4\times10^{-6}\,\text{m}$ ✓	*Accept θ in range 0.123 to 0.127 rad.* *Sine must be seen to award MP2.* *Allow ECF from (b)(i).* *Allow use of 2nd or 3rd maxima (0.25 rad and 3.46 μm or 0.375 rad and 3.5 μm with appropriate n).*	**2**
	c	i	primary maxima/fringes become brighter/more intense ✓ primary maxima become narrower/sharper ✓ secondary maxima become unimportant/less intense/disappear ✓	*Insist on "secondary" for MP3.*	**2 max**

Question			Answers	Notes	Total
10	c	ii	$N = \text{«}\frac{\bar{\lambda}}{m\Delta\lambda} = \text{»}\ \frac{589.2935}{2\times 0.5970}$ ✓ $N = 494$ ***or*** 500 ✓	*Allow use of 588.995 nm or 589.592 nm for* $\bar{\lambda}$ *.*	**2**

11	a	i	32 MeV converted using $32\times 10^6\times 1.6\times 10^{-19}$ «$=5.12\times 10^{-12}$ J» ✓ $d = \text{«}\frac{kQq}{E} = \frac{8.99\times 10^9\times 2\times 79\times\left(1.6\times 10^{-19}\right)^2}{32\times 10^6\times 1.6\times 10^{-19}}\ =\text{»}\ \frac{8.99\times 10^9\times 2\times 79\times 1.6\times 10^{-19}}{32\times 10^6}$ ***OR*** $7.102\times 10^{-15}\,\text{m}$ ✓ «$d\approx 7\times 10^{-15}\,\text{m}$»	*Must see final answer to 2+ SF unless substitution is completely correct with value for k explicit.* *Do not allow an approach via* $r = R_0 A^{\frac{1}{3}}$ *.*	**2**
	a	ii	$m\approx 197\times 1.661\times 10^{-27}$ ***OR*** $3.27\times 10^{-25}\,\text{kg}$ ✓ $V = \frac{4\pi}{3}\times\left(7\times 10^{-15}\right)^3$ ***OR*** $1.44\times 10^{-42}\,\text{m}^3$ ✓ $\rho = \text{«}\frac{m}{V} = \frac{3.2722\times 10^{-25}}{1.4368\times 10^{-42}}\ =\text{»}\ 2.28\times 10^{17}\approx 2\times 10^{17}\,\text{kg m}^{-3}$ ✓	*Allow working in MeV:* 1.28×10^{47} *MeV* c^{-2} m^{-3}*.* *Allow ECF from incorrect answers to MP1 or MP2.*	**3**

Question			Answers	Notes	Total
11	b		*Distance of closest approach*: charge ***or*** number of protons ***or*** force of repulsion is the same so distance is the same ✓ *Estimate of nuclear density*: « $\rho \propto \frac{A}{(A^{\frac{1}{3}})^3}$ so» density the same ✓		**2**
	c		$\Delta x \approx 7 \times 10^{-15}$ m ✓ $\Delta p \approx \frac{6.63 \times 10^{-34}}{4\pi \times 7 \times 10^{-15}}$ «$= 7.54 \times 10^{-21}$ Ns» ✓ $E \approx$ «$\frac{\Delta p^2}{2m} = \frac{\left(7.54 \times 10^{-21}\right)^2}{2 \times 6.6 \times 10^{-27}} = 4.3 \times 10^{-15}$ J $= 26897$ eV» ≈ 0.027 MeV ✓	*Accept* $\Delta x \approx 3.5 \times 10^{-15}$ *m or* $\Delta x \approx 1.4 \times 10^{-14}$ *m leading to* $E \approx 0.11$ *MeV or 0.0067 MeV.* *Answer must be in MeV.*	**3**