Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2019

Physics

Standard level

Paper 3

24 pages

Subject Details: Physics SL Paper 3 Markscheme

Candidates are required to answer **all** questions in Section A and **all** questions from **one** option in Section B. Maximum total = **35 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 <u>underlined</u> 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.

Section A

Question			Answers	Notes	Total
1.	a		ΔI is too small to be shown/seen ***OR*** Error bar of negligible size compared to error bar in V ✓		1
1.	b		evidence that ε can be determined from the y-intercept of the line of best-fit or lines of min and max gradient ✓ states $\varepsilon = 1.59$ ***OR*** 1.60 ***OR*** 1.61 **«**V**»** ✓ states uncertainty in ε is 0.02 **«**V**»** ***OR*** 0.03«V» ✓		3
1.	c		determine the gradient **«**of the line of best-fit**»** ✓ *r* is the negative of this gradient ✓		2

Question			Answers	Notes	Total
2.	a		Any curve that passes through ALL the error bars ✓		1
2.	b	i	$kg^{-1}\,m^{-1}$ ✓		1
2.	b	ii	f^2 AND T ***OR*** f AND $\sqrt{T}$ ***OR*** log f AND log T ***OR*** ln f AND ln T ✓		1
2.	b	iii	graph would be a straight line/constant gradient/linear ✓ passing through the origin ✓		2

Question			Answers	Notes	Total
3.	a		Evidence of $\frac{\Delta s}{s}$ AND $\frac{\Delta D}{D}$ used ✓ «add fractional/% uncertainties» obtains 11 % (or 0.11) ***OR*** 10 % (or 0.1) ✓		**2**
3.	b		***ALTERNATIVE 1:*** measure the combined width for several fringes ***OR*** repeat measurements ✓ take the average ***OR*** so the «percentage» uncertainties are reduced ✓ ***ALTERNATIVE 2:*** increase D **«**hence s**»** ***OR*** Decrease d ✓ so the «percentage» uncertainties are reduced ✓	*Do not accept answers which suggest using different apparatus*.	**2**

Section B

Option A — Relativity

Question			Answers	Notes	Total
4.	**a**	**i**	a coordinate system which is not accelerating/has constant velocity/Newtons 1st law applies ✓	OWTTE *Both "inertial" and "reference frame" need to be defined*	**1**
4.	**a**	**ii**	1.5*c* ✓		**1**
4.	**b**		*c* is the same in all frames ***OR*** c is maximum velocity possible ✓ velocity addition frame dependent ✓ length/time/mass/fields relative measurements ✓ Newtonian/Galilean mechanics valid only at low speed ✓		**2 max**

Question			Answers	Notes	Total
5.	**a**		moving charges give rise to magnetic fields ***OR*** magnetic attraction between parallel currents ✓		**1**
5.	**b**		protons at rest produce no magnetic field ***OR*** mention of $F = Bev$ where B and/or $v = 0$ ✓		**1**
5.	**c**		there is a repulsive electric/electrostatic force «in both frames» ✓ the attractive magnetic force «in the lab frame» is smaller than the repulsive electric force ✓ in all frames the net force is repulsive as all must agree that protons move apart ***OR*** mention of the first postulate of relativity ✓		**2 max**

Question			Answers	Notes	Total
6.	a		the length measured «in a reference frame» where the object is at rest ✓		1
6.	b	i	$\Delta t = «\frac{85}{0.5 \times 3 \times 10^8} =» 5.7 \times 10^{-7}$ «s» ✓		1
6.	b	ii	***ALTERNATIVE 1:*** «for $v = 0.6c$ » $\gamma = 1.25$ ✓ «uses LT with Δt' from 6(b)(i)» $\Delta t = 1.25\left(5.7 \times 10^{-7} + \frac{0.6 \times 85}{3 \times 10^8}\right)$ ✓ 9.2×10^{-7} «s» ***OR*** 9.3×10^{-7} «s» ✓ ***ALTERNATIVE 2:*** v of ball is $0.846c$ for platform ✓ length of train is 68m for platform ✓ $\text{time} = «\frac{68}{0.846c - 0.6c} =» 9.2 \times 10^{-7}$ «s» ***OR*** 9.3×10^{-7} «s» ✓ ***ALTERNATIVE 3:*** «$\gamma = 1.154$ for ball in train, so proper time for ball» $\Delta t_0 = «\frac{5.7 \times 10^{-7}}{1.154} =» 4.9 \times 10^{-7}$ «s» ✓ v of ball is $0.846c$ for platform ***OR*** $\gamma = 1.876$ ✓ $\Delta t = «\gamma \Delta t_0 = 1.876 \times 4.9 \times 10^{-7} =» 9.2 \times 10^{-7}$ «s» ***OR*** 9.3×10^{-7} «s» ✓		3

Question			Answers	Notes	Total
7.	a		*Evidence of finding 1/gradient such as:* use of any correct coordinate pair to find *v* - *eg* $\frac{4}{5}$ or $\frac{6}{7.5}$ ***OR*** measures tan of angle between *ct* and *ct'* as about 39° ***AND*** $\tan 39 \approx 0.8$ ✓	*Answer 0.8c given, so check coordinate values carefully.*	**1**
7.	b		E labelled at $x = 4$, $ct = 5$ ✓	*Check that E is placed on the worldline of S.*	**1**
7.	c	i	$\gamma = \frac{5}{3} = 1.67$ ✓ $t' = \frac{5}{\gamma} = 3\,\text{years}$ ***OR*** $ct' = 3\,\text{ly}$ ✓	*Allow solutions involving the use of Lorentz equations.*	**2**
7.	c	ii	$t = 5$ years ***OR*** $ct = 5\,\text{ly}$ ✓		**1**

(continued…)

(Question 7 continued)

Question			Answers	Notes	Total
7.	**d**		On return to Earth the astronaut will have aged less than Earthlings «by 4 years» ***OR*** time passed on Earth is greater than time passed for the astronaut «by 4 years» ✓ astronaut accelerated/changed frames but Earth did not ***OR*** for astronaut the Earth clock jumps forward at turn- around ✓	*OWTTE* *Treat as neutral any mention of both the Earth and astronaut seeing each other's clock as running slow.*	**2**

Option B — Engineering physics

Question			Answers	Notes	Total
8.	**a**		«translational equilibrium demands that the» resultant force in the horizontal direction must be zero✓ «hence $N_W = F$ »	*Equality of forces is given, look for reason why.*	**1**
8.	**b**		«clockwise moments = anticlockwise moments» $50 \times 2\cos 60 = N_W \times 4\sin 60$ ✓ «$N_W = F = \frac{50 \times 2\cos 60}{4\sin 60}$» $F = 14.4$ «N» ✓	*Moments can be equated at any of the three points (ground, wall or centre of mass) giving F=25cot60* *Award **[0]** (no ECF) if an incorrect equation for moments is used.* *Award **[2]** for a bald correct answer*	**2**
8.	**c**		maximum friction force = «0.4×50N» = 20 «N» ✓ $14.4 < 20$ ***AND*** so will not slip ✓	*For MP2 allow ECF if answer to part 8(b) is greater than 20 N ie "will slip"* *For MP2 the stated reason is required somewhere, so award **[0]** for a bald "will not slip"*	**2**

Question			Answers	Notes	Total
9.	**a**		$E_k = E_k$ linear $+ E_k$ rotational ***OR*** $E_k = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$ ✓ $= \frac{1}{2}mv^2 + \frac{1}{2} \times \frac{2}{5}mr^2 \times \left(\frac{v}{r}\right)^2$ ✓ **«**$= \frac{7}{10}mv^2$**»**	*Answer is given in the question so check working is correct at each stage.*	**2**
9.	**b**		Initial $E_K = \frac{7}{10} \times 1.50 \times 0.5^2$ **«**$= 0.26\,\text{J}$**»** ✓ Final $E_K = 0.26 + 1.5 \times 9.81 \times 0.45$ **«**$= 6.88\,\text{J}$**»** ✓ $v =$ **«**$\sqrt{\frac{10}{7} \times \frac{6.88}{1.5}}$ **=»** 2.56 **«**m s^{-1}**»** ✓	*MP2 is for adding E_P, this may be implied by a correct final answer.* *Other solution methods are possible* *MP2: Allow g = 10 (gives 7.01J)* *Allow ECF in MP2 & MP3 for incorrect E_k or E_p in earlier MP. eg Award **[2]** for 2.5m s^{-1} if original KE is not used.* *Award **[3]** for a bald correct answer*	**3**

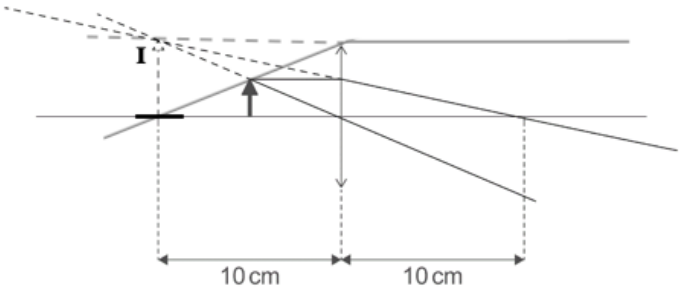
Question			Answers	Notes	Total
10.	**a**		evidence of work done equals area between AC and the Volume axis ✓ reasonable method to estimate area giving a value 425 to 450 J ✓	*Answer 440 J is given, check for valid working.* *Examples of acceptable methods for MP2:* *- estimates 17to18 small squares x 25J per square = 425 to 450 J.* *- 250 J for area below BC plus a triangle of dimensions 5 × 3, 3 × 5, or 4 × 4 small square edges giving 250J + 187.5 J or 250 J + 200 J.* *Accurate integration value is 438 J - if method seen award **[2]**.*	**2**
10.	**b**	**i**	**«**use of $U = \frac{3}{2}nRT$ and $pV = nRT$ to give**»** $\Delta U = \frac{3}{2}\Delta pV$ ✓ **«**$= \frac{3}{2} \times -2.5 \times 10^{5} \times 1 \times 10^{-3}$**»** $=$ **«**–**»**375**«**J**»** ✓	*Another method is possible: eg realisation that ΔU for BC has same magnitude, so ΔU = 3/2 PΔV.* *POT must be correct for MP2.* *Allow positive answer.* *Award **[2]** for a bald correct answer.*	**2**
10.	**b**	**ii**	$T_A = 816$**«**K**»** ***OR*** 543**«**°C**»** ✓		**1**

(continued…)

(Question 10 continued)

Question			Answers	Notes	Total
10.	**c**		for CA $\Delta U = 0$ so $Q = W = -440$ **«J»** ✓ for AB $W = 0$ so $Q = \Delta U = -375$ **«J»** ✓ 815 **«J»** transferred to the building ✓	*Must use the first law of thermodynamics for MP1 and MP2.* *Accept both positive or both negative values for both Q.* *Allow use of answer to 10a in MP1 and MP3 giving a range of 800 to 825 J.* *Allow ECF from bi in MP2 and MP3* *Award **[2]** for answer of **«–»**65 J (or ECF value) if MP1 and MP2 have opposite signs.* *Do not award MP3 for simply adding two completely incorrect values.* *Award **[3]** for a bald correct answer.*	**3**
10.	**d**		the temperature changes in the cycle are too large ✓ the cycle takes too long **«**because it contains an isothermal stage**»** ✓ energy/power output would be too small ✓		**2 max**

Option C — Imaging

Question			Answers	Notes	Total
11.	**a**	**i**	any two correct rays with extensions ✓ extensions converging to locate an upward virtual image labelled I with position within shaded region around focal point on diagram ✓		**2**
11.	**a**	**ii**	v = «–» 10 «cm» ✓ M «$= -\left(\frac{v}{u}\right) = -\left(\frac{-10}{5}\right)$» = «+» 2 ✓		**2**
11.	**a**	**iii**	magnifying glass ***OR*** Simple microscope ***OR*** eyepiece lens ✓		**1**

(continued…)

(Question 151continued)

Question			Answers	Notes	Total
11.	**b**	**i**	**I** labelled at 25 cm mark ✓		**1**
11.	**b**	**ii**	the second lens has f **«**$= \frac{10}{5}$**»** $= 2$ **«**cm**»** ✓ **«**so for telescope image to be at infinity**»** the second lens is placed at 27 **«**cm**»** ***OR*** separation becomes 12 **«**cm**»** ✓		**2**
11.	**b**	**iii**	image formed by 10 cm lens is greater than 10 cm/further to the right of the first lens ✓ so second lens must also move to the right ***OR*** lens separation increases ✓	*Award **[1 max]** for bald "separation increases".*	**2**

Question			Answers	Notes	Total
12.	a		refractive index of step index fibre is constant ✓ refractive index of graded index fibre decreases with distance from axis/centre ✓ graded index fibres have less dispersion ✓ step index fibre: path of rays is in a zig-zag manner ✓ graded index fibre: path of rays is in curved path ✓	*For MP2 do not accept vague statements such as "index increases/varies with distance from centre".*	**2 max**
12.	b	i	$v = \frac{c}{n} = v_{1299} = \frac{2.99792 \times 10^8}{1.45061} = 2.06666 \times 10^8$ «m s^{-1}» ***AND*** $v_{1301} = \frac{2.99792 \times 10^8}{1.45059} = 2.06669 \times 10^8$ «m s^{-1}» ***OR*** $\Delta v = \left(\frac{1}{1.45059} - \frac{1}{1.45061} \right) \times 2.99792 \times 10^8$ ✓ $\Delta v = 2.85 \times 10^3$ ***OR*** 3×10^3 «m s^{-1}» ✓		**2**

(continued…)

(Question 12 continued)

Question			Answers	Notes	Total
12.	**b**	**ii**	pulse wider ✓ pulse area smaller ✓	*For MP2 do not accept lower amplitude unless pulse area is also smaller.*	**2**
12.	**b**	**iii**	reference to dispersion ***OR*** reference to time/speed/path difference ✓ reference to power loss/energy loss/scattering/attenuation ✓		**2**
12.	**b**	**iv**	longer cables give wider pulses ✓ which overlap/interfere if T too small/f too high ✓	*OWTTE*	**2**

Option D — Astrophysics

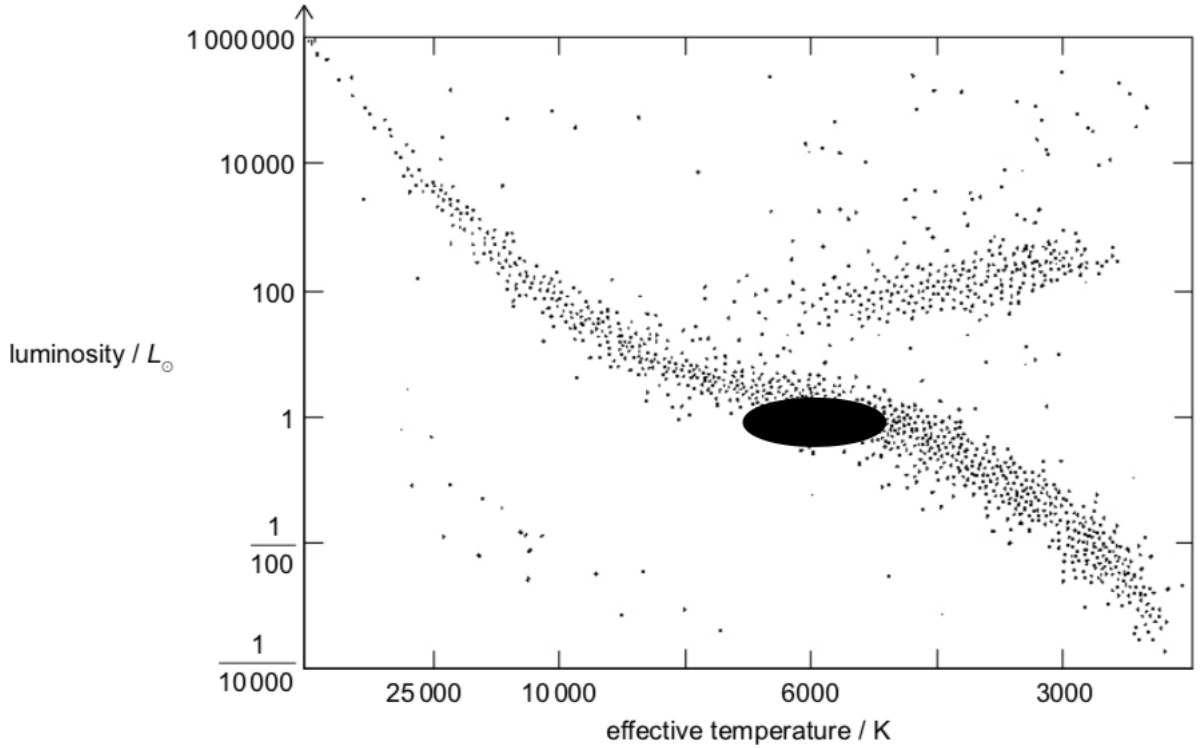
Question			Answers	Notes	Total
13.	**a**	**i**	Cepheid variables expand and contract ***OR*** Radius increases and decreases ***OR*** Surface area increases and decreases ✓ Surface temperature decreases then increases✓ Surface becomes transparent then opaque ✓	*OWTTE* *Do not reward 'change in luminosity/brightness' as this is given in the question.* *Accept changes in reverse order*	**2 max**
13.	**a**	**ii**	the «peak» luminosity/actual brightness depends on the period ***OR*** More luminous Cepheid variables have greater period✓ measurements of apparent brightness allow distance determination ***OR*** Mention of $b = \frac{L}{4\pi d^2}$ ✓	*OWTTE*	**2**

(continued…)

(Question 13 continued)

Question			Answers	Notes	Total
13.	**b**	**i**	$d = \text{«}273 \times 3.26 \times 9.46 \times 10^{15} =\text{»}\ 8.42 \times 10^{18}$ «m» ✓ $b = \text{«}\frac{L}{4\pi d^2} = \frac{7.70 \times 10^{29}}{4\pi\left(8.42 \times 10^{18}\right)^2} =\text{»}\ 8.6 \times 10^{-10}$ «Wm^{-2}» ✓	*MP1 may be implicit in the calculation* *Allow ECF in MP2 (eg answer $b = 8.2 \times 10^{23}$ if pc not converted to m)* *Award **[2]** for a bald correct answer*	**2**
13.	**b**	**ii**	«$T = \frac{2.9 \times 10^{-3}}{4.29 \times 10^{-7}}$» $= 6800$ «K» ✓		**1**
13.	**c**		Data subject to peer review/checks by others ✓ Compare light from stars with Earth based light sources ✓ measurements are corroborated by different instruments/methods from different teams ✓	*OWTTE*	**1max**

Question			Answers	Notes	Total
14.	**a**	**i**	$d = \text{«}1.6\times10^{8}\times9.46\times10^{15} =\text{»}\ 1.51\times10^{24}$ **«**m**»** ✓ $v = \text{«}H_0 d = 2.3\times10^{-18}\times1.51\times10^{24} =\text{»}\ 3.48\times10^{6}$ **«**m**»** ✓		**2**
14.	**a**	**ii**	$\Delta\lambda = \text{«}\frac{\lambda_0 v}{c} = \frac{4.86\times10^{-7}\times3.48\times10^{6}}{3\times10^{8}} =\text{»}\ 5.64$ **«**nm**»** ✓ observed $\lambda = \text{«}486 + 5.64 =\text{»}\ 492$ **«**nm**»** ✓	*Accept 5.67nm for MP1 when* 3.5×10^{6} *used.* *Allow ECF from MP1 only if* $\Delta\lambda$ *is correctly added to* λ_0*.* *Award* ***[0]*** *for not using correct value of* λ_0*.* *Award* ***[2]*** *for a bald correct answer.*	**2**
14.	**b**		all distant galaxies exhibit red-shift ✓	OWTTE	**1**

Question			Answers	Notes	Total
15.	a		the letter S should be in the region of the shaded area ✓ 		1

(continued…)

(Question 15 continued)

Question			Answers	Notes	Total
15.	**b**		the fusion of hydrogen in the core eventually stops **OR** core contracts ✓ the hydrogen in a layer around the core will begin to fuse ✓ Sun expands AND the surface cools ✓ helium fusion begins in the core ✓ Sun becomes more luminous/brighter✓	*Ignore any mention of the evolution past the red giant stage*	**3max**
15.	**c**		electron degeneracy <<prevents further compression>> ✓	*Ignore mention of the Chandrasekhar limit.* *Award **[0]** for answer mentioning radiation pressure or fusion reactions.*	**1**
15.	**d**		«use of $L = \sigma A T^4$ » $\frac{10^{-4}}{10^4} = \left(\frac{R_D}{R_G}\right)^2 \times \left(\frac{10000}{3000}\right)^4$ ✓ $\frac{R_D}{R_G} = 9 \times 10^{-6}$ ✓		**2**