M15/4/PHYSI/SP3/ENG/TZ2/XX/M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2015

Physics

Standard Level

Paper 3

18 pages

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

1. Follow the markscheme provided, award only whole marks and mark only in **RED**.

2. Make sure that the question you are about to mark is highlighted in the mark panel on the right-hand side of the screen.

3. Where a mark is awarded, a tick/check (✓) **must** be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark. **One tick to be shown for each mark awarded.**

4. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases use RM™ Assessor annotations to support your decision. You are encouraged to write comments where it helps clarity, especially for re-marking purposes. Use a text box for these additional comments. It should be remembered that the script may be returned to the candidate.

5. Personal codes/notations are unacceptable.

6. Where an answer to a part question is worth no marks but the candidate has attempted the part question, use the “ZERO” annotation to award zero marks. Where a candidate has not attempted the part question, use the “SEEN” annotation to show you have looked at the question. RM™ Assessor will apply “NR” once you click complete.

7. If a candidate has attempted more than the required number of questions within a paper or section of a paper, mark all the answers. RM™ Assessor will only award the highest mark or marks in line with the rubric.

8. Ensure that you have viewed **every** page including any additional sheets. Please ensure that you stamp “SEEN” on any additional pages that are blank or where the candidate has crossed out his/her work.

9. There is no need to stamp an annotation when a candidate has not chosen an option. RM™ Assessor will apply “NR” once you click complete.

10. Mark positively. Give candidates credit for what they have achieved and for what they have got correct, rather than penalizing them for what they have got wrong. However, a mark should not be awarded where there is contradiction within an answer. Make a comment to this effect using a text box or the “CON” stamp.

Subject Details: Physics SL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer questions from **TWO** of the Options **[2 × 20 marks]**.
Maximum total = **[40 marks]**

1. A markscheme often has more marking points than the total allows. This is intentional.

2. Each marking point has a separate line and the end is shown by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/). Either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

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

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. 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 markscheme 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).

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

9. 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.

10. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.

Option A — Sight and wave phenomena

1. (a) any standard "Gaussian" type shape, symmetric or not;
peaking at $500 \pm 100\,\text{nm}$; **[2]**
Ignore the height of the peak.
*Award **[0]** if more than 1 peak/curve is drawn.*

(b) after sunset intensity is low so rods are being used/rod cells used for scotopic vision;
sensitivity to red wavelengths is very low; } *(allow even if graph does not show lower sensitivity at 700nm)* **[2]**

2. (a) (i) travelling waves move down the tube;
which then interfere with the reflected waves (from the closed end of the tube/surface of the water); **[2]**
Accept superposition as an alternative to interference.

(ii) $\lambda = (4L = 4 \times 0.33 =)\, 1.32\,(\text{m})$;
$v = (f\lambda = 256 \times 1.32 =)\, 338\,(\text{m s}^{-1})$; **[2]**

(b) (i) vertical; **[1]**

(ii) X; **[1]**

3. (a) diffraction angle $= 0.05$ rad;
$b = \left(\frac{\lambda}{\theta} = \frac{7.0 \times 10^{-7}}{0.050} =\right) 1.4 \times 10^{-5}\,(\text{m})$; *(do not accept use of 1.22)* **[2]**
*Award **[2]** for a bald correct answer.*

(b) same shape with narrower central maximum; **[1]**
Ignore height of intensity peak.

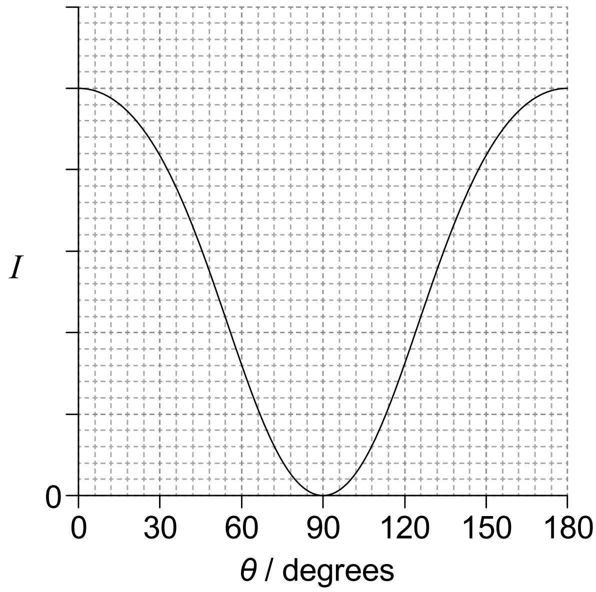
(c) blue light gives better resolution;
blue light has shorter wavelength than red light;
giving smaller angle of diffraction; **[2 max]**
Allow reverse argument for red light.

4. (a) light in which the electric vector oscillates on one plane/direction; **[1]**

(b) (i) completely (horizontally) polarized; **[1]**

(ii) $r = (90^\circ - \phi =)\ 37^\circ$; **[1]**

(iii)



maxima and minima at correct angles;
shape as shown; **[2]**
*Allow **[1 max]** for inverse of curve shown.*

Option B — Quantum physics and nuclear physics

5. (a) (i) photon energy $=\left(\frac{hc}{\lambda}=\frac{6.63\times10^{-34}\times3\times10^{8}}{450\times10^{-9}}=\right)4.4\times10^{-19}$ (J);

$=2.76$ (eV)**;**

$2.76-2.4=0.36$ (eV)**;** **[3]**

*Award **[3]** for a bald correct answer.*

*Award **[1 max]** if the energy of the photon is not converted from Joules to eV (giving $E_K=-2.4\,eV$).*

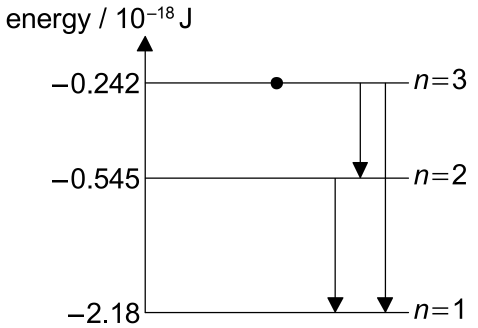
(ii) $2\times10^{15}\times1.6\times10^{-19}$;

3×10^{-4} (A); **[2]**

*Award **[2]** for a bald correct answer.*

(b) light consists of photons;
frequency of photons increases so energy of photons increases;
same intensity of radiation means fewer photons;
fewer photons means fewer (photo)electrons;
(the emitted number of electrons falls) **[4]**

6. (a)



two correct arrows;
a third correct arrow; **[2]**
*Award **[1]** for three upward arrows.*

(b) energy of photon is $E=\left(\frac{6.63\times10^{-34}\times3\times10^{8}}{656\times10^{-9}}=\right)3.03\times10^{-19}$ (J);

$((0.545-0.242)\times10^{-18}=3.03\times10^{-19}$ J) is the difference in energy between $n=3$ and $n=2$; **[2]**

7. (a) measurement of mass of sample / determination of molar mass;
determination of number of nuclei *N*;
measurement of activity *A*;
determination of decay constant from $\lambda = \frac{A}{N}$;
half-life from $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$; **[4 max]**

(b) $\lambda = \left(\frac{\ln 2}{T_{\frac{1}{2}}} = \frac{\ln 2}{9000} =\right) 7.70 \times 10^{-5}\ \text{yr}^{-1}$;
$m = (m_0 e^{-\lambda t} =) 1.8 \times e^{-7.70\times10^{-5}\times25000}$;
$m = 0.26$ (kg); **[3]**

or

$\frac{25000}{9000} = 2.77$ half-lives;
fractional mass left $= \left(\frac{1}{2}\right)^{2.77} = 0.15$;
mass left $= 1.8 \times 0.15 = 0.26$ (kg);
*Award **[3]** for a bald correct answer.*

Option C — Digital technology

8. (a) (i) 0; **[1]**

(ii) $1\times 2^4 + 1\times 2^3 + 0\times 2^2 + 1\times 2^1 + 0\times 2^0 (= 26)$; **[1]**

This or other equivalent working must be shown.

(b) $(2\times 16\times 44.1\times 10^3) = 1.41\times 10^6 (\text{bits s}^{-1})$;

$\text{duration} = \dfrac{210\times 10^6 \times 8}{1.41\times 10^6}$;

$= 1200\,(\text{s})$ ***or*** $20\,(\text{min})$; **[3]**

Allow ECF after missing factors of 2 and/or 8.

*Award **[3]** for a bald correct answer.*

9. (a) (i) area of one pixel $\left(\dfrac{866}{16\times 10^6} =\right) 5.41\times 10^{-5}\,(\text{mm}^2)$ ***or*** $5.41\times 10^{-11}\,(\text{m}^2)$;

size of pixel is $\left(\sqrt{5.41\times 10^{-5}} =\right) 7.4\times 10^{-3}\,(\text{mm})$ ***or*** $7.4\times 10^{-6}\,(\text{m})$; **[2]**

*Award **[2]** for a bald correct answer.*

(ii) using two pixel lengths as the smallest distance that the two points should have on the CCD; *(this mark may be implicit in the calculation)*

maximum observable distance between points is $\left(\dfrac{2\times 7.4\times 10^{-6}}{2.08\times 10^{-3}} =\right) 7.1\times 10^{-3}\,(\text{m})$; **[2]**

Allow ECF from (a)(i).

*Award **[1 max]** if factor of 2 missing giving $3.6\times 10^{-3}\,(m)$.*

*Award **[2]** for a bald correct answer.*

(b) incident photons cause the release of electrons;
pixel acts as a capacitor / electrons are stored by the pixel; **[2]**

(c) takes less time to form an image / shorter exposure time;
brighter image (than the other ccd);
fainter/more distant objects/stars can be seen; **[2 max]**

10. (a) very high (infinite) input resistance/impedance / zero input current;
very low (zero) output resistance/impedance;
very high (infinite) gain in the output voltage;
very high (infinite) bandwidth;
very low (zero) noise;
the output signal is proportional to the difference between the two input signals (assuming no saturation); **[2 max]**

(b) $V_- = V_+ = 0$;
$V_{IN} = I_1 \times R_1$ and $V_{OUT} = -I_2 \times R_2$; *(allow negative sign in either IR term)*
$I_1 = I_2$;
so $\frac{V_{IN}}{R_1} = -\frac{V_{OUT}}{R_2}$;
$\left(\text{therefore the gain is } \frac{V_{OUT}}{V_{IN}} = -\frac{R_2}{R_1}\right)$ **[3 max]**

*Award **[3 max]** for very concise proof:* $I = \frac{V_{IN}}{R_1} = -\frac{V_{OUT}}{R_2}$.

(c) $V_{OUT} = -15$ (V);
since $-12 \times 1.7\ \text{V} < -15\ \text{V}$; *(simple evaluation of –20.4 V gains no mark)* **[2]**
*Allow ECF **[1 max]** if* $G = +12$ *is used in giving* $+15$ *V.*

Option D — Relativity and particle physics

11. (a) (i) $\left(\frac{12\,\text{ly}}{0.60c}=\right)20\,(\text{yr})$ ***or*** 6.3×10^{8} (s); **[1]**

(ii) $\gamma=\left(\frac{1}{\sqrt{1-0.60^{2}}}=\right)1.25$;

$\Delta t_0=\left(\frac{\Delta t}{\gamma}=\frac{20}{1.25}=\right)16\,(\text{yr})$ ***or*** 5.0×10^{8} (s); *(allow ECF from (a)(i))* **[2]**

*This question is worth **[2]**, but it is easy to accidently award **[1]**.*

(b) (i) the length of a body in the rest frame of the body; **[1]**

Do not accept "event" instead of "object/body".
Do not accept "in the same frame" unless rest (OWTTE) is mentioned.

(ii) $l=\frac{310}{1.25}$; *(allow ECF from (a)(ii))*

$=250\,(\text{m})$; **[2]**

*This question is worth **[2]**, but it is easy to accidently award **[1]**.*

(c) according to the spacecraft observer, the space station observer receives light from B and F at the same time;
for the spacecraft observer the space station observer moves away from the waves from B/towards the waves from F;
but the speed of light is constant;
according to the spacecraft observer light from B must be emitted first; **[4]**
Do not award second marking point for answers that refer to light the spacecraft observer SEES or to distances to the spacecraft.

12. (a) (i) a particle with the same mass but opposite quantum numbers/charge; **[1]**

(ii) the neutron has baryon number $+1$, so the antineutron has baryon number -1;
so they are different; **[2]**

or

the neutron consists of three quarks (udd) and the antineutron consists of three antiquarks $(\bar{u}\bar{d}\bar{d})$;
so they are different;
*Award **[0]** for a bald correct answer.*

(b) (i) a short lived/virtual particle/(gauge) boson;
that transfers energy/momentum/force between interacting particles; **[2]**

(ii) W^{-}; **[1]**

(iii) zero; **[1]**

(iv) $\Delta S=0-(-1)=+1$; **[1]**

(c) $\left(R=\frac{h}{4\pi mc}\Rightarrow\right)m=\frac{h}{4\pi cR}$; *(the mark is for rearrangement)*

$m\left(=\frac{6.63\times10^{-34}}{4\pi\times3\times10^{8}\times10^{-15}}\right)\approx1.8\times10^{-28}\,(\text{kg})$; **[2]**

*Award **[2]** for a bald correct answer.*

Option E — Astrophysics

13. (a) *A*: white dwarf;
B: main sequence / blue giant / blue supergiant;
C: red giant / red supergiant; **[3]**

(b) $\frac{L_B}{L_A} = \left(\frac{\sigma 4\pi R_B{}^2 T^4}{\sigma 4\pi R_A{}^2 T^4} = \right) 10^6$;

$\frac{R_B}{R_A} = 10^3$; **[2]**

Award ***[2]*** *for a bald correct answer.*

(c) (i) *apparent brightness*: (total) power received per unit area/per m^2; *(accept luminosity for power)*

luminosity: (total) power radiated; **[2]**

Accept energy per second instead of power.

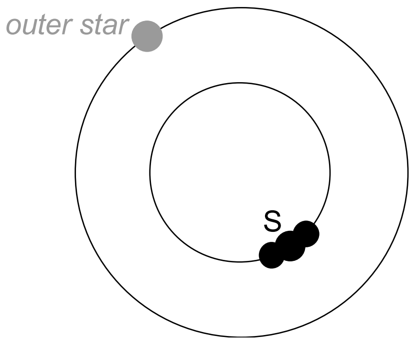
(ii) $d = \sqrt{\frac{L}{4\pi b}} \left(= \sqrt{\frac{10^4 \times 3.9 \times 10^{26}}{4\pi \times 3.8 \times 10^{-10}}} \right)$; *(mark is for rearrangement)*

$d = 2.9 \times 10^{19}$ (m); **[2]**

Award ***[1]*** *for* 2.9×10^{17} *(misses factor of 10 000).*
Award ***[2]*** *for a bald correct answer.*

(d) same shape as curve in graph and displaced to right;
peak at $10 \pm 2 \times 10^{-7}$ m with intensity ≤ 1; **[2]**

14. (a)

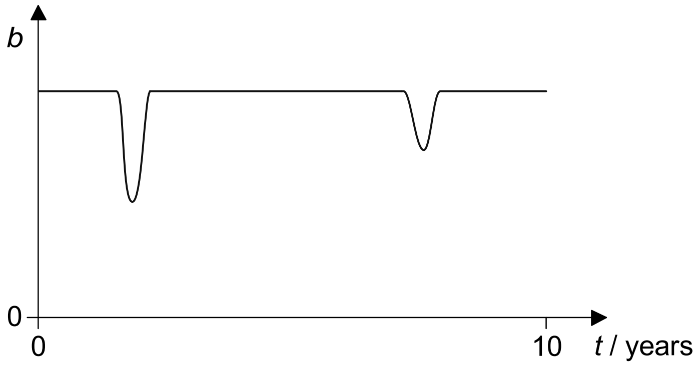


diametrically opposite on inner circle; } *(judge by eye – smaller dots show the range allowed)* **[1]**

Do not accept multiple positions for S.
Ensure S is placed on the inner circle – it is easy to make a mistake.

(b) the Earth/observer must be on the plane of the orbit;
alignment of stars is such that they can block the light from the other star as seen by the observer / *OWTTE*; **[1 max]**

(c)



exactly 2 minima in 10 years;
minima of different intensity and width of minima ≤ separation; **[2]**
*Award **[0]** for a single minimum.*
Accept minima of any shape.

15. (a) (distant) galaxies are all moving away from each other/Earth;
the distance between galaxies is increasing;
the volume/diameter/radius/scale factor of the universe is increasing;
space itself is stretching with time; **[1 max]**
Do not accept answers such as "everything is moving away from everything else" as this is clearly not true.

(b) (i) cosmic microwave background/CMB/CBR;
helium/hydrogen ratio/abundance;
darkness of night sky (Olbers' paradox); **[1 max]**
Do not accept answers that refer to Hubble's law/red-shift of galaxies.

(ii) CMB was a prediction of the Big Bang model;
radiation present in the early universe was at a high temperature/short wavelength;
as the universe expanded it cooled/wavelength increased;
so the radiation present today is in the microwave region / has temperature of 2.7 K; **[3 max]**

or

the early universe contained high energy neutrons/protons;
as the universe expanded and cooled (to 10^9 K) nucleosynthesis could start, producing helium;
as the temperature dropped further, nucleosynthesis stopped leaving an excess of protons/hydrogen;
the current abundance of hydrogen and helium is consistent with the predictions of the Big Bang/expansion;

or

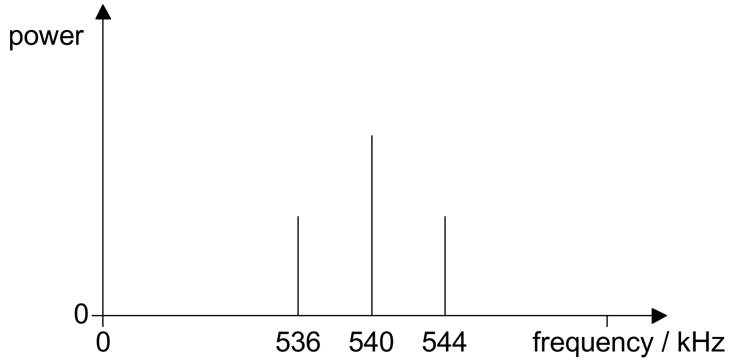
Olbers' paradox asks "why is the night sky dark?";
this cannot be explained if universe is infinite and static / *OWTTE*;
in an expanding universe some light is red-shifted out of visible range;
in a Big Bang universe some light from distant galaxies has not reached us yet;

Option F — Communications

16. (a) to transmit information/data;
the amplitude of a carrier wave is modified by signal waveform/displacement/ amplitude / *OWTTE*; **[2]**

(b) (i) $(2\times 4.0\,\text{kHz} =)\,8.0\,(\text{kHz})$; **[1]**

(ii) line labelled 540;
side bands labelled with correct frequencies (536 and 544) and heights smaller than carrier height; *(allow ECF from (b)(i))* **[2]**



(c) *X*: RF amplifier;
Y: AF amplifier; **[2]**

17. (a) (i) $32\times 44.1\times 10^{3} = 1.41\times 10^{6}\,(\text{bits s}^{-1})$; **[1]**

(ii) $\frac{1}{44.1}\,\text{kHz}$;
2.27×10^{-5} (s) ***or*** 23 (μs); **[2]**
Do not accept bit time (710 ns).
Award ***[2]*** *for a bald correct answer.*

(b) increase the sampling frequency;
less distortion / greater frequency range / better reproduction of original signal; **[2]**

or

increase number of bits per sample / increase bit rate/depth;
less noise / greater dynamic range / smaller changes in loudness/amplitude reproduced / better reproduction of original signal;
Do not accept "to improve quality" as this repeats the question.

(c) a method to transmit multiple signals along the same channel;
by placing samples of one signal in between samples of another signal;

Award ***[2]*** *for diagram showing*:
voltage versus time axes;
equally spaced samples of one signal and equally spaced samples of another signal in between; **[2 max]**

18. (a) for a ray attempting to move from a high to a low refractive index medium;
the phenomena in which the angle of incidence is greater than the critical angle;
(critical angle is) the angle of incidence for which the angle of refraction is 90° / *OWTTE*;
leading to a reflected but not to a refracted ray; **[3 max]**
*Award **[3 max]** for a clearly drawn annotated diagram.*

(b) $\frac{\sin\theta_c}{\sin 90^\circ} = \left(\frac{\sin\theta_c}{1} = \right)\frac{1.50}{1.62}$;
$\theta_c = 67.8^\circ$; **[2]**
*Award **[2]** for a bald correct answer.*

(c) pulse width/duration increases / pulse amplitude decreases / colour separation; **[1]**

Option G — Electromagnetic waves

19. (a) transverse waves / *OWTTE*;
consisting of an electric and a magnetic field at right angles to one another;
waves that can propagate in vacuum;
waves whose speed in vacuum is the speed of light/c; **[3 max]**

(b) *absorption*:
wave/photons transfer energy to atoms/molecules / cause excitation/ionization of atoms/molecules;

scattering:
change of direction of wave/photons as a result of interactions with particles; **[2]**
Accept answers which combine the two processes. For example reference to scattering where optical excitation of atoms or molecules (absorption) is immediately followed by emission in all directions.

(c) used in the storage and retrieval of data on CDs/DVDs/Blu-ray disks;
used in surveying/welding/machining metals/drilling holes in metals;
used in medical applications such as microsurgery (*eg*: eye-surgery);
used in guiding "smart" weapons to their target; **[1 max]**
Accept any other reasonable use.

20. (a) (i) identifying focal length from diagram ***or*** $f = 5.0\text{ cm}$;
$\left(P = \frac{1}{f} = \frac{1}{5.0}\right) = 0.20\,(\text{cm}^{-1})$ ***or*** 20 (D) ***or*** $20\,(\text{m}^{-1})$; **[2]**
*Award **[2]** for a bald correct answer.*

(ii) first ray from tip of object correctly refracted by lens;
a second ray from tip of object correctly refracted;
correct extrapolation back to tip of image; **[3]**
Accept rays without arrows and solid construction lines back to the image.

(iii) image is virtual;
image cannot be formed on a screen / rays do not cross; **[2]**

(b) (i) $\theta_0 = \left(\frac{82}{4 \times 10^3} =\right) 2.05 \times 10^{-2}\,(\text{rad})$;
$M = \left(\frac{0.1}{2.05 \times 10^{-2}} =\right) 4.9$; **[2]**
Allow ECF in second marking point for using incorrect angle.
*Award **[2]** for a bald correct answer.*

(ii) $(f_o = 4.9 \times 15) = 74\,(\text{cm})$ ***or*** $73\,(\text{cm})$; *(allow ECF from (b)(i))* **[1]**
Allow 75 (cm) due to rounding.

21. (a) *reference to*:
diffraction at slits / slits are coherent sources;
path/phase difference;
constructive and destructive interference; **[2 max]**
Do not reward just "interference" as this is mentioned in the question.

(b) for single fringe: $s = \frac{650 \times 10^{-9} \times 1.8}{2.2 \times 10^{-3}} (= 5.3 \times 10^{-4} \text{ (m)})$; *(also award this mark if the factor of 3 is seen in the numerator)*

distance $MP = (5.3 \times 10^{-4} \times 3 =) 1.6 \times 10^{-3}$ (m); **[2]**
Allow ECF from first marking point.
*Award **[2]** for a bald correct answer.*