N09/4/PHYSI/SP3/ENG/TZ0/XX/M+

International Baccalaureate®
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MARKSCHEME

November 2009

PHYSICS

Standard Level

Paper 3

15 pages

General Marking Instructions

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. Do **not** award more than the maximum marks allowed for part of a question.

2. Each marking point has a separate line and the end is signified 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 <u>underlined</u> 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 writing ***OWTTE*** (or words to that effect).

8. 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.

9. Only consider units at the end of a calculation. Omission of units should only be penalized once in the paper.

10. Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** for an **error of 2 or more digits** unless directed otherwise in the markscheme.

e.g. if the answer is 1.63:

2	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

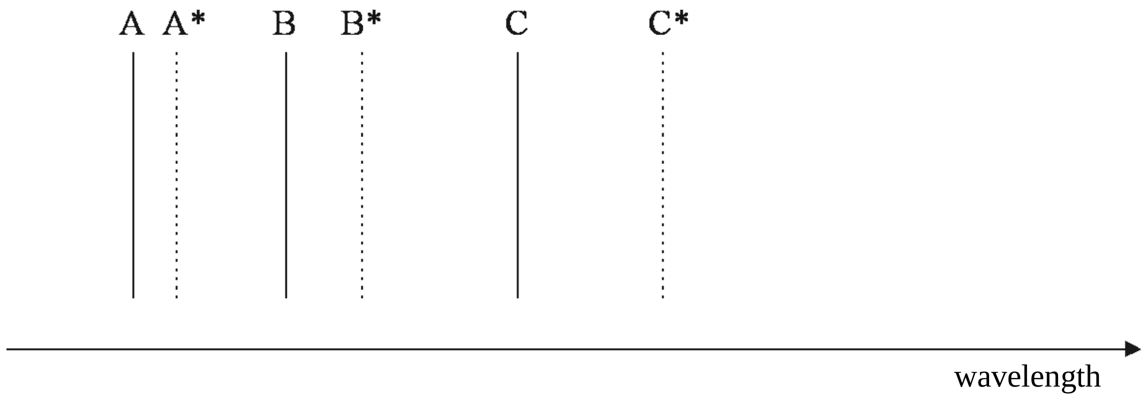
Option A — Sight and wave phenomena

A1. (a) (i) *Correct positioning of*:
lens, retina and optic nerve; ***[1]***

(ii) convert a light signal into an electrical signal;
rods are used for black and white vision/contrast/scotopic;
cones are used for colour vision/photopic; ***[3]***

(b) for objects at different distances from the eye;
for the image to be focused;
the (ciliary) muscle changes the shape of the lens; ***[3]***

A2. *The diagram should be as follows*:



lines shifted all in the same direction;
shift in B or the shift in C being noticeably larger than the shift in A;
lines shifted right; ***[3]***
*Award **[2 max]** if lines are not labelled.*

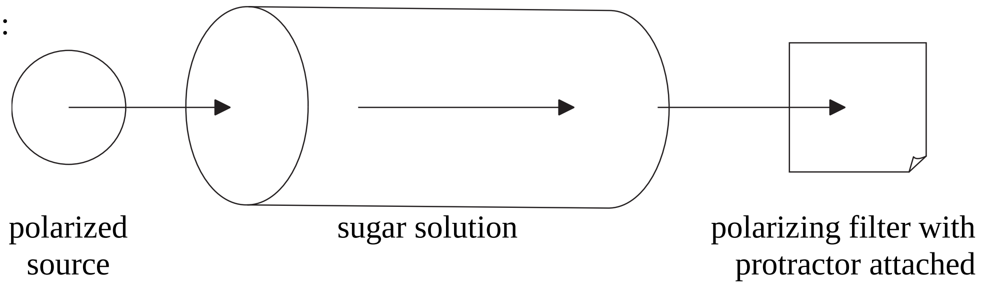
A3. (a) $\theta = \frac{1.22\lambda}{b} = 6.1 \times 10^{-6}$ radians;
distance $= \theta \times$ altitude;
$= 6.1 \times 10^{-6} \times 400 \times 10^{3} = 2.4\,\text{m}$; ***[3]***

(b) increase the lens diameter; ***[1]***

A4. (a) hold the sheets one at a time up to each source and rotate them / *OWTTE*;
the sheet and source which give a variation in intensity upon rotation are the polarizing/polarized ones / *OWTTE*; ***[2]***

(b) the solution rotates the plane of polarization;
light from polarized source is rotated by the solution;
the degree of rotation is measured by rotating the polarizing filter;
the angle of rotation gives an indication of the solution concentration / *OWTTE*;
measure angle of rotation for a standard solution; ***[4 max]***

apparatus is:



Option B — Quantum physics and nuclear physics

B1. (a) (i) $E = hf -$ work function $= \dfrac{6.63\times10^{-34}\times2.1\times10^{15}}{1.6\times10^{-19}} - 3.6 = 5.1\,\text{eV}$; ***[1]***

(ii) no change since energy depends only on frequency; ***[1]***

(b) (i) $p = mv \rightarrow p = \sqrt{2Em}$;

$\lambda = \dfrac{h}{p} \rightarrow \lambda = \dfrac{h}{\sqrt{2Em}}$;

$= \dfrac{6.6\times10^{-34}}{\sqrt{\left(2\times5.0\times10^{3}\times1.6\times10^{-19}\times9.1\times10^{-31}\right)}}$;

$= 1.7\times10^{-11}\,\text{m}$; ***[4]***

(ii) experiments show that electrons can be diffracted;
therefore they must be waves; ***[2]***

or

Outline of scattering experiment e.g.:
electrons scattered from a crystal;
form regions of maximum and minimum / *OWTTE*;

(c) (i) electron is confined by the box;
therefore only certain wavelengths allowed;
the energy of the electron is related to its wavelength; ***[3]***

(ii) each line is a well defined single frequency;
which corresponds to a single photon energy;
arising from electron transitions between discrete energy levels; ***[3]***

B2. (a) ${}^{124}_{53}\text{I} \rightarrow {}^{124}_{52}\text{X} + \beta^{+} + \nu$ ***or*** ${}^{124}_{53}\text{I} \rightarrow {}^{124}_{52}\text{X} + {}^{0}_{1}e^{+} + \nu$
nucleon number 124;
proton number 52;
ν; ***[3]***

(b) $\lambda = 0.17\left(\text{days}^{-1}\right)$;

$\text{A} = 810\text{e}^{-0.17\times6}$;
$\text{A} = 290\,\text{Bq}$; ***[3]***

Option C — Digital technology

C1. (a) (i) 12 V; ***[1]***

(ii) 1100; ***[1]***

(iii) 0;
it has the least effect on the value (of the number) / the value of the voltage is an even denary number / the last digit on the right of the number; ***[2]***

(b)

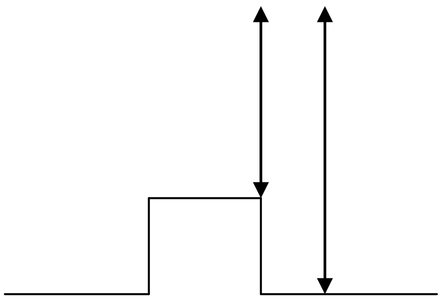


diagram showing light reflected from flat and edge of pit;
if there is just the right depth;
light reflected from the edge of a pit and flat interfere destructively such that there is 0 intensity at the detector;
light reflected from the flat/pits is a 0; ***[4]***
Accept answers in terms of non-reflective pit (=0) and reflective flat/land (=1) system.

(c) pd across $10\,\text{k}\Omega = V_{\text{in}} - 1.0 = 10^4 I$;
pd across $50\,\text{k}\Omega = 7.0 = 5.0\times10^4 I$;
$I = 1.4\times10^{-4}\,\text{A}$;
$V_{\text{in}} = 1.0 + 1.4\times10^{-4}\times10^4 = 2.4\,\text{V}$; ***[4]***

or

pd across $50\,\text{k}\Omega = \frac{50}{60}\left[V_{\text{in}} + 6.0\right]$;
$= 7.0\,\text{V}$;
$50V_{\text{in}} + 300 = 420$;
$V_{\text{in}} = 2.4\,\text{V}$;
*Award **[4]** if third marking point is omitted and answer is correct.*
*Award **[4]** for any other valid method that gives correct answer.*

C2. (a) the ratio of charge to potential difference/voltage; ***[1]***

(b) (i) number of photons per unit area per second $= \dfrac{1.2\times10^{-3}}{4.6\times10^{-19}} = 2.6\times10^{15}$;

number of photons per second on pixel $= 2.6\times10^{15}\times5.5\times10^{-10}$;

$=1.4\times10^{6}\ \text{s}^{-1}$ ***[2]***

(ii) charge emitted per second $=\left(1.4\times10^{6}\times1.6\times10^{-19}=\right)2.3\times10^{-13}\ (\text{C})$;

pd per second $=(V=)\dfrac{Q}{C}$;

$=\left(\dfrac{2.3\times10^{-13}}{2.2\times10^{-12}}=\right)0.1(\text{V})$;

time to reach $40\,\mu\text{V}=\left(\dfrac{4.0\times10^{-5}}{0.1}=\right)0.40\,\text{ms}$; ***[4]***

(iii) the quantum efficiency is unity (1)/100% / each incident photon ejects an electron from the pixel; ***[1]***

Option D — Relativity and particle physics

D1. (a) a reference frame that is not accelerating/moving with constant velocity / in which Newton's first law is valid / *OWTTE*; ***[1]***

(b) (i) Aibhe
since proper length is defined as the length of the object measured by the observer at rest with respect to the object / since she is at rest with respect to the object; ***[1]***

(ii) $\gamma = \frac{L_0}{L}$;
$= \left(\frac{1.50}{1.20} = \right) 1.25$;
$1 - \frac{v^2}{c^2} = \frac{1}{1.25^2}$ ***or*** other evidence of algebraic manipulation;
$v = 0.60c$ ***or*** $1.8 \times 10^8\ \mathrm{m\,s^{-1}}$; ***[4]***

(c) $3.0\,\mathrm{s}$; ***[1]***

(d) (because) the speed of light is the same for all <u>inertial</u> observers;
and because of their relative motion Aibhe and Euan will measure different time intervals for the two events;
events which are simultaneous for Aibhe will not be simultaneous for Euan; (*vice versa*) ***[3]***

D2. (a) two or more fermions with identical quantum numbers cannot occupy the same energy level/quantum state;
(whereas) bosons with identical quantum numbers can (occupy the same energy level/quantum state); ***[2]***
Award ***[1 max]*** *for "fermions obey the PEP, bosons do not".*

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

(ii) pion/meson/gluon; ***[1]***

(c) $m = \frac{h}{4\pi Rc}$;

$m = \left(\frac{6.6 \times 10^{-34}}{4 \times 3.14 \times 3 \times 10^{8} \times 10^{-15}} = \right) 0.18 \times 10^{-27}\ \text{kg}$;

$\frac{0.18 \times 10^{-27}}{1.68 \times 10^{-27}} \times 940$ ***or*** evidence of other suitable conversion;

$\approx 100\,\text{MeV}$ ***[3]***

(d) (i) *meson*: (positive) – because refers to quark sentence / up quark has charge $+\frac{2}{3}$ and anti-down quark has charge $+\frac{1}{3}$;

anti-muon: (positive) – because muon has negative charge; ***[2]***

Allow arguments in terms of charge conservation for one **or** *other particle.*
To award the mark the reason must be correct.

(ii) W^{+} / positively charged vector boson; ***[1]***

Option E — Astrophysics

E1. (a) (i) gives the relative (visual) brightness of stars as seen from Earth;
e.g. a magnitude 1 star is 100 times brighter than a magnitude 6 star; ***[2]***
*To award **[2]** the idea of a relative scale must be clear.*

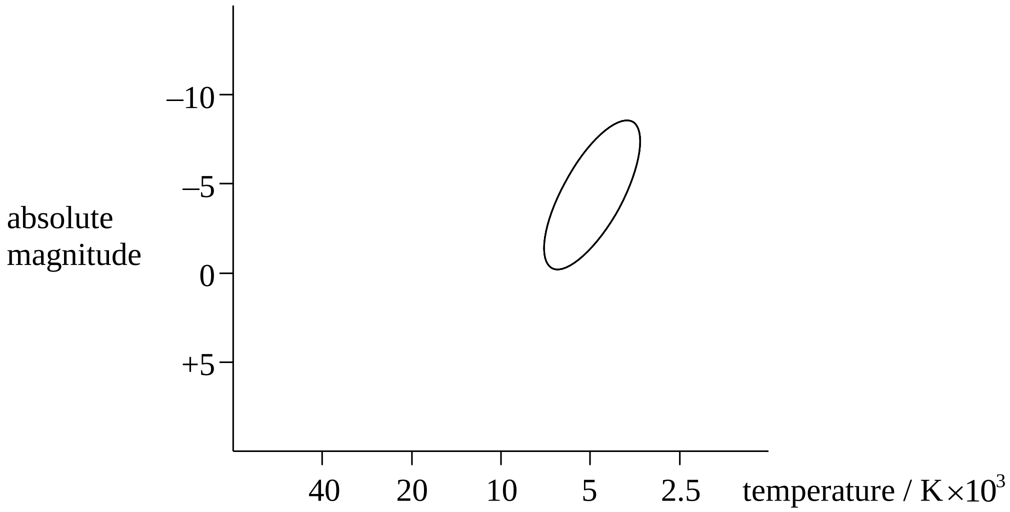
(ii) the apparent magnitude a star would have if it were 10 pc from Earth; ***[1]***

(b) (i) $\log\frac{d}{10}=\frac{m-M}{5}$;
$=1.03$;
$d=10\times10^{1.03}$;
$=108\,\text{pc}$ ***[3]***
Accept answer based on substitution for $d=108$.

(ii) $L=4\pi d^2 b$;
$\frac{L_B}{L_{Sun}}=\frac{d_B{}^2 b_B}{d_{Sun}{}^2 b_{Sun}}$;
$L_B=[108\times2.05]^2\times10^{10}\times7.00\times10^{-12}\,L_{Sun}$;
$=3.43\times10^3\,L_{Sun}$ ***[3]***
Accept answer based on substitution $L_B=3.43\times L_{Sun}$.

(c) in the region $[30\rightarrow50,\ -2.5\rightarrow-5.0]$; ***[1]***

(d)



Cepheid as shown; ***[1]***
Judge by eye for reasonable range of magnitude and temperature.

(e) the outer layers undergo a periodic expansion and contraction/periodic fluctuations in temperature; ***[1]***

(f) period/frequency with which luminosity varies;
apparent brightness / apparent magnitude; ***[2]***

E2. (a) Newton's model assumed a uniform infinite (and static) universe;
therefore number of stars in shell is proportional to R^2;
intensity of radiation/light from shell reaching Earth is proportional to $\frac{1}{R^2}$;
since according to Newton's model such shells stretch to infinity / the sky can never be dark/will always be light / *OWTTE*; ***[4]***

(b) the universe is expanding;
the universe has a beginning;
the stars (and galaxies) are not uniformly distributed; ***[2 max]***

Option F— Communications

F1. (a) *signal wave*:
the wave that carries information about the source / the information wave;

carrier wave:
the wave that transmits information from transmitter to receiver / the wave that is modulated by the signal wave; ***[2]***

(b) AM varies the amplitude (of the carrier wave) and FM varies the frequency (of the carrier wave); ***[1]***

(c) $A \to B$: constant/no change;
$B \to C$: increasing;
$C \to D$: decreasing; ***[3]***

(d) (i) $f_S = \left(\frac{1}{T} = \right)\frac{1}{1.2\times10^{-3}}$;
$= 830\,\text{Hz}$; ***[2]***

(ii) $f_C = \frac{2.2\times10^{5}}{1.2\times10^{-3}}$;
$= 180\,\text{MHz}$ ***or*** 1.8×10^{8} Hz; ***[2]***

F2. (a) (i) sampling frequency $= 10^4\ (\text{s}^{-1})$;
bit rate$(=$number of bits$\times$sampling frequency$) = 30\,\text{kb}\,\text{s}^{-1}$; ***[2]***

(ii) at $500\,\mu\text{s}$ output $= 3.6\,\text{V}$;
therefore digital output $= 111$; ***[2]***

(b) increasing the sampling frequency means smaller increments of voltage will be measured;
increasing number of bits means that that sampled voltage can be represented more accurately;
some conclusion *e.g.* the digital encoding will be a more accurate/faithful representation of the analogue signal; ***[3]***

(c) (i) $10\lg\frac{I}{I_0}$ where $I =$ input power and $I_0 =$ output power; ***[1]***

(ii) dB loss $= (10\lg 4 =) 6.0\,\text{dB}$;
distance $= 3.0\,\text{km}$; ***[2]***

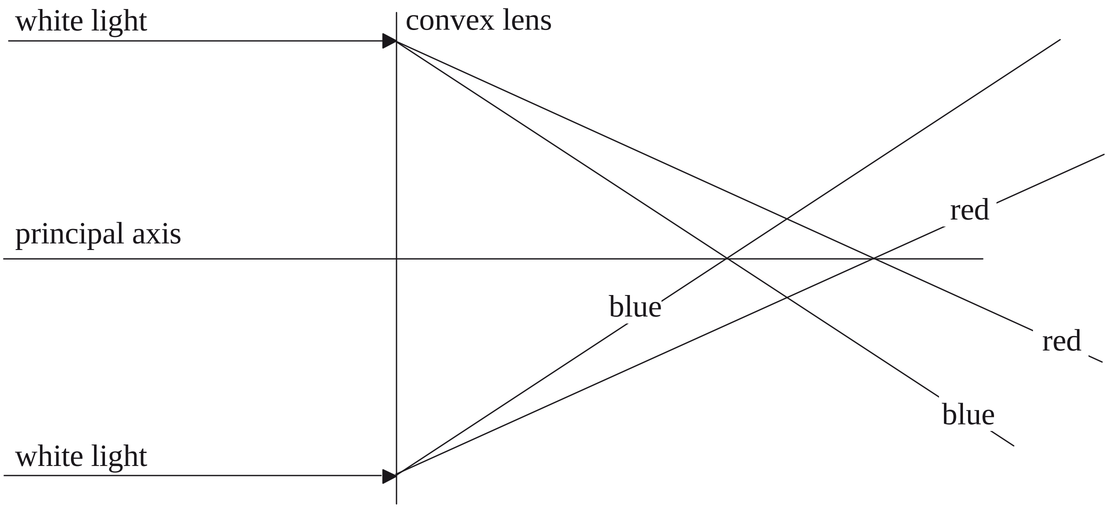
Option G — Electromagnetic waves

G1. (a) the field oscillates too fast for the compass to respond;
the field is too weak; ***[1 max]***

(b) (i) 10^{19} Hz ; *(or above)* ***[1]***

(ii) difficult to modulate the source (which will be a nuclear explosion/ radioactive decay);
difficult to build an appropriate receiver/detector;
negative health effects of exposure to gamma-rays; ***[1 max]***

G2. (a)



paths as shown:
red ray focused;
blue ray focused; ***[2]***
*Allow **[1 max]** if colours reversed.*

(b) a different image is formed for each colour of light in the white light;
therefore the resulting image will be multi-coloured;
and out of focus; ***[3]***

(c) use a lens of very long focal length / use a compound lens / use a diffractive optical element / achromatic doublet; ***[1]***

(d) (i) use of $\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \rightarrow \frac{1}{v}=\frac{1}{8}-\frac{1}{5}$;
$v=-13\text{cm}$; ***[2]***

(ii) ± 2.6; ***[1]***

G3. (a) (i) coherent source; ***[1]***

(ii) $\theta = \frac{\lambda}{d}$ and $\text{spacing} = L\theta \rightarrow \text{spacing} = L\frac{\lambda}{d}$ ***or*** use of $s = \frac{\lambda D}{d}$;

$\text{spacing} = \left(\frac{2.0 \times 700 \times 10^{-9}}{5 \times 10^{-4}} = \right) 2.8\,\text{mm}$; ***[2]***

(iii) sharpen the maxima / finer maxima;
greater contrast between minimum and maximum / brighter maxima; ***[2]***

(b) use of $d \sin\theta = n\lambda$;
with $\theta = 90, n = 4$;
$\text{number} = 9$; ***[3]***