International Baccalaureate®
Baccalauréat International
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MARKSCHEME

November 2011

PHYSICS

Standard Level

Paper 3

17 pages

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. 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. Indicate this with **ECF** (error carried forward).

10. Only consider units at the end of a calculation. Unless directed otherwise in the markscheme, unit errors should only be penalized once in the paper. Indicate this by writing **–1(U)** at the first point it occurs and **U** on the cover sheet.

11. 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*

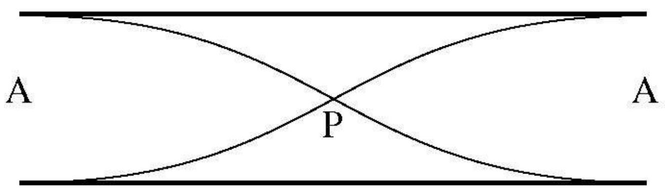
Indicate the mark deduction by writing **–1(SD)** at the first point it occurs and **SD** on the cover sheet.

Option A — Sight and wave phenomena

A1. (a) photopic vision is vision (of the eye) in well-lit/bright conditions and scotopic vision is vision in low level/dim lighting conditions; *[1]*

(b) *Look for these main points*:
cone cells are primarily concerned with colour vision;
they do not respond under low light conditions whereas the rod cells do;
rod cells are more responsive to green light than to red light / *OWTTE*; *[3]*

A2. (a)



(i) waveform showing node at centre and antinodes at end; *[1]*

(ii) P as shown; *[1]*

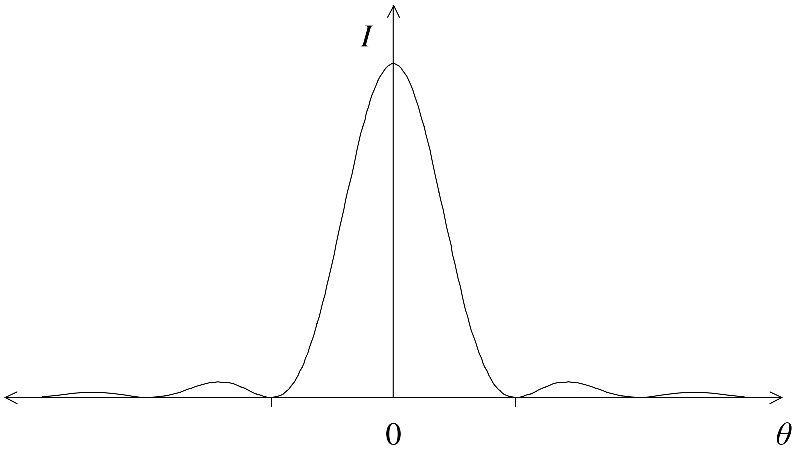
(iii) A as shown; *[1]*

(b) for open pipe $f = \frac{v}{2l}\left(=\frac{v}{3.0}\right)$;

for closed pipe $f = \frac{v}{4l} = \frac{v}{3.0}$;

so $l = 0.75\,\text{m}$ *[2]*

A3. (a) (i)



overall correct shape with central maxima at $\theta = 0$; *(only one secondary maximum required each side of $\theta = 0$)*

secondary maximum no greater than $\frac{1}{4}$ intensity of central maximum; *(judge by eye)* ***[2]***

(ii) $\theta = \frac{\lambda}{b} = \frac{x}{D}$ (where x is the half width of central maximum);

$2x = 2\frac{D\lambda}{b}$;

$\left(\frac{2\times1.2\times4.8\times10^{-7}}{10^{-4}}\right) = 12\,\text{mm}$; ***[3]***

(b) diameter of pupil $= 3.0\,\text{mm}$; *(accept answers in the range of 2.0 mm to 5.0 mm)*

$\theta = \left(1.22\times\frac{\lambda}{b} = 1.22\times\frac{4.8\times10^{-7}}{3.0\times10^{-3}} = \right)1.95\times10^{-4}$ (rad);

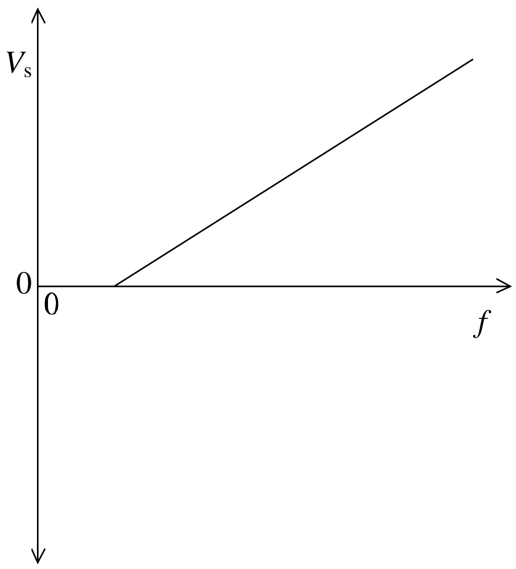
$d = \frac{8.0\times10^{-3}}{1.95\times10^{-4}} = 41\,\text{m}$; *(accept answer in the range of 20 m to 70 m)* ***[3]***

(c) in unpolarized light the plane of vibration of the electric (field) vector is continually changing / *OWTTE*;
in polarized light the electric vector vibrates in one plane only;
a polarizer is made of material that absorbs/transmits either the horizontal or vertical component/only one component of the electric vector; ***[3]***

Option B — Quantum physics and nuclear physics

B1. (a) the potential difference is varied (using the potential divider);
until the current registered by the ammeter is zero;
the maximum kinetic energy of the (ejected) electrons is this potential times the electron charge; ***[3]***

(b) (i)



straight line;
with non-zero intercept on *f* axis; ***[2]***

(ii) $V_s e = hf - hf_0$ ***or*** $V_s e = hf - \phi$;
$f_0 \rightarrow$ the frequency below which no electron emission takes place;
$h \rightarrow$ the Planck constant;
$\phi \rightarrow$ the minimum energy required to eject an electron from tungsten; ***[3 max]***
*Award **[2 max]** if the equation is not given.*

(iii) *Planck constant*: slope/gradient of graph$\times e$;
work function: extrapolation to intercept on V_s axis and $\phi = V_s$-intercept$\times e$ / when $V_s = 0$, $\phi = hf$ so intercept gives *f* when $V_s = 0$ and $\phi = h$ (*f*-intercept); ***[2]***

(c) use of $p = \frac{h}{\lambda}$ and $E_k = \frac{p^2}{2m}$;

$$\lambda = \frac{h}{\sqrt{2E_k m}};$$

$$= \frac{6.6\times10^{-34}}{2\times4.5\times1.6\times10^{-19}\times9.1\times10^{-31}} = 5.765\times10^{-10}\text{ m};$$

$\approx 0.6\,\text{nm}$ ***[3]***

B2. (a) (i) some statement of energy conservation *e.g.* loss in kinetic energy of α-particle at closest distance of approach distance = gain in potential energy;

$E_K = \frac{79 \times 2 \times [1.6 \times 10^{-19}]^2}{4\pi \times 8.85 \times 10^{-12} \times 3.0 \times 10^{-14}}$ (J);

$\frac{1.2 \times 10^{-12}}{1.6 \times 10^{-19}}$ (eV) (= 7.58 MeV);

≈ 8 MeV ***[3]***

(ii) the alpha particles have discrete energies; ***[1]***

(b) determine the activity A of a sample (of the isotope by measuring the number of decays in a given time);

determine the number of atoms N in the sample from the mass of the sample;

determine the decay constant λ from $A = (-)\lambda N$ and then half-life from $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$; ***[3]***

Option C — Digital technology

C1. (a) information is encoded on the surface as a series of lands and pits/bumps and flats;
laser light reflected from a pit is read as a binary 1;
the depth of the pit is such that light will be reflected from the edge of the pit and the pit will interfere destructively and be read as binary 0; ***[3]***
If the second marking point states 1 then the third must state 0 and vice versa.
Allow reference to transitions between 1 and 0.

(b) depth of pit $= \frac{\lambda}{4}$;
$\approx 200\,\text{nm}$; ***[2]***
*Award **[2]** for bald correct answer.*

C2. (a) the ratio of length of image on the CCD to the length of object; ***[1]***

(b) *Look for these main points*:

magnification:
the greater the magnification the greater the length of image on the CCD therefore the greater the number of pixels activated by light from object;
image is therefore more detailed;

resolution:
the greater the resolution the more pixels in a given length;
so again image is more detailed; ***[4]***

C3. (a) (i) the amplifier has a very high open loop gain $\left(\text{defined from } A = \frac{V_{\text{OUT}}}{V_+ - V_-}\right)$;
this means that $V_+ \approx V_-$;
since in the circuit $V_+ = 0$ then $V_- = 0$;
because of the very high input resistance no current will flow into the amplifier at V_- input so P remains at 0 V / *OWTTE*; ***[4]***

(ii) let I be the current at input then $V_{\text{IN}} = IR_1$ and $V_{\text{OUT}} = -IR_2$;
therefore $G = \frac{V_{\text{OUT}}}{V_{\text{IN}}} = -\frac{IR_2}{IR_1} = (-)\frac{R_2}{R_1}$; ***[2]***

(b) *look for these main points*:
(when the thermistor is cold) the variable resistor is used to set the potential at the inverting input (to some fixed value less than the potential at P);
the output of the amplifier is saturated at –15 V and so the LED is unlit;
as the thermistor warms up its resistance decreases;
the potential at P will increase until at a particular temperature, the potential at P is just greater than the potential at the inverting input;
the output now goes high (saturates) to +15 V and the LED will light; ***[4 max]***

Option D — Relativity and particle physics

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

(ii) the speed of light in a vacuum/free space is the same for all inertial observers; *[1]*

(b) *Look for these main points*:
signal from switch travels at same speed *c* to each lamp;
but during signal transfer C_1 moves closer to/C_2 moves away from source of signal;
since speed of light is independent of speed of source, signal reaches C_1 before C_2 /C_2 after C_1;
according to Vladamir C_1 registers arrival of signal before C_2/C_2 registers arrival of signal after C_1; *[4]*

(c) (i) $\gamma = \frac{1}{\sqrt{1-(0.70)^2}} = 1.4$;

$L_0 = \gamma L$;

$= 1.4\,\text{m}$; *[3]*

(ii) Natasha
since proper length is defined as the length of the object measured by the observer at rest with respect to the object; *[1]*

D2. (a) (i) particle that has no internal structure/is not made out of any smaller constituents; *[1]*

(ii) leptons; *[1]*

(b) $\Delta t = \frac{h}{4\Delta\pi E}$;

$= \frac{6.6\times10^{-34}}{4\times3.14\times1.5\times1.6\times10^{-19}}$;

$= 2.2\times10^{-16}\,\text{s}$ *[2]*

(c) (i) intermediate vector boson/W boson; *[1]*

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

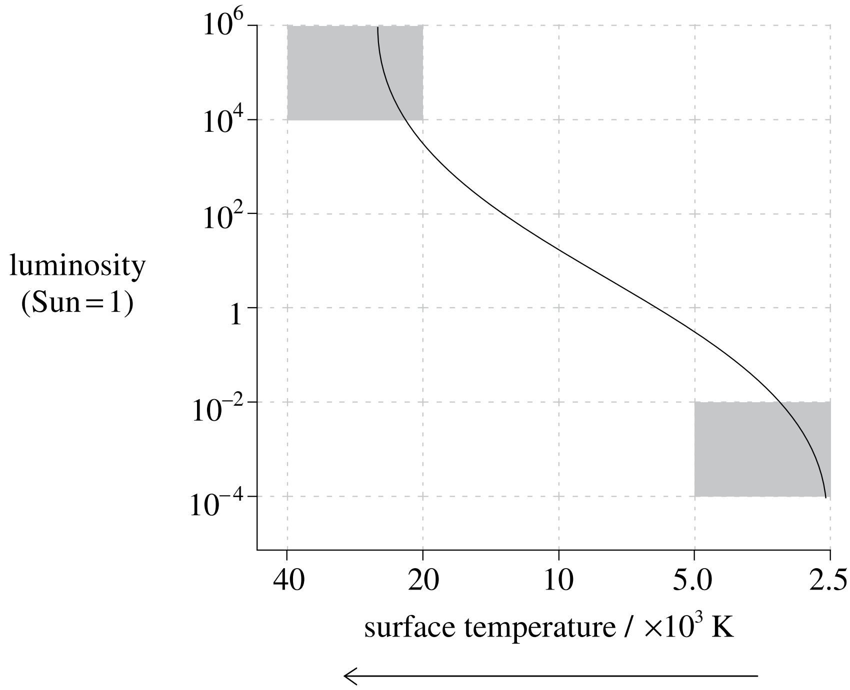
$= \left(\frac{6.6\times10^{-34}}{4\times3.14\times10^{-18}\times3.0\times10^{8}} = \right)1.75\times10^{-25}\,\text{kg}$;

$= \frac{1.75\times10^{-25}\,c^2}{e} = 109\,\text{GeV}\,\text{c}^{-2} \approx 10^2\,\text{GeV}\,\text{c}^{-2}$; *[3]*

(iii) the neutron quark structure is udd and the proton uud;
a d quark in the neutron changes to a u quark by emitting a W boson; *[2]*

Option E — Astrophysics

E1. (a)

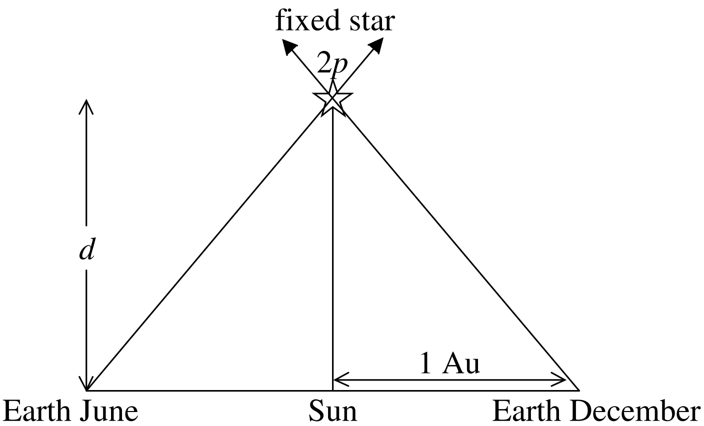


any suitable line from anywhere in top left-hand quadrant; *(accept a straight line)* to bottom right-hand quadrant; **[2]**
The shaded areas are the limits within which the line must be drawn.

(b) (i) distance at which 1 AU subtends an angle of 1 arcsec / distance at which the angle subtended by the radius of Earth's orbit is 1 arcsec; **[1]**

(ii) $p = \left(\frac{1}{d} = \right) 0.56$ arcsec; **[1]**

(c)



Labelled diagram should relate to the following points:
measure against the fixed stars the angle Barnard's star subtends at Earth in June and again in December;
difference between the two angles is twice the parallax angle;
orbital radius of Earth about Sun is 1 AU so distance to star is computed from $d = \frac{1}{p}$; **[3]**

(d) (i) $L = 4\pi b d^2$;
$= 4 \times 3.14 \times 3.6 \times 10^{-12} \times [1.8 \times 3.1]^2 \times 10^{32}$;
$= 1.4 \times 10^{23}$ W ;
$\approx 10^{23}$ W *[3]*

(ii) $A = \dfrac{L}{\sigma T^4}$;
$= \dfrac{1.4 \times 10^{23}}{5.67 \times 10^{-8} \times 3.8^4 \times 10^{12}}$; *(allow ECF from (d)(i))*
$= 1.184 \times 10^{16}$ m^2 ;
$\approx 10^{16}$ m^2 *[3]*

E2. (a) because of the Doppler effect;
light from sources moving away from an observer is observed to have a lower frequency than from the sources when stationary / redshift indicates motion away from observer/Earth; *[2]*

(b) (i) this is the value of density for which the universe will begin to contract after an infinite amount of time; *[1]*
Do not accept "density at which universe is flat".

(ii) if the density of the universe is less than the critical density it will continue expanding forever;
if the density is greater than the critical density then it will after a certain amount of time begin to contract;
the behaviour of galaxies suggests that there is more matter in the universe than is actually observed; *(allow other relevant comment about dark matter)*
without knowing the mass of this matter the density cannot be determined; *[4]*

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) (i) the frequency of the carrier wave is kept constant;
and the audio frequency signal wave is used to vary the amplitude of the carrier wave; ***[2]***

(ii) the amplitude of the carrier wave is kept constant;
the carrier wave frequency is varied;
in direct proportion to changes in the amplitude of the audio frequency signal wave; ***[3]***

(c) (i) the sideband frequencies are $[f_c + f_s]$ and $[f_c - f_s]$;
$\text{bandwidth} = ([f_c + f_s] - [f_c - f_s] =) 10$;
$2f_s = 10$ so $f_s = 5.0\,\text{kHz}$; ***[3]***

(ii) time between two maxima $= \dfrac{1}{5.0\times10^3} = 2.0\times10^{-4}$ (s);

frequency of carrier wave $= \dfrac{1.8\times10^4}{2.0\times10^{-4}}$;
$= 9.0\times10^7 = 90\,\text{MHz}$ ***[2]***

F2. (a) much less subject to noise / noise can be removed more easily;
transmission rate is not dependant on rate at which information is encoded;
different types of information can be transmitted using the same channel;
data can be compressed;
any other sensible advantage; ***[2 max]***

(b) (i) provides reference pulses/synchronization against which the 0s and 1s of the binary data can be distinguished / *OWTTE*; ***[1]***

(ii) converts the data/information to a string of binary digits; ***[1]***

(c) 0.25 MHz; ***[1]***

(d) ratio of $n = \frac{1.41}{1.44} (= 0.979)$;

path difference between B and A $= 2.00 \times 10^4 - \frac{2.00 \times 10^4}{0.979} = 4.00 \times 10^2$ (m);

time difference $= \frac{4.00 \times 10^2}{2.10 \times 10^8}$;

$\approx 2.00 \times 10^{-6}$ s ***[3]***

Option G — Electromagnetic waves

G1. (a) a varying magnetic and electric field at right angles to each other;
vibration of E and B fields at right angles to the direction of propagation of the wave;
transverse wave;
same speed in a vacuum; ***[2 max]***

(b) the energy required to excite ozone molecules/electrons in ozone molecules;
is equal to the energy of photons in UV light; ***[2]***

or

the resonance frequency of ozone molecules;
matches frequency of UV radiation;

G2. (a) (angular magnification = linear magnification so) $M = \frac{D}{u}$;

$\frac{1}{u} + \frac{1}{D} = \frac{1}{f}$;

so $\frac{D}{u} = \frac{D}{f} + 1 = M$; ***[3]***

(b) (i) ray through centre of objective lens and ray through f_o;
to show formation of intermediate image; ***[2]***

(ii) $\frac{1}{v} = \frac{1}{1} - \frac{1}{1.5}$;
$v = 3.0\,\text{cm}$; ***[2]***
*Award **[2]** for a bald correct answer.*

(c) (i) rays parallel to principal axis at edge of lens brought to different foci;
from those near to the centre of the lens; ***[2]***

(ii) different colours have different refractive indices/speeds;
different colour refracted at different amounts / image formed for each colour; ***[2]***

G3. (a) greater amplitude/intensity from both slits;
bright fringes are brighter;
dark fringes are unchanged; ***[3]***

(b) brighter / more intense
sharper / more well-defined ***[2]***