International Baccalaureate®
Baccalauréat International
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MARKSCHEME

May 2011

PHYSICS

Standard Level

Paper 3

13 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.

9. Only consider units at the end of a calculation.

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) $L = 4\lambda$ ***or*** $\lambda = \frac{L}{4}$; ***[1]***

(ii) two antinodes labelled;
with separation of integral number of wavelengths; ***[2]***

(b) $f\lambda$ is the speed of the wave;
standing wave formed by interference of an incident and a reflected progressive wave;
speed is the speed of this progressive wave; ***[3]***

A2. (a) (i) power = area × intensity;

$\text{ratio} = \left(\frac{2.0}{7.0}\right)^2 \times 10^6$;

$= 8.0 \times 10^4$; ***[3]***

(ii) if iris were to be the principal mechanism, then ratio would need to be about $\left(\frac{7}{2}\right)^2$ ***or*** $\left(\frac{2}{7}\right)^2$; ***[1]***

(b) (i) for two images (of two objects) just to be distinguished/to be seen as separate images;
maximum of one diffraction pattern must lie on first minimum of second; ***[2]***

(ii) images resolved when $\theta \geq \frac{(1.22)\lambda}{b}$;
where θ is angle subtended at eye by object and b is the diameter of the pupil;
wavelength unchanged;
larger diameter, better resolution; *(accept vice versa)* ***[4]***

(c) *rods*: scotopic vision / black and white vision;
function best in low light intensity such as moonlight;

cones: photopic vision / colour vision;
function best in high light intensity such as sunlight; ***[4]***

*Award **[3 max]** for omission of reference to moonlight and sunlight.*

Option B — Quantum physics and nuclear physics

B1. (a) ejection of electron from metal surface following absorption of em radiation/ photon; ***[1]***

(b) (i) energy of one photon $= 6.67\times10^{-34}\times8.7\times10^{14}\left(=5.8\times10^{-19}\ \text{J}\right)$;

number of electrons released from surface per second $= \dfrac{9.0\times10^{-6}\times1.1\times10^{-3}}{5.8\times10^{-19}}$

$= 1.7\times10^{10}$;

current $= 1.7\times10^{10}\times1.6\times10^{-19}$;

$= 2.7\,\text{nA}$ ***[3]***

(ii) $2.4\,\text{eV}$ ***or*** $3.9\times10^{-19}\ \text{J}$; ***[1]***

B2. (a) particles have an associated wavelength;

wavelength $= \dfrac{h}{mv}$ ***or*** $\dfrac{h}{p}$; *(symbols must be defined)* ***[2]***

(b) $\lambda = \dfrac{h}{\sqrt{2\text{meV}}}$;

$8.3\times10^{-13}\ \text{m}$; ***[2]***

(c) (Heisenberg suggests that) $\Delta p\Delta x$ is a constant ***or*** $\geq \dfrac{h}{4\pi}$;

if λ is known then Δp is zero therefore uncertainty in position Δx is infinite/very large; ***[2]***

*Award **[1 max]** if Δp and Δx not defined.*

or

(the Uncertainty Principle states that) it is impossible to know the position and momentum of a particle at the same time;

if λ is precise then momentum is precise so position is not known;

B3. (a) (i) probability that a nucleus decays in unit time; ***[1]***

(ii) $150 = 800\,e^{-1.2\times10^{-3}t}$;
1400 s; ***[2]***

(b) (i) 580 s; ***[1]***

(ii) activity/count rate measured at regular time intervals/for at least three half-lives;
plot graph activity/count rate versus time;
detail of determination of half-life from graph; ***[3]***

(c) beta energy spectrum is continuous and associated gamma spectrum is discrete;
difference in energies accounted for by existence of another particle; ***[2]***

or

if another particle not present;
then momentum not conserved in beta decay;

Option C — Digital technology

C1. (a) (i) two states only / series of "on" and "off" / ones and zeros; *[1]*

(ii) number of bits $= 2 \times 16 \times 44.1 \times 10^3 \times 3600$;
$= 5.1 \times 10^9$; *[2]*

(b) number of bits on one page $= 45 \times 65 \times 8$;
$= 2.34 \times 10^4$

number of pages $= \left(\frac{5.1 \times 10^9}{2.34 \times 10^4} = \right) 2.2 \times 10^5$; *[2]*

C2. (a) silicon chip divided into separate areas;
each of these areas is a pixel;
each pixel behaves as a capacitor; *[3]*

(b) (i) area of pixel $= \frac{16}{\left(5.6 \times 10^6\right)}$;
$= 2.86 \times 10^{-6}\ \text{cm}^2$
separation $= \sqrt{\left(2.86 \times 10^{-6}\right)}$
$= 1.7 \times 10^{-3}\ \text{cm}$; *[2]*

(ii) points on image must be about $2 \times 1.7 \times 10^{-3}\ \text{cm}$ apart;
separation of objects $= \frac{\left(3.4 \times 10^{-3}\right)}{0.03}$
$= 0.11\,\text{cm}$; *[2]*

C3. (a) $\text{gain} = 1 + \frac{150}{15}$;
$\text{gain} = 11$; *[2]*

(b) for saturation, $V_{\text{OUT}} = 9\ \text{V}$;
$V_{\text{IN}} = \frac{9}{11} = 0.82\ \text{V}$; *[2]*

C4. cellular exchange receives signal from base stations;
computer monitors signal strength;
selects base station with strongest signal;
routes call from base station to PSTN; *[4]*

Option D — Relativity and particle physics

D1. (a) (i) proper length is measured by observer at rest relative to object / Carrie is at rest relative to spaceship; *[1]*

(ii) $\gamma = \left(\frac{100}{91} =\right) 1.1$;

evidence of algebraic manipulation *e.g.* $\frac{v^2}{c^2} = 1 - \frac{1}{1.1^2}$ to give $v = 0.42\,\text{c}$;

$\approx 0.4\,\text{c}$ *[2]*

(b) travel time measured by Peter $= (10 \times \gamma =)\ 11$ years;
4.6 ly ***or*** 4.4 ly *(if 0.4 c used)*; *[2]*

(c) moves away at 0.42 c so is 4.2 ly away when signal emitted; *(allow ECF from (a)(ii))*
signal travel time *t* where $ct = 4.2 + 0.42ct$;
7.2 y ***or*** 7 y *(if 0.4 c used)*; *[3]*

D2. time interval for light to be reflected between two parallel mirrors / *OWTTE*;
observer must be in same reference frame / *OWTTE*; *[2]*

D3. (a) A: π^+ meson;
B: antimuon neutrino; *[2]*

(b) rest mass is non-zero for W, zero for photon;
range of photon is infinite, not for W;
photon carries electromagnetic force, W weak force;
photon is uncharged, W is charged; ***[2 max]***

(c) $m = \frac{6.63 \times 10^{-34}}{4\pi \times 10^{-18} \times 3 \times 10^{8}}$;
$= 1.76 \times 10^{-25}$ kg; *[2]*

D4. (a) property that is conserved in strong nuclear force interaction;
property not (always) conserved in weak/electroweak force; *[2]*

(b) baryon $(1 + 0 \rightarrow 0 + 0)$ not conserved and strangeness $(0 + 0 \rightarrow -1 + 0)$ not conserved;
so interaction not possible; *[2]*

Option E — Astrophysics

E1. (a) (i) a collection of stars that form a recognizable group (as viewed from Earth);
that need not be/are not close to each other/gravitationally bound; ***[2]***

(ii) stars that are gravitationally bound/forming an open arrangement/close to each other (in space); ***[1]***

(b) (i) $5.1+[0.6]=5\lg\left[\frac{d}{10}\right]$;

$(d=138\,\text{pc})$

$1\,\text{pc}=3.1\times10^{16}\,\text{m}$;

$138\times3.1\times10^{16}=4.3\times10^{18}$;

$\approx 4\times10^{18}\,\text{m}$ ***[3]***

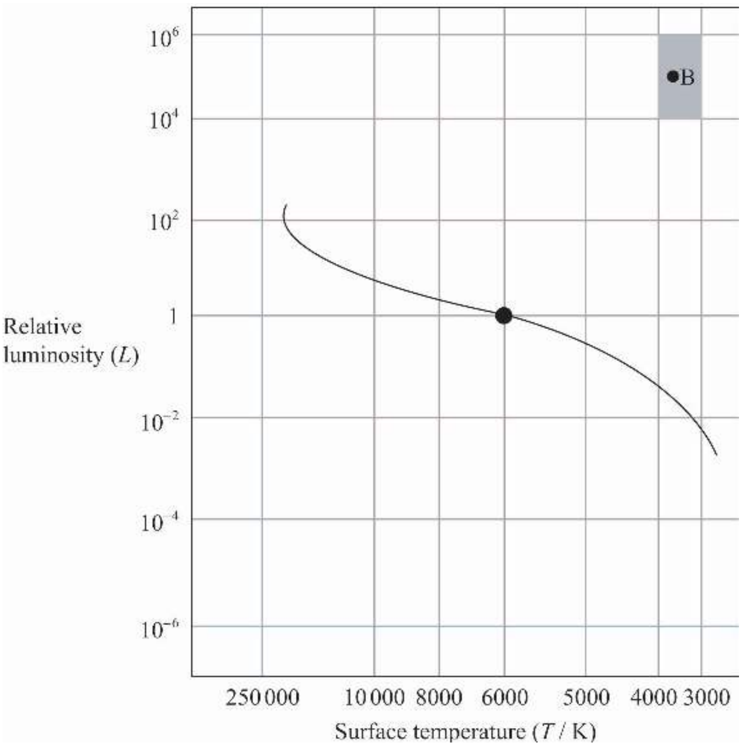
(ii) $L=\frac{1.6\times10^{-7}\times4\times\pi\times\left[4.3\times10^{18}\right]^2}{3.8\times10^{26}}$;

$9.8\times10^4\,L_{\text{Sun}}$ ***or*** $8.4\times10^4\,L_{\text{Sun}}$ *(if 4.0 used)*; ***[2]***

(iii) $T=T_{\text{Sun}}\sqrt[4]{9.8\times10^4\times\left(\frac{1}{790}\right)^2}$;

3600 K ***or*** 3500 K; ***[2]***

(c)



(i) position labelled B within shaded area; ***[1]***
*Award **[1]** if label B is missing but point is clear.*

(ii) generally the correct shape; *(allow broad line)* ***[1]***

(d) over time spectral lines regularly split into two lines and then recombine;
as one star approaches observer the other recedes;
leading to Doppler shifts in opposite directions; ***[3]***

E2. (a) if less than critical density, universe expands without limit;
if equal to critical density universe stops expanding after an infinite amount of time;
if greater than critical density, universe expands first then contracts; ***[3]***
*Award **[1 max]** if terms open, flat and closed are used and not defined.*

(b) there is matter that cannot be detected;
which is likely to consist of dark matter/neutrinos; ***[2]***

or

difficulty of measuring volume accurately;
because of difficulty of measuring distances accurately;

or

matter is not evenly distributed;
so density may vary from place to place;

Option F — Communications

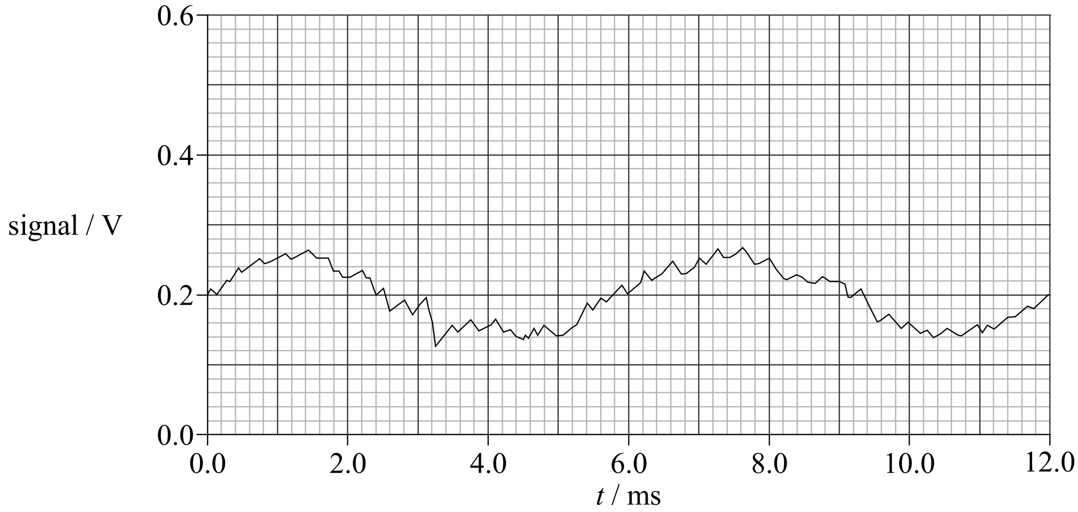
F1. (a) amplitude/frequency of wave is modified;
to carry information; ***[2]***

(b) (i) amplitude modulation/AM; ***[1]***

(ii) 40 kHz; ***[1]***

(iii) 16 kHz; ***[1]***

F2. (a)



waveform: lower mean signal/power/voltage;
smaller amplitude;
noise on waveform; ***[3]***

(b) (i) so that each bit can be transmitted simultaneously; ***[1]***

(ii) parallel-to-serial converter / serial-to-parallel converter; ***[1]***

(c) (i) need at least 22 levels;
(so) 5 bits required; *(allow ECF from wrong number of levels or bald correct answer)* ***[2]***

(ii) sampled every 0.5 ms;
(so) frequency = 2.0 kHz; *(allow ECF from wrong time or bald correct answer)* ***[2]***

(d) *advantage*: simpler circuitry / lower cost;
disadvantage: more noisy / shorter uninterrupted length; ***[2]***

F3. (a) use of ratio/dB $=10\lg\left(\frac{P_2}{P_1}\right)$;

$25=10\lg\left(\frac{P}{2.5\times10^{-18}}\right)$;

$P=7.9\times10^{-16}$ W ***[2]***

(b) total attenuation $=2.7\times48=130\,\text{dB}$;

$130=10\lg\left(\frac{P}{7.9\times10^{-16}}\right)$

$P=7.9\,\text{mW}$; ***[2]***

Option G — Electromagnetic waves

G1. (a) transverse;
can be polarized;
all have same speed in a vacuum; ***[2 max]***

(b) each colour/wavelength has different refractive index;
different focal lengths/amount of diffraction for each wavelength/colour;
so all coloured images do not overlap completely/not at same place; ***[3]***

(c) light is scattered by <u>molecules</u>;
greater scattering effect for shorter wavelengths/blue end of spectrum;
so it appears blue ***[2]***

G2. (a) ratio of angle subtended by image and angle subtended by object;
angles measured at eye; ***[2]***

(b) (i) $\frac{1}{u}-\frac{1}{24}=\frac{1}{4.5}$;
distance $=3.8\,\text{cm}$ ***[1]***

(ii) angular magnification $=\frac{h_I}{D}\div\frac{h_O}{D}$;
$=$ linear magnification;
$=\frac{v}{u}$;
$=\frac{24}{3.8}$
$=6.3$; ***[4]***
*Award **[2 max]** for use of linear magnification alone.*

(c) less spherical/chromatic aberration (than single lens);
greater aperture can be used/greater light-collecting ability (than single lens); ***[2]***

G3. (a) constant phase difference; ***[1]***

(b) path difference between beams $=n\lambda$, where n is an integer/is one wavelength; ***[1]***

(c) (i) wavelength decreases; ***[1]***

(ii) (effective/optical) path/phase difference changes; ***[1]***