M13/4/PHYSI/SP3/ENG/TZ2/XX/M

International Baccalaureate®
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MARKSCHEME

May 2013

PHYSICS

Standard Level

Paper 3

15 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.

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 <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 ***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.

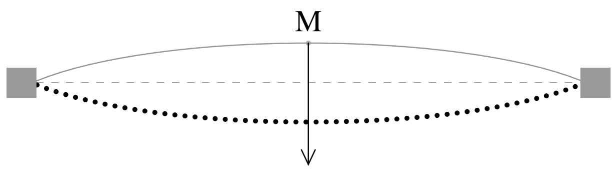
Option A — Sight and wave phenomena

A1. (a) the range of distance for which objects can be clearly focused; ***[1]***

(b) the depth of vision increases;
increased light intensity implies that the pupil diameter of the eye decreases; ***[2]***

A2. (a) standing waves do not transfer energy / travelling waves transfer energy;
(adjacent) points on a standing wave have different amplitudes / travelling waves have the same amplitude;
points in between nodes have the same phase for standing waves / the phase changes along the wave for travelling waves;
standing waves have points where the displacement is zero at all times; ***[1 max]***

(b)



(i) arrow vertically down; *(see diagram above)* ***[1]***

(ii) suitable line drawn below equilibrium position;
of amplitude shown; *(judge by eye – see diagram above)* ***[2]***

(c) apply forced vibrations to the string at the fundamental resonant frequency; ***[1]***

or

displace/pluck <u>middle</u> of string;

(d) 500 Hz; ***[1]***

A3. (a) the change in observed/perceived frequency when there is relative motion between a source and an observer; ***[1]***

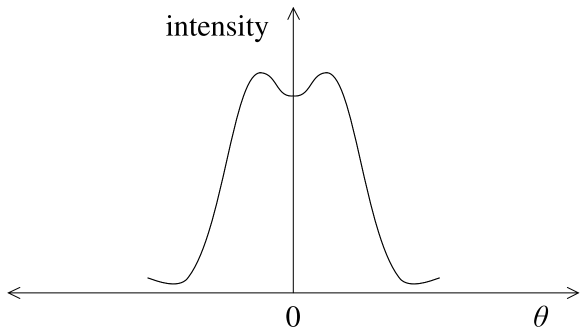
(b) $f_H = 1200 \times \frac{340}{340-45} \approx 1380\,\text{Hz}$;

$f_L = 1200 \times \frac{340}{340+45} \approx 1060\,\text{Hz}$;

range is all frequencies in between 1060 Hz and 1380 H); ***[3]***

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

A4. (a)



dip at $\theta = 0$;
overall correct shape clearly showing two maxima; ***[2]***
*Award **[2]** for correct diagram showing separate intensity patterns (just resolved) for each source.*

(b) (i) angle of first diffraction minimum is $1.22 \times \frac{480 \times 10^{-9}}{2.1 \times 10^{-3}} = 2.79 \times 10^{-4}$ rad ;

angular separation of sources is $\frac{3.0 \times 10^{-3}}{d}$;

$\frac{3.0 \times 10^{-3}}{d} = 2.79 \times 10^{-4} \Rightarrow d \approx 11\,\text{m}$; ***[3]***

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

(ii) the diffraction angle is greater / distance at which the dots are resolved smaller;
so they cannot be resolved; ***[2]***

Option B — Quantum physics and nuclear physics

B1. (a) (i) the energy carried by an electromagnetic wave would be gradually absorbed by electrons;
and this would take time; ***[2]***

(ii) the energy carried by photons is transferred to electrons;
and this happens immediately; ***[2]***

(b) (i) slope $= \frac{h}{e}$;
$\text{slope} = 3.8(\pm 0.2) \times 10^{-15}\ \text{V s}$;
hence $h = \left(e \times \text{slope} = 1.6 \times 10^{-19} \times 3.8 \times 10^{-15} =\right) 6.1(\pm 0.3) \times 10^{-34}\ \text{J s}$; ***[3]***
*Award **[1 max]** for calculation using equation and a data point.*

(ii) $(-)\,2.2(\pm 0.2)\ \text{eV}$ ***or*** $3.5(\pm 0.4) \times 10^{-19}\ \text{J}$; ***[1]***

(iii) electron energy is $3.2(\pm 0.6)\ \text{eV}$ ***or*** $5.1(\pm 0.9) \times 10^{-19}\ \text{J}$;
$\left(\frac{p^2}{2\text{m}} = 5.1 \times 10^{-19} \Rightarrow\right) p = 9.6(\pm 0.8) \times 10^{-25}\ \text{N s}$;
use of $\lambda = \frac{h}{p}$ to obtain a value within the range 5.5×10^{-10} to 7.6×10^{-10} m; ***[3]***

B2. (a) alpha/gamma emission are line spectra/discontinuous; ***[1]***

(b) (i) $0.54\ \text{MeV}$ ***or*** $8.6 \times 10^{-14}\ \text{J}$; ***[1]***

(ii) the energy is shared by (essentially) the positron and a neutrino;
hence the positron has a range of energies; ***[2]***

(iii) the nucleus of Ne is in an excited/higher energy level state;
a photon will be emitted when the nucleus makes a transition to a lower energy state; ***[2]***

(c) the decay constant is $\lambda = \frac{\ln 2}{2.6} = 0.267\ \text{yr}^{-1}$;
$0.80 = e^{-0.267 \times t}$;
$t = 0.84\ \text{yr}$; ***[3]***
*Award **[3]** for a bald correct answer.*
Accept alternative approaches, eg calculation based on $0.5^n = 0.8$.

Option C — Digital technology

C1. (a) reference to sampling / reference to analogue-to-digital conversion;
reference to (edge) of land/pit;
reference to binary 1/0; ***[2 max]***

(b) large information density / takes up less space;
the information may be edited/manipulated on a computer;
the information may be easily transported electronically/physically;
the information may be encrypted; ***[2 max]***
Award any other reasonable statement.

(c) incoming light releases electric charge;
the charge is proportional to the intensity of light;
the charge is transformed into a voltage;
the position of each pixel is recorded; ***[3 max]***

(d) size of one pixel is $\sqrt{\dfrac{32\times10^{-6}}{8.0\times10^{6}}}=2.0\times10^{-6}\text{ m}$;
separation of images of the two points is $1.2\times10^{-3}\times2.4\times10^{-3}=2.9\times10^{-6}\text{ m}$;
this is less than 2 pixel lengths and so the points cannot be resolved; ***[3]***

C2. (a) (i) the output voltage has opposite sign to that of the input / negative feedback fed into inverting input; ***[1]***

(ii) point between resistors next to inverting input; ***[1]***

(iii) realization that I is same through each R / op-amp current is zero;
pd across $R_1=V_{\text{IN}}$ and pd across $R_2=V_{\text{OUT}}$;
$G=\dfrac{V_{\text{OUT}}}{V_{\text{IN}}}=\dfrac{-IR_2}{IR_1}=$ required result; ***[3]***

(b) (i) -3.0 V; *(negative sign is required)* ***[1]***

(ii) -12 V; *(negative sign is required)* ***[1]***

C3. base stations and phone exchange signals;
base stations relay call to cellular exchange;
cellular exchange monitors signal strength from base stations;
cellular exchange selects the base station with the strongest signal;
cellular exchange allocates frequency for call; ***[3 max]***

Option D — Relativity and particle physics

D1. (a) the length of an object in its rest frame / the length of an object measured when at rest relative to the observer; ***[1]***

(b) (i) 1.67; ***[1]***

(ii) 72 m; ***[1]***

(iii) 43 m; ***[1]***

(c) Albert must agree that Mileva receives light from the two lamps simultaneously;
but for Albert the light from the exit lamp travels further than the light from the entrance lamp;
because Mileva is moving to the left/towards the light from the entrance lamp;
the speed of light is constant *ie* same in both directions/for both observers/from both sources;
(so for Albert the exit lamp must switch on first) ***[3 max]***

(d) (i) 3.0×10^{-7} s; ***[1]***

(ii) Mileva measures proper time;
$\left(\gamma\times\frac{72}{0.80\times3.0\times10^{8}}\right)=5.0\times10^{-7}$ s; ***[2]***

or

according to Albert a length of 120 (m) must move past him;
and this takes $\left(\frac{120}{0.80\times3.0\times10^{8}}\right)=5.0\times10^{-7}$ s;
Award ***[2]*** *for a bald correct answer.*

D2. (a) a baryon consists of three quarks/antiquarks while a meson has one quark and one antiquark; ***[1]***

(b) $\frac{\hbar}{2} = \frac{h}{4\pi} = 5.3 \times 10^{-35}$ J s ; ***[1]***

(c) (i) it is impossible for two identical fermions to occupy the same quantum state; ***[1]***

(ii) quarks have a quantum number called colour;
the three otherwise identical quarks in the baryon are distinguished by different colour quantum numbers; ***[2]***

(d) (i) positron on lower line with arrow going to the left; ***[1]***

(ii) the range is infinite;
because the exchange particle is the massless photon; ***[2]***

(e) $e^{+} + e^{+} \rightarrow p^{+} + p^{+}$: baryon number / lepton number;
$e^{-} + \nu \rightarrow e^{+} + \bar{\nu}$: electric charge / lepton number; ***[2]***

Option E — Astrophysics

E1. (a) apparent magnitude / (log scale of) brightness of star viewed from 10 pc / logarithmic scale of luminosity of a star; ***[1]***

(b) (i) star X
because it has a greater apparent brightness; ***[1]***
*To award **[1]** an explanation is needed.*

(ii) star X
looks brighter from Earth even though it has lower luminosity/greater absolute magnitude than star Y; ***[1]***
*To award **[1]** an explanation is needed.*

(c) (i) $d = \sqrt{\frac{L}{4\pi b}}$;

$d = \left(\sqrt{\frac{4.9\times10^{30}}{4\pi\times2.5\times10^{-8}}} = \right)3.9\times10^{18}\text{ m}$; ***[2]***

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

(ii) (star X is class M so its) temperature is about $3000\,(\pm1000)\,\text{K}$;

$R = \sqrt{\frac{L}{4\pi\sigma T^4}}\ \left(= \sqrt{\frac{4.9\times10^{30}}{4\times\pi\times5.68\times10^{-8}\times3000^4}}\right)$;

$R = 2.9\times10^{11}\text{ (m)}$; ***[3]***

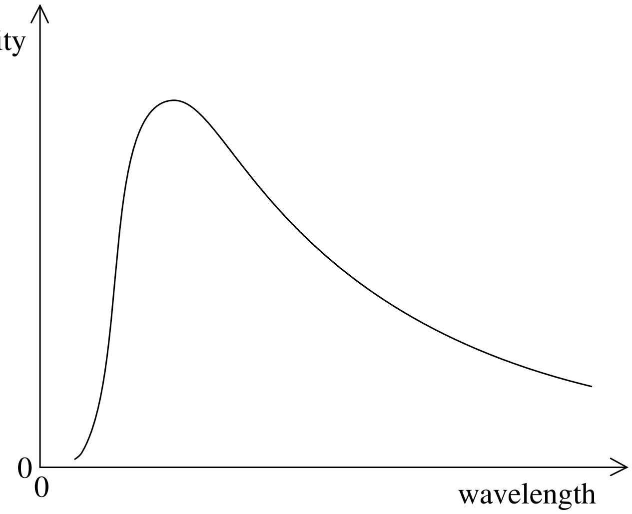
Accept a temperature range of 2000 (K) to 4000 (K) so that the radius range is 1.6×10^{11} (m) to 6.6×10^{11} (m).
*Award **[3]** for a bald correct answer.*

(iii) high luminosity / high radius / low temperature;
hence a red giant/red supergiant; ***[2]***

(d) star's absorption spectrum has dark lines indicating absorption of light of specific energy/frequency/wavelength;
the dark lines correspond to the emission line spectra of different elements / different elements have specific wavelengths absorbed; ***[2]***

E2. (a) black-body radiation (at a temperature of about 3 K);
electromagnetic radiation in the microwave region;
isotropic/uniform in all directions;
electromagnetic radiation that has no specific point of origin / *OWTTE*; ***[2 max]***

(b) (i)



standard black-body curve ie
shows maximum/peak;
curve not symmetric about peak, left-hand side much steeper than right-hand side; ***[2]***

(ii) the wavelength λ_0 at maximum intensity is measured;

the temperature is obtained from Wien's law / $T = \frac{2.9\times10^{-3}}{\lambda_0}$; ***[2]***

(iii) CMB, filling all space, was predicted by the Big Bang model;
the temperature/wavelength of the radiation is consistent with (cooling due to) expansion/red-shift; ***[2]***

Option F — Communications

F1. (a) (i) period is $10\,\mu s$;

$f_C = \frac{1}{10\,\mu s} = 100\,kHz$; ***[2]***

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

(ii) period is time from peak to peak *ie* $100\,\mu s$;

$f_S = \frac{1}{100\,\mu s} = 10\,kHz$; ***[2]***

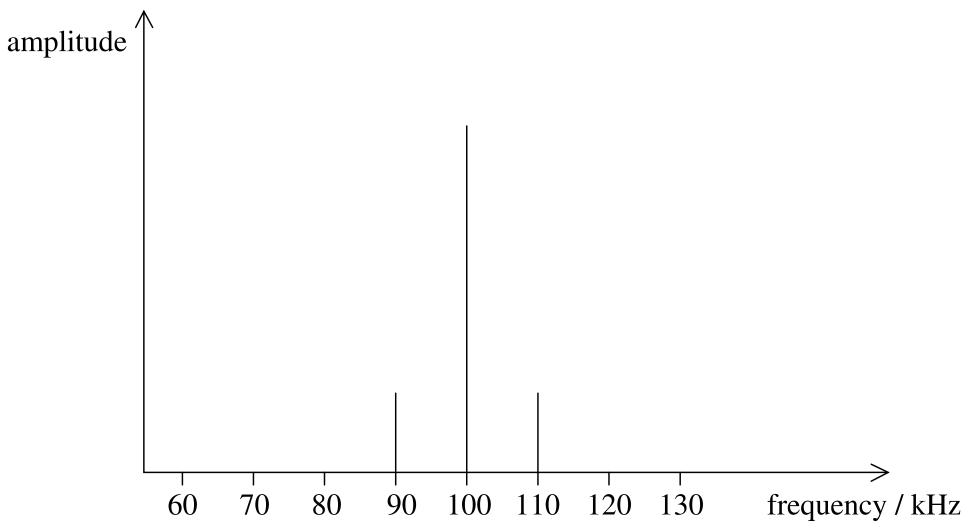
Award ***[2]*** *for a bald correct answer.*

(iii) 20 kHz; ***[1]***

(iv) valid working, *eg* $\frac{15-5}{2}$;

5.0 mV; ***[2]***

(b)



central maximum at 100 kHz;
shorter maxima at 90 kHz and 110 kHZ; ***[2]***

F2. (a) 22 kHz;
the reconstructed signal will not be a faithful reproduction of the original if the sampling frequency is not at least twice the highest frequency in the signal; ***[2]***

(b) (i) $(44 \times 10^3 \times 32 =)\ 1.4 \times 10^6$ bits s^{-1} ; ***[1]***

(ii) $\left(\frac{1}{1.4 \times 10^6} =\right) 0.71\,\mu s$; ***[1]***

F3. (a) (i) the loss of power/energy during the transmission of a signal; ***[1]***

(ii) resistive heating / EM radiation losses; ***[1]***

(b) (i) total allowed loss of power is $-10\lg\frac{12}{240}=13\,\text{dB}$;
$\text{loss}=120\times15-N\times52$;
$1800-N\times52=13$;
gives $N=34.4$ so $N=35$ required; ***[4]***

(ii) fewer amplifiers needed;
better quality of transmission;
greater bandwidth;
greater security;
no thermal/ohmic losses; ***[1 max]***

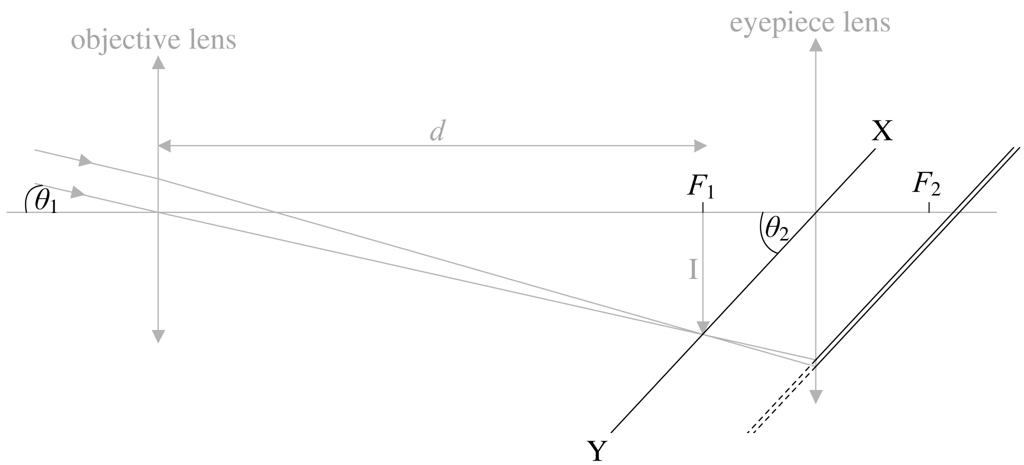
Option G — Electromagnetic waves

G1. (a) (i) no change (of 90°); ***[1]***

(ii) correct distance shown, *eg* from peak to peak/between any successive points in phase; ***[1]***

(b) all travel with the same speed in vacuum / in free space;
can propagate in vacuum;
are transverse;
can be polarized;
can carry energy/momentum; ***[1 max]***
Allow other valid properties.

G2. (a)



(i) $\frac{1}{d} = \frac{1}{f_0} - \frac{1}{u}$ where u is the object distance from the lens;

since u is very large $\frac{1}{u}$ is negligible/zero;

(and so $d = f_0$) ***[2]***

Accept equivalent answers.

(ii) at position of image in objective and an equal distance on the other side of the lens; *(judge by eye)* ***[1]***

(iii) *see diagram above*:
first ray, after refraction, as shown;
second ray, after refraction, parallel to first ray;
extrapolation to infinity; *(allow even if refraction angles are wrong)* ***[3]***
Accept alternative correct rays to those shown. For example a ray from the image parallel to the axis, a ray from the image along line XY.

(iv) both angles as shown or their equivalent; ***[1]***

(b) $M = \frac{26}{4.0} = 6.5$;

$6.5 \times 2.2 = 14^\circ$; ***[2]***

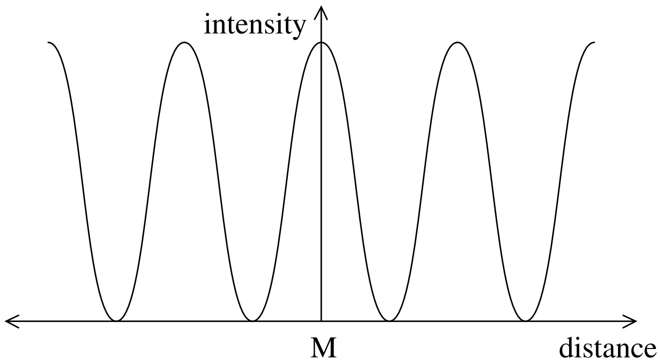
G3. (a) (i) the path difference between the two rays at M is zero;
so constructive interference occurs; ***[2]***

(ii) distance MP is $\frac{\lambda D}{2d}$;

and so $\lambda = \left(\frac{2.62\times10^{-3}\times2\times0.150\times10^{-3}}{1.20}=\right)6.55\times10^{-7}\text{ m}$; ***[2]***

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

(b)



maxima of equal intensity;
equally separated; *(judge by eye)* ***[2]***

(c) position of maxima the same;
maxima narrower/sharper;
maxima brighter;
appearance of secondary maxima; ***[2 max]***