M13/4/PHYSI/SP3/ENG/TZ1/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 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

A1. (a) overlapping of different (primary) colours on a (white) screen/object / *OWTTE*; ***[1]***

(b) (i) same peak wavelength shown;
reduced peak value shown; ***[2]***

(ii) more blue/bluish for the colour-blind eye;
since magenta is composed of red and blue;
and the red component would be attenuated in the colour-blind eye; ***[3]***

A2. (a) $\left(\text{since } \frac{v}{c} \ll 1\right),\ \Delta f \left(= \frac{v}{c} f\right) = \frac{6.0\times10^{6}}{3.0\times10^{8}} 6.0\times10^{9} \left(= 0.12\times10^{9}\text{ Hz}\right);$

$f' = f - \Delta f \left(= 5.9\times10^{9}\text{ Hz}\right);$

$\lambda' \left(= \frac{c}{f'} = \frac{3.00\times10^{8}}{5.9\times10^{9}}\right) = 5.1\times10^{-2}\text{ m};$ ***[3]***

(b) (i) the two (point-like) sources generate diffraction patterns with central maxima;
the central maximum of one pattern overlaps with the first minimum of the second diffraction pattern; ***[2]***

(ii) $\theta \approx \frac{d}{D} = \frac{5.0\times10^{19}}{2.0\times10^{21}} = 0.025\text{ rad};$

$\left(b > 1.22 \frac{5.1\times10^{-2}}{0.025} = \right) 2.5\text{ m};$ ***[2]***

*Allow **[1 max]** for solution that omits 1.22.*

A3. (a) wave travels down string and is reflected / *OWTTE*;
incident and reflected waves interfere/add/superpose to give a standing wave; ***[2]***

(b) $\lambda = 2L = 1.28\text{ m};$

$v = \lambda f = 420\text{ m s}^{-1};$ ***[2]***

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

A4. the optical activity of some (transparent) materials depends on the stress applied to them;
so placing these materials between two crossed polarizers (under white light);
results in a (coloured) stress pattern;
from which information can be gathered about the stress distribution in the material; ***[3 max]***

Option B — Quantum physics and nuclear physics

B1. (a) atomic spectra have discrete line structures / only discrete frequencies/wavelengths;
photon energy is related to frequency/wavelength;
photons have discrete energies;
photons arise from electron transitions between energy levels;
which must have discrete values of energy; ***[3 max]***

(b) de Broglie suggests that electrons/all particles have an associated wavelength;
this wave will be a stationary wave which meets the boundary conditions of the box;
the stationary wave has wavelength $\frac{2L}{n}$ (where L is the length of the box and where n is an integer); ***[3]***

(c) (i) wavelength of ψ_A larger than ψ_B;
therefore momentum of ψ_B larger than ψ_A (from de Broglie hypothesis);
therefore ψ_B has larger energy; ***[3]***

or

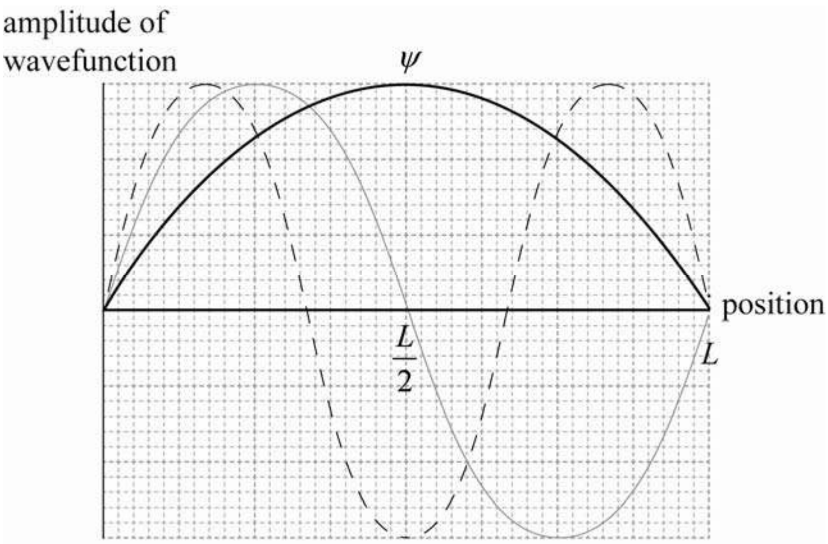
ψ_B has $n = 3$, ψ_A has $n = 2$;
$E_K \propto n^2$;
so ψ_B corresponds to the larger energy;

(ii) $\psi_A = 0$, $\psi_B \neq 0$ in the middle of the box/at $\frac{L}{2}$;
so ψ_B corresponds to the larger probability since probability $\propto |\psi|^2$;
Accept $\propto \psi^2$. ***[2]***

or

the probability (of finding the electron) is related to the amplitude;
amplitude of ψ_B is greater than amplitude of ψ_A so ψ_B is more likely to be found;

(iii)



correct sketch; *(accept $-\psi$)* **[1]**

Accept wavefunction with any amplitude.

B2. (a) $^{22}_{11}\text{Na} \rightarrow {}^{22}_{10}\text{Ne} + {}^{0}_{+1}e + {}^{0}_{0}\nu$

$^{22}_{10}\text{Ne}$;

$^{0}_{+1}e$; *(accept $^{0}_{+}e$)*

$^{0}_{0}\nu$; *(award **[0]** for $^{0}_{0}\bar{\nu}$)* **[3]**

(b) time taken for half/50% of the nuclei to decay / activity to drop by half/50%; **[1]**

(c) (i) $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$;

$\frac{0.693}{0.27\,\text{yr}^{-1}} = 2.6\ \text{years}$; **[2]**

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

(ii) $N = 5.0 \times 10^{23} \times e^{-0.27 \times 5.0}$;

$N = 1.3 \times 10^{23}$; **[2]**

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

Option C — Digital technology

C1. (a) infinite/very high gain;
infinite/very high input resistance; ***[2]***

(b) (i) $V_P = -15 + \frac{30 \times 100}{[50+100]}$ / other suitable working;
states that potential at midpoint of resistor chain = potential at P; ***[2]***

(ii) +5 V; ***[1]***

(iii) an op-amp amplifies the difference between the inputs (P and Q) (with a large gain);
if A less than *V* then Q is also less than *V* (and P);
so output will be driven strongly negative;
R will be at –15 V and pd across buzzer is 30 V (so it sounds); ***[3 max]***

C2. chemical pollution / land fill issues;
use of scarce/poisonous resources in manufacture of phones;
required increase in number/complexity of base stations / increased numbers of installations;
congestion of radio spectrum; ***[2 max]***
*Allow any one issue for **[1]**, do not allow repeat of an issue in different guise.*

C3. (a) incident energy $= 1.8\times10^{-5}\times2.5\times10^{-3}\times1.9\times10^{-5}\left(=8.6\times10^{-13}\text{ J}\right)$;

number of photons $= \frac{2.7\times10^{-13}}{1.6\times10^{-19}}\times\frac{1}{0.8}\left(=2.1\times10^{6}\right)$;

frequency $= \left(\frac{8.6\times10^{-13}}{2.1\times10^{6}}\times\frac{1}{6.63\times10^{-34}}=\right)6.1\times10^{14}\text{ Hz}$; ***[3]***

(b) light consists of photons;
the (photon) energy releases electron/hole;
the charge carriers/electrons/holes move to (appropriate) electrode;
storing charge (at a pd) / mention of capacitive action; ***[4]***

(c) laser light is monochromatic/coherent;
reflection from both sides of land-pit edge shown/described;
pit depth is $\frac{\lambda}{4}$;
bottom reflection is $\pi/180^\circ$ out of phase with top reflection; *(not "out of phase" only)*
so cancellation/interference/superposition occurs; ***[3 max]***

Option D — Relativity and particle physics

D1. (a) a coordinate system / set of rulers / clocks;
in which measurements of distance/position and time can be made; *[2]*

(b) light travels at same speed for both observers;
during transit time Officer Sylvester moves towards point of emission at front/away from point of emission at back;
light from front arrives first as distance is less / light from back arrives later as distance is more;
Officer Sylvester observes the front lamp flashes first;

or

time between lights arriving at Speedy is zero (according to Speedy) – (this is a proper time) so Sylvester (indeed all inertial observers) sees lights reaching Speedy simultaneously;
front lamp moving away from Speedy (according to Sylvester);
speed of light constant for all observers;
light from front lamp has to travel further to reach Speedy so must have flashed first (according to Sylvester); *[4]*

(c) (i) the two events occur at the same place (in the same frame of reference) / shortest measured time; *[1]*

(ii) $\gamma = \left(\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \right) 1.15$;
$\Delta t = 1.15 \times \Delta t_0$;
1.48×10^{-8} s; *[3]*

D2. (a) particle with no internal structure / cannot be broken down further; *[1]*

(b) (i) pion/meson/gluon; *[1]*

(ii) $m = \frac{h}{4\pi Rc}$;
1.8×10^{-28} kg; *[2]*

D3. (a) –3; *[1]*

(b) (i) anti u (quark) / $\overline{\mathrm{u}}$; *[1]*

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

(c) states or uses Pauli exclusion principle;
Ω^- has (three) identical (strange) quarks;
there must be a (further) property that distinguishes them (this is colour); ***[3]***

Option E — Astrophysics

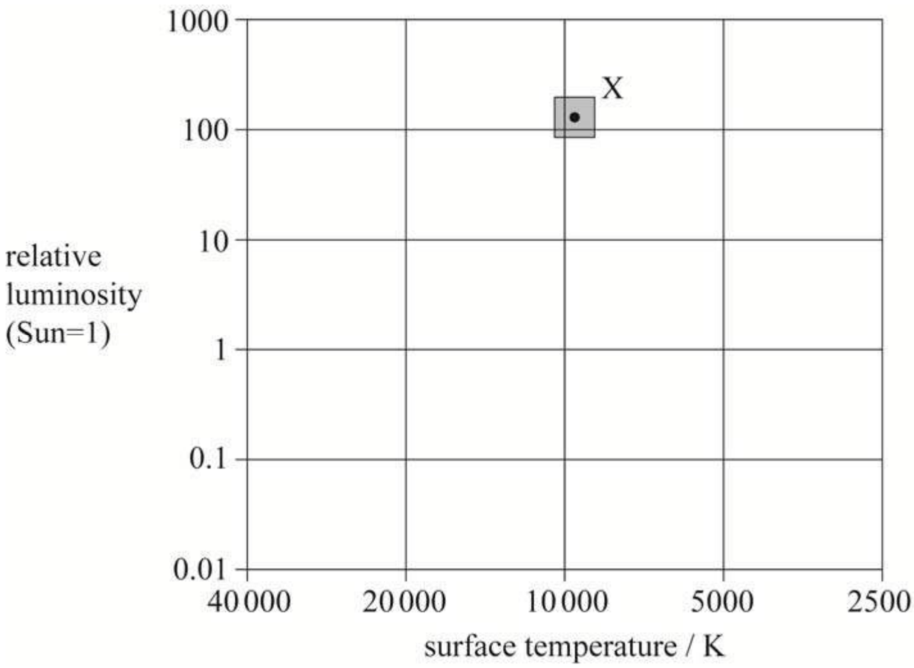
E1. (a) minor planet / rocky/icy/metallic body; *[1]*

(b) situated between (orbits of) Mars and Jupiter; *[1]*
Allow answers in terms of near-Earth asteroids or Trojan asteroids.

E2. (a) $T = \frac{2.9 \times 10^{-3}}{3.0 \times 10^{-7}}$;
9700 K; *[2]*

(b) $\frac{L_X}{L_S} = \frac{\sigma r_X{}^2 T_X{}^4}{\sigma r_S{}^2 T_S{}^4}$;
$= \frac{4.5^2 \times 9700^4}{5700^4}$;
$= 170$; *[3]*
Accept answers that use $T = 10\,000\text{ K}$ *to give an answer of 190.*

(c)



X marked correctly within range shown; *[1]*

E3. (a) (i) object of known luminosity/power; ***[1]***

(ii) luminosity varies with time in a regular way;
(average) luminosity related to period of variation;
high luminosity so visible from great distances; ***[2 max]***

(iii) the period of the variation of luminosity/apparent brightness/apparent magnitude is measured;
the luminosity/absolute magnitude is determined from period;
apparent magnitude/brightness is measured (on Earth);
$m - M = 5\lg\left(\frac{d}{10}\right)$ ***or*** $b = \frac{L}{4\pi d^2}$ is used to compute d; ***[3 max]***

(b) $13 - [-20] = 5\lg\left[\frac{d}{10}\right]$;
$10^{6.6} = \frac{d}{10}$;
40 Mpc; ***[3]***
*Award **[3]** for a bald correct answer.*

E4. *infinite:* cosmic microwave background is observed consistent with cooling from a finite beginning / use of the Hubble constant to find universe age / bright universe not observed whereas an infinite universe would be completely bright;
uniform: significant empty distances visible between galaxies / reference to galactic clusters/super clusters / the greater the observed distance of galaxies, the greater the red-shift;
static: red-shift indicates expansion of universe / galaxies observed to be moving relative to Earth; ***[3]***

Option F — Communications

F1. (a) (i) 0.0006 MHz or 600 Hz; *[1]*

(ii) 0.0012 MHz or 1200Hz; *[1]*

(b) amplitude is constant in FM transmission;
noise/interference tends to affect the amplitude of the carrier wave only;
receiver compensates for any changes in the (received) signal; *[3]*

(c) FM has shorter range than AM;
higher frequencies required;
equipment has higher cost (because more elaborate circuitry);
wider bandwidth needed / fewer channels possible; *(not "higher bandwidth")* ***[2 max]***

F2. (a) A: clock;
B: analogue-to-digital converter / C: parallel-to-serial converter; *[2]*

(b) (i)

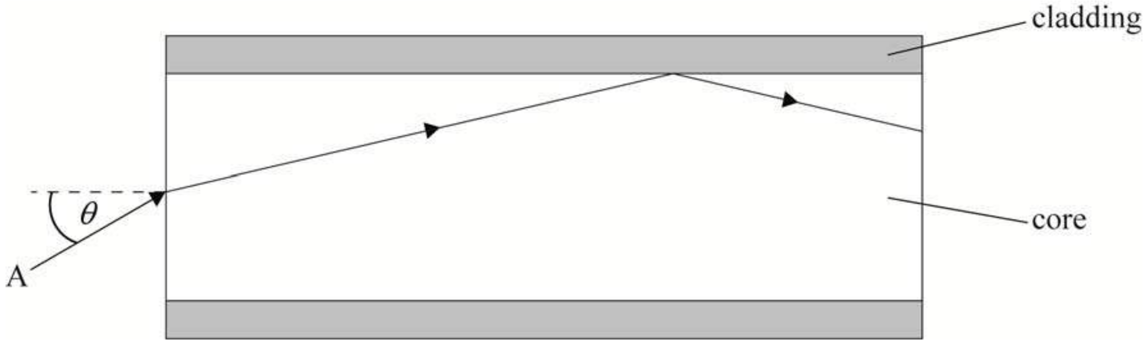
Time / ms	**Digital output equivalent**
3.5	010
4.0	011

times both correct;
digital values both correct; *[2]*

(ii) can more closely conform to variation in analogue / closer to rounded values / final output more faithful reproduction of input; *[1]*

F3. (a) refracted angle inside core $= 20^\circ$;
$\sin\theta = \sin 20^\circ \times 1.62$;
34°; ***[3]***

(b)

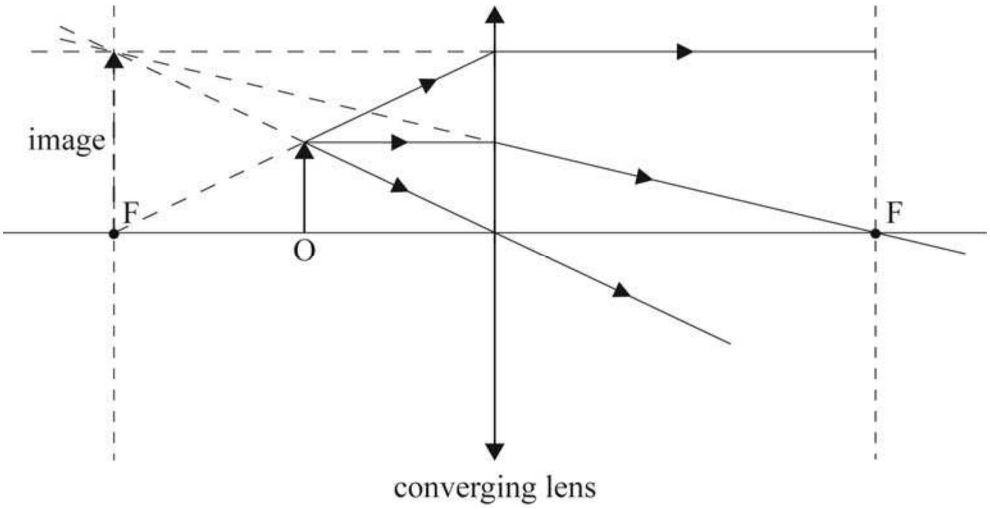


refraction angle on entering core sensible and smaller than incidence angle;
equal angles of reflection at cladding; *(judge by eye)* ***[2]***

(c) different path lengths so different times of travel;
ray 1 light will arrive first;
if successive pulses from different routes overlap then interference / *OWTTE*;
limit to the transmission rate/bandwidth of fibre; ***[3 max]***

Option G — Electromagnetic waves

G1. (a) (i)



any correct ray out of the three shown above;
second ray correct;
image correctly located and labelled; ***[3]***
Accept rays without arrows and solid construction lines back to image.

(ii) virtual because no rays pass through the image / image cannot be formed on a screen; ***[1]***

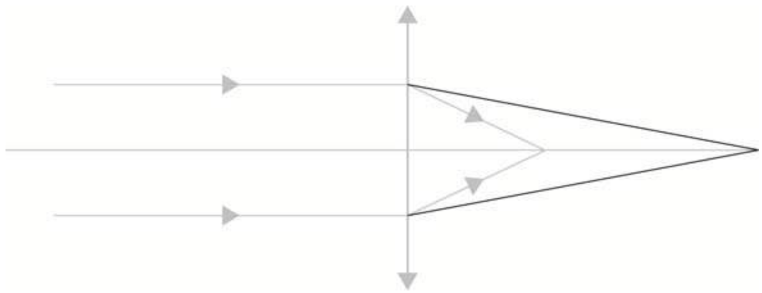
(b) (i) $\frac{1}{v} = \frac{1}{0.20} - \frac{1}{0.40}\left(= 2.5\,\text{m}^{-1}\right)$;
$\Rightarrow v = 0.40\,\text{m}$; ***[2]***

(ii) $m = -\frac{v}{u}$;
$m = -1$; ***[2]***

(c) (i) answer in range 320 – 480 nm; ***[1]***

(ii) answer in range 620 – 780 nm; ***[1]***

(d)



the refracted rays converge on the principal axis farther from the lens than for blue; ***[1]***

G2. (a) (i) single frequency/wavelength / narrow range of frequencies/wavelengths; ***[1]***

(ii) in phase;
constant phase difference/relationship; ***[2]***
Award ***[2]*** *for any correct reference to constant phase difference.*

(b) $\theta = \tan^{-1}\left[\frac{0.65}{2.0}\right]\left(=18^{\circ}\right)$;
recognition that $n=1$;
$d = \frac{1}{600}\left(=0.0017\,\text{mm}\right)$;
$\lambda\left(=d\sin\theta = 0.0017\times\sin 18^{\circ}\right)=520\,\text{nm}$; ***[4]***

(c) principal maxima broaden;
secondary maxima appear; ***[2]***