M09/4/PHYSI/SP3/ENG/TZ2/XX/M+

International Baccalaureate
Baccalauréat International
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MARKSCHEME

May 2009

PHYSICS

Standard Level

Paper 3

14 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. 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.

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

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*

Option A — Sight and wave phenomena

A1. (a) yellow; ***[1]***

(b) the eye responds to the frequency (or energy per photon) of the light;
the frequency is unchanged by changes in refractive index; ***[2]***

A2. (a) (i)  ; ***[1]***

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

(b) $f = \dfrac{v}{\lambda}$;
to give $f = 120\,\text{Hz}$; ***[2]***

(c) $\lambda = 4L = \left(\dfrac{330}{120}\right)$;
$L = 0.69\,\text{m}$; ***[2]***

A3. (a) when source is moving towards the observer the wavefronts are compressed/frequency is increased;
(when source is moving away) the wavefronts are expanded / frequency is decreased;
(this repeats so) a continuous rise and fall in pitch/frequency is heard; ***[3]***

(b) the maximum frequency occurs when the speaker is approaching the observer;
$f = \dfrac{1000 \times 330}{330 - 30}$;
$= 1100\,\text{Hz}$; ***[3]***

A4. (a) all possible polarization directions are equally represented / where the direction of polarization is random; ***[1]***

(b) $0.50\,\text{W m}^{-2}$;
$\left(I \propto \cos^2\theta\right)$ average value is $\frac{1}{2}$; ***[2]***

(c) polarizer and analyser separated by sugar solution; $\Big\{$ *Accept a diagram for this marking point.*
measure angle / rotation of plane of polarization;
concentration proportional to angle; ***[2 max]***

Option B — Quantum physics and nuclear physics

B1. (a) (i) a line horizontal; ***[1]***

(ii) light consists of photons;
photon energy only depends on frequency;
maximum kinetic energy of electrons depends on photon energy (therefore independent of intensity) / *OWTTE*;
increasing intensity produces more photons of same KE; ***[3 max]***

(b) $f = \left(\frac{c}{\lambda} =\right) 7.5\times10^{14}\,(\text{Hz})$;

$\phi(\text{eV}) = \frac{hf}{e} - K$;

$= 1.0\,\text{eV}$; ***[3]***

Allow all of calculation in J to give 1.6×10^{-16} J.

B2. (a) every particle has a wavelength associated with it / exhibits wave-like properties;
given by $\lambda = \frac{\text{Plank constant}}{\text{momentum of particle}}$; ***[2]***

(b) $\lambda = \frac{h}{p} = \left(\frac{2L}{n}\right)$;

kinetic energy $= \frac{p^2}{2m}$;

combined to get result; ***[3]***

(c) (i) $\Delta E = \frac{[16-4]h^2}{8m_eL^2}$;

$= 4.3\times10^{-19}\,\text{J}$; ***[2]***

(ii) $\lambda = \frac{hc}{E}$;

$= 4.6\times10^{-7}\,\text{m}$; ***[2]***

B3. (a) probability of decay per unit time; ***[1]***

(b) (i) $\frac{0.69}{2.4\times10^{4}}$; ***[1]***

$(\approx 3\times10^{-5}\ \text{yr}^{-1})$

(ii) $\frac{\ln\left[0.001\right]}{[3\times10^{-5}]}$;

2.3×10^{5} yr; ***[2]***

Accept use of 10 elapsed half lives (correct approximation) to give 2.4×10^{5} *yr*.

Option C — Digital technology

C1. (a) *bit*:
a binary digit;
either 0 or 1;

least significant bit:
determines whether a binary number is an odd or an even decimal number / determines the unit value of the decimal value of a binary number;
it is the most right-hand digit of a binary number; ***[3 max]***

(b) (i) 0; ***[1]***

(ii) (it is) encoded onto aluminium/metal surface of the CD as a series of "bumps/pits" and flats;
the edge of a bump/pit represents binary 1, the flats between edges represent binary 0; ***[2]***

or

reflection / no reflection from surface features;
that results in binary digits 1 or 0;

(c) vast numbers of CDs and DVDs are produced;
hence, problem of disposal as they are not biodegradable / manufacture produces greenhouse gases / toxic material involved in their manufacture; ***[2]***
Accept any other suitable alternative.

C2. (a) the ratio of charge to potential difference / $C = \frac{Q}{V}$ (with terms defined); ***[1]***

(b) photons (in the light) create electron-hole pairs (in the pixel);
these migrate to electrodes and so from $C = \frac{Q}{V}$ there will be a p.d. across the pixel / *OWTTE*; ***[2]***

(c) number of electron-hole pairs produced $\left(= 0.75 \times 1.2 \times 10^{4}\right) = 9.0 \times 10^{3}$;
charge produced $\left(= 9.0 \times 10^{3} \times 1.6 \times 10^{-19}\right) = 1.44 \times 10^{-15}\,\text{C}$;
$\left(\text{using } C = \frac{Q}{V}\right)$ then $V \left(= \frac{1.4 \times 10^{-15}}{2.2 \times 10^{-11}}\right) = 0.065\,\text{mV}$; ***[3]***

C3. (a) (i) very high/infinite open loop gain;
very high/infinite input resistance; ***[2]***

(ii) -10; ***[1]***

(b) (i) potential across $R_2 = (10+2=)\,12 = 150I$;
(to give $I = 0.08\,\text{mA}$) ***[1]***

(ii) potential across $R_1 = V_{\text{in}} - 2.0 = IR_1$;
$V_{\text{in}} = 0.08 \times 47 + 2.0$;
$(= 5.8\,\text{V})$ ***[2]***

Option D — Relativity and particle physics

D1. (a) the speed of light in a vacuum/free space is the same for all observers; *[1]*

(b) according to Barbara, Tom receives light from L_1 and L_2 simultaneously;
but Tom moves away from L_2;
hence light from L_2 was emitted first; *[3]*

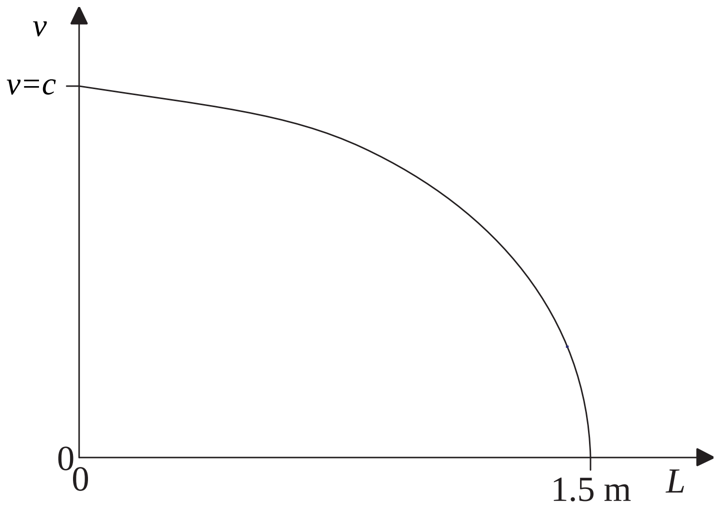
(c) (i) Tom
proper length is the length between objects as measured by the observer at rest with respect to the objects; *[1]*

(ii) $\gamma = 3$;

$$9 = \frac{1}{1 - \frac{v^2}{c^2}};$$

to give $v = 0.94c$; *[3]*

(iii)



data point 1.5, 0;
data point 0, c;
smooth curve (by sight); *[3]*

D2. (a)

Interaction	*Exchange particle(s)*
Electro-weak	photon, $W^{\pm}, Z^{0}$;
Strong	gluon;

[2]

All particles needed for electro-weak.

(b) they have no internal structure / not made out of smaller particles / cannot be divided into smaller particles; ***[1]***

(c) $\Delta t = \dfrac{h}{4\pi\Delta E}$;

$= \dfrac{6.6\times10^{-34}}{4\times3.14\times90\times10^{9}\times1.6\times10^{-19}}$;

$\approx 4\times10^{-27}$ s; ***[3]***

(d) (i) (green-antiblue) gluon; ***[1]***

(ii) so that three particles/quarks $\left(\text{with spin } \frac{1}{2}\right)$ can exist in the same state;
and not violate the Pauli exclusion principle; ***[2]***

Option E — Astrophysics

E1. (a) *red supergiant*: ***[3 max]***
appears red in colour;
(has a very) large luminosity;
(relatively) low (surface) temperature;
(very) large mass;
(very) large surface area;

constellation: ***[1 max]***
a group of stars that form a recognizable pattern (as viewed from Earth) / *OWTTE*; ***[4 max]***

(b) (i) apparent magnitude is a measure of how bright a star appears from Earth/observer;
absolute magnitude is the apparent magnitude of a star at a distance of 10 pc from Earth / how bright a star would appear if it were at a distance of 10 pc from Earth; ***[2]***

(ii) $5\lg\left[\frac{d}{10}\right] = (1.1 + 5.3 =)\,6.4$;
$d = 190\,\text{pc}$;
$= \frac{190 \times 3.26 \times 9.46 \times 10^{15}}{1.5 \times 10^{11}}$;
$(= 3.9 \times 10^{7}\ \text{AU})$ ***[3]***

(iii) stellar/spectroscopic parallax; ***[1]***

(c) (i) the power per square meter received at the surface of Earth/observer; ***[1]***

(ii) use of $L = 4\pi b d^2$;
$\frac{L_{\text{Antares}}}{L_{\text{Sun}}} = \frac{b_{\text{Antares}} d^2{}_{\text{Antares}}}{b_{\text{Sun}} d^2{}_{\text{Sun}}}$;
$L_{\text{Antares}}\left(\times L_{\text{Sun}}\right) = 4.3 \times 10^{-11} \times 3.9^2 \times 10^{14}$;
$(= 6.5 \times 10^{4})$ ***[3]***

E2. (a) Newton's model states that the universe is infinite (static) and uniform;
this means that stars are uniformly spaced;
and that if it is infinite there must be a star at every point in space / a star along every line of sight;
since there are regions without stars, Newton's model must be inadequate; ***[3 max]***

(b) both space and time originated with the Big Bang;
the universe is expanding (and not infinite);
due to the expansion, light from the Big Bang is red-shifted to the microwave region so regions between stars will not appear bright;
light from very distant stars will not have reached us yet;
the universe has not existed for all time; ***[3 max]***

Option F — Communications

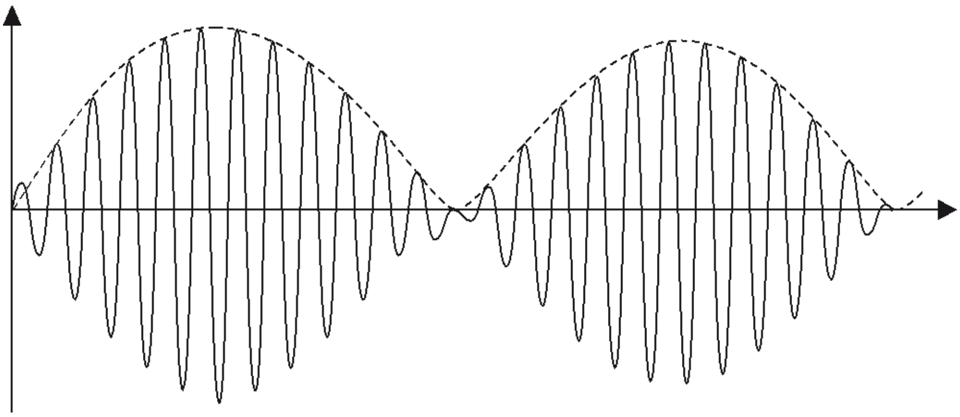
F1. (a) (i) a signal wave carries information / *OWTTE*;
the carrier wave is modulated by the signal wave / is an electromagnetic radio wave; ***[2]***

(ii) *amplitude modulation*: amplitude of carrier is altered;

frequency modulation: frequency of carrier is altered / amplitude stays the same (at the source); ***[2]***

(b) 12 to 13;
one cycle of the signal wave gives one loop of the modulated wave form, there are 12/13 oscillations in each loop of the modulated wave; ***[2]***

(c)



; ***[1]***

(d) *advantage*:
long range;
some justification *e.g.* waves reflected from ionosphere / no need for communication satellites / no need for sub-transmitters;

or

power requirements of transmitter can be reduced;
by use of sidebands;

disadvantage:
attenuation of carrier wave amplitude / restricted bandwidth / more susceptible to noise / *OWTTE*; ***[3]***

F2. (a) *X*: parallel to serial converter;
converts the binary word into a sequence of separate digital pulses;

Y: serial to parallel converter converts pulses back to the binary word; ***[3]***

(b) when control pulse is at 0/is at 1 switch connects to input 1 allowing input data 1 to be transmitted;
when control pulse is at 1/is at 0 switch connects to input 2 allowing input data 2 to be transmitted; ***[2]***
If the first marking point specifies 0 second marking point must specify 1 or vice versa.

(c) (i) the loss in power/intensity of the input signal;
due to scattering/absorption/dispersion; ***[2]***

(ii) $\text{power loss} = 10\lg\left[\dfrac{5.0\times10^{-3}}{8.2\times10^{-19}}\right]$;

$= 160\,\text{dB}$;
separation of amplifiers $= 79\,\text{km}$; ***[3]***
Accept 80 km ***do not apply*** *–1(SD).*

Option G — Electromagnetic waves

G1. the light from the sun is scattered by the molecules in the Earth's atmosphere;
blue light is scattered most;
on the moon, there is no atmosphere and no scattering; ***[3]***

G2. (a) the phase between the two sources is changing all the time;
there is interference/superposition between the beams of light;
the interference pattern is changing too rapidly to be observed; ***[3]***
*Award **[2 max]** for a response stating that sources are not coherent so no interference pattern.*

(b) (i) stimulated emission of a group of atoms with a population inversion;
(a single stimulus triggers the) spontaneous production of many other photons simultaneously / *OWTTE*;
photons emitted have same wavelength / phase; ***[2 max]***

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

(c) laser scans the barcode / the laser light is not reflected where the ink is dark;
the reflected light is detected; ***[2]***

(d) distance between maxima is $(100 \times 5) = 500\,\text{m}$;

$L = \dfrac{xd}{\lambda}$;

$L = \left(\dfrac{500 \times 200}{5} = \right) 2.0 \times 10^4\,\text{m}$; ***[3]***

G3. (a) $\dfrac{\text{image height}}{\text{object height}}$ ***or*** $\dfrac{\text{image distance}}{\text{object distance}}$; ***[1]***

(b) (i) $\dfrac{1}{x} = \dfrac{1}{f} - \dfrac{1}{v}$;
substitute to get $x = 13\,\text{cm}$; ***[2]***

(ii) 3.5; ***[1]***

(c) rays striking different parts of the lens are focused to different points / *OWTTE*;
spherical aberration may be reduced by using non-spherical lenses / by using more than one lens / reduce aperture / use centre part of lens only; ***[2]***