M10/4/PHYSI/SP3/ENG/TZ2/XX/M+

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

MARKSCHEME

May 2010

PHYSICS

Standard Level

Paper 3

17 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. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded.

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

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) used in bright light/day-time;
there are three types of cone cells sensitive to different colours;
few are connected to the same nerve implying greater detail of the image formed;
used for photopic vision; ***[1 max]***

(ii) used in dim light/night-time;
insensitive to colour;
different rod cells are connected to the same nerve implying loss of detail in the image formed;
used for scotopic vision; ***[1 max]***

(b) *cone cells*: their distribution increases as the principal axis is approached (reaching a maximum at the fovea) / maximum in centre, fewer away from principal axis;

rod cells: few, near the principal axis, most on the edges of the retina / minimum in centre, more away from principal axis; ***[2]***

(c) since the light is dim rod cells will be used;
and these are mostly on the edge of the retina/they are far from the principal axis; ***[2]***

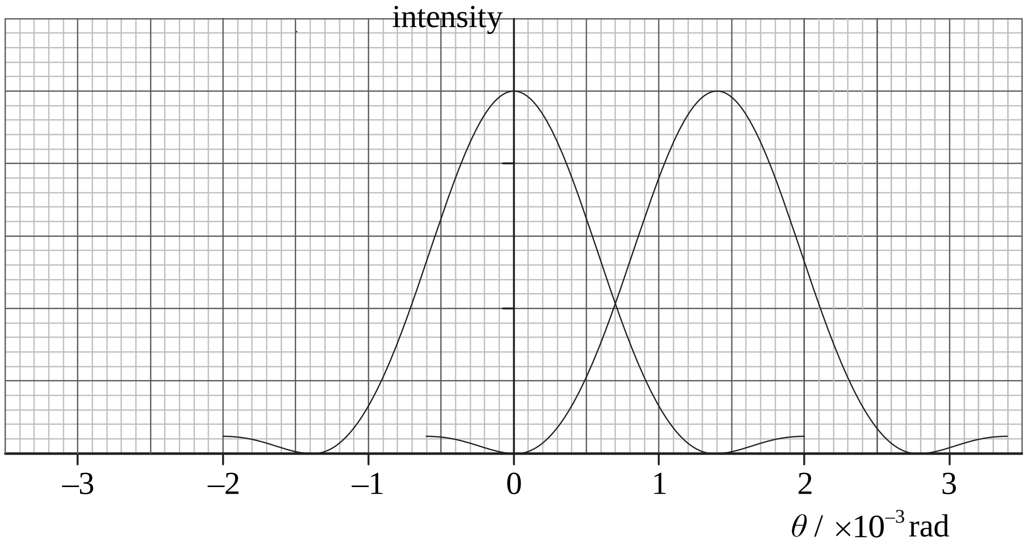
A2. (a) (comparison with the SHM displacement formula shows that) the amplitude is A and this depends on x; ***[1]***

(b) frequency is $\frac{500\pi}{2\pi}$;
$f = 250\,\text{Hz}$; ***[2]***

(c) at $x = 2.0\,\text{m}$, the amplitude is always equal to $A = 12\sin\pi = 0$ as required for a node; ***[1]***

A3. (a) (i) angle of first minimum is 0.0014 rad;
thus $\lambda = b\theta = 0.0014 \times 4.0 \times 10^{-4} = 5.6 \times 10^{-7}$ m; ***[2]***

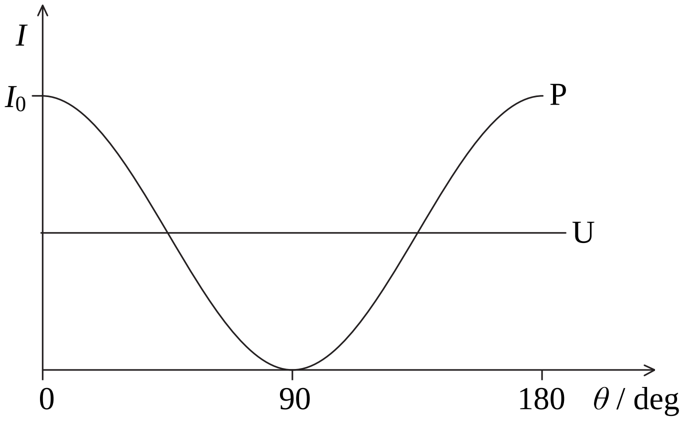
(ii)



as shown above; ***[1]***
Accept if second pattern is drawn to the left of the other.

(b) wavelength is $\left(\frac{3.0 \times 10^{8}}{43 \times 10^{9}}\right) = 7.0 \times 10^{-3}$ m;
telescope can resolve an angular separation of
$\theta = \left(1.22\frac{\lambda}{b} = 1.22\frac{7.0 \times 10^{-3}}{36 \times 10^{3}} = \right) 2.4 \times 10^{-7}$;
and so $L = D\theta = 2.4 \times 10^{-7} \times 4.7 \times 10^{23} = 1.1 \times 10^{17}$ m; ***[3]***

A4.



(a) horizontal line; *(labelled U)*
through half the incident intensity; ***[2]***

(b) curve starting at I_0; *(labelled P)*
with minima and maxima as shown; ***[2]***

Option B — Quantum physics and nuclear physics

B1. (a) light arrives at the surface as <u>photons</u>, each carrying an energy *hf*;
electrons will absorb this energy at one step and so will be emitted immediately / single event, no energy accumulates; ***[2]***

(b) (i) (by extrapolating the line) $\phi = 1.6\times10^{-19}$ J; *(accept answers in the range of 1.5 to 1.8)* ***[1]***

(ii) kinetic energy is $E_K = 1.7\times10^{-19}$ J; *(accept answers in the range of 1.6 to 1.8)*

and so $v = \sqrt{\frac{2\times1.7\times10^{-19}}{9.11\times10^{-31}}}$;

$v = 6.1\times10^{5}$ m s^{-1}; ***[3]***

B2. (a) energy that takes certain values and not others / energy values that are not continuous / energies that give rise to a discreet/line spectrum / transition energies are discreet / *OWTTE*; ***[1]***

(b) (i) choice of levels $n=1$ and $n=2$;

$$\Delta E_{min} = \frac{(6.63\times10^{-34})^2 \times (2^2 - 1^2)}{8\pi (9.11\times10^{-31})(1.0\times10^{-10})^2};$$

$\Delta E_{min} = 5.8\times10^{-18}$ J ***[2]***

The formula has been quoted on the paper. However, accept the use of the formula quoted in the booklet, correctly not including π, leading to a ΔE_{min} *of* 1.8×10^{-17} *J.*

(ii) $\frac{hc}{\lambda} = 5.8\times10^{-18}$ J;

hence $\lambda = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{5.8\times10^{-18}}$;

$\lambda = 3.4\times10^{-8}$ m; ***[3]***

Use of 1.8×10^{-17} *J leads to a* λ *of* 1.1×10^{-8} *m.*

(c) no it cannot;
because the box spectrum has spectral lines crowding in the infrared rather than in the ultraviolet as in the real H spectrum; ***[2]***

Accept any other plausible explanation e.g. the box model does not take into account any electrical potential energy or the hydrogen atom is not one-dimensional or the hydrogen atom is not a box etc.

*Award **[0]** for a bald no and/or a no with an incorrect explanation.*

B3. (a) (i) the probability of decay per unit time (of a particular nucleus) / the constant of proportionality between activity and number of nuclei present; ***[1]***

(ii) expected number to decay is (approximately) $2.0\times10^{12}\times0.048=9.6\times10^{10}$; ***[1]***

or

number decayed is $\Delta N=2.0\times10^{12}\left[1-e^{-0.048}\right]=9.4\times10^{10}$;

Accept either numerical answer. The first estimate is approximate; the discrepancy between the two answers becomes negligible as the decay constant becomes smaller.

(b) (i) (with one isotope present), after each half-life, half the radioactive nuclei would be decaying;
and this is not the case here; ***[2]***

(ii) finding time for number of nuclei to reduce by half by using the extreme right part of the curve which is mainly due to the decay of the other isotope;
to get approximately $0.70\,\text{s}$; *(accept answers in the range of 0.65 to 0.75 s)* ***[2]***

Option C — Digital technology

C1. (a) the potential difference is proportional to the intensity of light;
the position of each pixel is recorded forming an image/an intensity map / *OWTTE*; ***[2]***

(b) (i) the ratio of the number of emitted electrons to the number of incident photons; ***[1]***

(ii) energy supplied is $1.4\times 22\times 10^{-6}\times 85\times 10^{-3} = 2.62\times 10^{-6}\,\text{J}$;

number is $\dfrac{2.62\times 10^{-6}}{3.6\times 10^{-19}} = 7.3\times 10^{12}$;

number per pixel is $\dfrac{7.3\times 10^{12}}{5.0\times 10^{6}}$;

i.e. 1.5×10^{6} ***[3]***

(iii) electric charge created is $0.75\times 1.5\times 10^{6}\times 1.6\times 10^{-19} = 1.8\times 10^{-13}\,\text{C}$;

voltage is $V = \left(\dfrac{Q}{C} = \right)\dfrac{1.8\times 10^{-13}}{12\times 10^{-12}}$;

i.e. $15\,\text{mV}$ ***[2]***

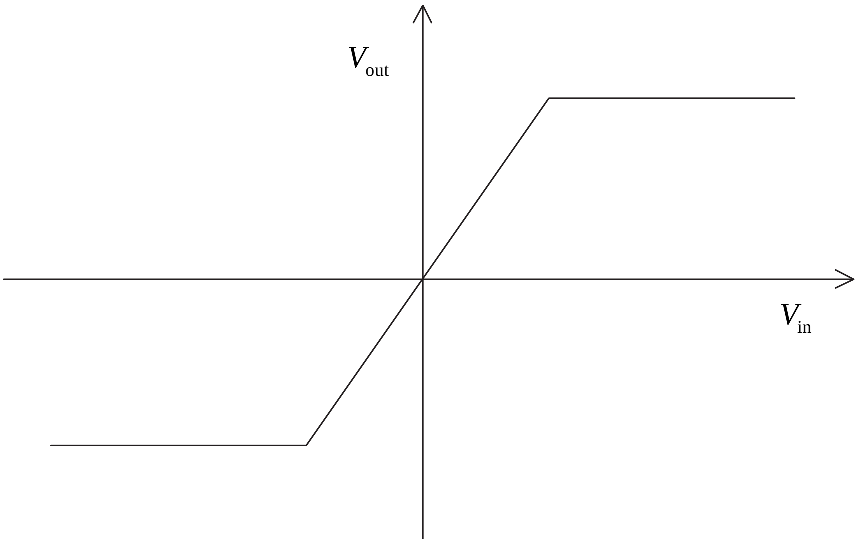
(iv) $15 = 8 + 4 + 2 + 1 = 1111$; ***[1]***

(c) it gives the patient less exposure to X-rays (because a high quantum efficiency detector means the image would be formed quickly); ***[1]***

C2. *base stations*: ***[2* max*]***
located at the centre of a cell receiving and transmitting radio signals from and to mobile phones;
communicates with the cellular exchange;
selects from the frequencies allotted to it by the cellular exchange for a particular call;

cellular exchange: ***[2 max]***
allows entry into the fixed telephone network;
allocates different frequencies to base stations;
in order to avoid interference between different calls;
reroutes calls to different base stations when a mobile phone leaves one cell area and enters another; ***[4 max]***

C3. (a)



linear as shown;
saturation shown; ***[2]***

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

(ii) when the temperature rises above 50°C the resistance of the thermistor falls below *R*;
and so the voltage at the non-inverting input of the op-amp is negative;
(the output voltage then saturates at –12 V) giving the required potential difference for the buzzer to sound; ***[3]***

Option D — Relativity and particle physics

D1. (a) *proper length*:
is the length of an object in the object's rest frame / the length of the object as measured by an observer at rest relative to the object;

proper time interval:
is the time interval between two events taking place at the same point in space / the shortest time interval between two events; ***[2]***

(b) (i) realization that 6.00 s is the proper time;
so that time interval $= \gamma \times 6.00 = 7.50\,\text{s}$; ***[2]***

(ii) realization that 5.00 m is the proper length;
so that length $= \left(\dfrac{5.00}{\gamma} =\right) 4.00\,\text{m}$; ***[2]***
Do not apply SD deduction here.

(c) (i) laser B was fired first; ***[1]***

(ii) during the delay time *T*, space station moved backward a distance $vT = 6.25 - 4.00 = 2.25\,\text{m}$;
and so $T = \left(\dfrac{2.25}{0.600c} =\right) 1.25 \times 10^{-8}\,\text{s}$; ***[2]***

D2. (a) (i) *meson*: $u\bar{d}$;
baryon: sss ; **[2]**

(ii) 0 ***or*** 1 ***or*** –1; **[1]**

(b) two identical fermions cannot occupy the same quantum state; **[1]**

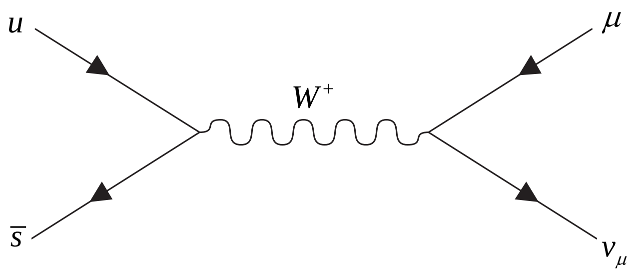
(c) (the three quarks are identical because they also have the same spin in this baryon and so) are distinguished by their three different colour quantum numbers; **[1]**

(d) (i) down; **[1]**

(ii) blue-antired / blue-cyan; **[1]**

(e) violates strangeness conservation which is a property of only the weak interaction; **[1]**

(f)



correct topology as shown above, including arrows;
intermediate particle labelled as W^+;
other four particles $u, \bar{s}, \mu, v_\mu$ labelled at correct position; **[3]**

Option E — Astrophysics

E1. (a) *stars*: $\frac{75}{4.19(17)^3} = 3.6\times10^{-3}\,(\text{ly}^{-3})$;

galaxies: $\frac{26}{4.19\;\;4.0\times10^6\;\;^3} = 9.7\times10^{-20}\,(\text{ly}^{-3})$; ***[2]***

*Award **[1 max]** if the reponse does not use the volume of the sphere but uses the cube instead.*

(b) $\frac{10^{-3}}{10^{-19}} = (3.8\times)10^{16}$ ***or*** star population density greater than galaxies population density by an order of magnitude 16; ***[1]***

E2. (a) (i) luminosity is a function of surface and temperature (of star);
(same class) same temperature (therefore greater surface area); ***[2]***

(ii) $L_C = 80\,L_S$; *(accept answer in the range of 60 to 100)* ***[1]***

(iii) $\frac{L_C}{L_S} = \left[\frac{r_C}{r_S}\right]^2 = 80$;

$r_C^{\ 2} = 80 r_S^{\ 2} \Rightarrow r_C = 8.9 r_S$; ***[2]***

(b) (i) 0.6; *(accept answer in the range of 0.4 to 0.8)* ***[1]***

(ii) $\left(\text{use of } m - M = 5\log\frac{d}{10}\right)$

$0.0 - 0.6 = 5\log\frac{d}{10}$;

$\frac{d}{10} = 10^{-0.12}$;

$d = 7.6\,\text{pc}$; ***[3]***

(iii) Vega appears dimmer;
hence distance over-estimated; ***[2]***

accept:
Vega will look redder (because blue light scatters more in dust);
so Vega looks cooler/lower apparent temperature (thus wrong position on HR diagram);

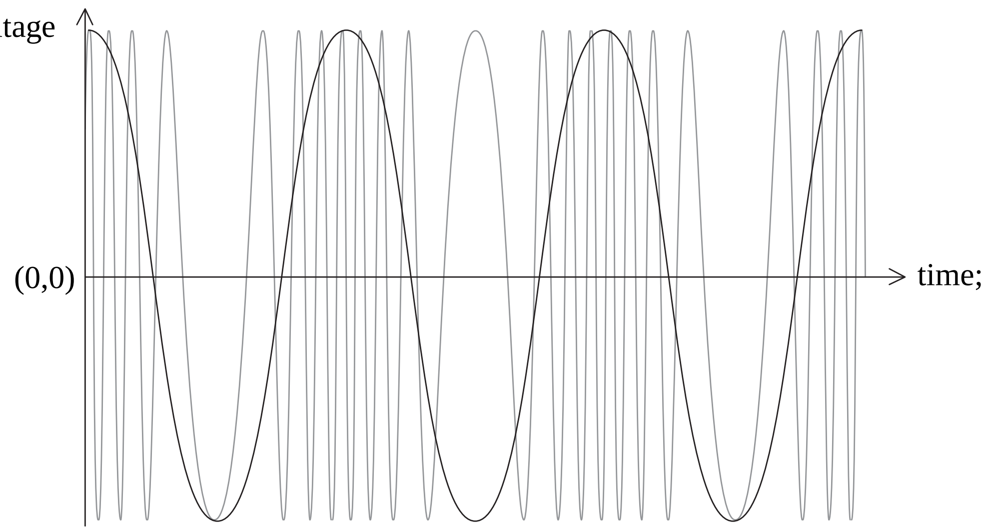
(c) the inward gravitational pressure is balanced by the outward radiative pressure; ***[1]***

E3. (a) (Big Bang theory predicts that CMB will) correspond to the black-body at $3\,\mathrm{K}$;
the graph is of a black-body curve;
$T = \frac{2.9\times10^{-3}}{10^{-3}} \approx 3\,\mathrm{K}$; ***[3]***

(b) measurement of mass in a given volume is (very) uncertain/difficult;
there exists dark matter that is difficult to observe;
measurement of distances is uncertain/difficult;
matter not uniformly distributed; ***[2 max]***

Option F — Communications

F1. (a)



[1]

Accept any signal with this frequency.

(b) FM has a better signal-to-noise ratio (than AM);
noise gets added to amplitude and since FM is modulated by frequency FM is less susceptible to noise; *[2]*

or

FM has a greater bandwidth (than AM);
and so provides for a better quality transmission;

or

in FM most of the power is in the sidebands (where the information is) rather than the carrier;
and so transmissions can take place at less power (than AM);

F2. (a) time between samples $=\frac{1}{8000}=0.125\,\text{ms}$ ***or*** $0.13\,\text{ms}$;
duration of sample $4\times 4.0=0.016\,\text{ms}$;
hence separation $=0.125-0.016=0.109\,\text{ms}$ ***or*** $0.13-0.02=0.11\,\text{ms}$; *[3]*

(b) extra signals may be carried on the same transmission line;
in unused time on the transmission line in between samples; *[2]*

F3. (a) (i) Snell's law: $1.56 \times \sin \theta_C = 1.38 \times \sin 90^\circ$;

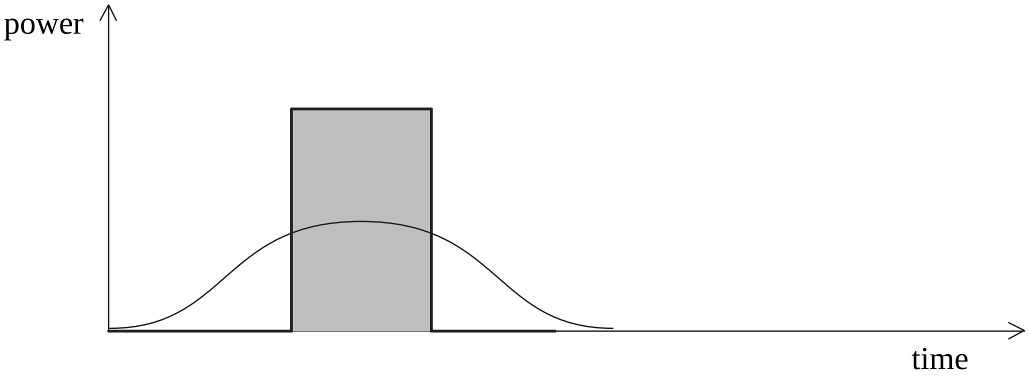
$\theta_C = \sin^{-1} \frac{1.38}{1.56} = 62.2^\circ$; ***[2]***

(ii) realization that angle of refraction in core is $90^\circ - 62.2^\circ$;
Snell's law: $1.00 \times \sin \theta_{max} = 1.56 \times \sin[90^\circ - 62.2^\circ]$;
to give $\theta_{max} = 46.7^\circ$ ***[2]***

(b) modal dispersion is dispersion due to rays of light taking different paths in the fibre;
material dispersion is dispersion due to the dependence of the speed of light on wavelength; ***[2]***

(c) (i) the total energy of the signal; ***[1]***

(ii)



lower <u>and</u> wider;
with a curved (Gaussian-like) shape; ***[2]***
Accept the signal starting at any time position.

(iii) loss in dB is $1.24 \times 3.40 = 4.22\,\text{dB}$;

$-4.22 = 10 \log \frac{P}{15.0}$;

so $P = 15.0 \times 10^{-0.422} = 5.68\,\text{mW}$; ***[3]***

Option G — Electromagnetic waves

G1. (a) *Look for these main points.*
(a metastable state *i.e.*) an excited state in which electrons stay (for unusually) longer times than in normal excited states;
population inversion (in which the number of electrons in a metastable state is larger than in the ground state);
stimulated emission in which an electron of the same energy as the difference in energy of atomic energy levels forces a transition from an excited state; ***[3]***
Mark generously as all of these points may not be expressed precisely.

(b) (the laser light is) monochromatic;
(and) coherent;
unidirectional/single beam; ***[2 max]***

G2. (a) (i) correct general shape with uniform spacing of maxima;
and equal intensity at maxima; ***[2]***
Accept a small reduction in amplitude if consistently shown from peak to subsequent peak.
Award ***[1 max]*** *if minima do not touch horizontal axis.*

(ii) $s = \left(\frac{\lambda D}{d} = \right)\frac{6.80\times10^{-7}\times1.40}{0.120\times10^{-3}}$;
$s = 7.93\,\text{mm}$; ***[2]***

(b) (i) pattern will be shifted horizontally such that the maxima and the minima are interchanged / *OWTTE*;
because the path difference has introduced a path length of $\frac{\lambda}{2}$ / phase difference of π ***or*** 180° ***[2]***

(ii) no change;
since pattern has shifted by a constant amount; ***[2]***

G3. (a) (i) correct use of sign convention $\left(\frac{1}{20}=\frac{1}{24}+\frac{1}{v}\right)$;

$v = 120\,\text{mm}$; ***[2]***

(ii) real because $v > 0$ / image is formed by real rays (and not their extensions) / can be focused on a screen / rays are convergent; ***[1]***

(iii) correct use of sign convention $\left(\frac{1}{60}=-\frac{1}{240}+\frac{1}{u}\right)$;

$u = 48\,\text{mm}$; ***[2]***

(b) $M=\left[\frac{120}{24}\right]\times\left[\frac{240}{48}\right]$ ***or*** $M=\frac{120}{24}\times\left[\frac{240}{60}+1\right]$;

$M = 25$; ***[2]***

*Award **[1 max]** for answer of 20.*