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MARKSCHEME

May 2009

PHYSICS

Standard Level

Paper 3

17 Pages

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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 **no**t 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. Unless directed otherwise in the mark scheme, unit errors 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) Scotopic vision / uses rod cells/is used in low intensity light/does not distinguish between colours/does not see detail;
Photopic vision / uses cone cells/is used in high intensity light/distinguishes colours/sees detail; ***[2]***

(b) Scotopic vision using rods is to be used;
sensitivity for blue wavelengths is high for rod cells;
and so blue will be seen most clearly;
*Award **[0]** for bald answer, blue only, or incorrect argument.* ***[3]***

(c) (i) $\theta = \left(\frac{1.22\lambda}{d} = \frac{1.22 \times 680 \times 10^{-9}}{1.5 \times 10^{-3}} = \right) 5.5 \times 10^{-4}$ rad; ***[1]***

Accept answer missing the factor of 1.22 i.e. 4.5×10^{-4} *rad .*
Do not penalize absence of rad.

(ii) $d = \left(\frac{s}{\theta} = \right) \frac{4.0 \times 10^{13}}{5.5 \times 10^{-4}}$;
$d = 7.2 \times 10^{16}$ m; ***[2]***

Accept answer that uses rounded answer from (i) i.e. $d = 7.3 \times 10^{15}$ *m or has missed the factor of 1.22 i.e.* $d = 8.9 \times 10^{15}$ *m .*

A2. (a) light in which the electric field is oscillating on only one plane; ***[1]***

(b) (i) refracted ray shown <u>at right angles</u> to reflected ray; ***[1]***
Judge by eye.

(ii) $\sin\varphi = n\sin(90^o - \varphi)$;
$\sin\varphi = n\cos\varphi$;
$n = \tan\varphi$; *(this marking point must be justified)* ***[3]***

(iii) $\varphi = 52^\circ$ ***or*** 0.92 rad; ***[1]***

A3. (a) the change in the observed frequency;
when there is <u>relative</u> motion between the source and the observer / when either source or osbserver is moving; ***[2]***

(b) (i) Doppler effect occurs twice / moving detector (blood cells) and moving source (blood cells in reflection) / "image" source moves at twice velocity of red blood cells / *OWTTE*; ***[1]***

(ii) $\Rightarrow\left(\frac{3.5}{5.2\times10^{3}}=\frac{2v}{1.5\times10^{3}}\Rightarrow\right)v=0.50\text{ m s}^{-1}$;
Accept 1.0×10^{5} *ms*$^{-1}$ *if* 3.0×10^{8} *ms*$^{-1}$ *has been used for c.* ***[1]***

or

use of Doppler formulas to give

$$\left(f''=f\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)\Rightarrow 5.2\times10^{3}-3.5=5.2\times10^{3}\frac{1-\frac{v}{1.5\times10^{3}}}{1+\frac{v}{1.5\times10^{3}}}$$

$\therefore v=0.50\text{ m s}^{-1}$;

(iii) the blood cells have a range of speeds;
the direction at which the ultrasound is incident on the cells varies / cells are rotating/tumbling / ultrasound reflects from objects other than blood cells; ***[2]***

Option B — Quantum physics and nuclear physics

B1. (a) eject an electron from the surface a minimum amount of energy/the work function must be supplied;
light consists of photons;
each photon has energy hf ***or*** $\frac{hc}{\lambda}$;
if the wavelength is not below a certain maximum, the energy carried by a photon cannot supply the minimum amount of energy required; ***[3 max]***

(b) (i) $I = \left(\frac{\Delta Q}{\Delta t} = 1.6 \times 10^{-19} \times 4.0 \times 10^{10}\right) = 6.4 \times 10^{-9}$ A; ***[1]***

(ii) $\phi = \frac{hc}{\lambda_{\text{max}}} = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{5.50 \times 10^{-7}}$;
$\phi = 3.6 \times 10^{-19}$ ***or*** 2.3 eV; ***[2]***

(iii) $P = N\frac{hc}{\lambda}$ where N is the number of photons emitted per second;
and so $N = \frac{3.0 \times 4.60 \times 10^{-7}}{6.63 \times 10^{-34} \times 3.00 \times 10^{8}} = 6.9 \times 10^{18}$;

ratio of electrons to photons is $\left(\frac{4.0 \times 10^{10}}{6.9 \times 10^{18}} =\right) 5.8 \times 10^{-9}$; ***[3]***

(c) (the wavelength is larger than the maximum necessary for ejection of electrons and so) the current will be zero; ***[1]***

B2. (a) the wave function (squared) is a property of the electron that gives/is a measure of/is proportional to the <u>probability</u> of finding the electron somewhere; ***[1]***

(b) (i) the wavelength of the electron is $\left(\frac{2.0 \times 10^{-10}}{6} =\right) 3.3 \times 10^{-11}$ m;
and so $p = \left(\frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{3.3 \times 10^{-11}} =\right) 2.0 \times 10^{-23}$ N s; ***[2]***

(ii) uncertainty in position is $\Delta x = 2.0 \times 10^{-10}$ m;
and so the uncertainty in momentum is
$\Delta p = \left(\frac{h}{4\pi \Delta x} = \frac{6.63 \times 10^{-34}}{4\pi \times 2.0 \times 10^{-10}} =\right) 2.6 \times 10^{-25}$ N s;
Accept use of $\Delta x = 1.0 \times 10^{-10}$ and $\Delta p = 5.3 \times 10^{-25}$ *N s.* ***[2]***

B3. (a) $\lambda = \left(\frac{hc}{\Delta E}\right) = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{4.4\times10^{6}\times1.6\times10^{-19}}$;

$= 2.8\times10^{-13}$ m; ***[2]***

(b) $13.4 - 4.4 = 9.0$ MeV; ***[1]***

(c) neutrino / another particle <u>is produced</u> in beta decay;
and therefore the energy of 9.0 MeV is shared between the produced particles; ***[2]***

Option C — Digital technology

C1. (a) $d = \frac{\lambda}{4}$;
rays reflected from land and pit interfere;
path difference is $2d$;
destructive interference takes place if path difference is $\frac{\lambda}{2}$; ***[4]***

(b) $d = \left(\frac{640}{4} = \right) 160\,\text{nm}$; ***[1]***

(c) (i) number of pits $= \frac{5 \times 10^3}{2 \times 1900 \times 10^{-9}}$;
$= 1.32 \times 10^9$

number of bits $= 4 \times 1.32 \times 10^9 (= 5.3 \times 10^9)$;
$\approx 5 \times 10^9$ ***[2]***

(ii) $5 \times 10^9 = 44.1 \times 10^3 \times 2 \times 16 \times t$;
$t = \left(\frac{5 \times 10^9}{44.1 \times 10^3 \times 2 \times 16} = 3.5 \times 10^3\ \text{s} = \right) 59\,\text{min} \approx 60\,\text{min}$; ***[2]***

(d) easier to transport;
takes up less space;
less noise/distortion during playback;
play stored items in any order;
less liable to damage; ***[1 max]***

C2. (a) the sign of the output voltage is the same as that of the input voltage; ***[1]***

(b) (i) $G = \left(1 + \frac{90}{10} = \right) 10$; ***[1]***

(ii) $V_{\text{out}} (= GV_{\text{in}} = 10 \times 2.0) = 20\,\text{mV}$; ***[1]***

(c) op-amp has a high input resistance and so takes little current;
(open loop) gain is very large so potential difference between non-inv input and inv input is (effectively) zero;
i.e. $V_{\text{out}} = V_{\text{in}}$;
so $G = 1$ ***[3]***

(d) (i) $3.0\,\text{V}$; ***[1]***

(ii) the resistance between A and B is smaller than $2\,\text{M}\Omega$ / the voltmeter draws current; ***[1]***

(iii) the voltmeter reads the output voltage of the amplifier and the input voltage is the potential difference to be measured;
the two are equal since the gain is 1; ***[2]***

Option D — Relativity and particle physics

D1. Hermann measures a zero time difference between the arrival of the light pulses; because these occur at the same point in space this is a proper time interval;
so any other observer will measure a time interval of $= \gamma \times 0 = 0$ *i.e.* events will be simultaneous; ***[3]***
*Award **[2 max]** for an answer based on "events are simultaneous in one frame and occurring at the same point therefore are simultaneous for everybody".*

D2. (a) (i) $\left(\dfrac{52\text{ ly}}{0.80c}\right) = 65\,y$; ***[1]***

(ii) $\left(\dfrac{52\text{ly}}{\frac{5}{3}}\right) = 31.2\text{ly} \simeq 31\text{ly}$; ***[1]***

(iii) time to reach planet according to spacecraft is $\left(\dfrac{31.2\text{ly}}{0.80c}\right) = 39\text{ y}$;
so Amanda is 59 years old;

or

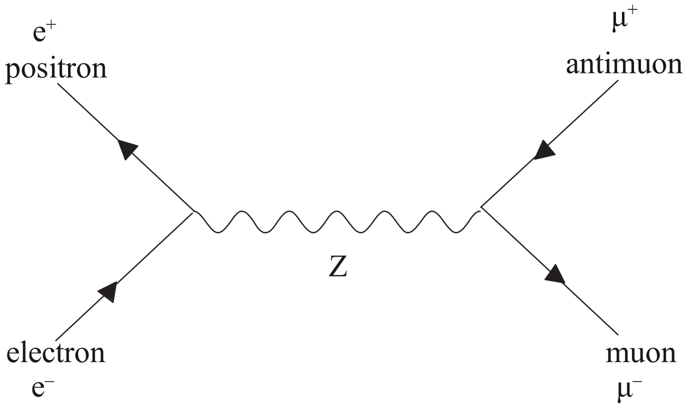
leaving earth and arriving at planet occur at the same point for Amanda;
so time taken is $\dfrac{65}{\frac{5}{3}} = 39\text{ y}$, hence age is 59 years old; ***[2]***

(b) let the required time be denoted by T
signal reaches Earth after travelling a distance of cT;
this distance is 31.2 ly plus the distance travelled by earth in time T *i.e.* $31.2 + 0.80cT$;
$cT = 31.2 + 0.80cT \Rightarrow T = 156\text{ yr}$; ***[3]***
*Award **[2]** for use of ct = 0.80 ct + 52 and an answer for 260 years.*

or

the events "spacecraft leaves Earth" and "signal arrives at Earth" are separated by a proper time interval for the earth observers;
this time interval is 65 + 52 = 117 yr;
so spacecraft observers measure a time interval of $\frac{5}{3} \times 117 = 195$ yr so signal takes $195 - 39 = 156$ yr to arrive on Earth;

D3. (a) (i)



[1]

*Award **[0]** if arrow directions are not consistent with labels.*

(ii) Z^0; ***[1]***

(b) realization that the distance 9×10^{-19} m is the range of the interaction;

$m=\left(\frac{h}{4\pi Rc}=\right)\frac{6.63\times10^{-34}}{4\pi\times9\times10^{-19}\times3\times10^{8}}$;

$m=1.95\times10^{-25}\approx2\times10^{-25}$ kg ***or*** 1×10^{2} GeV c^{-2}; ***[3]***

D4. (a) (i) circle around the point with $Q = S = 0$; ***[1]***

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

(b) weak;
the reaction violates strangeness;
the other interactions conserve strangeness/only the weak interaction violates strangeness;

or

weak;
the reaction changes quark flavour;
and only the weak does that; ***[3]***

Option E — Astrophysics

E1. (a) apparent magnitude is a measure of how bright a star appears from Earth;
absolute magnitude is a measure of how bright a star would appear from a distance of 10 pc; ***[2]***

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

(ii) stars differ by $\Delta M = 16$;
for $\Delta M = 1$ we have a ratio of luminosities by a factor of $\sqrt[5]{100} \approx 2.51$ ***or*** 2.5;
so $\frac{L_A}{L_E} = \left(\sqrt[5]{100}\right)^{16} \approx 2.5 \times 10^6$ ***or*** 2.3×10^6; ***[3]***
Award ***[2 max]*** *for use of apparent magnitude difference and an answer for the ratio of* 6.3×10^5.

(iii) $d = \left(10 \times 10^{\frac{m-M}{5}}\right)$;
$\approx 10 \times 10^{\frac{3.5}{5}}$;
≈ 50 pc ***[2]***

(c) $\frac{L_M}{L_A} = 1$;
$1 = \frac{\sigma 4\pi R_M^2 T^4}{\sigma 4\pi R_A^2 (5T)^4}$;
$\frac{R_M}{R_A} = 25$; ***[3]***

(d) it has to be hot star/a B star;
with low luminosity/high <u>absolute</u> magnitude;
hence EG129; ***[3]***

E2. (a) $T = \dfrac{2.9 \times 10^{-3}}{1.07 \times 10^{-3}}$;
$T = 2.7\ \text{K}$; ***[2]***
Accept wavelengths in the range 1.05 to 1.10 for a temperature range 2.64 to 2.76 K.
*Award **[0]** for bald answer.*

(b) according to the Big Bang model the temperature of the universe (and the radiation it contained) in the distant past was very high;
the temperature falls as the universe expands and so does the temperature of the radiation in the universe; ***[2]***

(c) (Hubble's law shows that) the universe is expanding;
therefore in the distant past the universe must have been a very small/hot/dense point-like object;

or

Doppler shift of spectral lines;
indicates galaxies moving away so in the past they were close to each other; ***[2]***

Option F— Communications

F1. (a) (i) 3.0 MHz; ***[1]***

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

(iii) 80 kHz; ***[1]***

(b) $\left(\frac{320}{80}\right)=4$; ***[1]***

F2. (a) P: analogue signal is sampled at the sampling frequency and stored;
Q: each sample is converted into a binary word (in the diagram a word of 4-bits);
R: parallel to serial converter / *OWTTE*;
S: the digital signal converted into an analogue signal; ***[4]***

(b) (i) $15=\left(1\times 2^3+1\times 2^2+1\times 2^1+1\times 2^0\right)=1111$; ***[1]***
Award ***[1]*** *for bald answer.*

(ii) bit-rate = $f_{\text{sampling}}\times$ bits per word

sampling frequency is $\left(\frac{1}{0.01\times 10^{-3}}\right)=100$ kHz;

$100\times 4=400$ kHz; ***[2]***

(c) *advantage*:
signal can be reconstructed more accurately from its samples;

disadvantage:
more memory/storage space is required/increased bit-rate required; ***[2]***

F3. (a) *attenuation*:
impurities in the glass core of the fibre;

dispersion:
material dispersion *i.e.* dependence of refractive index on wavelength/
modal dispersion *i.e.* rays of light of the same wavelength that follow different paths along the fibre; ***[2]***

(b) (i) loss of $5.4 \times 2.8 = 15\ \text{dB}$;

$\left(-15 = 10\log\frac{80}{P} \Rightarrow\right) P = 2.5\ \text{mW}$; ***[2]***

(ii) 15 dB; ***[1]***
Watch for e.c.f. from (i).

(c) after amplification the signal and noise powers are

$\left(15 = 10\log\frac{P'_{\text{signal}}}{P_{\text{signal}}} \Rightarrow\right) P'_{\text{signal}} = 10^{1.5} P_{\text{signal}}$ and $P'_{\text{noise}} = 10^{1.5} P_{\text{noise}}$;

and so the new signal-to-noise ratio is $10\log\frac{P'_{\text{signal}}}{P'_{\text{noise}}} = 10\log\frac{P_{\text{signal}}}{P_{\text{noise}}} = 20\ \text{dB}$; ***[2]***

Accept for full marks answers that state that both signal and noise get amplified by the same amount and so SNR remain the same.

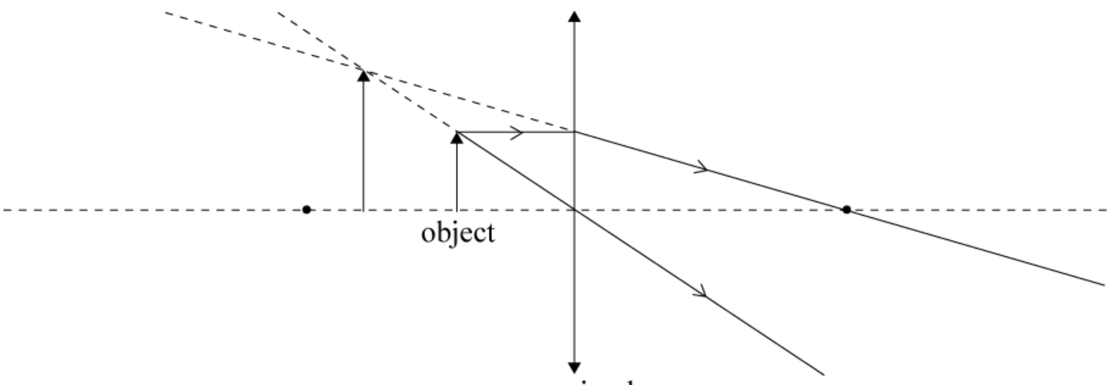
Option G — Electromagnetic waves

G1. *blue sky*:
(the colour of the sky in the course of a clear day) is determined by the colour that scatters the most;
and that the colour is blue $\left(\text{since the amount of scattering is proportional to } \frac{1}{\lambda^4}\right)$; ***[2]***

red sky:
during sunset light has to travel a very long distance through the atmosphere;
most of the blue has been scattered away, leaving behind red; ***[2]***
No ECF if first marking point is wrong.

G2. (a) the nearest point at which the human eye can focus comfortably/without straining; ***[1]***

(b) *Award **[1]** for each correct ray.* ***[2]***



Accept ray passing through left focal point and emerging parallel to the principal axis.
Arrows are not required on the rays.

(c) (i) $\frac{1}{u} = \frac{1}{9.0} - \left[-\frac{1}{25}\right]$;
$u = 6.6\ \text{cm}$; ***[2]***

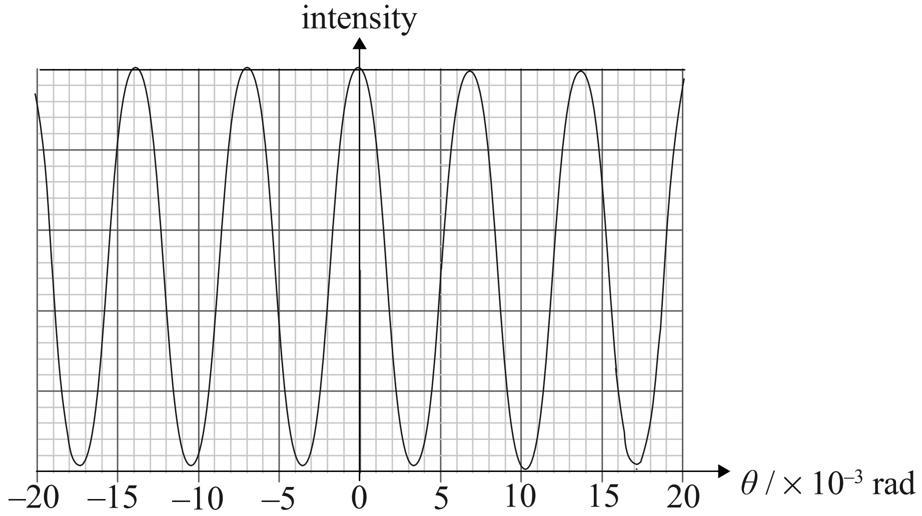
(ii) $M = \left(1 + \frac{25}{9.0} = \right) 3.8$; ***[1]***
Accept answer that uses lateral magnification which, in this case, gives the same answer.

(d) aberrations (spherical/chromatic) increase; ***[1]***

G3. (a) (i) at $\theta = 0$ the path difference (between light from the two slits) is zero;
and so constructive interference takes place; ***[2]***

(ii) $\sin\theta = \frac{\lambda}{d} = \frac{6.80\times10^{-7}}{1.13\times10^{-4}}$;
6.02×10^{-3} rad; ***[1]***

(iii) spacing of maxima by 6.02×10^{-3} rad;
equal heights of maxima / maxima decreasing to the sides due to diffraction effects;
maximum at zero; ***[3]***



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

(ii) stays the same; ***[1]***

(iii) gets smaller; ***[1]***