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MARKSCHEME

May 2010

PHYSICS

Standard Level

Paper 3

16 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. 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 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 writing ***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. Indicate this with **ECF** (error carried forward).

10. Only consider units at the end of a calculation. Omission of units should only be penalized once in the paper. Indicate this by writing **–1(U)** at the first point it occurs and **U** on the cover sheet.

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*

Indicate the mark deduction by writing **–1(SD)** at the first point it occurs and **SD** on the cover sheet.

Option A — Sight and wave phenomena

A1. (a) ability to focus light / see clearly images;
of objects that are at different distances from the eye; ***[2]***

(b) (ciliary) muscles;
change shape of lens / change focal length of lens;
thicker lens / more curvature, focus for objects nearer the eye; ***[3]***

(c) extra red colour/longer wavelengths gives impression of warmth;
additional blue colour/shorter wavelengths gives impression of cold; ***[2]***

A2. (a) (i) ***either***

observer sees image of blood cell;
moving at twice speed of blood cell;

or

Doppler shift "observed" by blood cell;
superposed on shift when cell acts as moving source; ***[2]***
*Award **[1]** if mentioned that Doppler effect occurs twice.*

(ii) need component of velocity of cell along direction of ultrasound beam; ***[1]***

(b) $740 = \frac{2 \times 4.5 \times 10^{6} \times v \times \cos 40}{1.5 \times 10^{3}}$;
$v = 0.16\ \text{m s}^{-1}$; ***[2]***
*Award **[1]** if the speed of light is used.*

A3. (a) light with (electric field vector) vibrating in one direction only;
in plane normal to direction of energy transfer; ***[2]***

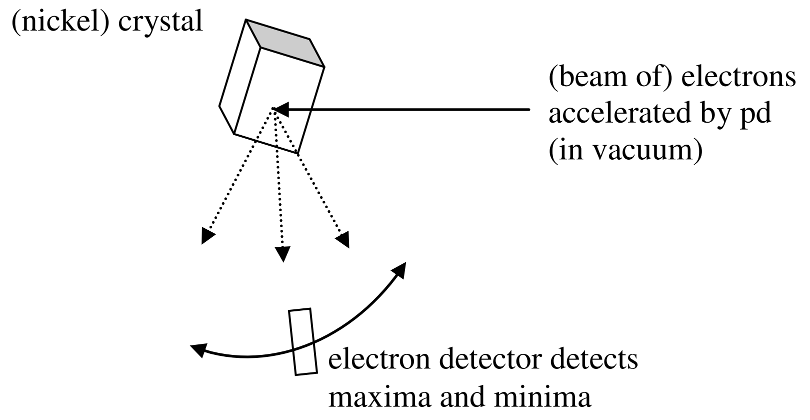
(b) model made of perspex/polythene *etc.*;
light passed through crossed polaroids;
with model between the polaroids;
when stressed, ***either*** colours seen if white light used
or light & dark regions seen if monochromatic light used;
colour/shade depends on degree of stressing;
stress causes rotation of plane of polarization in perspex; ***[6]***

Option B — Quantum physics and nuclear physics

B1. (a) all particles have an associated wavelength / *OWTTE*;

wavelength is given by $\lambda = \frac{h}{p}$, where h is Planck's constant and p is momentum; ***[2]***

(b) (beam of) electrons accelerated through a potential difference (in a vacuum);
incident on (nickel) crystal;
scattered beam shows maxima and minima (at specific positions of detector); ***[3]***
Above points could be indicated in a diagram such as the one below:



(c) $E_K = eV = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$;

$\lambda = \frac{h}{\sqrt{2meV}}$;

$\lambda = \frac{6.6\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times1.6\times10^{-19}\times150}}$;

$\lambda = 1.0\times10^{-10}\text{m}$ ***[3]***

B2. (a) using conservation of energy, Initial $E_K = E_P$;

$E_K = 5.0\,\text{MeV} = 5.0\times1.6\times10^{-13} = 8.0\times10^{-13}\,\text{J}$;

$E_P = \frac{k.2e.79e}{d}$;

$d\left(= \frac{9.0\times10^9\times2\times79\times\left[1.6\times10^{-19}\right]^2}{8.0\times10^{-13}}\right) = 4.6\times10^{-14}\,\text{m}$; ***[4]***

Accept answers that combine any of the above steps.

B3. (a) (i) in a discrete energy spectrum, the energy is restricted to certain values / in a continuous energy spectrum, the energy can take on any value / *OWTTE*; ***[1]***

(ii) total energy of decay is constant;
energy is shared between positron and neutrino; ***[2]***

(b) (i) the probability of decay of a nucleus per unit time; ***[1]***
Accept ln 2/T provided T is identified as the half-life.

(ii) $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = \frac{\ln 2}{2.6} = 0.27\ \text{yr}^{-1}$ ***or*** $8.5 \times 10^{-9}\,\text{s}^{-1}$; ***[1]***

(iii) $A = A_0 e^{-\lambda t}$;
$= 6.2 \times 10^9 \times e^{-0.27 \times 8.0}$;
$= 7.2 \times 10^8\,\text{Bq}$; ***[3]***

Option C — Digital technology

C1. (a) *analogue:* continuously variable (between two limits);
digital: two states only / discrete; ***[2]***

(b) (i) *e.g.* video tapes / LPs; ***[1]***

(ii) *e.g.* floppy discs / CDs; ***[1]***

(c) reason: better quality reproduction;
explanation: because noise can be eliminated / signals can be re-shaped;
reason: faster retrieval;
explanation: switching on-off only;
reason: ease of portability;
explanation: high density of information storage / little physical space required for storage; ***[4 max]***
Accept any two of the above reason and explanation.

(d) amount of data generated increasing rapidly, so harder to store;
difficult to catalogue so much information;
personal data can be easily stored and accessed;
flawless copying leads to increased piracy / copyright issues;
requires many data centres that consume a lot of power;
data needs to be backed up in case of hardware/software failure;
one mouse click can lose huge amount of data;
ease of losing portable data storage devices; ***[2 max]***
Accept any other sensible suggestion.

C2. (a) gain $=1+\frac{R_F}{R_{\text{IN}}}$;
$=1+\frac{10}{2}=6$; ***[2]***

(b) (i) 5.4 V;
negative; ***[2]***

(ii) 9.0 V; ***[1]***

C3. when switched on, phone sends out (identifying) signal;
picked up by base station<u>s</u>;
communicated by base stations to cellular exchange;
computer at cellular exchange;
selects base station with strongest signal;
allocates carrier wave frequency / channel;
and time slot; ***[5 max]***

Option D — Relativity and particle physics

D1. (a) a co-ordinate system (in which measurements of distance and time can be made); which is not accelerating/in which Newton's laws are valid; ***[2]***

(b) (i) $\text{Time}=\frac{\text{Distance}}{\text{Speed}}\left(=\frac{8.8}{0.80}\right)=11$ years; ***[1]***

(ii) Ann;
according to Ann, the two events of leaving Earth and arriving at Sirius occur at the same point in space; ***[2]***
*Award **[0]** for bald correct answer or incorrect explanation.*

(iii) $\gamma=\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\left(=\frac{1}{\sqrt{1-\frac{0.8^2c^2}{c^2}}}=1.667\right)\approx 1.7$;

Time for Ann $\left(=\frac{11}{1.667}=\right)6.6$ years; ***[2]***

(iv) let t be the time signal takes to reach Earth according to Ann. In this time, Ann would move further away from the Earth by the distance vt, where $v=0.80\text{c}$;
starship and Earth originally separated by 5.28 light-years, according to Ann;
so $5.28=ct-vt\Rightarrow t\left(=\frac{5.28\text{ light years}}{\text{c}-0.8\text{c}}\right)=26$ years; ***[3]***

D2. (a) (i) W^+ / W^- / Z^0 (boson); ***[1]***
Do not insist on superscripts.

(ii) photon / γ; ***[1]***

(b) range of interaction is inversely proportional to mass of exchange particle / range of interaction is given by $\frac{h}{4\pi mc}$ <u>with symbols defined</u>;
bosons have mass, photons do not, hence range of electromagnetic interaction is infinite, range of weak interaction is finite / *OWTTE*; ***[2]***

(c) electromagnetic interaction between two electrons / electron-electron scattering / collision of electron with electron; ***[1]***

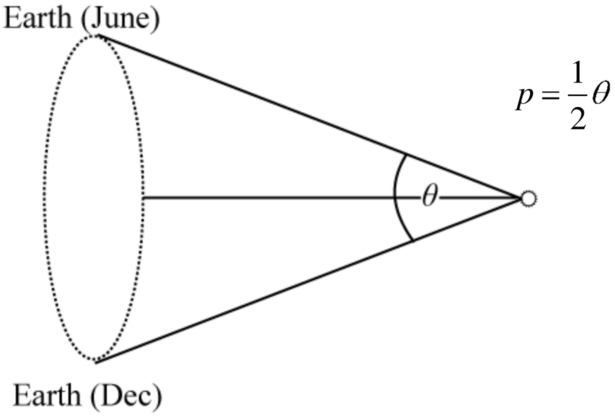
(d) a particle that appears as an intermediate particle in a Feynman diagram / a particle that is not (directly) observed / (temporarily) violates energy/momentum conservation; ***[1]***

(e) $\Delta E \Delta t \geq \frac{h}{4\pi}$ with symbols defined;
virtual photon can exist, temporarily breaching energy conservation, for a time that depends on its energy; ***[2]***

(f) $\Delta E = \frac{h}{4\pi \Delta t}$;
$\left(= \frac{6.6 \times 10^{-34}}{4\pi \times 1.6 \times 10^{-16}} \right) = 3.3 \times 10^{-19}$ J; ***[2]***

Option E — Astrophysics

E1. (a) (i)



angular position of star measured;
relative to the background of fixed stars;
in two positions six months apart;
p is $\frac{1}{2}$ of the angle of separation / p indicated on diagram; ***[4]***

(ii) $d = \frac{1}{p}\left(= \frac{1}{0.419} = 2.3866 \text{ pc}\right) \approx 2.39 \text{ pc};$
$= 2.3866 \times 3.26 \text{ ly} = 7.78 \text{ ly};$ ***[2]***
*Award **[2]** for bald correct answer.*

(iii) beyond this distance the parallax angle is too small to be measured (accurately) / *OWTTE*; ***[1]***

(b) $L = 4\pi d^2 b;$

$\frac{L_w}{L_s} = \frac{d_w{}^2 b_w}{d_s{}^2 b_s};$

$d_s = 1 \text{ AU}, d_w = 7.78 \times 6.3 \times 10^4 = 4.9 \times 10^5 \text{ AU};$

$\frac{L_w}{L_s} = [4.9 \times 10^5]^2 \times 3.7 \times 10^{-15} = 8.9 \times 10^{-4};$ ***[4]***

Allow ECF from (a)(ii).

(c) $A = \frac{L}{\sigma T^4}\left(= \frac{3.5 \times 10^{23}}{5.7 \times 10^{-8} \times 2800^4}\right) = 1.0 \times 10^{17} \text{ m}^2;$

$r = \sqrt{\frac{A}{4\pi}}\left(= \sqrt{\frac{1.0 \times 10^{17}}{4\pi}}\right) = 8.9 \times 10^7 \text{ m};$ ***[2]***

(d) temperature too low to be white dwarf;
luminosity too low to be red giant;
radius too small to be a red giant; ***[2 max]***
Answer must be consistent with answer in (c) for third marking point.

E2. (a) density at which universe will expand forever but rate of expansion will approach zero / the density at which the universe will begin to contract after infinite amount of time / the density for which the curvature of the universe is zero / *OWTTE*; ***[1]***
Reference to "flat" model without definition does not gain mark.

(b) value of density determines whether or not universe will expand forever, or at some point, begin to contract;
at density less than critical density, universe will expand forever;
at density greater than critical density, universe will stop expanding and contract; ***[3]***
If second and third marks gained, first mark is also gained by implication.

(c) dark matter does not radiate/cannot be directly measured/seen; ***[1]***

Option F— Communications

F1. (a) (i) (amplitude / frequency of) wave is modified/changed; ***[1]***

(ii) to carry information; ***[1]***

(b) amplitude constant (at 8.0 V);
frequency changes by ± 18 kHz;
from 482 kHz to 518 kHz and back to 482 kHz;
2500 times per second; ***[4]***

F2. (a) (i) area (under line) represents energy;
smaller area so energy loss; ***[2]***

(ii) (output) curve is not smooth;
showing random additional power/energy; ***[2]***
*Accept for **[1]** height in output power curve is smaller.*

(b) (i) material dispersion (dependence of wave speed on wavelength);
modal dispersion (dependence of wave speed on path taken); ***[2]***
*Award **[1]** if only dispersion is mentioned.*

(ii) pulses would overlap; ***[1]***

F3. (a) (i) satellite that orbits with a period of 24 hours / same period of rotation as Earth;
hence remaining above the same position on the Earth's surface/above equator; ***[2]***

(ii) do not need to be tracked;
can be used for continuous communication; ***[2]***

(b) polar-orbiting satellite closer to Earth's surface / lower orbit;
so less expensive to put into orbit;
so lower power signals required;
so time delay between transmission and reception less; ***not** faster speed of transmission*
covers whole of Earth's surface during several orbits;
so communication over whole of surface; ***[3 max]***

Option G — Electromagnetic waves

G1. (a) (i) between lenses and between eye lens and F; *[1]*

(ii) further from eye lens than image X and same distance from eye lens for both points; (*judge by eye*) *[1]*

(iii) final image near object and not between lenses; *[1]*
Accept markings of positions even when shown off the principal axis except for the focal points.

(b) central cross shown straight;
sides curved (outwards or inwards); *[2]*

(c) lens has different refractive indices for different wavelengths/colours;
so each wavelength/colour has a different focal length; *[2]*

G2. (a) (i) λ_{red} : allow 620 nm → 780 nm; *[1]*

(ii) λ_{blue} : allow 320 nm → 480 nm; *[1]*

(b) light travels (towards observer) further through atmosphere at sunset (compared to during the day);
(short wavelength) blue light scatters the most;
and so with blue removed (from the light reaching the observer) the Sun looks red; *[3]*
Award second and third marks for reversal of wavelengths in (a).

G3. (a) (i) (light from the slits has) constant phase difference; ***[1]***

(ii) when two (or more) waves meet;
resultant displacement;
is sum of individual displacements; ***[3]***

or

when the path difference;
is an integral/half-integral multiple of the wavelength;
constructive/destructive interferences take place;
Allow amplitude for 3rd mark.

(b) $x = \frac{\lambda d}{a} \quad = \frac{640 \times 10^{-9} \times 2.4}{0.85 \times 10^{-3}}$;
$= 1.8 \times 10^{-3}\,\text{m}$; ***[2]***

(c) bright fringes are less bright;
dark fringes are brighter; ***[2]***