IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

N04/4/PHYSI/SP3/ENG/TZ0/XX/M+

MARKSCHEME

NOVEMBER 2004

PHYSICS

Standard Level

Paper 3

16 pages

General Marking Instructions

Subject Details: Physics SL Paper 3 Markscheme

General

A markscheme often has more specific points worthy of a mark than the total allows. This is intentional. Do not award more than the maximum marks allowed for part of a question.

When deciding upon alternative answers by candidates to those given in the markscheme, consider the following points:

- Each marking point has a separate line and the end is signified by means of a semicolon (;).
- An alternative answer or wording is indicated in the markscheme by a "/"; either wording can be accepted.
- Words in ( ) in the markscheme are not necessary to gain the mark.
- The order of points does not have to be as written (unless stated otherwise).
- If the candidate's answer has the same "meaning" or can be clearly interpreted as being the same as that in the mark scheme then award the mark.
- Mark positively. Give candidates credit for what they have achieved, and for what they have got correct, rather than penalising them for what they have not achieved or what they have got wrong.
- Occasionally, a part of a question may require a calculation whose answer is required for subsequent parts. If an error is made in the first part then it should be penalized. However, if the incorrect answer is used correctly in subsequent parts then **follow through** marks should be awarded.
- Units should always be given where appropriate. Omission of units should only be penalized once. Ignore this, if marks for units are already specified in the markscheme.
- Deduct **1 mark in the paper** for gross sig dig error *i.e.* for an **error of 2 or more digits**.

e.g. if the answer is 1.63:

2	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

However, if a question specifically deals with uncertainties and significant digits, and marks for sig digs are already specified in the markscheme, then do **not** deduct again.

Option A — Mechanics Extension

A1. (a) attractive force is proportional to the product of the point masses;
and inversely proportional to the square of the separation; ***[2]***
*Award **[1]** if the response is not clear that they are point masses or if the force is attractive. Award **[0]** for quoting the formula from data booklet without any further explanation.*

(b) use of $g = \frac{GM}{r^2}$;

appropriate substitution: $g = \frac{6.67\times10^{-11}\times6.0\times10^{24}}{(6.4\times10^{6})^2} = 9.77 \approx 10\,\text{N kg}^{-1}$; ***[2]***

(c) (i) point marked on Earth's surface that is nearest to Moon;
since force of attraction from Moon greatest; ***[2]***
Accept other sensible comment.

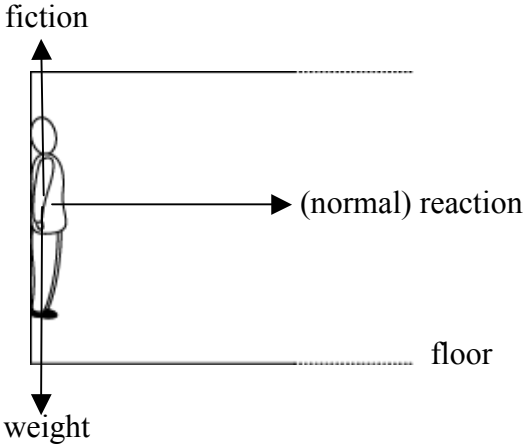
(ii) same point as above; (*accept point on directly opposite side of Earth*)
explanation of why the resultant field is a minimum at this point
e.g. forces from Earth and Moon are in opposite directions; ***[2]***

(iii) each relevant point;
e.g. Earth is rotating;
Moon orbits the Earth *etc.*;
position of Sun also affects resultant field *etc.*; ***[2 max]***

A2. (a) ratio between (maximum) friction and normal reaction / *OWTTE*; ***[1]***
Don't accept equation without definitions of symbols.

(b) (i) static; (*Award this mark for bald statement even if the reason is wrong.*)
since person is not moving vertically / *OWTTE*; ***[2]***

(ii) *Award **[1]** for each force labelled to show understanding.* ***[3 max]***



Use benefit of the doubt and accept things like mg or W for weight etc.
***Note**: "centripetal force" is **not** a correct label for the reaction force.*
*Award **[2 max]** for correct forces with no labels.*

(c) (i) friction, $F = mg = 800\,\text{N}$;
$R = \frac{F}{\mu}$ ***or*** $R = \frac{800}{0.4} = 2000\,\text{N}$; ***[2]***

(ii) attempted use of $\frac{mv^2}{r}$ = answer to (c) (i) *i.e.* 2000;

*Award **[0]** for $\frac{mv^2}{r} = 800$ or equivalent.* ***Note**: Watch for ECF.*

Recall of $F = \frac{mv^2}{r}$ not sufficient without link to (c) (i).

$v^2 = \frac{2000 \times 6.0}{80} = 150$

to give correct answer: $v = 12.247 \approx 12\ \text{m s}^{-1}$; ***[2]***

Accept calculation of angular velocity = 2.0 radians s^{-1}.

Option B — Quantum Physics and Nuclear Physics

B1. (a) Hadron; (*Award this mark for "bald" statement and if reason is wrong.*)
any sensible justification; ***[2]***
e.g. "contains two quarks" or "hadrons are either Baryons or mesons".

(b) any combination of three quarks;
correct answer: UUD; ***[2]***

(c) attempt (even if unsuccessful) to balance quarks left and right;
to get: $\begin{pmatrix} s \\ \bar{u} \end{pmatrix} + \begin{pmatrix} u \\ u \\ d \end{pmatrix} \rightarrow \begin{pmatrix} d \\ \bar{s} \end{pmatrix} + \begin{pmatrix} u \\ \bar{s} \end{pmatrix} + \begin{pmatrix} s \\ s \\ s \end{pmatrix}$
correct discussion on how the equation balances for all quark types; ***[2 max]***
e.g. compare numbers of quarks on LHS and RHS:
u: $-1 + (1+1) \rightarrow 1$
d: $1 \rightarrow 1$
s: $1 \rightarrow -1-1+(1+1+1)$

B2. (a) the emission of an electron from the surface of a substance;
as a result of the absorption of EM (accept UV) energy / *OWTTE*; ***[2]***

(b) (i) work function of K is smaller than 4.2 eV and any reasonable justification; ***[1]***
e.g. energy of UV photon is greater than energy of visible photon
Do not award mark for "smaller" without appropriate justification.

(ii) appropriate substitution into correct formula;
e.g. $energy = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{2.1\times10^{-7}} = 9.47\times10^{-19}\ J$
appropriate division by 1.6×10^{-19} to convert joules into eV;
e.g. $9.47\times10^{-19}\ J = 5.92\ eV$
KE of electron $= 5.92 - 4.2\,\text{eV} = 1.72\,\text{eV} \approx 1.7\,\text{eV}$; ***[3 max]***

(c) *Award **[1]** for any relevant piece of information up to **[3 max]**. e.g.*
electron diffraction - beam of accelerated electrons fired onto a graphite target;
many electrons detected in some directions, few in others;
pattern equivalent to diffraction pattern; ***[3 max]***

B3. (a) the time taken for the activity of a sample to fall to half its original value / *OWTTE*; ***[1]***
Do not accept definitions that are ambiguous or wrong.

(b) appropriate substitution into $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$;
to get $0.13\,\text{yr}^{-1}$ ($\approx 4.1\times10^{-9}\,\text{s}^{-1}$); ***[2]***

(c) appropriate substitution into $A = A_0 e^{-\lambda t}$;
to get $t = \frac{\ln 3}{\lambda} = 8.4\,\text{yr}\left(\approx 2.6\times10^{8}\,\text{s}\right)$; ***[2 max]***

Option C — Energy Extension

C1. (a) (i) no thermal energy into or out of the system / *OWTTE*; ***[1]***

(ii) overall work done BY the gas; ***[1]***

(b) $B \rightarrow C$;
any sensible justification; ***[2]***
e.g. increase in volume at constant pressure requires thermal energy or temperature increase etc.

(c) (i) idea of alternating isothermal and adiabatic changes;
correct description; ***[2]***
i.e. isothermal expansion, adiabatic expansion, isothermal contraction, adiabatic contraction.

(ii) attempted use of *efficiency* $= \frac{T_h - T_c}{T_h}$; (*even if conversion into Kelvins is missing*)
to give efficiency $= \frac{700}{1273} = 0.550 \approx 55\%$; ***[2]***

(iii) use of efficiency $= \frac{\text{(useful work out)}}{\text{total energy absorbed}}$; (*seen or implied*)
so rate of energy absorption $= \frac{2.0}{0.55} = 3.6\,\text{kW}$; ***[2]***

C2. (a) idea of thermal energy $\rightarrow$ mechanical energy/KE $\rightarrow$ electrical energy;
idea of where or how this takes place; ***[2]***
e.g. in turbines or coil rotated in a magnetic field etc.

(b) *Mark the answers for the two energy sources together.*
both non renewable;
appropriate justification for both; ***[2]***
e.g. in both cases a resource is being used and isn't being replaced / OWTTE.

(c) (i) to slow down fast moving neutrons;
so as to increase chances of neutron capture by another uranium nucleus / *OWTTE*; ***[2]***

(ii) to absorb neutrons;
so as to control rate of reaction / *OWTTE*; ***[2]***

(d) any appropriate advantage that coal fired power station does not have;
e.g. does not release CO_2 / SO_2 into atmosphere / OWTTE.
appropriate discussion relating to advantage;
e.g. so global warming / acid rain effects reduced. ***[2]***
*Allow argument that 1 kg of uranium "fuel" releases more energy w.r.t. 1 kg of coal. Award **[0]** for imprecise statements that are not clear e.g. bald "nuclear power stations pollute less".*

Option D — Biomedical Physics

D1. (a) (i) $\propto L^2$; ***[1]***

(ii) $\propto L^2$; ***[1]***

(iii) realization that mass scales as L^3;
i.e. $\propto L^{-1}$ or inversely proportional to L; ***[2]***

(b) $\dfrac{\text{rate of oxygen absorption for giant amoeba}}{\text{rate of oxygen absorption for normal amoeba}} = \dfrac{(8.0\times10^{-5})}{(5.0\times10^{-2})}$;
$= 1.6\times10^{-3} = 0.16\%$; ***[2]***

(c) giant amoebae not feasible since rate of oxygen absorption per unit mass is too low;
thus goldfish cannot rely on same method of oxygen intake / *OWTTE*; ***[2]***

D2. (a) photoelectric effect;
which is when a photon is absorbed causing ionization. A second photon is produced when another electron falls into the vacant level / *OWTTE*; ***[2]***

(b) (i) probability of a single photon being absorbed in 1 m of the material / reference to $I = I_0 e^{-\mu x}$ with definitions of symbols;
reference to $\dfrac{\Delta I}{I} = -\mu\Delta x$ with definitions of symbols; ***[2]***
*Award **[0]** for quoting a formula from the data booklet without any definitions. Award partial credit to candidates who include minor errors.*

(ii) thickness required to reduce the intensity of radiation to half its initial value;
reference to $x_{\frac{1}{2}} = \dfrac{\ln 2}{\mu}$ with definitions of symbols; ***[2]***
*Award **[0]** for quoting a formula from the data booklet without any definitions. Award partial credit to candidates who include minor errors.*

(c) (i) substitution into ratio $= \dfrac{(13.9)^3}{(7.4)^3}$;
to get ratio $= 6.62 \approx 6.6$; ***[2]***

(ii) these X-rays able to provide good contrast for broken bone diagnosis;
importance of the fat-muscle ratio of attenuation coefficients ($= 1.97$);
realization that this is not very different from 1;
therefore not enough contrast for muscle-fat boundary / must use another technique for muscle-fat boundary; ***[4]***

Option E — The History and Development of Physics

E1. (a) experiments into flow of electricity through gas at low pressure / Crooke's tubes / *OWTTE*;
showed that the glass behind the anode glowed / *OWTTE*; ***[2]***

(b) particle nature / *OWTTE*;
*Award **[0]** for bald "rays".*
since waves don't carry charge / *OWTTE* / any other sensible reason; ***[2]***

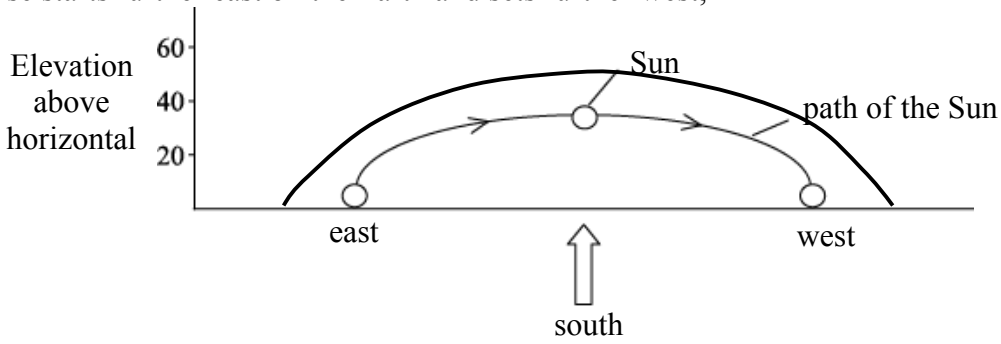
(c) wave nature / *OWTTE*;
*Award **[0]** for bald "light".*
since waves not deflected by electric field / *OWTTE*; ***[2]***

(d) (i) (Professor J J) Thompson; (*accept any spelling of "Thompson"*) ***[1]***

(ii) general idea of beam of electrons able to be deflected by E and B fields;
each appropriate detail that would allow the measuring of e/m; ***[3 max]***
*Award **[2 max]** for experiments that are described along the right lines but would not get result in a successful calculation of e/m.*

E2. (a) northern hemisphere since Sun always to the south / *OWTTE*; ***[1]***
*Answers must have some appropriate explanation to receive **[1]**. Do not accept "since the sun rises in the east and sets in the west" as appropriate.*

(b) path of Sun still peaks in the centre and shown to rise higher;
rise starts further east on the Earth and sets further west; ***[2]***



(c) *For both part (i) and (ii) **[1]** is available for a simple description of the appropriate model, and **[1]** is available for showing how the model explains **the change** in observations over a year. If everything including the explanations are correct but the models have been "swapped", award **[2 max]**.*

(i) Sun is on a (crystal) sphere that rotates around the Earth in one day;
the motion of the sphere also changes over the course of a year; ***[2]***

(ii) apparent motion of the Sun is due to the rotation in one day;
Earth moves around the Sun in a year and the Earth's axis of rotation is not the same as the axis of its rotation around the Sun / *OWTTE*; ***[2]***

(d) (i) appropriate similarity; ***[1]***
e.g. the stars and the planets maintain their relative positions over one night as the whole pattern rotates around the pole star.
appropriate difference; ***[1]***
e.g. over several nights, the planets slowly change position ("wander") relative to the positions of the whole pattern of stars.

(ii) from accurate observational data of the positions of the planets at different times (from Tycho Brahe); ***[1]***

Option F — Astrophysics

F1. (a) apparent magnitude is a measure of (comparative) brightness as seen from Earth (with 1 being brightest and 6 being dimmest);
absolute magnitude is the apparent magnitude that the star would have if it were a fixed distance from the Earth of 10 parsecs; ***[2]***

(b) yes plus reason; ***[1]***
Note*: an explanation must be provided. Award* ***[0]*** *for bald "yes" without an attempt at a reason. e.g. since apparent magnitude low (less than one) therefore one of the brightest stars.*

(c) (i) distance away $= \frac{3.39\times10^{17}}{9.46\times10^{15}} = 35.8\,\text{ly} = 11.0\,\text{pc}$; ***[1]***

(ii) since this is less than 100 pc;
the star is close enough for stellar parallax; ***[2]***
Award ***[1]*** *for a bald answer. Also allow ECF if conversion of units is muddled.*

(iii) *Award* ***[1]*** *each relevant piece of experimental description up to* ***[4 max]****.*
e.g. position of star compared with other star positions;
at different times of the year;
the maximum angular variation from the mean p is recorded;
the distance (in parsecs) can be calculated using geometry $d = \frac{1}{p}$ if p is in arcseconds;
Note*: watch for ECF. If the response has suggested one of the other techniques in (ii) then award full marks for appropriate descriptions.*

example:
spectroscopic parallax: light from star analysed (relative amplitudes of the absorption spectrum lines);
to give indication of stellar class;
HR diagram used to estimate the luminosity;
distance away calculated from apparent brightness;

Cepheid variables: these stars' brightness vary over time;
the time period of the variation is related to their luminosity;
thus measurements of the time period of one star can be used to calculate its luminosity;
its distance away is calculated from maximum apparent brightness; ***[4 max]***

(d) spectral type / K / *OWTTE*;
thus at low end of temperature scale: OBAFGKM / Sun is G / *OWTTE*; ***[2]***

(e) (i) correct substitution into $L = \sigma A T^4$;

to get $A = \frac{3.8 \times 10^{28}}{(5.67 \times 10^{-8} \times 4000^4)} = 2.62 \times 10^{21}\ m^2$; ***[2]***

(ii) use of $4\pi r^2 = 2.62 \times 10^{21}\ m^2$;

to get $r = 1.44 \times 10^{10}\ m\ (= 0.10\ AU)$; ***[2]***

(iii) use of $\lambda_{max} = \frac{2.90 \times 10^{-3}}{4000}$;

$= 725\ nm \approx 730\ nm$; ***[2]***

(f) red giant;
since it's big and it's red / *OWTTE*; ***[2]***

Option G — Relativity

G1. (a) speed of light <u>in a vacuum</u> is the same for all <u>inertial</u> observers;
laws of physics are the same for all <u>inertial</u> observers; ***[2]***
*The words underlined are needed for the mark. Award **[1 max]** if both are on the right lines but not precise. Give benefit of the doubt if inertial is only mentioned once.*

(b) constancy of the speed of light / *OWTTE*;
any sensible comment; ***[2]***
e.g. Maxwell's equations predicted a value for the speed of propagation of electromagnetic radiation from constants associated with the medium that was independent of the motion of the source or the observer.

(c) idea or name of appropriate experiment;
e.g. muon experiments
outline of evidence;
e.g. number of muons at a given height in the atmosphere in a given time compared with number arriving at the ground. Number at ground seems high given the lifetime of a muon.
link to a prediction; ***[3 max]***
e.g. numbers consistent with time dilation formula.

G2. (a) rest mass energy is the energy that is needed to create the particle at rest / reference to $E_0 = m_0c^2$;
total energy is the addition of the rest energy and everything else (kinetic *etc.*) / reference to mass being greater when in motion / $E = mc^2$; ***[2 max]***

(b) realization that betas are electrons;
so $m_e = 0.511\,\text{MeV}\,\text{c}^{-2}$;
$\gamma = \dfrac{2.51}{0.511};\ (= 4.91)$ ***[3]***
Ignore any spurious calculation from Lorentz factor equation here as the use of this equation is rewarded below.

(c) (i) correct substitution into Lorentz factor equation;
to give $v = 0.979c = 2.94 \times 10^8\,\text{m}\,\text{s}^{-1}$; ***[2]***

(ii) correct substitution into $\text{speed} = \dfrac{\text{distance}}{\text{time}}$;
to give time $= 1.26\,\text{ns}$; ***[2]***

(d) (i) the detector / the laboratory / *OWTTE*; ***[1]***

(ii) same answer as (c) (i) $= 2.94 \times 10^8\,\text{m}\,\text{s}^{-1}$; ***[1]***

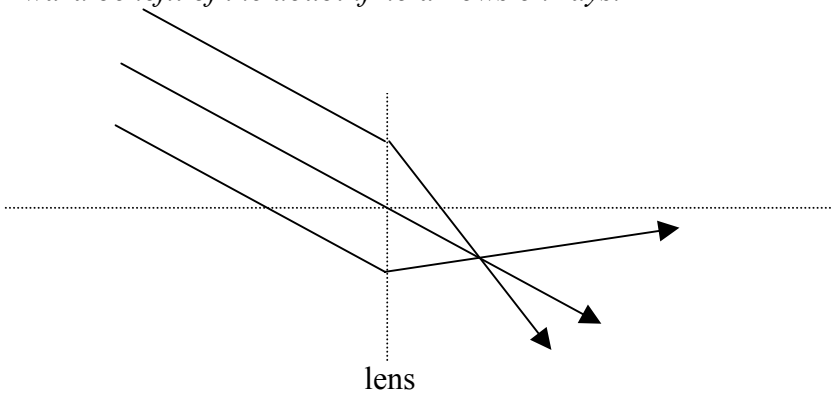
(iii) realization that length contraction applies;
$\text{distance} = \dfrac{37}{\gamma} = 7.5\,\text{cm}$; ***[2]***

Option H — Optics

H1. (a) (i) the position of the closest object that can be brought into focus by the unaided eye / *OWTTE*; ***[1]***
Accept the distance to the closest object etc.

(ii) the position of the furthest object that can be brought into focus by the unaided eye / *OWTTE*; ***[1]***
Accept the distance to the furthest object etc.

(b) (i) two (or more) parallel rays into lens;
which all converge after refraction at the lens;
correctly off axis; ***[3]***
Award benefit of the doubt if no arrows on rays.



*Award **[2 max]** for a correct ray diagram showing rays diverging from an object at twice the focal length (or more) from the lens.*

(ii) about 1.7 cm; ***[1]***

(c) (i) use of the lens equation with $u = 50\,\text{cm}$, $v = 1.7\,\text{cm}$;
to get $f = 1.64 \approx 1.6\,\text{cm}$; ***[2]***
*Award **[1 max]** for a scale diagram since accuracy is inappropriate.*

(ii) lens gets fatter / *OWTTE*;
since focal length goes down; ***[2]***

(d) (i) ratio of speed of EM waves;
in vacuum to their speed in medium;
*Award **[0]** for quoting from the data booklet without additional information.*
or
definition as ratio of sin (angle of incidence) to sin (angle of refraction);
explanation of how these angles are measured; ***[2]***

(ii) normally the refraction is from air to cornea and the difference in refractive index is large;
if under water refraction is from water to cornea and the difference in refractive index is negligible so no image is formed / *OWTTE*;
or
rays crossing the water-eye boundary will undergo little refraction since the n's are nearly equal;
hence, rays cannot be brought to a focus (focussed); ***[2]***

H2. (a) (i) single frequency / single colour / *OWTTE*; ***[1]***

(ii) waves with a constant / predictable phase / *OWTTE*; ***[1]***
Be generous as it is hard to describe in a few words. Look for understanding.

(b) *Award **[1]** for each correct row or column, up to **[3 max]**.*

	Electromagnetic	***Monochromatic***	***Coherent***
light from a laser			
sound from a loudspeaker			
light from a filament lamp	Yes	No	No
γ -rays from a radioactive source	Yes	Yes / No	No
infra-red rays from the Sun	Yes	No	No

[3 max]

(c) any general application of laser light; ***[1]***
*To achieve **[1]** it must be a situation where the use of laser light is appropriate and there is sufficient outline detail to understand the situation. Accept any use (so long as not ambiguous) without description.*