IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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N04/4/PHYSI/HP3/ENG/TZ0/XX/M+

MARKSCHEME

NOVEMBER 2004

PHYSICS

Higher Level

Paper 3

17 pages

General Marking Instructions

Subject Details: Physics HL 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 markscheme then award the mark.
- Mark positively. Give candidates credit for what they have achieved, and for what they have got correct, rather than penalizing 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 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) $$\frac{\text{rate of oxygen absorption for giant amoeba}}{\text{rate of oxygen absorption for normal amoeba}} = \frac{(8.0\times10^{-5})}{(5.0\times10^{-2})};$$
$$=1.6\times10^{-3} = 0.16\%;$$ ***[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]***

(d) (i) dose received $= 330\,\mu\text{Sv} \div 1 = 330\,\mu\text{Gy}$; ***[1]***

***Note**: Correct unit needed.*

*Accept J kg^{-1}. Losing this mark **does not** count towards the general unit mark on the paper.*

(ii) any sensible estimate for the mass of the upper body;
e.g. 30 kg, (accept 10 kg to 50 kg)
so total energy received $= 330\,\mu\text{Gy} \times 30 = 9.9\,\text{mJ}$; ***[2]***
*Award **[1 max]** for an answer of 19.8 mJ (using 60 kg).*

(e) *Award **[1]** for each sensible and appropriate precaution for the operator, up to **[2 max]**.*
e.g. shielding (works behind lead glass screen);
distance away (controls are remote from machine);
film badge monitoring *etc.*; ***[2 max]***

(f) *Award **[1]** for each appropriate possible biological effect, up to **[2 max]**.*
e.g. sterility;
cancer;
shortening of life expectancy;
any other examples; ***[2 max]***

(g) (i) to kill cancer cells / *OWTTE*; ***[1]***

(ii) *Award **[1]** for each sensible and appropriate comment, up to **[2 max]**.*
e.g. cancer cells targeted to received a high dose;
aim is to minimize danger to other healthy cells while killing cancerous ones;
malignant cells are preferentially susceptible to X-rays;
targeting achieved from different angles with tumour in overlap region;
any other examples; ***[2 max]***

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]***

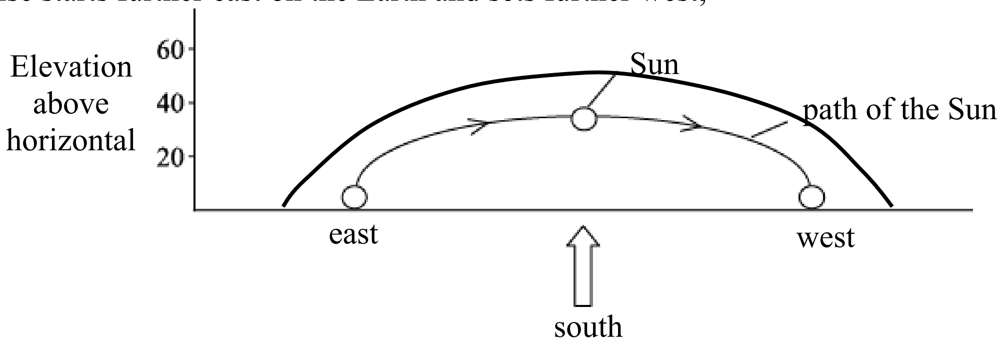
(c) wave nature / *OWTTE*;
*Award **[0]** for bald "light".*
since waves not deflected by electric field / *OWTTE*; ***[2]***

(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]***

E3. (a) explanation of symbols in the Rydberg formula $\frac{1}{\lambda} = R_H\left(\frac{1}{n^2} - \frac{1}{m^2}\right)$:

and n and m are integers;
R_H is the Rydberg constant;
λ is wavelength in atomic hydrogen emission spectrum; ***[3 max]***

(b) correct application of Rydberg formula for Balmer series:
$n = 2$;
$m = 3,\ 4,\ 5$ *etc.*; ***[2 max]***

(c) realization that for ionization, $n = 1$ and $m = \infty$;
and thus the ionization wavelength is given by $\frac{1}{\lambda} = R_H$;
the minimum frequency for ionization is given by
$f = 3.0\times10^{8}\times1.10\times10^{7} = 3.30\times10^{15}$ Hz
so ionization energy $= hf = 2.19\times10^{-18}$ J $= 13.7$ eV; ***[3 max]***

(d) each appropriate limitation of the Bohr model;
e.g. only works for hydrogen;
no theoretical justification of postulates;
does not predict the fine structure;
etc.; ***[2 max]***

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 $= \dfrac{3.39\times10^{17}}{9.46\times10^{15}} = 35.8\,\text{ly} = 11.0\,\text{pc}$; ***[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 $d = \dfrac{1}{p}$ 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 $L = \sigma \mathrm{A} \mathrm{T}^4$;

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

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

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

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

$= 725\,\mathrm{nm} \approx 730\,\mathrm{nm}$; ***[2]***

(f) red giant;

since it's big and it's red / *OWTTE*; ***[2]***

F2. (a) Milky Way is a spiral galaxy with "concentration" of stars in the centre;
NGC5128 is an elliptical galaxy - form is different; ***[2]***
Ignore guessed references to band of dark dust outside our galaxy.

(b) (i) recession velocity is proportional to the distance away / *OWTTE*; ***[1]***
*Award **[0]** for formula taken from data book unless symbols are defined.*

(ii) a measurement to get recession velocity;
e.g. red shift measurement
a measurement to get distance away;
e.g. Cepheids
repeat procedure for many galaxies to get relationship from graph; ***[3]***

(c) (i) correct substitution into $v = Hd$;
and correct conversion of units to get
$v = 60 \times \left(\frac{15 \times 10^6}{3.26 \times 10^6} \right) = 276.1\,\text{km}\,\text{s}^{-1} \approx 300\,\text{km}\,\text{s}^{-1}$; ***[2]***

(ii) correct substitution in $T = \frac{1}{H}$;
and correct conversion of units to get
$T = 0.0167\,\text{km}^{-1}\text{s}\,\text{Mpc}$
$= 0.0167 \times \frac{(10^6 \times 3.26 \times 9.46 \times 10^{15})}{10^3}$
$\approx 5 \times 10^{17}\,\text{s}$; ***[2]***
Assumption that the rate of expansion has remained the same should be given credit and can replace the marking point above if a mathematical slip has been made.

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 $m_e = 0.511\,\text{MeV}\,\text{c}^{-2}$;
$\gamma = \frac{2.51}{0.511}$; $(= 4.91)$ ***[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 $\text{speed} = \frac{\text{distance}}{\text{time}}$;
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;
distance $= \frac{37}{\gamma} = 7.5\,\text{cm}$; ***[2 max]***

G3. (a) correct <u>substitution</u> into $E^2 = p^2c^2 + m_0{}^2c^4$;

$p^2c^2 = (1.533)^2 - (0.511)^2 = 2.089\,(\mathrm{MeV}^2)$

so $p = 1.45\,\mathrm{MeV\,c^{-1}}\ (= 7.71\times10^{-22}\ \mathrm{Ns})$; ***[2]***

(b) realization that energy is sufficient to create electron / positron pair (at rest);
momentum must be conserved so some particles must have KE so not all the 1.533 is available for particle creation / *OWTTE*;
so it is not possible; ***[3]***
*Award **[0]** for a "bald" statement without any attempt at justification.*

G4. (a) an observer cannot tell the difference between the effect of acceleration (in one direction) and a gravitational field (in the opposite direction); ***[1]***
*Accept "It is impossible to distinguish between inertial or gravitational forces" **or** "there is no way in which gravitational effects can be distinguished from inertial effects" / OWTTE.*

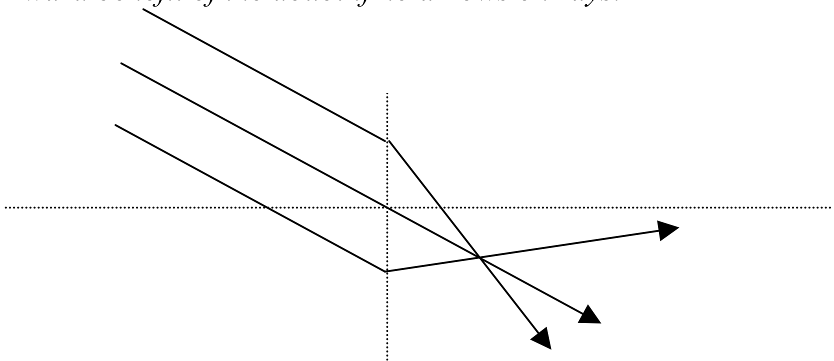
(b) any correct argument to show that light would be expected to be bent in an accelerating frame (*e.g.* observer in lift/rocket *etc.*);
application of principle of equivalence to show that light must also be bent in a gravitational field;
gravitational lensing is the bending of light around a massive astronomical object;
to produce multiple images or magnified images of a region of space that is further away / *OWTTE*; ***[4]***
*The final **[2]** marks can be awarded for a clearly drawn and fully labelled diagram.*

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 <u>distance</u> 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 <u>distance</u> to the furthest object etc.

(b) (i) two (or more) <u>parallel</u> 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 <u>diverging</u> 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 max]***

(ii) waves with a constant / predictable phase / *OWTTE*; ***[1 max]***
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 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.*

H3. (a) identification of path length differences from slit to slit;
to give constructive interference at a particular angle for a particular wavelength;
thus different wavelengths will constructively interfere at different angles *i.e.* light will be separated in component wavelengths; ***[3 max]***
Award full marks for other explanations not of this format but the response must explain the creation of the spectrum.

(b) correct substitution into $n\lambda = d\sin\theta$;
to give $\sin\theta = 5.896\times10^{-7}\times600\,000 = 0.35376$ so $\theta = 20.7^{\circ} \approx 21^{\circ}$; ***[2]***

H4. (a) the diffraction pattern of one point source has its central maximum on the first minimum of the diffraction pattern of the other point source / *OWTTE*; ***[2]***
Full marks can be awarded for a clearly drawn and fully labelled diagram. Partial credit is for answers that have some idea but lack precision.

(b) 3 (± 2) mm; ***[1]***

(c) correct calculation of Rayleigh criteria angle;
e.g. $\theta = 1.22\ \dfrac{\lambda}{d} = 1.22\times590\times10^{-9}\ /\ 0.003 = 2.4\times10^{-4}$ *radians.*
Accept answers that miss the factor of 1.2 to get 2.0×10^{-4} *radians.*
correct comparison and answer; ***[2 max]***
e.g. this will be resolved as minimum angle is less than the separation of the point sources.
Watch for ECF – this angle may or may not be resolved depending on the estimation of the diameter of the aperture.