INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

MARKSCHEME

May 2004

PHYSICS

Higher Level

Paper 3

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 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 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. Indicate this with **"ECF"**, error carried forward.
- 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) mass ***or*** volume $\propto$ dimension^3 ***or*** height $=175\times\sqrt[3]{\left(\frac{85}{70}\right)}$;

height $=187$ cm; ***[2]***

Allow "bald" correct answer.

(ii) surface area $\propto$ dimension^2 ***or*** ratio is $\left(\frac{187}{175}\right)^2$;

ratio is 1.1(4); ***[2]***

Allow "bald" correct answer.

(b) because ratio of masses > ratio of surface areas;
rate of heat loss per unit area must be greater for 85 kg man;
it is 1.07 times greater; *(allow for ecf)*
must have increased heat loss mechanism / *e.g.* sweating; ***[4]***

D2. (a) presbycusis / sensory hearing loss / hearing loss due to ageing; ***[1]***

(b) hearing loss is 14 dB;

$14 = 10\,\lg\left(\frac{I}{1.0\times10^{-12}}\right)$

$I = 2.5\times10^{-11}\ \mathrm{W\,m^{-2}}$; ***[2]***

(c) steep drop to about –65 dB at 4 kHz; *(clear indication of a hearing loss is essential)*
then levels out; ***[2]***

D3. (a) shows up **outline** of stomach/intestines ;
because barium meal absorbs the X-rays / other good comment; ***[2]***

(b) prevents reflections of ultrasound at skin surface;
because much reflection at skin/air boundary / other good comment; ***[2]***

(c) localizes the resonating atoms;
because resonance depends on magnitude of magnetic field;
any further detail in (a), (b) or (c); ***[3]***
The final mark is "floating" and can be awarded only once for further detail given in ***either*** *part (a)* ***or*** *part (b)* ***or*** *part (c).*

D4. (a) (i) α-radiation; ***[1]***

(ii) effect depends on ionization;
α-radiation causes more ionization;
per unit length of its track; ***[3]***

(b) risk increases as dose rate increases;
because more ionisation (per unit volume) at any one time;
and less chance of repair mechanism to operate (or other good physics); ***[3]***

(c) $\frac{1}{T_e} = \frac{1}{T_p} + \frac{1}{T_b}$ ***or*** $\frac{1}{T_e} = \frac{1}{8} + \frac{1}{21}$;
$T_e = 5.8$ days;
so time = 11.6 days; ***[3]***
*Award **[1]** for ecf from wrongly calculated effective half-life.*

Option E — The History and Development of Physics

E1. (a) it is a pole star; ***[1]***

(b) from Earth, stars appear to move in circles;
with pole star on its axis / any other good physics; ***[2]***

(c) arc subtends 22.5° ($\pm 2^{\circ}$) at pole star;
length of day / time for one revolution $= \left(\frac{360}{22.5}\right) \times 1.5$;
= 24 hours; ***[3]***

E2. (a) (i) caloric fluid leaves the body; ***[1]***

(ii) flow of caloric;
due to its self-repellent nature; ***[2]***

(iii) different absorption abilities of caloric by different substances; ***[1]***

If (i), (ii) or (iii) refers to "calories", rather than caloric then award ***[3 max]*** *overall.*

(b) *Any three of the following.*
observed heat produced during the boring of cannons;
this seemed to be inexhaustible;
s.h.c. of shavings same as s.h.c. of barrel;
although caloric squeezed out of shavings; ***[3 max]***

E3. (a) electrons in orbit round nucleus;
these orbit at very high speed;
so "smear out", giving impression of being solid; ***[3]***

(b) (i) neutron is not charged; ***[1]***

(ii) "rays" emitted were highly penetrating;
"rays" caused protons to be ejected from hydrocarbons;
(Chadwick) proved "rays" to be neutral particles, mass same as proton; ***[3]***

E4. (a) *e.g.* electron as wave — electron as particle;
probability function — definite orbits;
quantisation by fitting wave — quantisation postulated; ***[3]***
*Award any sensible alternatives — **[1]** for each pair, correctly identified with model.*

(b) (i) any correct position; ***[1]***

(ii) 2.0×10^{-10} m; ***[1]***

(iii) $p=\dfrac{h}{\lambda}=3.32\times10^{-24}$ N s;
$E_{\mathrm{k}}=\dfrac{p^2}{2m}=\dfrac{(3.32\times10^{-24})^2}{(2\times9.1\times10^{-31})}$;
$=6.05\times10^{-18}$ J; ***[3]***
***Note**: 1 significant figure answer is acceptable here.*

(c) equation $\Delta p\Delta x$ = constant explained in “words”;
so if (approximate) position is known p cannot be determined precisely; ***[2]***

Option F — Astrophysics

F1. (a) massive body of gas / gas/plasma;
giving off light / radiant energy / electromagnetic radiation *etc.*; ***[2]***
Allow alternative acceptable comments.

(b) *constellation*:
pattern of stars as seen from Earth;
not close to one another in space;

galaxy:
large group of stars;

other detail *e.g.* $\approx 10^{10}$ stars, diameter $\approx 10^{5}$ ly *etc.*; ***[4]***
*Award other detail **[1]** for constellation or galaxy.*

F2. (a) if less than ρ_0, Universe will expand for evermore;
if greater than ρ_0, Universe will expand;
and then contract; ***[3]***

(b) (i) substitution to give $\rho_0 = 1.3 \times 10^{-26}$ kg m^{-3}; ***[1]***

(ii) number density $= \dfrac{(1.3 \times 10^{-26})}{(1.66 \times 10^{-27})}$, about 7 or 8 m^{-3}; ***[1]***
***Note**: unit is m^{-3}.*

F3. (a) (i) light output varies periodically;
rapid brightening, gradual dimming; ***[2]***

(ii) caused by expansion / contraction of surface;
brighter as it expands; ***[2]***

(b) (i) apparent magnitude: how **bright** a star is, as measured on Earth;
absolute magnitude: apparent magnitude if star were to be 10 pc from Earth; ***[2]***

(ii) M = –6.2 (± 0.1);
(5.2 + 6.2) = 5 lg*d* – 5;
d = 1900 pc; ***[3]***
*Award **[2 max]** if lg(d – 5) is used and results in d = 195 pc*
***or** if (5.2 – 6.2) is used and results in d = 6.3 pc*
***or** if ln and not lg is used and results in d = 26.6 pc.*

F4. (a) (i) N on line between 10^2 s and 10^3 s ; ***[1]***

(ii) G labelled on line at about 10^{13} s ; ***[1]***
Award 10^{12} s to 10^{14} s .

(b) light takes millions of years to reach Earth;
so observations made in the past when universe was warmer; ***[2]***

F5. (a) (i) R shown amongst scattered points in upper right of diagram
W shown in lower region below main sequence, about centrally; ***[1]***

(ii) S shown on main sequence, about $\frac{1}{3}$ way up; ***[1]***
Allow the position of S anywhere between $\frac{1}{4}$ and $\frac{1}{2}$ the way up.

(iii) path shown to region of red giant;
then continuing to region of white dwarf; ***[2]***

(b) (when forming a red giant) the star is expanding;
more power but over a much larger area, so cooler; ***[2]***

Option G — Relativity

G1. (a) frame moving with constant velocity / frame in which Newton's first law is valid; *[1]*

(b) $T_0 = \dfrac{2D}{c}$; *[1]*

(c) (i) light reflected off mirror when midway between F and R; *[1]*

(ii) FR $= vT$; *[1]*

(iii) $(\tfrac{1}{2}L)^2 = D^2 + (\tfrac{1}{2}vT)^2$;
$L = 2\sqrt{\{D^2 + (\tfrac{1}{2}vT)^2\}}$; *[2]*

(iv) $T = \dfrac{2\sqrt{\{D^2 + (\tfrac{1}{2}vT)^2\}}}{c}$;
$c^2T^2 = 4\{D^2 + (\tfrac{1}{2}vT)^2\}$;
use of $4D^2 = c^2{T_0}^2$;
hence $T = \dfrac{T_0}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$; *[4]*

G2. distance $= vT$ and $T = \dfrac{T_{\frac{1}{2}}}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$;
$T = 8.63\times10^{-6}$ s;
distance $= 2.8\times10^8 \times 8.63\times10^{-6} = 2.4\times10^3$ m; *[3]*

G3. (a) mass of object in observer's frame of reference;
or
mass when not moving;
relative to observer; *[2 max]*

(b) for large V, calculated value of v would be greater than c;
this is not possible;
mass increases, so mass is not m_0 / other comment; *[3]*

(c) $c^2\Delta m = eV$ ***or*** $\Delta m = \dfrac{(1.6\times10^{-19}\times5.0\times10^6)}{(3.0\times10^8)^2}$;
$\Delta m = 8.9\times10^{-30}$ kg; *[2]*

G4. (a) (i) centre is single point to which all mass would collapse;
surface is where the escape speed is equal to c;
within this surface, mass has "disappeared" from the universe; ***[3]***

(ii) distance from point of singularity to the event horizon / *OWTTE*; ***[1]***

(iii) $R_{\mathrm{SCH}} = \dfrac{2GM}{c^2} = \dfrac{(2 \times 6.67 \times 10^{-11} \times 2 \times 10^{31})}{(3 \times 10^8)^2}$;
$= 3.0 \times 10^4$ m; ***[2]***

(iv) at 10^7 km, space is not warped;
so Newtonian physics applies;
or other good comment; ***[2 max]***
*Award **[0]** for a statement of "no" without justification.*

(b) theory suggests that light is affected by gravitational fields;
diagrams or "words" to explain formation of two images; ***[2]***

Option H — Optics

H1. (a) distribution of colours;
separated according to wavelength / frequency; ***[2]***

(b) dispersion at both faces of prism;
refraction at both faces correct (by eye) – rays cross normal, $i > r$, $i < r$;
greater deviation for the blue than for the red; ***[3]***

H2. (a) diagram showing ray emerging along flat face; ***[1]***

(b) $\tan\theta = \frac{138}{120}, \theta = 49.0^\circ$;
critical angle $= 41.0^\circ$;
$n = \frac{1}{\sin C} = 1.52$; *(allow ecf if sensible)* ***[3]***
*Award **[1 max]** if the critical angle is* $= 49.0^\circ$ *(answer* $n = \frac{1}{sinC} = 1.33$*).*

(c) n is greater at higher frequency;
so C is smaller;
hence AB is larger; ***[3]***
*Award **[2]** if logic totally reversed.*

H3. (a) rays continued to eye lens, emerging parallel and in correct direction;
broken (dashed) parallel lines to left of eyepiece to imply image formation at infinity; ***[2]***

(b) (i) $\frac{\text{angle subtended by image } \textbf{at eye}}{\text{angle subtended by object } \textbf{at eye}}$; ***[1]***
Allow α/β *if* α *and* β *are shown correctly on the diagram.*

(ii) correct identification of angles;
realizes $\tan\alpha \to \alpha$ for small angles;
$\alpha_{\text{O}} = \frac{h}{f_{\text{O}}}, \alpha_{\text{E}} = \frac{h}{f_{\text{E}}}$;
magnification $= \frac{f_{\text{O}}}{f_{\text{E}}}$; ***[4]***
*Award **[1 max]** for correct quote of final answer only.*

(c) *e.g.* bigger diameter, collects more light / less diffraction / greater resolution; ***[1]***

H4. (a) surfaces are flat (to less than $\frac{\lambda}{4}$); *[1]*

Expect some reference to the wavelength of the light – not necessarily $\frac{1}{4}\lambda$.

(b) no geometrical path difference;
but π phase change on reflection from surface of less (optically) dense medium;
so destructive interference; *[3]*

(c) fringe separation corresponds to change in thickness of $\frac{1}{2}\lambda$;

there are $\frac{90}{1.4} = 64$ fringes;

thickness $64 \times 5.89 \times 10^{-7} \times \frac{1}{2} = 1.8(8) \times 10^{-5}$ m; *[3]*

*Award **[2 max]** if fringe separation corresponds to λ, not $\frac{1}{2}\lambda$, answer is 3.8×10^{-5} m.*

(d) (i) there are many different wavelengths / *OWTTE*; *[1]*

(ii) complete destructive interference for one wavelength / colour;
remaining wavelengths give coloured appearance; *[2]*