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

MARKSCHEME

May 2007

PHYSICS

Higher Level

Paper 3

18 pages

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.
- Words that are underlined are essential for 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.
- Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
- 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. Indicate this by **"U-1"** at the first point it occurs. 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*

Indicate the mark deduction by **"SD-1"**. 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) Frank;
<u>at 70 Hz</u>, Albert's threshold is lower than Frank's;
so he can hear lower intensity sounds / his hearing is better; ***[3]***
Do not award marks for bald answers or answers with fallacious argument.

b) threshold is $60\,\text{dB}$;

(substitution into $\beta = 10\log\left(\frac{I}{I_0}\right)$) to give $I = 1.0\times10^{-6}\,\text{W m}^{-2}$;

$1.0\times10^{-6}\,\text{W m}^{-2} = \frac{0.027}{4\pi r^2}$;

to give $r = 46\,\text{m}$ *(no mark for answer)* ***[3]***

(c) Albert's threshold is lower at $4000\,\text{Hz}$ than at $70\,\text{Hz}$;
so loudness will increase / he hears it more clearly; ***[2]***

D2. (a) mass scales with volume;

$$\frac{\text{mass}_{\text{LION}}}{\text{mass}_{\text{CAT}}} = \frac{\text{volume}_{\text{LION}}}{\text{volume}_{\text{CAT}}} \propto \frac{\text{length}_{\text{LION}}^{\,3}}{\text{length}_{\text{CAT}}^{\,3}} = 4.0^3 = 64;$$ ***[2]***

*Award **[2]** for bald answer.*

(b) (i) $\text{stress} = \frac{\text{force}}{\text{area}} \Rightarrow \text{force} \propto \text{area} \propto \text{diameter}^2 \Rightarrow \text{diameter} \propto \sqrt{\text{force}}$;

$$\frac{\text{diameter}_{\text{LION}}}{\text{diameter}_{\text{CAT}}} = \sqrt{64} = 8;$$ ***[2]***

*Award **[1]** for bald answer.*

(ii) because the legs need to support a weight that scales with length^3
but the strength only scales with thickness^2;
since the weight and strength are proportional, length and thickness are not; ***[2]***

D3. (a) X-ray image taken of target from many directions;
computer produces detailed image of slice;
repeated for many slices;
<u>to build up</u> a 3-D image; ***[4]***

(b) large X-ray dose;
long-term effect of X-ray exposure;

or

long duration of procedure;
difficult to work with children; ***[2]***

D4. (a) $(40\,\text{W} \rightarrow 200\,\text{W})$ increased;
$(30\,\text{W} \rightarrow 30\,\text{W})$ remained the same;
$(320\,\text{W} \rightarrow 10\,\text{W})$ decreased;
$(10\,\text{W} \rightarrow 160\,\text{W})$ increased; ***[4]***

(b) radiation, evaporation and respiration unchanged; *(any two of the three mechanisms)*
convection increased; ***[2]***
*Award **[1 max]** if any of radiation, evaporation and respiration changes.*

D5. (a) energy absorbed per unit mass (of tissue); *(ratio idea essential)* ***[1]***

(b) takes into account density of ionisation / deposition of energy; ***[1]***

(c) (i) risk is $5 \times 2.2 \times 10^{-3} = 1.1 \times 10^{-2}\,\%$; ***[1]***

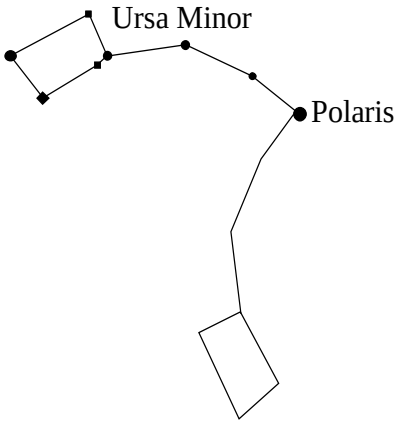
(ii) person is ill with a much greater risk if illness not diagnosed / comment as regards "balanced risk" concept; ***[1]***

Option E — The History and Development of Physics

E1. (a) the model proposed that the Earth was spinning, accounting for the passage of stars through the night;
and that the Earth passed around the Sun, (causing it to appear as though the Sun was moving against the background of fixed stars); ***[2]***

(b) Ptolemy's model is geocentric/Earth-centered ***or*** Aristarchus' model is heliocentric/ Sun centered;
Ptolemy's model includes epicycles;
Earth does not spin; ***[2 max]***

(c) stars remain in the same position relative to each other (same shape and size); *Award credit for approximate similarity in shape, a perfect drawing is not necessary.*
rotated by 90°; *allow* $\pm 10^\circ$ *rotation on line from Polaris*
counter-clockwise; ***[3]***



(d) the Earth is spinning; ***[1]***

E2. (a) Rumford observed that "heat" was generated by friction/motion/rubbing; ***[1]***

(b) the supply of thermal energy did not depend on the material/volume/mass;
so could not be contained within it; ***[2]***

E3. Coulomb's investigation was experimental;
Franklin/Priestly had a theoretical approach;
further detail *e.g.* charge on surface only / no field inside conductor / found force between charges; ***[3]***

E4. (a) electrons are more easily produced (with an example of process *e.g.* heating of a wire / thermionic emission);
electrons (are more easily detected because they) have charge; ***[2]***

(b) charged particles could not penetrate lead to that depth (given the energies available then);
so the radiation could not be charged;
gamma-rays would not knock out protons / need a particle to knock out a proton;
particle mass must be about the same as that of proton; ***[4]***

E5. (a) line spectrum (of H-atom) is in a distinct series;
wavelengths (of H-atom) can be determined from $\lambda^{-1} = R(n^{-2} - m^{-2})$ where m and n are integers; *some reference to H is needed somewhere.*
and R is an (empirical) constant called the Rydberg constant; ***[3]***

(b) (i) algebra leading to $\frac{1}{\lambda} = \frac{4\left(\frac{1}{4} - \frac{1}{m^2}\right)}{A}$;

hence $R = \frac{4}{A} = 1.1 \times 10^7 \text{ m}^{-1}$; ***[2]***

*Award **[2]** for bald answer.*

(ii) clear substitution of $m = 3$;
leading to $\lambda = 655 \text{ nm}$; ***[2]***

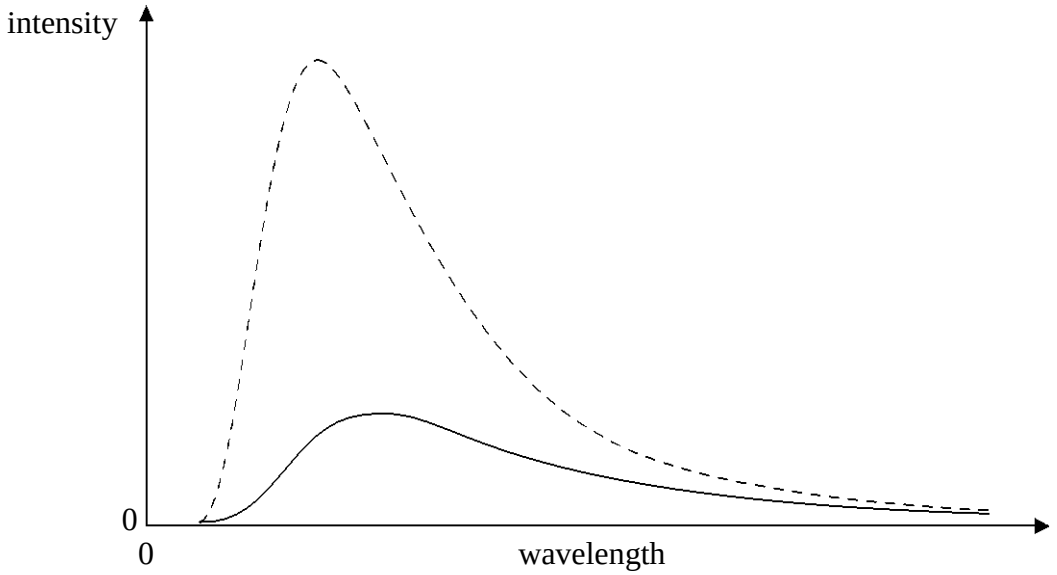
E6. (a) use of $\Delta x \Delta p = \frac{h}{2\pi}$;
to give $\Delta p = 1.1 \times 10^{-29} \text{ N s}$; ***[2]***
accept Δx being half slit width

(b) normal to direction of beam / parallel to plane of slit; ***[1]***

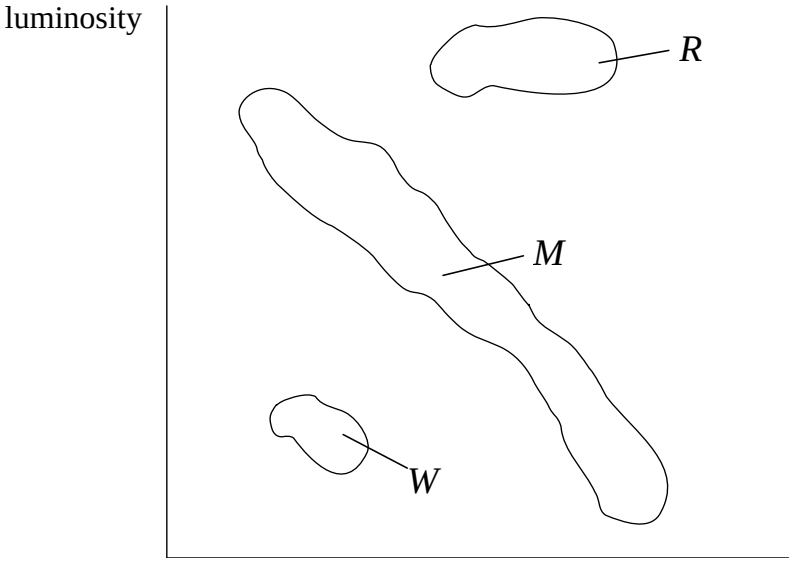
Option F — Astrophysics

F1. (a) (total) power radiated / energy radiated per unit time; ***[1]***

(b) the curve should be above the existing curve at all locations with sharper peak;
the peak should be shifted to shorter wavelengths; ***[2]***



(c) *Award **[1]** for one correct label, award **[2]** for all three correct.*



[2]

(d) luminosity depends on temperature;
luminosity depends on area/radius;
so different temperatures can have different luminosities / graph does not include area; ***[3]***

F2. (a) apparent magnitude is a measure of how bright an object appears (from Earth);
absolute magnitude is a measure of, how bright an object appears / the apparent magnitude, when observed from a distance of $10\,\text{pc}$; ***[2]***

(b) (i) $b = \frac{L}{4\pi d^2} \Rightarrow \frac{b_A}{b_B} = \frac{L_A d_B^{\ 2}}{L_B d_A^{\ 2}}$;

rearrange to give $d_B = \sqrt{\frac{b_A L_B}{b_B L_A}} d_A$;

substitution to give $d_B = \sqrt{25} d_A$; (hence $500\,\text{pc}$) ***[3]***

(ii) if star A was at 10 pc, it would be 100 times brighter (because brightness scales with d^{-2});
so absolute magnitude is five below the apparent magnitude; (hence 0.0) ***[2]***
N.B. *Award maximum credit for detailed calculation leading to correct answer.*

F3. (a) light from distant galaxies/stars is red-shifted / existence of CMB / interstellar gas temperature in distant galaxies is $> 3\,K$; ***[1]***

(b) (i) the critical density is the density of the Universe that would be necessary to stop the expansion after an infinite amount of time; ***[1]***
Do not accept answers based on "the density at which the universe is flat".

(ii) whether the universe will expand forever or close back in on itself is determined by the comparison of these values;
at low density, the universe will continue to expand forever;
at high densities, the universe will stop expanding and then contract / eventually contract; ***[3]***
Award of second and third marks means, by implication, that the first has been scored.

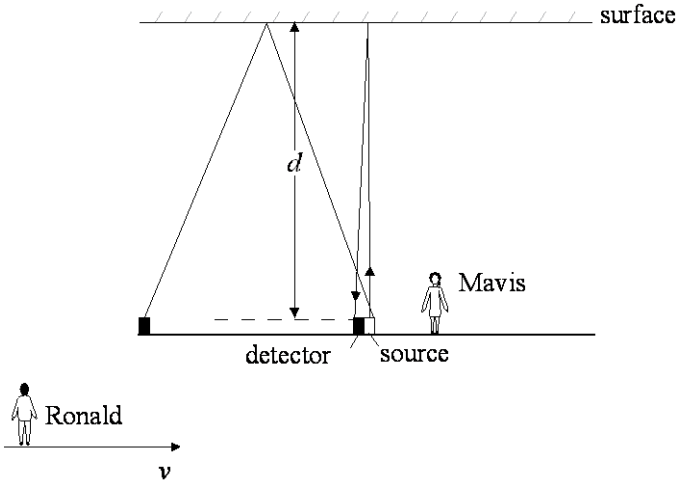
F4. (a) fusion/burning of elements higher than helium;
(in final stages) matter ejected as a supernova explosion;
core collapses to a neutron star; ***[3]***

(b) neutron star rotates rapidly (and has large magnetic field);
charged particles accelerated due to large magnetic field;
produce directed beams of radiation; ***[3]***

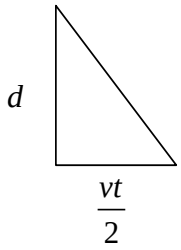
F5. use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$;
to give $v = 6.48\times10^{6}\ \text{m s}^{-1}$;
use of $v = H_0 d$;
to give $d = 93\,\text{Mpc}$; ***[4]***
*Award **[3 max]** if candidate divides by 401.8nm, v = 6.35 x 10^6m s^{-1}which gives 91 Mpc.*

Option G — Relativity

G1. (a) the detector drawn some distance away from the original pair and off to the left;
Accept indication with arrow(s).
a light beam symmetric about a vertical line passing through the point where the beam hits the mirror joining the emitter and detector; ***[2]***



(b)
(b) identifies triangle with a base equal to $\frac{vt}{2}$ and height $= d$;



application of Pythagoras' theorem;
total path twice hypoteneuse; ***[3]***

(c) (i) $t_0 = \frac{2d}{c}$; ***[1]***

(ii) observed time,

$t = \frac{L}{c} = \frac{2\sqrt{d^2 + \left(\frac{vt}{2}\right)^2}}{c}$;

rearrange to give

$t^2(c^2 - v^2) = 4d^2$;

thus

$t = \frac{2d}{c}\left(\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}\right)$; ***[3]***

$\left(\text{and hence } t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}\right)$

G2. light from clock A travels further to Frank than light from clock B;
at the same constant speed *c* / speed of light is same for both observers;
light from clock A takes longer to reach Frank / if Frank observes clock A change to 1, clock B will already have changed;
therefore, clocks do not read the same time;

or

events are simultaneous to Albert;
so cannot be simultaneous in a different/Frank's frame of reference;
light from B travels shorter distance at speed *c*;
so B changes first/runs faster; ***[4]***

G3. (a) if the muon measures 4500 m in its reference frame; *recognizes the idea of two frames of reference*
the muon/Earth would have to travel at $2.0 \times 10^9\ \text{m s}^{-1}$ / faster than the speed of light;
which is not possible;
distance travelled, <u>as measured in muon's reference frame</u> must be less/contracted; ***[4]***

(b) $mc^2 = Ve + m_0c^2$;
$= 210\,\text{MeV} + 105\,\text{MeV}$
$= 315\,\text{MeV}$;
$m = 315\,\text{MeV}c^{-2}$ ***or*** $3m_0$; ***[3]***

G4. (a) each proton must have two rest-mass energies $(=1860\text{ MeV})$ / rest mass energy of products is $4\times930\ (=1860\,\text{MeV})$;
particles after collision have no kinetic energy; ***[2]***

(b) use of $E^2 = p^2c^2 + m_0{}^2c^4$; ***or*** $mc^2 = \gamma m_0 c^2$;

$1860^2 = p^2c^2 + 930^2$; $\gamma = \dfrac{m}{m_0} = \dfrac{1860}{930} = 2$;

$p = \sqrt{\dfrac{(1860^2 - 930^2)}{c^2}}$; use of $\left(1-\dfrac{v^2}{c^2}\right)^{-\frac{1}{2}}$ to give $v = 0.866c$;

$p = 1610\,\text{MeV c}^{-1}$; $p = 1860\times0.866 = 1610\,\text{MeV c}^{-1}$; ***[4]***

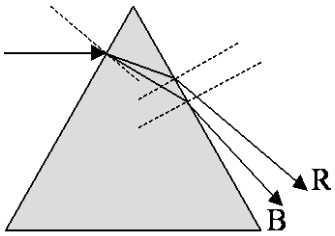
G5. (a) Earth causes warping of spacetime;
satellite follows shortest path in spacetime $\rightarrow$ curve; ***[2]***

(b) black hole causes <u>extreme</u> warping of space in its vicinity;
extreme warping causes photons/light to curve back into the black hole; ***[2]***

Option H — Optics

H1. (a) light (that is a combination of colors/wavelengths/frequencies) is divided/split into its component colours/wavelengths/frequencies; ***[1]***

(b)

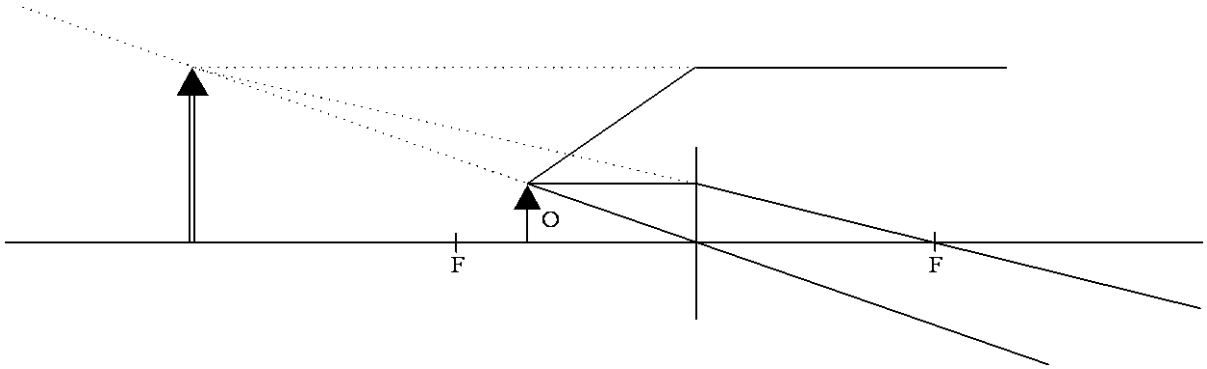


bends towards the normal at first surface;
away from normal at second;
blue is deviated to a greater degree than red at both interfaces; ***[3]***
Normals do not need to be drawn.
*Award **[1 max]** if dispersion is shown at second face only.*

(c) refraction angle for blue light is less than for red light (at the first boundary);
since $n = \frac{\sin i}{\sin r}$;
n for blue is greater / *n* for red is less; ***[3]***
Do not award marks for bald answers or answers with fallacious argument.
Allow ECF for consistent argument for switching of B and R from (b).

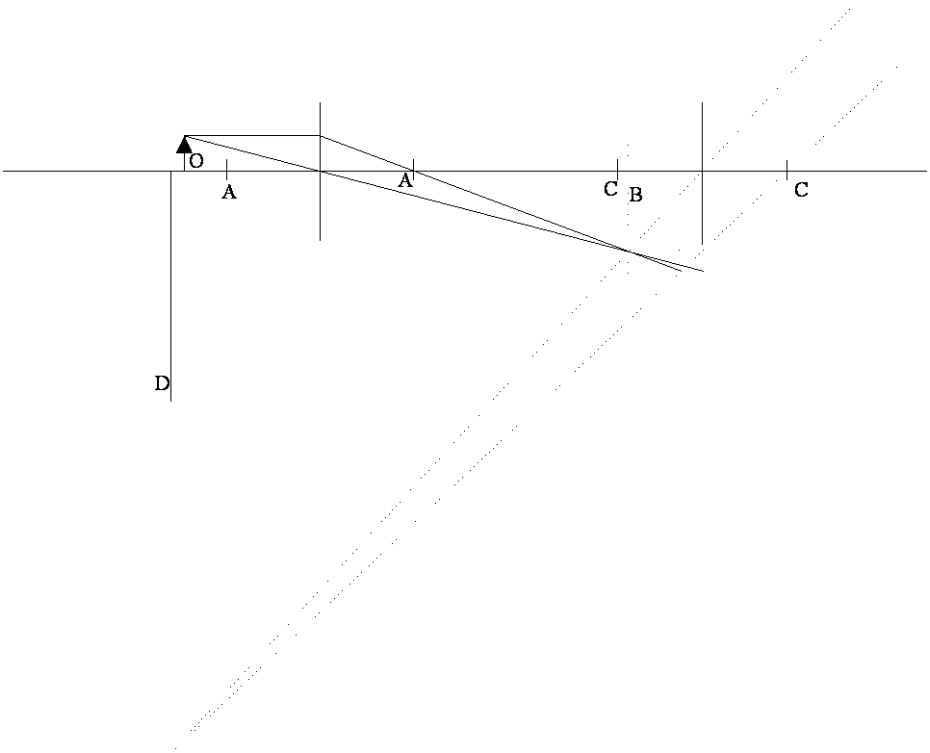
(d) recombined / white light;
parallel to the incoming beam; ***[2]***
ignore displacement and/or rays within block

H2. (a) one ray through the optical centre of the lens;
one through a focal point;
back traced to locate image; ***[3]***
No need for arrows or dotted lines



(b) virtual, magnified, erect; ***[2]***
*Award **[2]** for all three and **[1]** for any two.*

(c)



A between object and objective, and equidistant on opposite side of lens;
B located between two lenses;
C located (just) further from eyepiece lens than B, and equidistant on opposite side;
do not allow if B is not between lenses
D located near O; *accept anywhere to the left of the objective* ***[4]***
Rays do not need be drawn.

(d) less distortion;
less chromatic aberration; ***[2]***

H3. (a) uses idea that max n when $\sin\theta = 1$;
use of $d = \frac{1}{6.0 \times 10^5}$;
to give $n = 2.8$;
hence there are five orders; ***[4]***

(b) separation of lines greater in second order / lines more likely to be seen separately in second order;
lines are brighter in first order; ***[2]***

H4. (a) interference; ***[1]***

(b) for one angle of viewing, one colour will interfere destructively;
leaving white minus that colour;
at another angle, a different colour will interfere destructively / changing angle of viewing changes path difference; ***[3]***