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

MARKSCHEME

May 2005

PHYSICS

Higher Level

Paper 3

17 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.
- 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) rate of thermal energy loss $\propto L^2$;
mass $\propto L^3$;
$Q \propto \frac{1}{L}$;
$\frac{Q_{adult}}{Q_{child}} = \frac{1.20}{1.80} = 0.67$; ***[4]***

(b) the child because it has higher value of Q;
*Award **[0]** for bald statement without a reasonable justification.* ***[1]***

D2. (a) 15-30 Hz to 15-20 kHz; ***[1]***

(b) sounds of different frequency force different hair cells to vibrate;
at different amplitude depending on the length / thickness / stiffness of the hair cells;
the (electrical) signals sent to the brain from the different vibrating receptors allow the brain to distinguish different frequencies; ***[3]***
*As candidates are unlikely to answer at this level of detail, be generous and award marks accordingly if they show **understanding** of each of the processes involved.*

(c) (i) $\beta = 10\log\frac{I}{10^{-12}}$
$\beta = 10\log\frac{2.7\times10^{-5}}{10^{-12}}$;
$\beta = 74$ dB; ***[2]***

(ii) the response of the ear is logarithmic;
the sound intensity level β is defined in terms of the logarithm of sound intensity;
so equal changes in β correspond to equal changes in *ratios* of intensity; ***[3]***

D3. (a) (i) X-rays: to detect broken bones, because bone and tissue show different attenuation / good distinction between bone and flesh; ***[1]***

(ii) ultrasound: any soft tissue analysis, that takes advantage of reflections off organ boundaries / pre-natal scans because there is no risk from ionizing radiation; ***[1]***

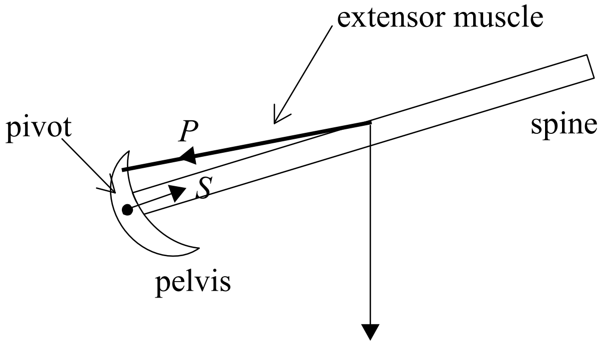
(iii) NMR: any situation where detailed tomography / slicing / imaging is required / large scale investigations where dose of ionizing radiations would be too great; ***[1]***
*Award **[1 max]** for statement of situation without explanation and **[2 max]** for two correct explanations.*

(b) *Look for an overall answer that includes **three** of the following points.*
We need techniques that can:
have different absorption / attenuation properties for different types of tissue and bone;
distinguish boundaries of organs;
be used to provide two dimensional slice imaging / complete three dimensional images;
monitor static / dynamic conditions;
investigate at small / large scales;
be used to study concentrations of specific types of tissue <u>or</u> pharamaceuticals;
monitor specific organ functions; ***[3 max]***

D4. (a) in order for the spine to be in equilibrium;
the pelvis must exert a force on the spine; ***[2]***

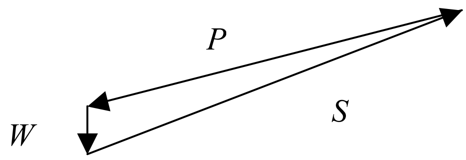
Accept alternative such as:
W and *P* have components down the spine;
the pelvis force is in opposite direction causing a compression;

(b) parallel to the spine - force must be shown acting at pelvis directed toward the point of intersection of *W* and *P* making it parallel to the spine; ***[1]***



(c) the angle that *P* makes parallel to the spine is small and the angle that *S* makes parallel to the spine is zero;
so both *P* and *S* must be much larger than *W* in order to balance the components of *W* perpendicular and parallel to the spine / *OWTTE*;

or
from triangle of forces:



for equilibrium *S*, *P* and *W* will form a triangle of forces;
correct diagram;

or
$P \sin\theta = W$;
θ is small so *P* and hence *S* are large; ***[2 max]***

D5. (a) biological half-life is the time it takes the body to eject by natural bodily processes; half of an ingested sample of a radioactive isotope; ***[2 max]***

*To award **[2]** some mention must be made of the general or specific method by which the amount of the isotope in the body is reduced.*

(b) $\frac{1}{T_E} = \frac{1}{21} + \frac{1}{8}$;

to give $T_E = 5.8$ days; ***[2]***

(c) because of its short physical half life it is much less likely to cause damage to the thyroid gland / because person is radioactive for a shorter time / because total dose received would be smaller / *OWTTE*; ***[1]***

Option E — The History and Development of Physics

E1. (a) (i) the stars are fixed on a celestial sphere;
which rotates around the Earth; ***[2]***
N.B. *the second point may awarded only if the first has been awarded.*

(ii) the Earth rotates about its axis (in 24 hours);
so the stars appear to cover circular arcs; ***[2]***
N.B. *the second point may awarded only if the first has been awarded.*

(b) (i) in the Ptolemaic model, the planets move around the Earth in circular paths;
and so since the distance from the Earth remains the same so should the brightness; ***[2]***
Make sure you do not again award marks for a statement here that has already been made in part (a)(i).

(ii) the planets move around the Sun;
and so their distance from the Earth is not constant and so neither is their brightness; ***[2]***
Make sure you do not again award marks for a statement here that has already been made in part (a)(ii).

E2. (a) (i) the net force on each body is non-zero;
and is larger on body A because it moves with higher speed; ***[2]***

(ii) the net force is zero on both bodies;
because a constant velocity implies zero acceleration and hence no net force; ***[2]***

(b) the stone has a larger mass;
and so a larger force acts on it; ***[2]***
Do not accept answers that mention air resistance.

E3. (a) Phlogiston was the name given to the fluid of heat which was released when a body burned / the fluid of heat; ***[1]***

(b) Lavoisier noticed that in some cases, the remnants of a combustion / oxidation process had a larger mass than before;
indicating that the phlogiston fluid had a negative mass; ***[2]***
Be generous here and accept ***any*** *experimental evidence for* ***[1]*** *and award* ***[1]*** *for explanation. You may want to mark (b) and (c) together and award points for clear, precise statements.*

(c) the large quantities of the generated heat indicated that large quantities of caloric had moved from somewhere else;
and therefore the temperature somewhere else must have dropped as a result;
which was something that was not observed;
or
shavings in cannon boring were observed to have a very high temperature;
which implied the presence of large quantities of caloric (fluid);
and yet the mass of the shavings was so small that it could not hold the fluid; ***[3 max]***

E4. (a) the angular momentum must be an integral number of $\frac{h}{2\pi}$ where h is the Planck constant / orbit can fit an integral number of wavelengths associated with the electron; ***[1]***
If quoted mathematically, then terms must be defined.

(b) *Look for these general points.*
whilst in a stable orbit the electron does not emit radiation;
when it makes a transition to a lower energy orbit it emits a photon whose frequency is determined by the difference in energy of the orbits;
transitions between orbits will give rise to the wavelengths in the line spectrum; ***[3]***

(c) $E = \frac{hc}{\lambda} = \frac{k}{n^2}$;

$= k\left(\frac{1}{4} - \frac{1}{9}\right) = 0.139\,k$;

$k = \frac{hc}{0.14\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{362\times10^{-9}\times0.139} = 3.95\times10^{-18}$ J;

recognize that k is the ionisation energy; ***[4]***
Allow use of 2 significant figures.

(d) *Look for some of these points.*
the electron has wave properties;
the "electron wave" in the atom has to fit boundary conditions;
only certain wavelengths are allowed / standing waves by boundary conditions;
the wavelength of the electron determines its energy; ***[2 max]***
To award ***[2]*** *boundary conditions must be mentioned.*

Option F — Astrophysics

F1. (a) (i) the distance of both stars from the Earth are approximately the same (since they are part of the binary system);
and so apparent brightness is proportional to just luminosity; ***[2]***

*Award **[1]** for use of* $b = \dfrac{L}{4\pi d^2}$ *and **[1]** for a statement that distance is the same.*

(ii) $b = \dfrac{L}{4\pi d^2}$, $L = \sigma A T^4$

$$\frac{b_B}{b_A} = \frac{\dfrac{L_B}{4\pi d^2}}{\dfrac{L_A}{4\pi d^2}} = \frac{A_B T_B^4}{A_A T_A^4};$$

$$\frac{2.0\times10^{-14}}{8.0\times10^{-13}} = \frac{T_B^4}{10^4\, T_A^4};$$

$$\frac{T_B^4}{T_A^4} = 250;$$

$$\frac{T_B}{T_A} = \sqrt[4]{250} = 3.97 \approx 4;$$ ***[4]***

(b) (i) Diagram at 5 years

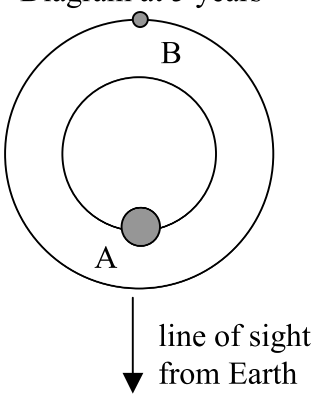
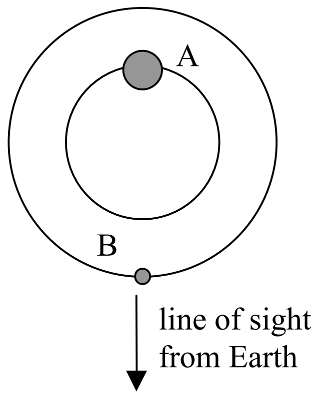


Diagram at 10 years



stars shown eclipsing each other;
stars in correct positions; ***[2 max]***

(ii) 10 years; ***[1]***

(iii) the <u>total</u> mass of the binary; ***[1]***
To receive the mark, it must be clear that the total mass is referred to.

F2. (a) critical density is that value of the (mass / energy) density of the universe for which the universe (the geometry of the universe) is flat (in the Big Bang model); ***[1]***

(b) it implies that the universe will expand forever; ***[1]***

(c) (i) matter that makes up for most of the mass in the universe;
but cannot easily be detected because it does not emit radiation / light; ***[2]***

(ii) **two** of Neutrinos / WIMPS / MACHOS / black holes / exotic super symmetric particles / grand unified predicted particles / magnetic monopoles *etc.*; ***[2]***

F3. (a) (isotropic) EM radiation (in the microwave region) that fills the universe / radiation left over from the Big Bang;
(characteristic of a black body) at a temperature of approximately 3 K; ***[2]***

(b) accept any curve with the same overall shape;
with the peak shifted to the right since temperature is lower; ***[2]***

F4. (a) *Award **[1]** for each correct answer. If the super red giant and supernova are in the wrong order award **[2 max]**.* ***[3 max]***

main sequence star mass $> 8M_{\text{Sun}}$ → super red giant → supernova → black hole / neutron star

(b) (i) if the mass is greater than this then electron degeneracy pressure;
can no longer prevent gravitational collapse; ***[2]***

(ii) because a large amount of mass is lost / ejected from the star during the planetary nebula stage / leaving core with a mass less than 1.4 solar masses; ***[1]***

F5. (a) the expansion of the universe; ***[1]***

(b) the recessional speed of a galaxy is proportional to its distance from the Earth / galaxies move away from each other with a speed proportional to their separation; ***[1]***
Accept $v = Hd$ *if symbols are defined.*

(c) consider a galaxy that has moved a distance d from the Big Bang in time T then if the speed of recession is constant $v = \frac{d}{T}$;

but $v = Hd$ therefore substituting gives $T = \frac{1}{H}$; ***[2]***

Option G — Relativity

G1. (a) the speed of light <u>in vacuum</u> is the same for all inertial observers;
the laws of Physics are the same in all <u>inertial</u> frames of reference; ***[2]***

(b) (i) this faster than light speed is not the speed of any physical object / inertial observer and so is not in violation of the theory of SR; ***[1]***

(ii) $u' = \dfrac{u-v}{1-\dfrac{uv}{c^2}}$ with $v = -0.80c$ and $u = 0.80c$ so that

$$u' = \frac{0.80c + 0.80c}{1+\dfrac{0.80c \times 0.80c}{c^2}};$$

$$u = \frac{1.60c}{1.64};$$

$$u = 0.98c;$$ ***[3]***

G2. (a) (i) $\gamma = \frac{1}{\sqrt{1-0.98^2}} = 5.03$;

time $= \gamma \times$ proper time $= 5.03 \times 2.2 \times 10^{-6} = 1.1 \times 10^{-5}$ s ; ***[2]***

*Award **[1]** for a time of* 4.4×10^{-7} s *which indicates correct calculation of the gamma factor. Award **[1]** for incorrect gamma factor but calculation otherwise correct.*

(ii) $x = vt$

$x = 0.98 \times 3 \times 10^8 \times 1.1 \times 10^{-5}$;

$x = 3200\,\text{m}$; ***[2]***

(iii) $x = vt$

$x = 0.98 \times 3 \times 10^8 \times 2.2 \times 10^{-6}$;

$x \approx 650\,\text{m}$; ***[2]***

(iv) ***1.*** *The observer at rest on the surface of the Earth*:

distance travelled by muon is 3200 m > 3000 m;

hence a few muons arrive on Earth's surface before decaying; ***[2]***

2. *The observer at rest relative to the muon*:

distance separating muon and Earth is length contracted to

$3.0\,\text{km} \times \sqrt{1-0.98^2} \approx 600\,\text{m}$;

distance travelled by Earth is 650 m > 600 m;

hence when Earth meets particles a few are still muons; ***[3]***

(b) $qV = \Delta E = (\gamma - 1) m_o c^2$;

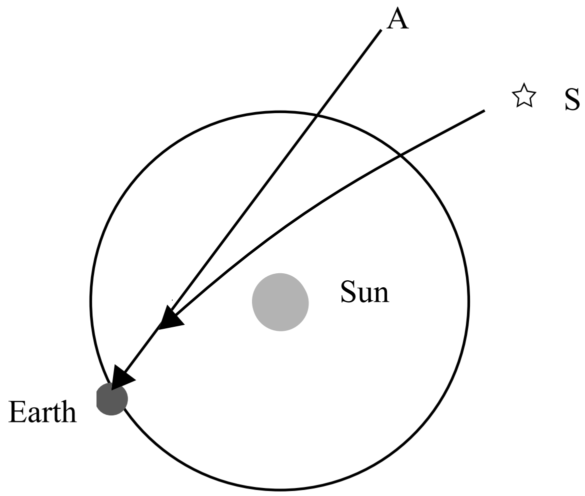
$qV = (5.03-1) \times 106\ \text{MeV}\,\text{c}^{-2} = 427\ \text{MeV}$;

$\Rightarrow V = 427\ \text{MV} \approx 430\ \text{MV}$; ***[3]***

G3. (a) in order that the star could be seen; ***[1]***

(b) in order that the degree / amount of bending of the light by the Sun can be measured / *OWTTE*; ***[1]***

(c) path showing bending by the Sun; ***[1]***
Note that a correct diagram may also include rays from the other side of the Sun. Only accept rays from the star that at the point of closest approach to the Sun are no more than about 1 cm from the Sun's surface.



(d) the theory predicts that space-time is curved/warped by the presence of matter;
the light ray takes the shortest path between the star and Earth in the curved/warped space; ***[2 max]***
*To award **[2]**, space-time must be mentioned. An answer such as "gravity bends light" would only receive **[1]**.*

(e) see diagram; ***[1]***
Position must be consistent with bent ray.

G4. (a) $E = 2m_p c^2$; ***[1]***

(b) use $E^2 = p^2c^2 + m_p{}^2c^4$ to give $4m_p{}^2c^4 = p^2c^2 + m_p{}^2c^4$;

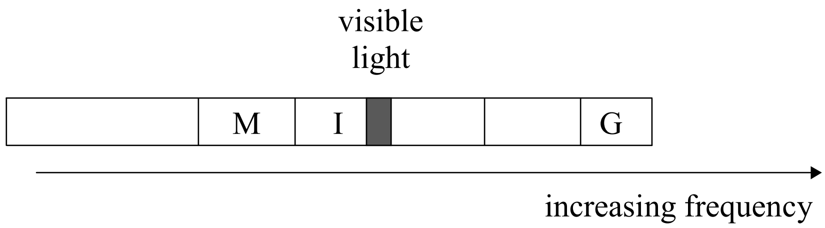
such that $3m_p{}^2c^4 = p^2c^2$;

to give $p = 1.6 \times 10^3\ \text{MeV c}^{-1}$; ***[3]***
Watch for correct units.

Option H — Optics

H1. (a) light consists of oscillating magnetic and electric fields at right angles to each other; which transfer energy at speed *c* in vacuum (in a direction at right angles to both fields); ***[2]***

(b)

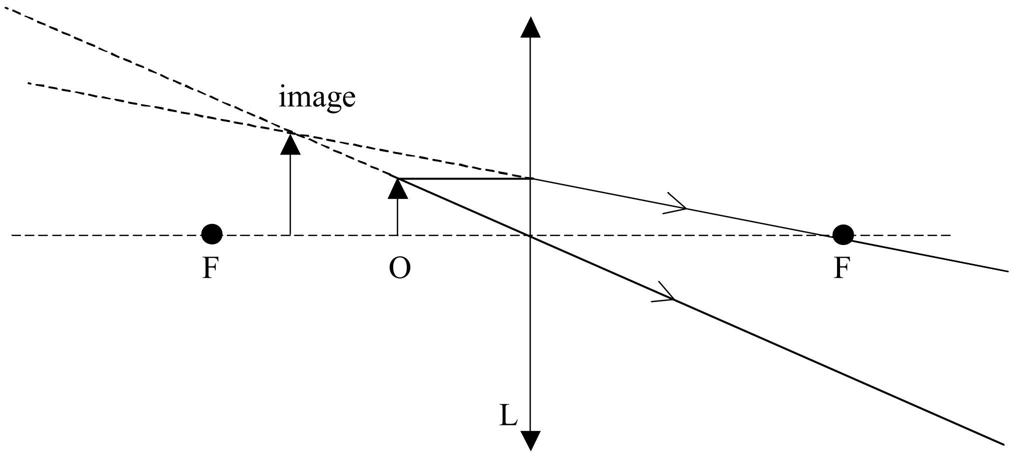


(i) correct labelling of infrared waves; ***[1]***

(ii) correct labelling of microwaves; ***[1]***

(iii) correct labelling of gamma rays; ***[1]***
*Award **[1]** if all positions are incorrect but order MIG is right.*

H2. (a)



(i) it is the point on the principal axis;
through which a ray parallel to the principal axis passes after going through the lens; ***[2]***
*Award **[0]** if focal point is defined as a distance.*

(ii) *Award **[2]** for any **two** appropriate rays and **[1]** for correct positioning of the image (upright).* ***[3]***

(iii) it is virtual because no rays pass through the image / cannot be formed on a screen; ***[1]***
*Award **[0]** if no explanation is provided.*

(b) (i) $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$

$\frac{1}{v}=\frac{1}{6.25}-\frac{1}{5.0}$;

$v=-25$ cm, so distance is 25 cm; ***[2]***
A*ccept negative sign in answer for distance.*

(ii) $M=\frac{v}{u}$

$M=\frac{-25}{5}=-5$; $\left(Accept\;\; M=-\frac{v}{u}=5\right)$

$L'=5\times 0.8=4.0\,\text{cm}$; ***[2]***

H3. (a) $u = 23.0 - 15.6 = 7.4\text{ cm}$; ***[1]***

(b) $\frac{1}{v} = \frac{1}{11.0} - \frac{1}{7.4}$;

$v = -22.6\text{cm}$, so distance is 22.6cm; ***[2]***

Accept negative sign in answer for distance.

(c) $M = \frac{22.6}{7.4} \times \frac{15.6}{1.3}$;

$M = 36.7 \approx 37$; ***[2]***

*Award **[0]** for adding the individual magnifications to get 15.*

H4. (a) $\angle\text{YXP}$; ***[1]***

(b) $\frac{\lambda}{2}$;

for the waves to interfere destructively at P, their path difference must be $\left(n + \frac{1}{2}\right)\lambda$ and since this is the first minimum $n = 0$ / *OWTTE*; ***[2]***

Look for some reasonable justification for the second mark.

(c) $\theta = \phi$ with some justification, such as angles are small / screen is far away;

$\varphi = \frac{ZW}{\frac{b}{2}}$;

since $ZW = \frac{\lambda}{2}$, $\theta = \frac{\lambda}{b}$; ***[3]***

Allow use of single slit diffraction formula $b\sin\theta = n\lambda$ if it is clear that the candidate knows what they are doing, i.e. they are not using the diffraction grating formula. $n = 1$, θ is small, with a justification, so $\sin\theta \approx \theta$, $\theta = \frac{\lambda}{b}$.

(d) $\theta = \frac{4.5 \times 10^{-7}}{1.5 \times 10^{-4}} = 3.0 \times 10^{-3}\text{ rad}$;

angular width $= 6.0 \times 10^{-3}$ rad; ***[2]***

(e) recognize to use $d\psi = n\lambda$ with $n = 4$;

$d = \frac{4 \times 4.5 \times 10^{-7}}{3.0 \times 10^{-3}} = 6.0 \times 10^{-4}$ m;

or

recognize for missing orders that $\frac{d}{b} = 4$;

so $d = 4b = 6.0 \times 10^{-4}$ m; ***[2 max]***

*Award **[1 max]** if n = 3 is used.*