IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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M05/4/PHYSI/SP3/ENG/TZ1/XX/M+

MARKSCHEME

May 2005

PHYSICS

Standard Level

Paper 3

19 pages

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) (i) $x = v_x t$

$80 = v_x \times 4$;

$v_x = 20\,\text{m s}^{-1}$; ***[2]***

Warning that use of $v^2 = 2gs$ *with* $g = 10\,\text{ms}^{-2}$ *and* $s = 80\,\text{m}$ *gives numerically correct result. Award **[1]** for ECF if wrong value of time has been used.*

(ii) $v_y = u_y - gt$

$v_y = 0$ at $t = 2.0\,\text{s}$;

$0 = 40 - 2g$;

$g = 20\,\text{ms}^{-2}$; ***[3]***

(iii) $y = u_y t - \frac{1}{2} g t^2$

$y = 40 \times 2 - \frac{1}{2} \times 20 \times 2^2$;

$y = 40\,\text{m}$; ***[2]***

*Award **[1]** if plus sign is used to give 120 m.*

(b) $\tan\theta = \frac{v_y}{v_x}$;

$\theta = \arctan\frac{40}{20} = 63.4^\circ \approx 63^\circ$; ***[2]***

(c) parabolic path;
with half the range;
and half the maximum height; ***[3]***

A2. (a) The work done per unit mass;
in bringing a (small test) mass from infinity to the point; ***[2]***
Idea of ratio crucial for first mark.

(b) (i) $g = \frac{GM}{r_1^2} - \frac{Gm}{r_2^2}$;

$0 = \frac{M}{0.8^2} - \frac{m}{0.2^2}$;

$\frac{M}{m} = 16$; ***[3]***

(ii) $K = m\Delta V$;
$K = 1500 \times (4.6 - 0.20) \times 10^7$ J;
$K = 6.6 \times 10^{10}$ J; ***[3]***
Award ***[2 max]*** *if attempted use of* ΔV *but value used is wrong and* ***[1 max]*** *if an individual potential value rather a difference is used.)*

Option B — Quantum Physics and Nuclear Physics

B1. (a) *Mark the both processes, 1 and 2, together.*

*Award **[1]** any two of the following.*
collisions with (external) particles;
heating the gas to a high temperature;
absorption of photons; ***[2 max]***

(b) (i) $E = \frac{hc}{\lambda}$

$E = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{658 \times 10^{-9}} \text{J}$;

$E = \frac{3.02 \times 10^{-19}}{1.6 \times 10^{-19}} \text{eV}$;

$= 1.89 \text{eV}$ ***[2]***

(ii) electrons absorb photons (of energy 1.89eV) to make a transition from $n = 2$ to $n = 3$;
on de-excitation, photons of energy 1.89eV, *i.e.* wavelength 658 nm are emitted;
in **all directions**, however, and not just along the initial direction, hence intensity is reduced; ***[3]***

(iii) (the Schrödinger model unlike Bohr's)
does not have well defined orbits for the electrons / does not treat the electron as a localized particle / assigns to an electron a probability wave;
predicts the relative intensities of various spectral lines; ***[2]***

B2. (a) electric charges emit EM radiation when they are accelerated;
when electrons hit target they suffer rapid decelerations;
the decelerations have a range of values leading to radiation with a range of wavelengths;
the minimum wavelength corresponds to the maximum possible deceleration / when electron converts to energy of just one photon; ***[4]***

(b) $eV = \frac{hc}{\lambda}$;

$\lambda = \frac{hc}{eV} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{1.6 \times 10^{-19} \times 20 \times 10^{3}} = 6.2 \times 10^{-11} \text{m}$; ***[2]***

(c) (i) the minimum wavelength shifts to the left; ***[1]***

(ii) the positions of the characteristic lines do not change; ***[1]***

B3. (a) zero; *[1]*

(b) weak / electroweak interaction (force); *[1]*

(c) they have opposite lepton number; *[1]*

Option C — Energy Extension

C1. (a) (i) kinetic energy of the fission products / neutrons / photons; ***[1]***
Do not accept themal energy or heat.

(ii) if mass of uranium is too small too many neutrons escape;
without causing fission in uranium / reactions cannot be sustained; ***[2]***

(iii) the moderator (and the fuel rods); ***[1]***

(iv) mass of uranium atom $= 235 \times 1.661 \times 10^{-27} = 3.90 \times 10^{-25}$ kg ***or*** $\frac{0.235}{6.02 \times 10^{23}}$ kg ;
mass of uranium per second $= 3.90 \times 10^{-25} \times 8 \times 10^{19} = 3.12 \times 10^{-5}$ kg s^{-1};
mass of uranium per year $= 3.12 \times 10^{-5} \times 365 \times 24 \times 60 \times 60 = 984 \approx 9.8 \times 10^{2}$ kg yr^{-1}; ***[3]***

(b) (i) 800 MW; ***[1]***

(ii) 200 MW; ***[1]***

(iii) 1600 MW; ***[1]***

(iv) the second law of thermodynamics; ***[1]***

(v) $\eta = \frac{800}{2400} = 33\ \%$; ***[1]***
Answer does not need to be expressed as a percentage.

(vi) $0.33 = 1 - \frac{300}{T_H}$;
$T_H = 450\,\text{K}$; ***[2]***

C2. (a) (i) $P \propto v^3$;
$= 15 \times 2^3 = 120\,\text{kW}$; ***[2]***

(ii) the wind speed will not be reduced to zero after impact with blades;
power will be less because of frictional losses / turbulence; ***[2]***
The place where frictional losses take place must be identified.

(b) wind power is renewable;
while fossil fuels are finite; ***[2]***
*Award **[0]** for statement that wind generators do not cause pollution.*

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 or pharamaceuticals;
monitor specific organ functions; ***[3 max]***

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]***
***Note**: 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]***
***Note**: 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]***

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

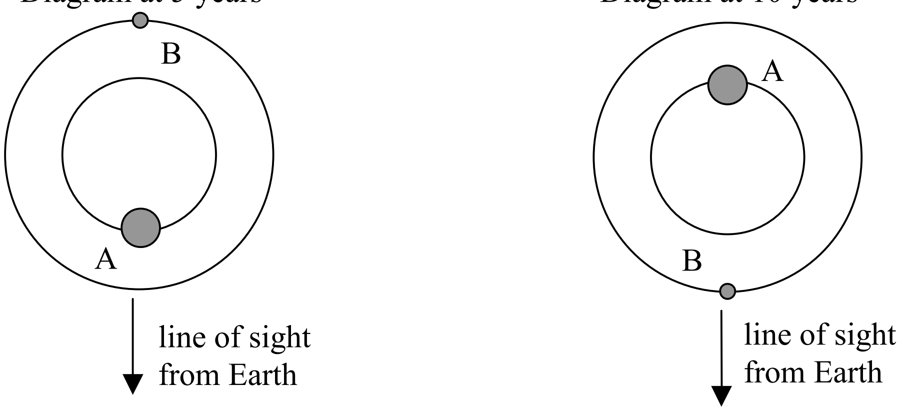
$$\frac{b_B}{b_A} = \frac{\frac{L_B}{4\pi d^2}}{\frac{L_A}{4\pi d^2}} = \frac{A_B T_B^4}{A_A T_A^4};$$

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

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

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

Option G — Relativity

G1. (a) the speed of light in vacuum is the same for all inertial observers;
the laws of Physics are the same in all inertial 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) $qV = \Delta E = (\gamma - 1)m_o c^2$;

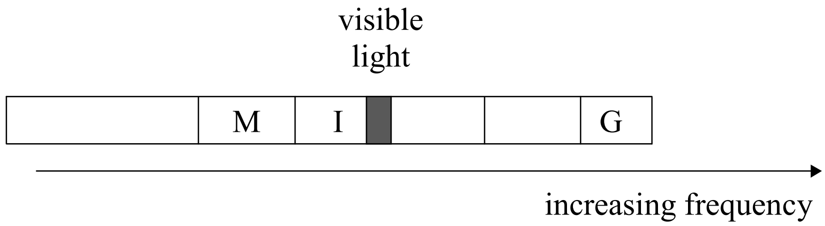
$qV = (5.03-1) \times 106\ \text{MeV c}^{-2} = 427\ \text{MeV}$;

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

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)

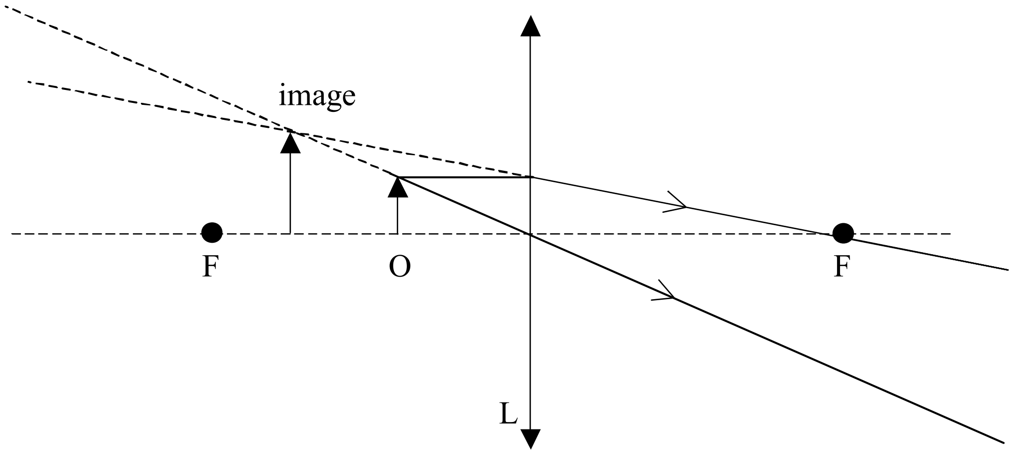


(i) correct labelling of infrared waves; ***[1]***

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

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

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

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

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

$L'=5\times 0.8=4.0\,\text{cm}$; ***[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 22.6 cm; ***[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.*