MARKSCHEME

November 2006

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 <u>underlined</u> 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) (i) 4; *[1]*

(ii) 8; *[1]*

(b) $\frac{\text{needs}}{\text{absorption}} \propto \frac{L^3}{L^2} = L$;
as an insect becomes larger, absorption cannot keep pace with needs / *OWTTE*; *[2]*

D2. (a) intensity is power incident per unit area;
loudness is the response of the ear to intensity; *[2]*

(b) substitution into $\beta = 10db\lg\left(\frac{I}{1\times10^{-12}}\right)$
$82 = 10\lg\left(I \times 10^{12}\right)$;
$I = 1.58\times10^{-4}\ \text{W m}^{-2}$;
$I = \frac{2.4}{4\pi r^2}$;
rearrange to give $r^2 = \frac{2.4}{4\pi\times1.58\times10^{-4}}$;
$r = 35\,\text{m}$; *[5]*

D3. (a) the thickness needed to cause a beam to attenuate/be reduced in intensity by 50% / *OWTTE*; *[1]*

(b) indication that the ratio between the linear attenuation coefficients must be the same as the ratio between attenuation coefficients / $\mu_T x_T = \mu_B x_B$;
(therefore) linear attenuation coefficient $= 150\times0.035$;
$= 5.3\,\text{cm}^{-1}$ *[2]*

(c) (i) substitution into $I = I_0 e^{-\mu x}$
$I_B = I_A\ e^{-0.035\times5.0}$;
$\frac{I_B}{I_A} = 0.84$; *[2]*

(ii) substitution to give $\frac{I_C}{I_B} = 3.1\times10^{-12}$; *[1]*

(d) all X-rays stopped by bone so total shadow;
few X-rays stopped by soft tissue/muscle;
so (good) contrast between (air), muscle and bone; *[3]*

D4. (a) clockwise moment $= 50X$ anticlockwise moment $= (22\times160)+(8\times380)$
equate $50X = (22\times160)+(8\times380)$;
to give $X = 130\,\text{N}$ ***[1]***

(b) $\dfrac{\text{distance moved by effort}}{\text{distance moved by load}} = \dfrac{50}{220+160}$;
$= 0.13$ ***[1]***

(c) $MA = \dfrac{8.0}{130}(=0.06)$;

$eff = \dfrac{8.0}{130\times0.13} = 0.47\,(47\,\%)$; ***[2]***

(d) work has to be done to lift the forearm / *OWTTE*; ***[1]***
Do not accept bending of forearm.

D5. (a) the energy absorbed per unit mass; ***[1]***

(b) for the same absorbed dose;
this measures the relative effectiveness of different radiations in destroying cells / *OWTTE*; ***[2]***

(c) $\dfrac{dN}{dt} = -N\lambda = 8.0\times10^{18}\times5.3\times10^{-10} = 4.2\times10^{9}$;
dose equivalent $= 4.2\times10^{9}\times4\times10^{-14} = 0.17\,\text{mSv}\,/\,\text{J kg}^{-1}$; ***[2]***

Option E — The History and Development of Physics

E1. (a) *Moon*:
moves constantly from west to east;
moves faster than Mars / Mars moves slower than the Moon;

Mars:
sometimes moves east-west / exhibits retrograde motion; ***[3]***

(b) Geocentric model;
Moon, Mars and background stars at different levels above the Earth;
Moon is closer than Mars so moves faster;
Mars moves on <u>epicycles</u> on its path; ***[4]***
Award marks for the use of a diagram with explanation.

(c) Newton realized that the planets were accelerating;
therefore needed a force on the planet;

or

there is a force of attraction between Sun and planets;
that provides a centripetal force / *OWTTE*; ***[2]***

E2. (a) a second charged sphere is brought close to the sphere (in diagram);
such as to cause the insulating rod to deflect / *OWTTE*;
the deflection and separation of charges is measured;
deflection is proportional to force; ***[4]***

(b) a series of identical spheres;
one is charged, then the others charged by repeated sharing of charge with the first sphere / *OWTTE*;

or

two identical spheres;
one charged, then charge shared, one discharged and process repeated / *OWTTE*; ***[2]***

E3. (a) diagram with labels to show the glass envelope, (region of vacuum), anode <u>and</u> cathode;
high voltage between the anode and cathode;
shadow seen on glass behind anode; ***[3]***

(b) with the application of magnetic field/electric field (normal) to rays;
rays were deflected, meaning they must be charged; ***[2]***

E4. (a) the integer *n* determines the values of the energy levels / *OWTTE*;
the integer *m* gives the value of the energy level from which an (excited) electron makes a transition to a lower energy level given by the integer *n* / *OWTTE*;
in making the transition, a photon is emitted, the wavelength of which is given by the Rydberg formula / determined by the difference in energy of the levels *m* and *n*;
if the value of *n* is fixed then electron transitions from higher levels given by values of *m* give rise to one of the (hydrogen atomic) spectral series / *OWTTE*; ***[3 max]***

(b) (i) $\frac{hc}{\lambda} = 2.2 \times 10^{-18}$;
to give $\lambda = 90\,\text{nm}$; ***[2]***

(ii) $R_{\text{H}} = \frac{1}{\lambda_{\text{min}}}$;
to give $R_{\text{H}} = 1.1 \times 10^{7}\ \text{m}^{-1}$; ***[2]***

E5. $\Delta x \Delta p \geq \frac{h}{2\pi}$ where Δx is the uncertainty in the position of the particle and Δp is the uncertainty in the momentum of the particle and $p = \frac{h}{\lambda}$;
if λ has just one value / *OWTTE*, then there in no uncertainty in momentum / $\Delta p = 0$;
a statement to the effect that this means that that although the momentum is known exactly all knowledge of the particle's position is lost / Δx is infinite; ***[3]***

Option F — Astrophysics

F1. (a) between Mars and Jupiter; ***[1]***

(b) as the Earth orbits the Sun, the Sun moves against the background of stars;
constellations cannot be seen when they are behind the Sun / *OWTTE*; ***[2]***
*Award **[1]** for realization that the Earth-Sun-star line falls on different stars through the year and **[1]** for realization that we cannot see those stars at that time.*

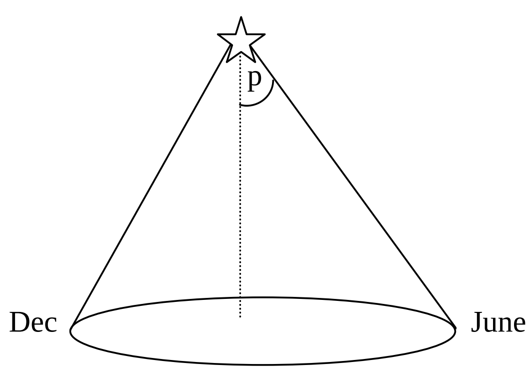
F2. (a) (i) the total power emitted (by the star); ***[1]***

(ii) the (incident) power per unit area on/received at the (surface of) Earth; ***[1]***

(b) (i) spectroscopic parallax; ***[1]***

(ii) use of $b = \frac{L}{4\pi d^2}$ to give $d = \sqrt{\frac{L}{4\pi b}}$;
$d = 5.3\times10^{19}$ m;
unit conversion gives 1700 pc; ***[3]***

(c) (i) measure angular position of star (against background of fixed stars);
at six month intervals;
$d = \frac{1}{p}$;
p identified; ***[4]***



(ii) $d = \frac{1}{5\times10^{-3}} = 200\,\text{pc}$; ***[1]***

F3. (a) spectral lines/frequency/wavelength of light from galaxies/distant objects are Doppler shifted to the red;
suggesting that galaxies/distant objects are moving away from each other;

or

Accept argument of Cosmic Microwave Background radiation.
everywhere in space there is a (uniform) radiation corresponding to a (black-body) temperature of 3K / *OWTTE*;
(suggesting) an initially hot universe that has cooled has it has expanded / *OWTTE*; ***[2]***

(b) (the critical density) is the density of the universe for which the expansion rate (of the universe) will slow to zero but never reverse / produces a flat universe; ***[1]***

(c) a knowledge of the density gives knowledge of the future/past of the universe / *OWTTE*;
if $\rho < \rho_C$ then universe will expand forever;
if $\rho > \rho_C$ then universe will eventually reverse its expansion/contraction; ***[3]***

F4. (a) (i) $v = H_0 d$
the further galaxies are away (from Earth) the more difficult it is to accurately determine their distance away / *OWTTE*;
because of the difficulty of locating a standard candle/Cepheid variable (in the galaxy) / difficulty of accurately measuring luminosities (of the galaxy / of the standard candle); ***[2]***

(ii) to determine an accurate value of the age of the universe / to determine an accurate value of the rate of expansion of the universe / to determine an accurate value to very distant galaxies; ***[1]***

(b) $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$

$\Delta\lambda = 90\times10^{-9}\text{ m}$;

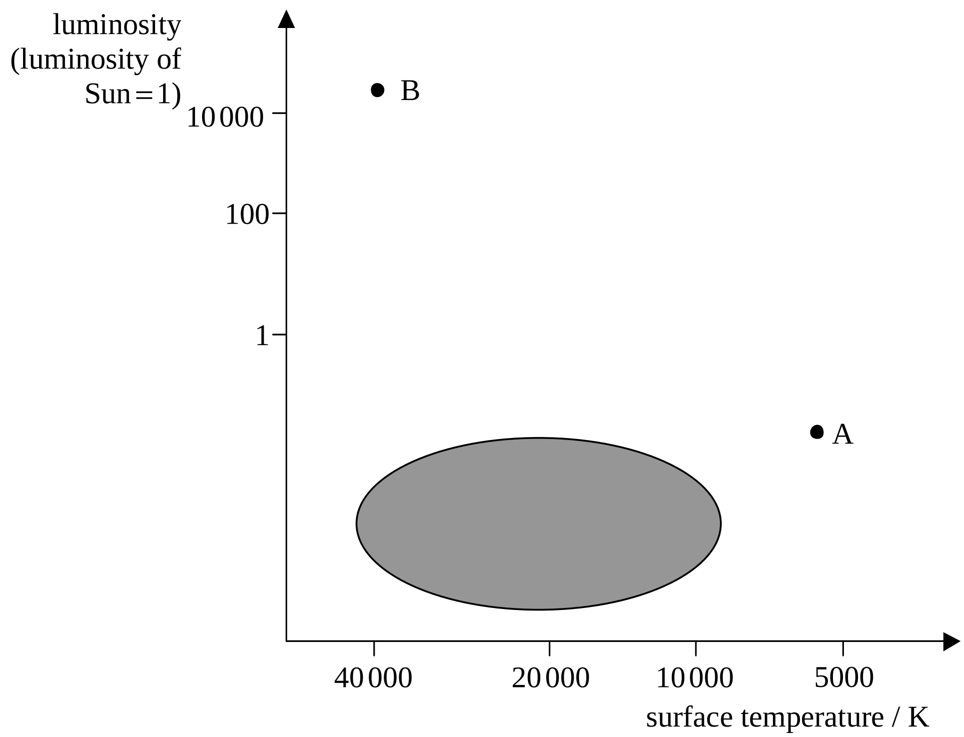
$v = 3\times10^{8}\times\frac{90\times10^{-9}}{660\times10^{-9}} = 4.1\times10^{7}\text{ m s}^{-1}$;

$d = \frac{v}{H} = \frac{4.1\times10^{4}}{75} = 550\text{ Mpc}$; ***[3]***

F5. (a) star B since much brighter and hotter (than star A);
indicating much greater amount of nuclear fusion taking place / is therefore radiating more energy / *OWTTE*; ***[2]***

(b) star B is able to fuse elements with higher atomic number than helium / is able to fuse silicon/carbon/neon/oxygen; ***[1]***

(c)



roughly in the shaded area; ***[1]***
Be generous – essentially "bottom left hand corner".

Option G — Relativity

G1. (a) a coordinate system (in which measurements can be made);
that is not accelerating / Newton's first law holds; ***[2]***

(b) there is no preferred inertial reference frame / the laws of physics are the same for all inertial observers;
the speed of light in a vacuum is constant;
in all inertial reference frames/for all inertial observers; ***[3]***

(c) (i) calculation of $\gamma = \frac{1}{\sqrt{1-0.80^2}} = 1.7$;
substitution into $L = \frac{L_0}{\gamma} = 140\,\text{m}$; ***[2]***

(ii) substitution into $u_x{}' = \frac{u_x - v}{1 - \frac{u_x v}{c^2}}$
$u_x{}' = +0.60\text{c}$ and $v = -0.80\text{c}$;
calculation to give $u_x = -0.38\text{c}$;

or

$u_x{}' = -0.60\text{c}$ and $v = +0.80\text{c}$;
(signs are irrelevant, as long as they are opposite)
calculation to give speed $= 0.38\text{c}$ ***or*** $u_x = -0.38\text{c}$; ***[2]***
*Award **[0]** if non-relativistic kinematics is used.*

(iii) towards the star / to the left; ***[1]***

(d) $E = \gamma m_0 c^2 = \left(5.1\times10^3\,\text{kg}\right)\times\left(9.0\times10^{16}\,\text{m}^2\,\text{s}^{-2}\right)$;
$E = 4.6\times10^{20}\,\text{J}$; ***[2]***
Allow calculation from $E^2 = p^2c^2 + m_0{}^2c^4$.
Do not deduct unit mark.

G2. (a) the time between any two events that occur at the same place in an inertial reference frame / the proper time in particular reference frame will be measured to be longer;
by observers in any other inertial reference frame; ***[2]***

(b) muons (are produced in the upper atmosphere and) can be detected on the ground;
the half-life/life/average life of a muon in its own frame of reference is not long enough according to an observer on the ground for many of the muons to survive long enough to reach the ground / *OWTTE*;
the observed (ratio of) number detected on the ground (to number detected in the upper atmosphere) is higher than expected;
because the half-life/life/average life of a muon as measured by the an observer on the ground is long enough to for the muons to reach the ground / *OWTTE*;

or

muons (are produced in the upper atmosphere) and can be detected on the ground;
the half-life/life/average life of a muon in its own frame of reference is less than the time it takes to travel through the atmosphere as measured by an observer on the ground / *OWTTE*;
the measured lifetime of such a muon by an observer on the ground is longer than would be measured if the observer were moving with the muon / *OWTTE*;
the difference indicates that time has been dilated (from the short lifetime to the long transit time); ***[4]***

(c) lifetime as measured by Earth observer $\gamma \times 2.20\,\mu\text{s} = 2.20 \times 10^{-5}$ s ;
distance $= 0.995 \times 3 \times 10^{8} \times 2.20 \times 10^{-5} = 6.57 \times 10^{3}$ m ; ***[2]***

G3. (a) $mc^2 = m_0c^2 + E_K$;
$mc^2 - m_0c^2 = E_K$ and $mc^2 = \gamma m_0 c^2$;
so $m_0c^2(\gamma - 1) = E_K$ ***[2]***

(b) $E_K = 1.450 - 0.510 = 0.940$;
therefore $\gamma = \dfrac{0.940}{m_0c^2} + 1 = 2.84$;
$2.84 = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$ to give $v = 0.936c$; ***[3]***

G4. (a) (the frequency is) lower; ***[1]***

(b) the principle says that it is impossible to distinguish between an accelerating reference frame and a gravitational field;
therefore light emitted from Y will have a lower frequency when compared to light from X / *OWTTE*; ***[2]***

(c) $f = \frac{c}{\lambda} = \frac{3\times10^{8}}{6.6\times10^{-7}} = 4.5\times10^{14}\text{ Hz}$;

$\Delta f = f\,\frac{g\Delta h}{c^{2}} = \frac{9.81\times4.5\times10^{14}\times1.4\times10^{4}}{9\times10^{16}} = 690\text{ Hz}$; ***[2]***

Option H — Optics

H1. (a) splitting/separation (of white light) into its component colours;
because different frequencies have different refractive indices; ***[2]***

(b) (i) both bending away from the normal;
blue greater deviation than red; ***[2]***

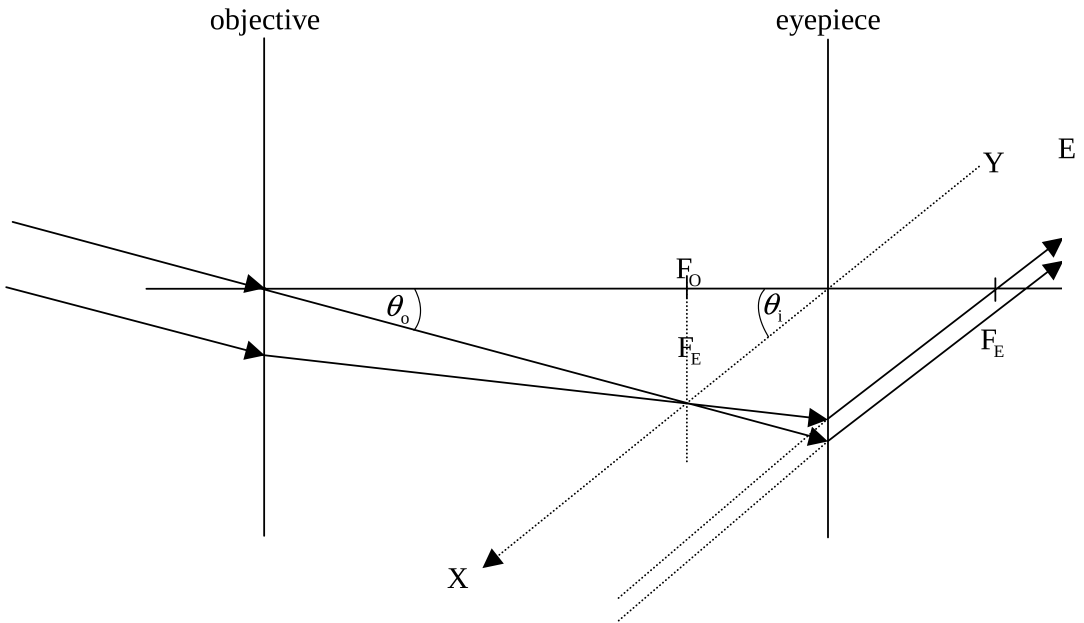
(ii) recognize maximum angle = critical angle, $\sin c = \frac{1}{n}$;

$c = \sin^{-1}\frac{1}{n} = 41.1^{\circ}$; ***[2]***

(iii) the blue light would not pass into the air;
since the refractive index for blue light is greater, therefore critical angle is smaller; ***[2]***
*Award **[0]** for wrong explanation or no explanation.*

H2. (a) θ_i – the angle that the image subtends at the eye / at which rays enter/exit the eyepiece lens;
θ_o – the angle that the object subtends at the eye / at which rays enter/exit the objective lens; ***[2]***

(b)



(i) F_E coincident with F_O and correct position on other side of lens-judge by eye; ***[1]***

(ii) two rays passing through focal plane of F_O;
line XY showing direction of final image;
rays emerging from eyepiece parallel to XY; ***[3]***

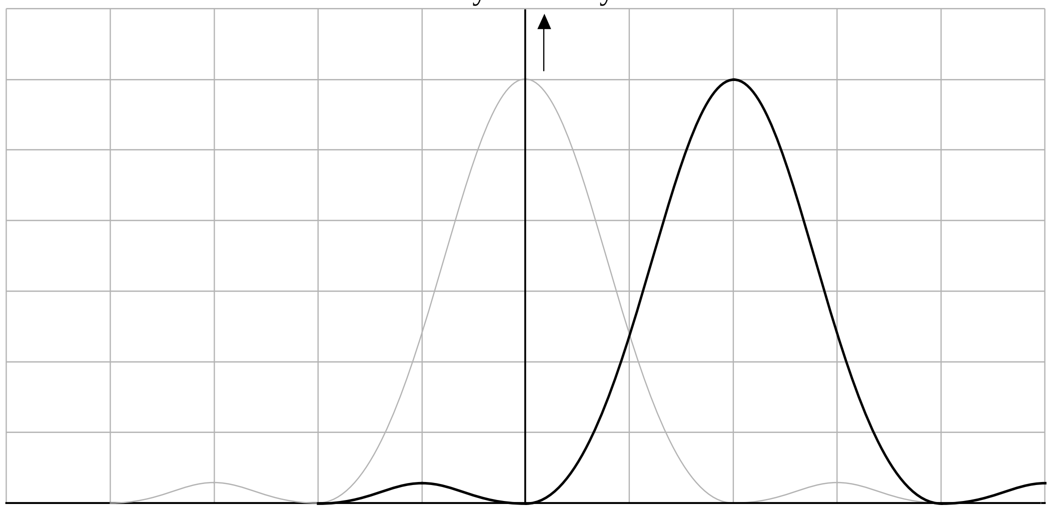
(iii) to the right of the eyepiece lens; ***[1]***

(iv) correct positions of the angles; ***[1]***

(c) (i) outside edges curve inwards/outwards;
no change to cross; ***[2]***

(ii) no distortion;
all four outside edges appear coloured / *OWTTE*; ***[2]***

H3. (a)



maxima to coincide with minima and minimum at maximum of first source;
minima to touch x-axis and intensity of maxima to equal intensity of maximum of first source; ***[2]***
Only one maximum and minimum need be shown.

(b) angle subtended at eye $= \frac{2.3\times10^{6}}{4.5\times10^{12}} = 5.1\times10^{-7}$ rad;

$= 1.22\frac{\lambda}{b}$ to give $b = \frac{1.22\times5\times10^{-7}}{5.1\times10^{-7}} = 1.2$ m;

Do not penalize if 1.22 not used (1.0 m).
some comment to the effect that this much larger than the diameter of the pupil so that Pluto <u>cannot</u> be resolved as a disk / is a point source; ***[3]***
Accept an answer based on a reasonable estimate for pupil diameter and therefore, shows that Pluto would have to be much nearer to be resolved.

H4. (a) light reflected from the top surface of the wedge interferes with light reflected from the bottom surface;
some statement about the condition for <u>either</u> maximum <u>or</u> minimum in relation to the thickness of the film; ***[2]***
e.g. path difference depends on wedge thickness so goes through maximum and minimum / OWTTE (no need to mention phase change on reflection).

(b) number of fringes in 5.0×10^{-2} m $= 4.2\times10^{2}$;
path difference at edge of tape $= m\lambda = 4.2\times10^{2}\times4.8\times10^{-7}$;
$= 2d$ to give $d = 1.0\times10^{-4}$ m; ***[3]***