M08/4/PHYSI/HP3/ENG/TZ1/XX/M+

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MARKSCHEME

May 2008

PHYSICS

Higher Level

Paper 3

17 pages

Subject Details: Physics HL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer questions from **TWO** of the Options **[2 × 30 marks]**.
Maximum total = **[60 marks]**.

1. A markscheme often has more marking points than the total allows. This is intentional. Do **not** award more than the maximum marks allowed for part of a question.

2. Each marking point has a separate line and the end is signified by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/) – either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

5. Words that are <u>underlined</u> are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by writing ***OWTTE*** (or words to that effect).

8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. Indicate this with **ECF** (error carried forward).

10. Only consider units at the end of a calculation. Unless directed otherwise in the mark scheme, unit errors should only be penalized once in the paper. Indicate this by writing **–1(U)** at the first point it occurs and **U** on the cover page.

11. Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** for an **error of 2 or more digits** unless directed otherwise in the markscheme.

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 writing **–1(SD)** at the first point it occurs and **SD** on the cover page.

Option D — Biomedical Physics

D1. (a) $D \propto L^3$;
$R \propto L^2$;
$\frac{D}{R} \propto L$; ***[3]***

(b) as L increases demand cannot keep up with rate of absorption / *OWTTE*;
<u>hence upper limit</u> to size; ***[2]***

D2. (a) conductive: vibrations are not passing from outer to inner ear;
sensory: no nerve response; ***[2]***

(b) line always above given line;
limits close up to give smaller range; ***[2]***

(c) $10\lg(\text{ratio}) = 15\,\text{dB}$;
and so ratio $= \left(10^{1.5}\right) = 32$; ***[2]***

D3. (a) the transmitted intensity is reduced to $\frac{1}{e}$ of the incident intensity when the distance through the material is the inverse of the attenuation coefficient / the constant in $I = I_0 e^{-\mu x}$ where the symbols are <u>all defined</u> / $\frac{\ln 2}{x_{\frac{1}{2}}}$ with $x_{\frac{1}{2}}$ <u>defined / stated as half value thickness</u>; ***[1]***

(b) recognize to use $x_{\frac{1}{2}} = \frac{\ln 2}{\mu}$;
the half-value thickness is about 1.12 mm;
and so the attenuation coefficient is $\frac{\ln 2}{1.12} = 0.62\,\text{mm}^{-1}$; ***[3]***
Accept answers in the range 0.618 to 0.630.

(c) the attenuation coefficient for bone is greater than that for muscle;
more attenuation for bone so lighter image for bone / *OWTTE;* ***[2]***

(d) X-ray image of section taken at different angles;
these images combined using computers;
to form a two-dimensional image of section;
images of many sections obtained;
image can be rotated for viewing from any angle; ***[3 max]***

D4. (a) $40mgd\sin\theta$;
$= 40 \times 700 \times 1.10 \times \sin 25^{\circ}$;
$= 13\,\text{kJ}$; ***[3]***

(b) energy needed for basal metabolism;
energy needed for other functions in the body;
muscle inefficiency / most energy is lost due to inefficiency of muscles; ***[3]***
Accept references to specific functions for first and second marking points.

D5. (a) the charge per unit mass;
produced as a result of ionization; ***[2]***

(b) energy per unit mass required to produce this exposure is
$40 \times \dfrac{8.6 \times 10^{-3}}{1.6 \times 10^{-19}} \times 1.6 \times 10^{-19}\,\text{J kg}^{-1}$;
i.e. absorbed dose is 0.344 J kg^{-1};
i.e. 340 mSv ***[2]***

Option E — The History and Development of Physics

E1. (a) (i) the stars were permanently fixed on the (celestial sphere);
which rotated around the Earth; ***[2]***

(ii) the Earth rotates around its axis so stars appear to move on arcs; ***[1]***

(b) 6 ± 2 hours; ***[1]***

E2. (a) Brahe made very extensive observations of the motion of the planets (which were characterized by extraordinary accuracy);
Kepler used Brahe's observations to work out the path of the planets (that gave agreement with the observations); ***[2]***

(b) Newton used his laws of gravitation and mechanics;
to derive Kepler's laws;
the derivation implies application to all bodies including comets / *OWTTE*; ***[3]***

E3. (a) caloric is a massless, frictionless fluid;
flows from hot to cold;
amount determines the temperature of the body; ***[2 max]***

(b) heating by friction / change of phase / change of mass in burning; ***[2]***
Award second point for any <u>explanation</u> appropriate to example given.

E4. (a) one metal sphere is charged and placed at the end of the horizontal rod;
another charged sphere is brought close to it;
the angle of twist is measured;
angle of twist is proportional to force;
separation of spheres measured;
the separation was varied and the force measured again $\left(\text{to reveal that } F \propto \dfrac{1}{d^2}\right)$; ***[5 max]***

(b) two identical spheres, one with charge Q and the other neutral, will have equal charges $\dfrac{Q}{2}$ when touched;
this process is repeated to get a charge $\dfrac{Q}{4}$ and so on; ***[2]***

E5. (a) (i) a photon is emitted for every transition from a high to a lower energy state;
whose energy is equal to the difference in energy between the two levels;
the photon energy is given by $E = hf$;

and so the frequency is determined by equating $hf = 2.18 \times 10^{-18} \left(\frac{1}{n^2} - \frac{1}{m^2} \right)$

where n and m are the integers specifying the two levels; ***[4]***

(ii) $h\frac{c}{\lambda} = 2.18 \times 10^{-18} \left(\frac{1}{1^2} - 0 \right)$;

to get $\lambda = \frac{hc}{2.18 \times 10^{-18}} = 9.12 \times 10^{-8} m$; ***[2]***

(iii) does not predict the intensities of the spectral lines;
does not predict the splitting of the lines in a magnetic field;
does not predict the fine structure of the lines;
etc.; ***[1 max]***

(b) the Schrödinger theory assigns a wave function to the electron that is a measure of the probability for finding it somewhere;
<u>therefore</u> the position of the electron is uncertain;
resulting in an uncertainty in its momentum; ***[3]***

Option F — Astrophysics

F1. (a) comets have long periods;
the orbits are very elliptical;
many have orbits off the plane of the ecliptic; ***[1 max]***

(b) volume occupied by a star is about $2^3 = 8\,\text{pc}^3$;
so number of stars is $\dfrac{10^{12}}{8} \approx 10^{11}$; ***[2]***
Accept any answer from 1.0×10^{11} *to* 2.4×10^{11} *(for those using sphere packing) to at most 2 s.f.*

F2. (a) power received (from a star) by an observer (on Earth) per unit area (of the detector);

a measure of the brightness of a star as it appears from Earth (in a relative classification system); ***[2]***

(b) (i) Delta Cephei because it has a larger apparent brightness; ***[1]***

(ii) Delta Cephei is closer;
because although (intrinsically) dimmer, appears brighter; ***[2]***
Award the first marking point only if second is also awarded.

(c) the surface of the star is pulsating / getting larger and smaller;
the luminosity varies because the surface area changes; ***[2]***

(d) (i) locate a Cepheid in the galaxy;
measure period to find luminosity;
distance may be determined from the relation between apparent brightness and luminosity; ***[3]***

(ii) the period is 10 days and so the peak luminosity is
$3000\times3.9\times10^{26} = 1.17\times10^{30}$ W;
correct substitution $d = \sqrt{\dfrac{L}{4\pi b}} = \sqrt{\dfrac{1.17\times10^{30}}{4\pi\times7.2\times10^{-10}}}$
$d = 1.1\times10^{19}\ \text{m}\left(=1200\ \text{ly} = 370\ \text{pc}\right)$; ***[2]***

F3. (a) electromagnetic radiation/(blackbody) radiation in the microwave region that fills the universe;
and is received from all directions in the universe / is essentially isotropic / *OWTTE*; ***[2]***

(b) CMB is characteristic of black body radiation at 3 K;
the universe was hot in its early stages;
and has cooled down because of the expansion of the universe; ***[3]***

F4. (a) (most) of the hydrogen fused to helium; ***[1]***

(b) luminosity increases;
the surface area increases; ***[2]***

(c) F is the part of the H-R diagram where white dwarfs are found;
Main sequence stars that end up with a mass under the Chandrasekhar limit / 1.4 solar masses will become white dwarfs; ***[2]***

(d) path starting on MS above the sun, leading to the super red giant region and either stopping there or shown curving downwards towards (and below) white dwarfs; ***[1]***

F5. (a) the speed of recession of distant galaxies is proportional to their separation; ***[1]***
Accept answers in terms of distances of galaxies from Earth.
Accept equation with terms defined.

(b) at the time of the Big Bang any two points were essentially at zero separation;
now a time T later they are separated by a distance d and are moving with a relative velocity of $v = Hd$;
assuming a constant rate of expansion $\frac{d}{T} = Hd$ from which we deduce that $T = \frac{1}{H}$;
Award ***[1 max]*** *for correct answer without accompanying reasoning.* ***[3]***

Option G — Relativity

G1. (a) (i) 1.90 c; ***[1]***

(ii) $u = \dfrac{u' + v}{1 + \dfrac{u'v}{c^2}}$;

correct substitution to get $u = \dfrac{c + 0.900\,c}{1 + \dfrac{c \times 0.900\,c}{c^2}}$;

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

Do not accept bald answer $u = c$.

Award ***[1 max]*** *for use of incorrect formula* $u' = \dfrac{u - v}{1 - \dfrac{uv}{c^2}}$ *leading to answer* $u' = c$.

G2. (a) (i) time is $\dfrac{6.0\,\text{ly}}{0.80\,c} = 7.5\,\text{y}$; ***[1]***

(ii) calculation of gamma factor $\gamma = \dfrac{1}{\sqrt{1 - 0.8^2}} = \dfrac{5}{3} = 1.67$;

to get time $= \dfrac{7.5}{\gamma} = 4.5$ y;

or

calculation of gamma factor $\gamma = \dfrac{1}{\sqrt{1 - 0.8^2}} = \dfrac{5}{3} = 1.67$;

length contraction of 6.0ly to get $d = \dfrac{6.0}{\gamma} = 3.6$ ly and so time is $\dfrac{3.6}{0.80\,c} = 4.5$ y; ***[2]***

(b) (i) the length of an object in its rest frame / length measured by (inertial) observer with respect to whom object is at rest; ***[1]***

(ii) $L = \dfrac{40}{\gamma}$;

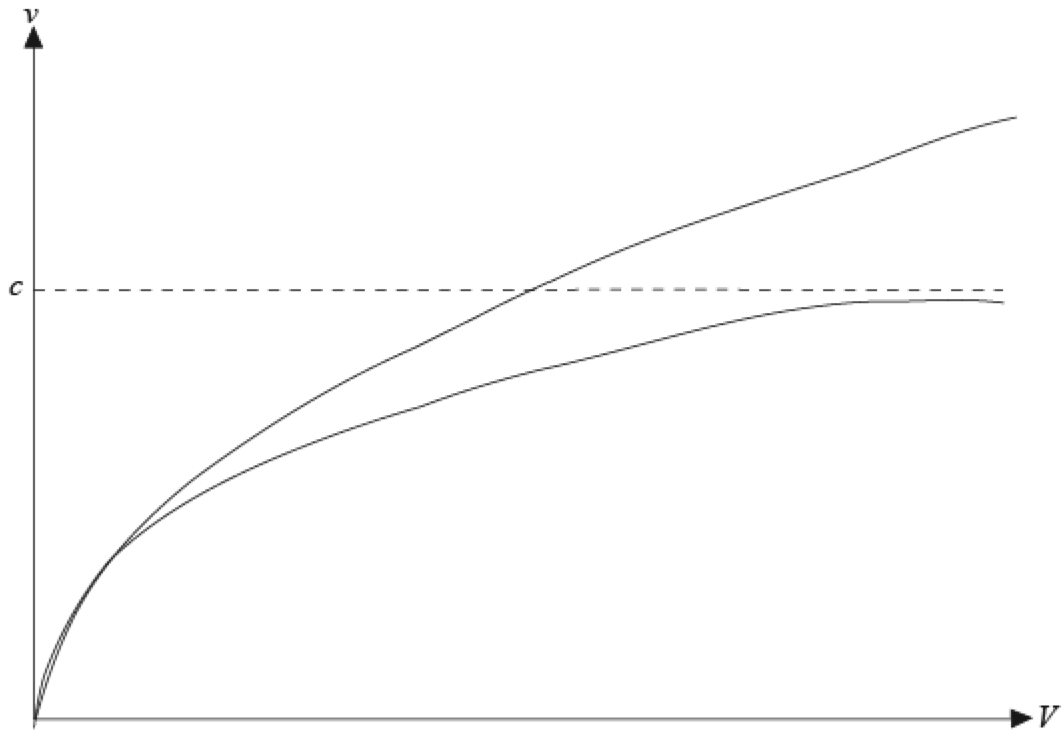
$= 24$ m; ***[2]***

(c) (i) from Tom's point of view both signals travel at the same speed (and have been emitted simultaneously);
so since the front of the station moves towards the signal, the front gets the signal first; ***[2]***
*Award **[1]** for the correct answer without explanation or incorrect explanation.*
Beware of the incorrect argument that Tom travels towards the front mirror.

(ii) arrivals of reflected signals are simultaneous for Jerry (because he is in the middle of the space station);
since arrivals occur at the same point in space they are simultaneous for all other observers as well, including Tom; ***[2]***
*Award **[1]** for the correct answer without explanation or incorrect explanation.*

G3. (a) calculation of gamma factor from $\gamma = \frac{1}{\sqrt{1-0.998^2}} = 15.8$;
total energy of proton is then $E = 15.8 \times 938 = 14.8\,\text{GeV}$;
hence electrical potential energy is $(14.8 - 0.938) = 13.9\,\text{GeV}$;
and so accelerating voltage is $V = 13.9\,\text{GV}$; ***[4]***

(b) curve that is identical to Newtonian curve for small velocities / curve that is below Newtonian curve;
and approaches speed of light asymptotically;
as in the following graph:



[2]

G4. total energy of the two Y particles is 3520 MeV;

so total energy of one of them is $\frac{3520}{2} = 1760$ MeV;

$E^2 = \left(m_0c^2\right)^2 + p^2c^2 \Rightarrow \left(m_0c^2\right)^2 = 1760^2 - 1490^2 = 8.775 \times 10^5$;

$m_0c^2 = \sqrt{8.775 \times 10^5}\ \text{MeV} = 937\ \text{MeV}$; ***[4]***

G5. (a) the radius from within which nothing can escape to the outside / the distance from the black hole where the escape speed is equal to the speed of light; ***[1]***

(b) the black hole is likely to increase in mass due to material falling into it;

since $R = \frac{2GM}{c^2}$ the radius is likely to increase / reference to radius being proportional to mass; ***[2]***

(c) (i) any <u>curved</u> path from observer to spacecraft that does not cross the event horizon; ***[1]***

Do not accept paths that start straight and then curve around event horizon.

(ii) the black hole curves / "warps" spacetime;

Radio signal follows <u>shortest distance</u> / geodesic of the curved spacetime; ***[2]***

Option H — Optics

H1. (a) the ratio of the speed of light in vacuum to the speed of light in the medium /
the ratio of the sine of the angle of incidence to the sine of the angle of refraction; ***[1]***

(b) (i) $45°$; ***[1]***

(ii) critical angle must be at most $45°$;
$n \sin 45° = 1$;
to give $n = 1.4$; ***[3]***
Award full marks for correct answer even if work is not shown.

(c) blue light has a larger index of refraction;
and so the critical angle is less than $45°$ (so total internal reflection still occurs); ***[2]***

or

blue light has a larger index of refraction so total internal reflection takes place;
all colours follow same path;

H2. (a) the point on the principal axis of the lens;
through which a ray parallel to the principal axis goes after refraction in the lens / *OWTTE*; ***[2]***

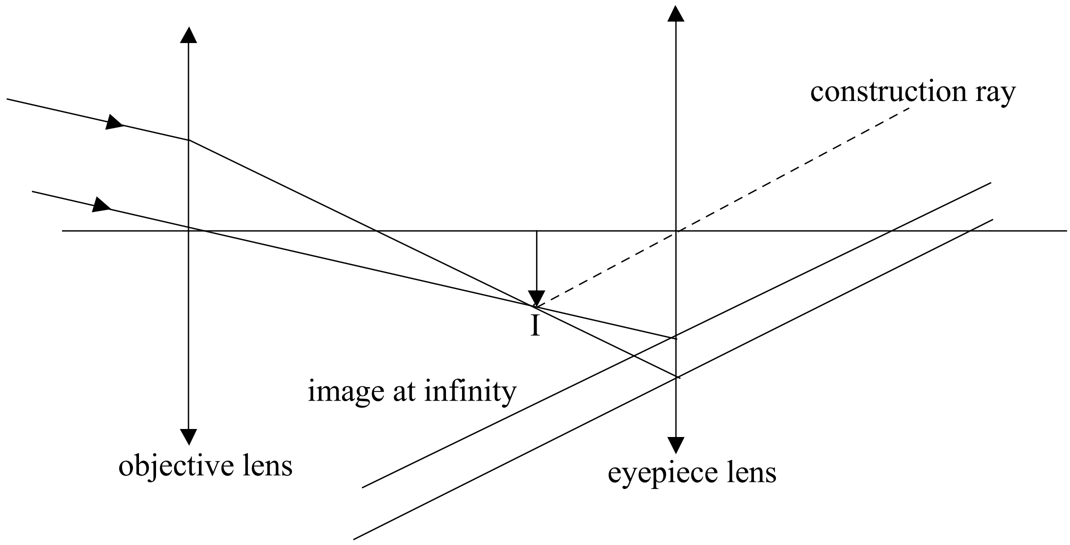
(b) for $u = 30$ cm, $v = 30$ cm;
for $u = 25$ cm, $v = 37.5$ cm;
distance moved $= 7.5$ cm;
away from lens;

or

for those using a scaled diagram:
choice of suitable scale;
correct construction of both images;
measurement of separation between 6.0 and 9.0 cm;
correct statement of direction of displacement; ***[4]***

H3. (a) $f_0 + f_e$; *[1]*

(b) construction of ray from tip of image through pole of eyepiece / parallel to principal axis from tip of image and then through F to right eyepiece;
rays from image extended to eyepiece lens;
rays from eyepiece parallel to construction ray;
rays produced to show final image at infinity; *[4]*
Do not penalize if rays do not have arrows.



(c) (i) ratio of angle subtended by image at eye to angle subtended by object at eye; *[1]*

(ii) $\frac{f_0}{f_e}$; *[1]*

H4. (a) first diffraction minimum at $\theta = 4.25 \times 10^{-3}$ rad
$\lambda \approx b\theta = 1.2 \times 10^{-4} \times 4.25 \times 10^{-3} = 5.1 \times 10^{-7}$ m; *[1]*
Accept answers in the range 5.0×10^{-7} m *to* 5.2×10^{-7} m.

(b) central maximum (of any height) and width less than that of the single slit central maximum;
one secondary maximum (at approximately $\pm 2.1 \times 10^{-3}$ rad) within the enveloping single slit pattern; *[2]*

H5. (a) because they originate from the same incident ray / they come from the same source; ***[1]***

(b) phase change at top surface, no phase change at bottom surface;
path difference is $2d$;
condition for destructive interference is $2d = \lambda$;
$d = \frac{\lambda}{2}\left(= \frac{4.52 \times 10^{-7}}{2}\right) = 226\ \text{nm}$; ***[4]***

(c) the film will be coloured;
the colour being white minus the colour that suffers destructive interference; ***[2]***