N08/4/PHYSI/HP3/ENG/TZ0/XX/M+

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MARKSCHEME

November 2008

PHYSICS

Higher Level

Paper 3

15 pages

General Marking Instructions

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. 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.

9. Only consider units at the end of a calculation. Unless directed otherwise in the markscheme, unit errors should only be penalized once in the paper.

10. 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*

Option D — Biomedical Physics

D1. (a) (i) mass scales as length^3;

so length scales as $\sqrt[3]{4}$ ***or*** ratio $= \dfrac{\sqrt[3]{10}}{\sqrt[3]{4}}$;

$= 1.6$ ***[2]***

(ii) (average) densities are the same / similar bone and muscle structure; ***[1]***

(b) power/<u>rate of</u> energy loss scales with [length]^2;
for a given energy loss temperature change scales with [length]$^{-3}$;
rate of temperature change scales with [length]$^{-1}$;
(so is smaller for the larger animal) ***[3]***

or

power/<u>rate of</u> energy loss scales with [length]^2;
power production/rate of energy production scales as [length]^3;
ratio of $\dfrac{\text{energy production}}{\text{energy loss}}$ scales as length;
(so is greater for larger animal)

D2. (a) the threshold of hearing for Frank is higher / *OWTTE*;
(suggesting) that he might have suffered hearing loss due to having been exposed to loud noise / *OWTTE*; ***[2]***
*Award **[0]** for just naming Frank.*

(b) difference of 40 dB; (*accept 35 to 45*)
$\left(40 = 10\log\dfrac{I_{\text{Frank}}}{I_{\text{Albert}}}\right)$ $\dfrac{I_{\text{Frank}}}{I_{\text{Albert}}} = 10^4$; ***[2]***

or

$50\text{ dB} = 10^{-7}\text{ Wm}^{-2}$ and $10\text{ dB} = 10^{-11}\text{ Wm}^{-2}$;
$\dfrac{I_{\text{Frank}}}{I_{\text{Albert}}} = \left(\dfrac{10^{-7}}{10^{-11}}\right) = 10^4$;

(c) (Frank has) preferential loss at selected/higher frequencies (which is) typical of sensory hearing loss; ***[1]***

(d) speech contains many different frequencies (at the same time);
loss of sensitivity to some of those frequencies results in similar signals being received by the brain for different sounds / *OWTTE*;
any explicit comment that ties loss of discrimination at ear to loss of ability by brain to interpret *e.g.* inability to correctly distinguish sounds; ***[3]***

D3. (a) CT involves taking multiple images/readings / *OWTTE*;
processed by computer;
to produce a three-dimensional representation; ***[3]***

(b) X-ray images require different amounts of absorption by different tissues/organs;
soft tissues are very similar;
Ba is added to enhance the contrast of a particular organ such as the digestive tract; ***[3]***
Award ***[0]*** *for discussion of radioactivity.*

D4. (a) rate of consumption of energy/energy expenditure by the body;
due to involuntary actions *e.g.* breathing *etc.* / asleep / *OWTTE*; ***[2]***

(b) sensible reason for difference *e.g.* teenager's body still growing whereas adult is not; ***[1]***
Do not accept answers suggesting teenager is more active than adult.

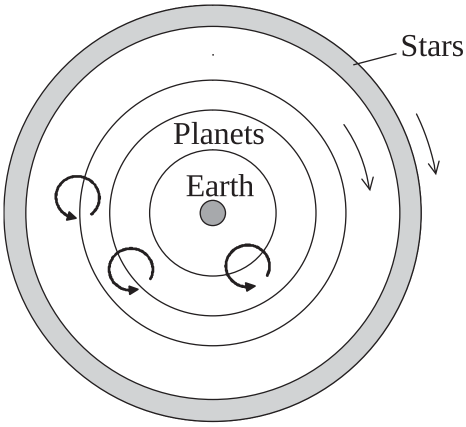
(c) (i) evaporation associated with sweat;
ambient temperature for Ann $>$ Suki so Ann is likely to be sweating more so evaporation higher value/proportion; ***[2]***
Award marks for any sensible comment if the response makes an assumption about moisture content of air and/or existence of breeze etc.

(ii) likely to be similar/proportionally less significant for Ann / *OWTTE*; ***[1]***
Award marks for any sensible comment if response makes an assumption about moisture content of air and/or existence of breeze etc.

D5. correct use of $\frac{1}{T_{\mathrm{E}}}=\frac{1}{T_{\mathrm{P}}}+\frac{1}{T_{\mathrm{B}}}$ *i.e.* $\frac{1}{T_{\mathrm{E}}}=\frac{1}{10}+\frac{1}{15}$;
to get $T_{\mathrm{E}}=6$ days;
realization that 30 days $=5T_{\mathrm{E}}$;
so fraction remaining $=\left(\frac{1}{2}\right)^5=0.03$; ***[4]***
Award ***[4]*** *for a response that calculates the correct answer by considering the two processes separately i.e. physical processes accounting for a reduction of* $\left(\frac{1}{2}\right)^2$ *and biological processes accounting for a reduction of* $\left(\frac{1}{2}\right)^3$.

Option E — The History and Development of Physics

E1. (a)



Earth at centre;
stars all on outer celestial sphere going around Earth, concentric with Earth;
planets on closer spheres (concentric with Earth);
epicycles drawn; ***[4]***

(b) Kepler model is heliocentric whereas Ptolemaic model is geocentric;
Kepler model requires elliptical orbits whereas Ptolemaic model orbits are circular;
Kepler model does not include epicycles;
Kepler identified qualitative relationship between period and orbital radius; ***[3 max]***
*Award **[3]** for a correct statement of Kepler's three laws but only if some reference is made to Ptolemaic model as well and **[2 max]** if no reference made.*

E2. (a) the caloric passed from one region to another;
(making one area cooler by its absence) and one region hotter by its presence; ***[2]***

(b) cannon (being bored) got hotter without being close to any other hot object;
hence, there was no source of caloric / and caloric was appearing from nowhere;
in an inexhaustible supply; ***[3]***

E3. (a) (i) there were two types of electrical charge/fluid;
an object could be charged by having one of the two types of fluid flow into the object; ***[2]***

(ii) atoms have (orbital) electrons (that are negatively charged);
they can be transferred to other atoms;
the excessive presence of electrons makes the material negatively charged / the excessive absence of electrons makes the material positively charged; ***[3]***

(b) he used a cathode ray moving/fired into a magnetic field;
and measured the deflection/radius of the ray by the field;
crossed electric and magnetic fields used to determine velocity of electrons / *OWTTE*; ***[3]***

E4. (a) quantization of angular momentum $\left(\text{into units of } \dfrac{h}{2\pi}\right)$;

there exists a stable orbit in which the electron does not radiate energy / a photon of energy $E\,(=hf\,)$ is emitted when an electron falls between two stable orbits that differ in energy by E / *OWTTE*; ***[2]***

(b) $hf = E_{\mathrm{m}} - E_{\mathrm{n}}$;

$$\frac{hc}{\lambda} = 13.6\left(\frac{1}{n^2} - \frac{1}{m^2}\right);$$

$$\frac{1}{\lambda} = \frac{13.6}{hc}\left(\frac{1}{n^2} - \frac{1}{m^2}\right) \Rightarrow R_{\mathrm{H}} = \frac{13.6}{hc}\,\mathrm{eV};$$

$$R_{\mathrm{H}} = \frac{13.6 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34} \times 3.0 \times 10^{8}} = 1.1 \times 10^{7}\ \mathrm{m}^{-1};$$ ***[4]***

*Award **[0]** for only the answer (it is given in data booklet) the calculation is important.*

E5. (a) statement of $\Delta E \Delta t \geq \dfrac{h}{4\pi}$ ***or*** $\Delta E \Delta t \geq \dfrac{h}{2\pi}$ with definition of all symbols;
idea that it is not possible for both the energy of the electron and time to be determined precisely / any sensible comment; ***[2]***

(b) realization that uncertainty principle implies that measurements/initial conditions/ current state can never be determined precisely / *OWTTE*;
hence predictions for future can never be determined precisely / *OWTTE*; ***[2]***

Option F — Astrophysics

F1. (a) (i) the apparent brightness is the power/rate of energy received per unit area at Earth; ***[1]***

(ii) a measure of the brightness of a star as it appears from Earth;
in a relative classification / on a 1-6 scale/logarithmic scale; ***[2]***

(iii) the apparent magnitude a star would have if viewed from a distance of 10 pc; ***[1]***

(b) luminosity; ***[1]***

(c) since apparent magnitude less than the absolute magnitude;
the star is close / closer than 10 pc;
*answers must make the link between these two points to get the **[2]** marks. No link then award **[1]***
stellar parallax can be used for distance up to 100/300 pc / less than 10 pc is close enough for parallax to be used; ***[3]***

(d) observation of spectrum allows determination of type of star (Main sequence, red giant, supergiant, *etc*.);
peak wavelength determines surface temperature;
hence position on HR is determined and hence luminosity;
if the luminosity is known then the absolute magnitude can be found / absolute magnitude is a measure of/related to luminosity; ***[4]***

(e) $d^2 = \frac{L}{4\pi b}$;
$d = 1.1 \times 10^{17}$ m;
$= 3.4$ pc; ***[3]***

F2. (a) universe is expanding / the galaxies are receding (from Earth); ***[1]***

(b) as the universe expands, it cools;
the microwave radiation corresponds to the radiation emitted by a hot early universe that has subsequently cooled / the microwave radiation is the red-shifted radiation from the big bang / *OWTTE*; ***[2]***

(c) the Doppler shift will get larger;
any sensible comment *e.g.* because the recessional speed is getting greater it is observable only over a very long-time period / not (a directly) observable effect; ***[2]***

(d) $\Delta\lambda = 33.50\,(\text{nm})$;
$\frac{\Delta\lambda}{\lambda} = 7.150\times10^{-2}\left(=\frac{v}{c}\right)$;
$v = 2.145\times10^{7}\ \text{m s}^{-1}$; ***[3]***

(e) (i) $H_0 = \frac{v}{d}$;
$H_0 = 74\,\text{km s}^{-1}\,\text{Mpc}^{-1}$ ***or*** $2.4\times10^{-18}\ \text{s}^{-1}$; ***[2]***

(ii) substitution into $T = \frac{1}{H_0} = 0.013\,\text{km}^{-1}\,\text{s Mpc}$;
$T(= 0.013\times10^{-3}\times3.26\times10^{6}\times9.46\times10^{15}) = 4.2\times10^{17}\ \text{s}$; ***[2]***

F3. (a) star A;
it has the smallest mass/mass closest to the Chandrasekhar limit/1.4 solar mass; ***[2]***

(b) any path shown from A to red giant region and then down to white dwarf region; ***[1]***
Allow ECF from part (a).

Option G — Relativity

G1. (a) a frame that is not accelerating / a frame in which Newton’s first law is valid; ***[1]***

(b) (i) *Alice*:
the signal has equal distances to travel at constant speed / the signal takes the same time to reach the lamps;
they turn on simultaneously/together; ***[2]***

(ii) *Bob*:
the signals move away from Alice at the same speed, but lamp X moves towards the signal and lamp Y away from it;
lamp X receives the signal first (and turns on first); ***[2]***

(c) the electromagnetic path from switch to lamp X to Bob;
is longer than from switch to lamp Y to Bob; ***[2]***

(d) (i) the time measured by Alice, t_A, is proper time;
because the events happen at the same location;
therefore, Bob will measure a longer/dilated time; ***[3]***

(ii) the time dilation formula is independent of direction of motion;
there is no difference; ***[2]***

(e) (i) $30.0\,\text{m}$
the lamps are at rest in Alice’s frame so she measures the proper length; ***[1]***
*Award **[0]** for a bald answer and/or incorrect explanation.*

(ii) $\gamma = 2.3$;
$13.0\,\text{m}$; ***[2]***

G2. (a) $u' = \dfrac{0.900c + 0.950c}{1 + (0.900) \times (0.950)}$;

$u' = 0.997c$; ***[2]***

or

$0.900c = \dfrac{u - 0.950c}{1 - \dfrac{0.95u}{c}}$;

$u' = 0.997c$;

(b) $\gamma_{\mathrm{P}} = \left(\dfrac{1}{\sqrt{1 - 0.900^2}} \right) = 2.29$;

$\gamma_{\mathrm{L}} = \left(\dfrac{1}{\sqrt{1 - 0.997^2}} \right) = 12.9$;

$\Delta m = (10.6 \times 940) = 999\,\mathrm{MeV\,c^{-2}}$; ***[3]***

*Award **[2 max]** for use of* $\Delta_m = \gamma m_0 - m_0$, *answer* $= \Delta_m = 1120\,\mathrm{MeV\,c^{-2}}$.

G3. (a) energy of each pion $\left(=\frac{498}{2}\right)=249\,\text{MeV c}^{-2}$;

$p=\sqrt{\frac{E^2-m_0{}^2c^4}{c^2}}$;

$=\sqrt{249^2-135^2}$;

$\simeq 209\,\text{MeV c}^{-1}$ ***[3]***

(b) $\gamma m_0=249\left(\text{MeV c}^{-2}\right)$;

$p=209=249\text{u}$;

$u=0.84\text{c}$; ***[3]***

or

$\gamma=\left(\frac{E}{m_0c^2}\right)=\left(\frac{249}{135}\right)=1.84$;

$v=\frac{p}{\gamma m_0}$ ***or*** $\gamma=\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$;

$v=\left(\frac{209}{1.84\times 135}\right)$ ***or*** $\sqrt{\frac{1.84^2-1}{1.84^2}}=0.84\text{c}$;

or

$v=\frac{p}{\gamma m_0}$;

$v^2=\left[\frac{209}{135}\right]^2\times\left[1-v^2\right]$;

$v=\left(\sqrt{\frac{2.41}{3.41}}\right)=0.84\text{c}$;

G4. (a) (i) spacetime is four dimensional quantity / three dimensions of space and one of time; ***[1]***

(ii) the path of an object in spacetime will be a line representing the geodesic/shortest spacetime displacement/distance; ***[1]***

(b) mass causes <u>spacetime</u> to curve / the mass of the black hole causes the curvature of <u>spacetime</u>;
such that shortest distance in spacetime is a path confined to region of black hole; ***[2]***

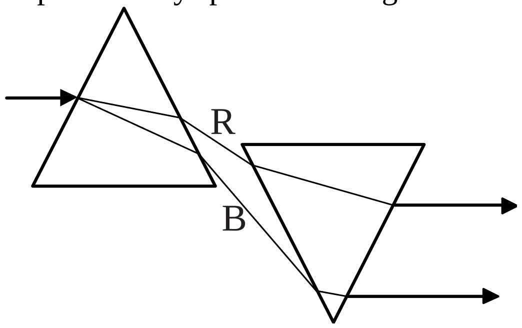
or

the black hole causes extreme curvature of <u>spacetime</u>;
such that no light/object/anything can escape from the surface;

Option H — Optics

H1. (a) (i) correct refraction at both surfaces;
red on top, blue on bottom; ***[2]***

(ii) rays bending on both prism surfaces;
to produce rays parallel to original incident ray; ***[2]***



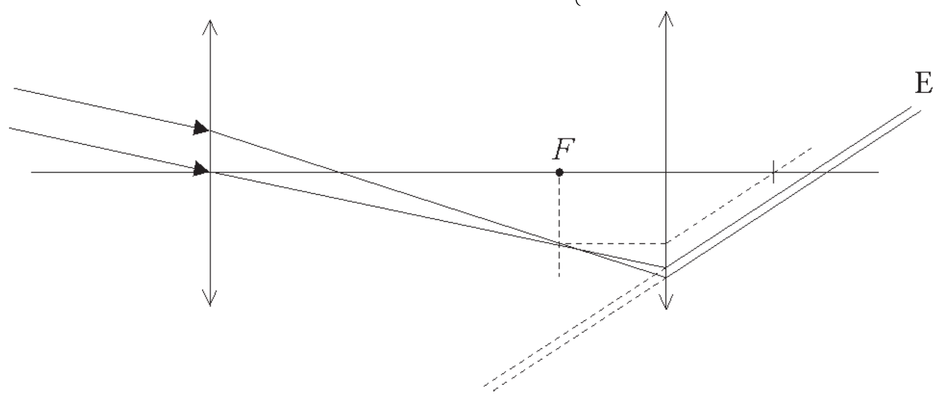
(b) white light;
with red and blue fringe/border; ***[2]***

H2. (a) the ratio of the speed of light in a vacuum to the speed of light in a substance; ***[1]***
Accept ratio of sin(i) to sin(r) provided that the angles i and r are unambiguously defined.

(b) (i) line (R) bent away from normal <u>and</u> line (L) obeying law of reflection; ***[1]***
Judge by eye.

(ii) sin (critical angle) $= 0.67$ / critical angle $= 42^{\circ}$;
the refracted ray eventually disappears;
when the <u>critical angle</u> has been passed for angles greater than the critical angle;
the light undergoes <u>total internal reflection</u> / all the light is internally/totally reflected; ***[4]***

H3. (a) (i) two rays meeting underneath point *F* with the lower ray not deflected;
rays continue, diverging;
rays angled back up to principal axis at the appropriate angle and parallel; } *additional construction lines, shown here, optional* **[3]**



(ii) E as shown; ***[1]***

(iii) (the image is located) at infinity because the rays are parallel / there is a virtual image at infinity, since the object for the eyepiece lens is at its focal length; ***[1]***

(b) (i) because the rays are at a greater angle from the principal axis;
so outlying parts of the image appear further from central part of the image; ***[2]***

or

the angle subtended by image;
is greater than angle subtended by object;

or

$M = \frac{f_o}{f_e}$ $f_o > f_e$;
M > 1;

(ii) the two rays have switched orientation / *OWTTE*; ***[1]***

H4. (a) (i) realization that missing fringes are related to the diffraction pattern of individual slits;
at the expected angle for constructive interference from the double slit, the individual slits have a minimum / *OWTTE*; ***[2]***

(ii) missing fringe corresponds to fourth fringe so path difference corresponds to $4\lambda(at\ \theta = 0.01857\,\text{rad})$;

first slit minimum at $\theta = \frac{\lambda}{b} \therefore b = \frac{\lambda}{\theta} = \frac{650\,\text{nm}}{0.01857} = 3.5\times10^{-5}\ \text{m}$; ***[2]***

Accept substitution which avoids calculating angle e.g.

$$\theta = \frac{4\lambda}{d} = \frac{\lambda}{b} \therefore b = \frac{d}{4} = 3.5\times10^{-5}\ m.$$

(b) fringes will be brighter;
more slits therefore more light getting through;
sharper;
slightly away from constructive interference, each subsequent slit further out of phase, so net result will be zero amplitude / *OWTTE*;
not have missing fringes; ***[3 max]***
*To award **[3]** answers must include two changes and one corresponding explanation.*

H5. (a) path drawn to lower surface to correctly show reflections and refractions at upper and lower surfaces, ray exits upper surface parallel to first reflection; ***[1]***
Accept further reflections for ray that emerges parallel to reflected ray. Ignore any transmitted rays at lower surface.

(b) reflection upper surface marked as π-phase change; $\Big\{$ *do not award mark if shown in more than one place*
since reflection is taking place from region of lower to higher optical density; ***[2]***