N08/4/PHYSI/SP3/ENG/TZ0/XX/M+

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MARKSCHEME

November 2008

PHYSICS

Standard Level

Paper 3

15 pages

General Marking Instructions

Subject Details: Physics SL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer questions from **TWO** of the Options **[2 × 20 marks]**.
Maximum total = **[40 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. Omission of units 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 A — Mechanics Extension

A1. (a) force per unit mass;
acting on point mass/small mass/test mass; ***[2]***
Accept "(negative) gradient of the gravitational potential" for full marks.

(b) $F = \frac{GMm}{r^2}$ and $g = \frac{F}{m}$;
evidence of substitution;
to show $g \propto \frac{M}{r^2}$ ***[2]***

(c) $g \propto \frac{M}{r^2} \Rightarrow M_V = \frac{g_V}{g_E} \times \frac{{r_V}^2}{{r_E}^2} \times M_E$;
$M_V \left(= 0.87 \times 0.96^2 \times M_E\right) = 0.80\, M_E$; ***[2]***

(d) (i) $KE = \frac{1}{2}mv^2$ and $PE = -\frac{GM_V m}{R_V}$;
$KE + PE = \text{zero}$ ***or*** $v^2 = \frac{2GM_V}{R_V}$;
substitution of $g_V = -\frac{GM_V}{{R_V}^2}$;
to get $v = \sqrt{2g_V R_V}$ ***[3]***

(ii) less; ***[1]***

A2. (a) friction force $= 15\,\text{N}$;
when forces are balanced, object just able to start moving; ***[2]***

(b) coefficient of static friction;
since object is stationary and force is opposing its movement / *OWTTE*; ***[2]***
Award ***[0]*** *for a correct bald statement and incorrect or no explanation.*

(c) resultant force on object $(= ma = 5.0 \times 0.6) = 3.0\,\text{N}$;
so friction $= (15 - 3) = 12\,\text{N}$;
$\mu \left(= \dfrac{F}{mg} = \dfrac{12}{50} \right) = 0.24$; ***[3]***

(d) (i) realization that centre of mass is in the middle;
$F = \dfrac{50}{2} = 25\,\text{N}$; ***[2]***

(ii) $50\,\text{N}$; (*accept 49 N*) ***[1]***

Option B — Quantum Physics and Nuclear Physics

B1. (a) appropriate reference to the energy of electrons within the atom *e.g.* the electrons of an atom have energy;
not all energy values are possible (within an atom) / energy can only take discrete values; ***[2]***

(b) electrons accelerated through p.d.;
travel through a vacuum;
strike surface of tungsten (and emit X-rays); ***[3]***
Look for the above marking points in the form of a diagram or description.

(c) characteristic peaks identified as evidence for quantization;
these correspond to photon energy due to transitions between allowed levels / *OWTTE*; ***[2]***

(d) $f\left(=\frac{c}{\lambda}\right)=7.32\times10^{14}\ \text{Hz}$;
$E=hf=4.85\times10^{-19}\ \text{J}$;
this corresponds to the energy difference between the two energy levels that give rise to photons of this wavelength/frequency; ***[3]***

B2. (a) ${}^{13}_{6}\text{C}$ ***or*** carbon nucleus $A=13$, $Z=6$;
${}^{0}_{1}\beta^{+}$ ***or*** ${}^{0}_{1}e^{+}$ ***or*** β^{+} $A=0$, $Z=1$ ***or*** positron $A=0$, $Z=1$;
${}^{0}_{0}\nu$ ***or*** neutrino $A=0$, $Z=0$; *(do not accept antineutrino)* ***[3]***

(b) carbon nucleus; ***[1]***

(c) substitution into $\lambda=\frac{\ln(2)}{T_{\frac{1}{2}}}$;
to give $\lambda=6.9\times10^{-2}\ \text{min}^{-1}$ ***or*** $1.1\times10^{-3}\ \text{s}^{-1}$; ***[2]***

(d) (i) initial number of nuclei
$=\frac{0.13\,\text{mg}}{13\,\text{g}}=6\times10^{18}$;
initial rate of decay $\left(=6\times10^{18}\times6.9\times10^{-2}\ \text{min}^{-1}\right)=4.1\times10^{17}\ \text{min}^{-1}$ ***or*** $6.9\times10^{15}\ \text{s}^{-1}$; ***[2]***

(ii) amount $=0.13e^{-6.9\times10^{-2}\times15}$;
$=0.050\,\text{mg}$; ***[2]***

or

15 minutes $=1.5$ half lives;
therefore remaining mass $=\frac{0.13}{2^{1.5}}=0.050\,\text{mg}$;

Option C — Energy Extension

C1. (a) (i) internal energy decreases;
temperature of gas must have decreased; ***[2]***

(ii) energy transferred from gas to surroundings / yes;
decrease of temperature and no work done / no change in volume; ***[2]***
*Award **[0]** for a correct bald statement and incorrect or no explanation.*

(b) work is done by the gas on its surroundings;
expansion of gas (means work is done) / gas is expanding; ***[2]***
*Award **[0]** for a correct bald statement and incorrect or no explanation.*

(c) realization that energy transferred in one cycle $=$ area;
$\text{energy} = 10^5 \times 2 \times 10^{-3} = 200\,\text{J}$; ***[2]***

(d) internal energy stays the same;
gas is returned to its original state (after one cycle) / no overall change in temperature / *OWTTE*; ***[2]***

C2. (a) *fossil fuel power*: non-renewable – finite amount available / *OWTTE*;
solar power: renewable – source is directly from the Sun; ***[2]***

(b) chemical energy in fuel $\rightarrow$ thermal energy;
thermal energy in steam $\rightarrow$ (rotational) mechanical/kinetic energy;
(rotational) mechanical/kinetic energy $\rightarrow$ electrical energy (in turbines);
at each stage energy dissipated $\rightarrow$ thermal energy / sound energy; ***[4]***
Each mark should be awarded for an energy transformation clearly identified. Do not award marks for a list of the energies involved without idea of transformation process.

(c) *photovoltaic cells*: converts solar energy to electrical energy;
active solar heater: converts solar energy to thermal energy; ***[2]***

(d) *Award **[1]** for an appropriate disadvantage for each power source provided it is identified with source e.g.*:
fossil fuel power production: causes pollution / emits CO_2 (greenhouse gas);
solar power devices: large area needed / only provide energy in daylight hours; ***[2]***

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]***

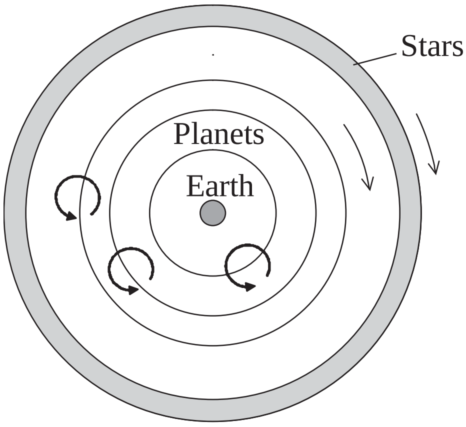
(d) speech contains many different frequencies (at the same time);
loss of sensitivity to some of those frequencies results in similar signals being received by the brain for different sounds / *OWTTE*;
any explicit comment that ties loss of discrimination at ear to loss of ability by brain to interpret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

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]***

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 <u>relative</u> 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) $d^2 = \dfrac{L}{4\pi b}$;
$d = 1.1\times10^{17}$ 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 <u>red-shifted</u> 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]***

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

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

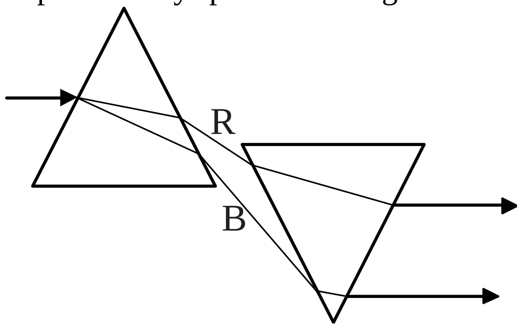
$\Delta m = (10.6 \times 940) = 999\,\text{MeV}\,c^{-2}$; **[3]**

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

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]***



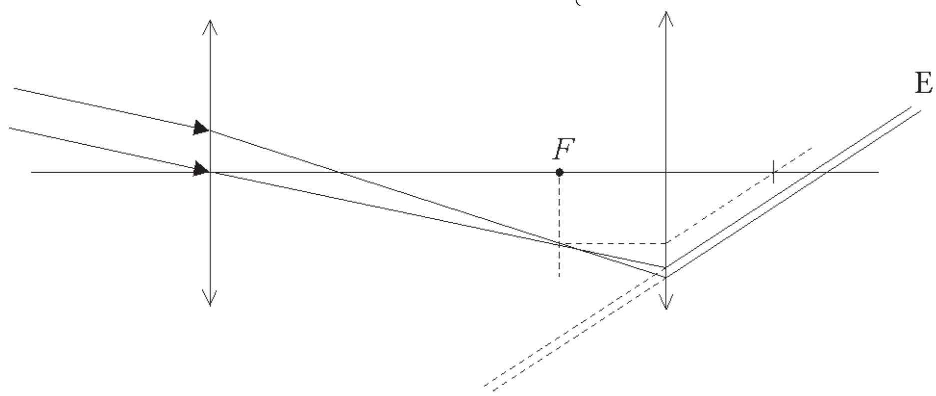
(b) white light;
with red and blue fringe/border; ***[2]***

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]***