International Baccalaureate®
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MARKSCHEME

May 2008

PHYSICS

Higher Level

Paper 3

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.   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.

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.

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*

Option D — Biomedical Physics

D1. (a)   (i)   27;   *[1]*
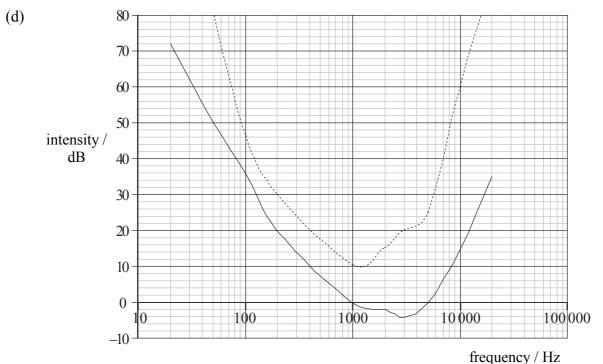
(ii)   9;   *[1]*

(b)   ratio of pressures $= 3$;
therefore mother exerts greater pressure and will sink further / some comment to
justify conclusion;   *[2]*

D2. (a)   (minimum) intensity (in $\mathrm{W\,m^{-2}}$) that can just be detected by the ear;   *[1]*

(b)   recognize that change in intensity
level $= 10\lg\left(\dfrac{3\times10^{-6}}{10^{-6}}\right)$;   *Accept also use of $I = 1\times10^{-6}$ to get 60 dB,*
then use of 3×10^{-6} to get 64.8 dB.

$= 4.8\,\mathrm{dB}$;   *[2]*

(c) $20 = 10\lg\left(\dfrac{I}{I_0}\right)$;

$\left(\dfrac{I}{I_0}\right) = 100$;   *[2]*

(d)

increased intensity at all frequencies;
frequency range is reduced;
overall shift as shown / larger difference in intensity for higher frequencies;   *[3]*

D3. (a) $3\,\text{MHz}\,(\pm 2\,\text{MHz}) \rightarrow 15\,\text{MHz}\,(\pm 5\,\text{MHz})$;   *[1]*

   (b)   *A-scan*:   one dimensional;
         B-scan: two dimensional;   *[1]*
         Both needed to receive the mark.

   (c)   *advantage*:   good resolution / produces sharp image;
         disadvantage: poor depth penetration / not able to scan organs deep within the
                                body / *OWTTE*;   *[2]*

   (d)   bone thickness $= 5 \times$ half-value thickness : muscle thickness $= 2 \times$ half-value thickness;

         bone intensity reduced by $\dfrac{1}{32}$: muscle by $\dfrac{1}{4}$; $\left(accept\ use\ of\ \dfrac{31}{32} : \dfrac{3}{4} \right)$

         ratio $= \dfrac{1}{8}$;   *[3]*

   (e)   much greater reduction in intensity by bone, therefore image gives good contrast
         between muscle and bone;   *[1]*

D4. (a)   maximum height accessible $= \dfrac{\text{energy}}{\text{weight}} = \dfrac{3 \times 10^5}{700} = 420\,\text{m}$ so possible;   *[1]*

         or

         energy change $= 400 \times 700\,\text{J}$ so possible;
         Do not accept numbers only.

   (b)   energy required to keep body organs running / basal metabolism;
         inefficiency of muscles;
         inefficiency of digestion / any further detail regarding BMR/muscles;   *[3]*

D5. (a)   the time it takes for half the sample to be eliminated from the body (by natural
         processes);   *[1]*

   (b) $\dfrac{1}{T_{\text{eff}}} = \dfrac{1}{8} + \dfrac{1}{21}$ to give $T_{\text{eff}} = 5.8$ days;

         $\lambda_{\text{eff}} = \dfrac{0.69}{5.8} = 0.12$;
         ratio of activities $= e^{-\lambda t}$;
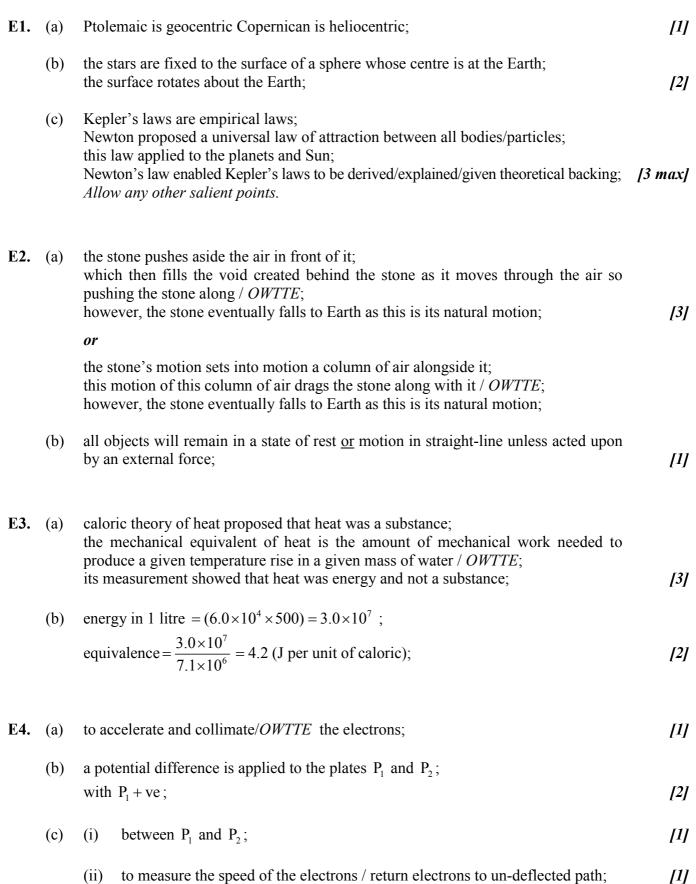   substitute to get 0.24;   *[4]*

   (c)   the short radioactive half-life means that there is less risk of overall damage / ease of
         production / small sample size / *OWTTE*;   *[1]*

Option E — The History and Development of Physics

E1. (a)   Ptolemaic is geocentric Copernican is heliocentric;   *[1]*

   (b)   the stars are fixed to the surface of a sphere whose centre is at the Earth;
      the surface rotates about the Earth;   *[2]*

   (c)   Kepler's laws are empirical laws;
      Newton proposed a universal law of attraction between all bodies/particles;
      this law applied to the planets and Sun;
      Newton's law enabled Kepler's laws to be derived/explained/given theoretical backing;   *[3 max]*
      Allow any other salient points.

E2. (a)   the stone pushes aside the air in front of it;
      which then fills the void created behind the stone as it moves through the air so
      pushing the stone along / *OWTTE*;
      however, the stone eventually falls to Earth as this is its natural motion;   *[3]*

      or

      the stone's motion sets into motion a column of air alongside it;
      this motion of this column of air drags the stone along with it / *OWTTE*;
      however, the stone eventually falls to Earth as this is its natural motion;

   (b)   all objects will remain in a state of rest <u>or</u> motion in straight-line unless acted upon
      by an external force;   *[1]*

E3. (a)   caloric theory of heat proposed that heat was a substance;
      the mechanical equivalent of heat is the amount of mechanical work needed to
      produce a given temperature rise in a given mass of water / *OWTTE*;
      its measurement showed that heat was energy and not a substance;   *[3]*

   (b)   energy in 1 litre $= (6.0 \times 10^4 \times 500) = 3.0 \times 10^7$;

      equivalence $= \dfrac{3.0 \times 10^7}{7.1 \times 10^6} = 4.2$ (J per unit of caloric);   *[2]*

E4. (a)   to accelerate and collimate/*OWTTE* the electrons;   *[1]*

   (b)   a potential difference is applied to the plates P_1 and P_2 ;
      with $P_1 + ve$;   *[2]*

   (c)   (i)   between P_1 and P_2 ;   *[1]*

      (ii)   to measure the speed of the electrons / return electrons to un-deflected path;   *[1]*

E5. (a)   the angular momentum of the electron is an integral number of $\dfrac{h}{2\pi}$;   *[1]*

      Accept use of h only.

  (b)   (i)   *n* takes a fixed integer (and this defines the series) / *OWTTE*;
          integer values of *m* for *m>n* give the wavelengths of the lines in the series defined by *n* / *OWTTE*;   *[2]*

      (ii)   *m* and *n* (are integers that) specify the allowed values of angular momentum;
          and hence the allowed energy levels / *OWTTE*;
          determine the energy of the emitted/absorbed photon / *OWTTE*;   *[2 max]*

      Allow up to [4 max] for answers that combine (b)(i) and (b)(ii).

  (c)   (i)   as *m* increases, the lines become closer together / *OWTTE*;   *[1]*

      (ii)   therefore $R_{\rm H} = \dfrac{n^2}{\lambda}$;
          $n = \sqrt{R_{\rm H}\lambda} = \sqrt{1.097\times10^7 \times 3.645\times10^{-7}} = 2$;   *[2]*

  (d)   the minimum wavelength (in the spectrum) is determined by the ionization energy;
      the ionization energy is greater for helium so the minimum wavelength is shorter;   *[2]*

    or

    difference between energy levels is greater;
    therefore similar transitions give rise to shorter wavelength;

Option F — Astrophysics

F1. (a) *stellar cluster*: a group of stars (with gas and dust) held together by gravity/
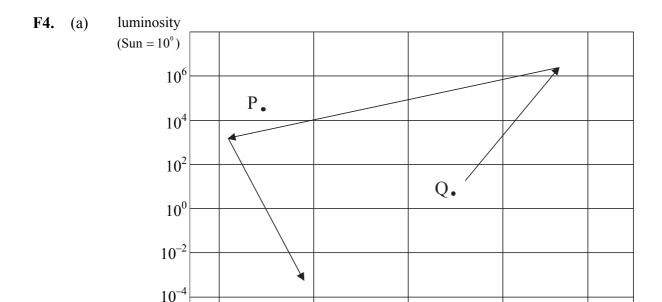   forming a globular/open arrangement;

      galaxy: a large-scale collection/large number of stars/star clusters, <u>gas</u>, <u>and</u>
                    <u>dust</u>;   *[2]*

   (b) 10^{-6};   *[1]*
        Accept interval within 10^{-5} and 10^{-7}.

F2. (a) *apparent brightness*: power incident per square metre of <u>surface of Earth</u>;
        apparent magnitude: a measure of how bright a star appears (to the eye) viewed
                              <u>from Earth</u>;   *[2]*

   (b) measure the blackbody spectrum (of the star) / analysis of intensity-wavelength
        graph;
        to find the wavelength at which the emitted energy is a ⎰ *Accept statements in terms*
        maximum;   ⎱ *of peak wavelength.*

        use Wien's displacement law *or* $\lambda_{max} = \dfrac{2.90 \times 10^{-3}}{T}$ to find temperature;   *[3]*

   (c) (i) $4.93 \times 10^{5}\,\text{AU} = 2.39\,\text{pc}$ *or* distance less than $100\,\text{pc}$;
             (which is easily) measured by (stellar) parallax;   *[2]*

        (ii) lower temperature than the Sun and further away from the Sun;
              therefore <u>less bright</u> so apparent magnitude is greater;   *[2]*

        (iii) $L = 4\pi d^{2} b$;
              $d = (4.93 \times 10^{5} \times 1.50 \times 10^{11}) = 7.40 \times 10^{16}\,\text{m}$;
              $L = 4 \times 3.14 \times 7.40^{2} \times 10^{32} \times 1.97 \times 10^{-12}$;
              $= 1.35 \times 10^{23}\,\text{W}$ *[3]*
              Carefully verify the correct use of numerical values to reach the answer.

   (d) $A = \dfrac{L}{\sigma T^{4}}$;

        $= \left(\dfrac{1.35 \times 10^{23}}{5.67 \times 10^{-8} \times (4.00 \times 10^{3})^{4}} \right) = 9.30 \times 10^{15}\,\text{m}^{2}$;   *[2]*

F3. (a) that it is uniform / stars are uniformly distributed;   *[1]*
        Accept also homogenous or isotropic.

   (b) in every direction that one looked one would see a star;
        hence the sky should never be dark;   *[2]*
        Accept reasoning based on intensity $\propto r^{-2}$ but number $\propto r^{2}$.

F4. (a)

luminosity ($Sun = 10^0$)

10^6

10^4

10^2

10^0

10^{-2}

10^{-4}

P.

Q.

40   20   10   5.0   2.5

temperature / $K \times 10^3$

to red giant region;
ends in white dwarf region;   *[2]*
Paths do not need to be straight and be generous with regions.

(b)   P becomes a neutron star/black hole as opposed to white dwarf;   *[1]*

(c)   the maximum mass for a white dwarf is $1.4 M_{sun}$;
       star P has much more than this;
       star could lose enough mass to bring it within the Chandrasekhar limit / *OWTTE*;   *[3]*

F5. (a)   spiral, elliptical, irregular;   *[1]*
       All three needed to receive the mark.

(b)   the universe is expanding;
       due to Doppler shift (observed) light is red shifted;   *[2]*
       Do not accept "galaxies are moving away from us".

(c)   the further away the greater the recessional speed of the galaxies / *OWTTE*;   *[1]*

Option G — Relativity

G1. (a)   a system of coordinates;
that enables the position of various objects to be specified / that enables measurements
to be made / *OWTTE*;   *[2]*

(b)   (i)   Myron: $L' = x_2' - x_1'$;
Linda: $L = x_2 - x_1 = (x_2' + vt) - (x_1' + vt)$
$L = x_2' - x_1' = L'$;   *[2]*

(ii) $\gamma(x_1 - x_2) = x_1' - x_2'$;
where $\gamma = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$ with c being the free space speed of light / speed of light
in a <u>vacuum</u>;   *[2]*

(iii) Linda and Myron are inertial observers;
if not measured simultaneously the distance between the ends of the rod can
have different values;
(because one of the postulates of relativity states) the speed of light in a
vacuum is the same for all inertial observers;   *[3]*

(iv)   Michelson and Morley could detect no difference in the time it takes light to
travel equal path lengths that are perpendicular to each other / *OWTTE*;
this indicates that the speed of light is constant for all inertial observers;   *[2]*

(c)   (i)   Myron
(since this is) the time interval between two events measured in the reference
frame;
in which the events occur at the same place;   *[2]*

(ii) $\gamma = \dfrac{1.20}{0.800} = 1.5$;
$1.5 = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$;
to give $v = 0.75c$;   *[3]*

G2. (a)   same up to about 0.3;
then curve asymptotic to 1.0;   *[2]*

(b)   calculation of $\gamma = 2.3$;
$E = (\gamma m_0 c^2) = 1.2\,\text{MeV}$;   *[2]*

G3. $E_{tot} = Ve + m_0 c^2$;

$\quad\quad = (500 + 938) = 1438\,\text{MeV}$;

$(E_{tot}{}^2 = p^2 c^2 + m_0{}^2 c^4$) $p^2 c^2 = 1438^2 - 938^2$;

$p = 1090\,\text{MeV}\,c^{-1}$;   *[4]*

G4. (a)   a coordinate system in which a time axis is constructed at right angles to the *x*-axis / *OWTTE*;
the motion of the particle is plotted as a series of points in this system / is described by a line in this system / *OWTTE*;   *[2]*

   (b)   (i)   all particles/objects take the shortest path between two points in spacetime;
Earth warps spacetime;
the satellite follows the shortest path in this warped spacetime;   *[3]*

   (ii)   the closer to Earth the greater the degree of warping of spacetime / *OWTTE*;   *[1]*

   or

   the further from Earth the less the degree of warping of spacetime / *OWTTE*;

Option H — Optics

H1.

Name of associated region	Frequency / Hz	Possible source
gamma radiation	10^{18}	radioactive decay
infra red;	10^{13}	hot objects / laser / remote control device;
radio waves;	10^6	(accelerated) motion of electrons in conductors/aerials/electric currents;

[4]

Do not apply ECF from region to possible source.

H2. (a)   (i)   when the (transmitted) ray/light in medium 2 is along the boundary/refracted at $90°$;
the angle of incidence in medium 1 is the critical angle;   **[2]**

or

when a ray/light is incident on the boundary at an angle greater than the critical angle;
the ray is not transmitted / no light is transmitted but is totally reflected at the boundary / is totally internally reflected;

(ii)   reflected ray with angle of reflection = angle of incidence;
transmitted ray with angle of refraction greater than angle of incidence;   **[2]**
Judge both by eye.

(b) $n_1 \sin \theta_1 = n_2 \sin \theta_2$
$\theta_1 = \phi_c$ and $\theta_2 = 90°$;
$n_1 \sin \phi_c = n_2$;   **[2]**

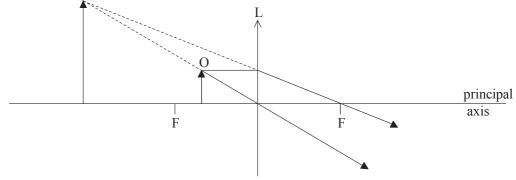**H3.** (a) (i) *principal axis*: a line at right angles to the plane of the lens and that passes through the (optical) centre of the lens / *OWTTE*;
principal focus: a point on the principal axis to which rays parallel to the principal axis pass after refraction (through the lens) / *OWTTE*; **[2]**

(ii)

two rays as shown;
extrapolated back to locate image; { *Do not penalise if rays do not have arrows.* **[2]**

(iii) virtual
the rays diverge after passing through the lens;
cannot be focused onto a screen / appear to come from a point / *OWTTE*; **[2]**
Award [1 max] for an explanation based on the image on the same side of the lens.

(b) (i) $M = \left(\dfrac{\theta_i}{\theta_o}\right) = \dfrac{h_i}{h_o}$;

$6 = \left(\dfrac{h_i}{h_o} = \dfrac{v}{u}\right) = \dfrac{25}{u}$;

$u = \left(\dfrac{25}{6.0}\right) = 4.2\,\text{cm}$; **[3]**

(ii) maximum magnification; **[1]**

H4. (a) each element of the slit acts as a secondary source of waves;
the interference between these waves produces the diffraction pattern; **[2]**

(b) (i) half width of central maximum $= 3.1(\pm 0.1)\,\text{mm}$;

slit width $= \dfrac{2.4 \times 6.3 \times 10^{-7}}{3.1 \times 10^{-3}}$;

$= 0.50\,\text{mm}$; **[3]**
Award [1 max] for use of 4.5×10^{-3} followed by use of $\sin\,(\text{max}) = n\lambda$.

(ii) greater intensity;
decrease in width of central maximum; **[2]**

H5. light reflected from bottom surface (that emerges from top surface);
interferes with light reflected from top surface;
for a particular thickness of oil;
certain colours/wavelengths are removed by destructive interference;
white light less this colour/wavelengths is observed; **[3 max]**