IBO IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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M06/4/PHYSI/HP3/ENG/TZ2/XX/M

MARKSCHEME

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PHYSICS

Higher Level

Paper 3

14 pages

Option D — Biomedical Physics

D1. stress $= F/A$;
maximum stress $= W/A$;
in new bone $A_2 = 4A_1$;
$\Rightarrow$ new $W_2 = 4W_1$; ***[4]***
Award full marks for correct answer with any sensible reasoning.

D2. (a) IL (sound intensity level) $= 10\ \lg\ (I/I_0)$;
where $I_0 = 1.0 \times 10^{-12}\ \text{W m}^{-2}$; ***[2]***

(b) intensity at eardrum $= \dfrac{2.8 \times 10^{-7}}{1.9 \times 10^{-5}} = 1.5 \times 10^{-2}\ \text{W m}^{-2}$;

$IL = 10\ \lg\left(\dfrac{1.5 \times 10^{-2}}{1.0 \times 10^{-12}}\right)$;
$= 100\,\text{dB}$; ***[3]***
Accept 102 dB.

(c) long exposure / loud sound would cause deafness/tinnitus; ***[1]***

D3. (a) (i) $3.0\,(\pm 0.1)\,\text{mm}$; ***[1]***

(ii) $\mu = \dfrac{\ln 2}{t_{½}}$;

$\mu = \dfrac{\ln 2}{3.0\,\text{mm}} = 0.23\,\text{mm}^{-1}$; ***[2]***
Allow ECF from (i) above range gives values from 0.20 mm^{-1} to 0.28 mm^{-1}.

(b) $\dfrac{I}{I_0} = e^{-\mu x}$;
$\dfrac{I}{I_0}$ greater $\Rightarrow \mu$ smaller;
$\Rightarrow$ half-thickness will be greater (greater intensity for same thickness of bone); ***[3]***
*Award **[2 max]** for correct statements with no explanation.*

(c) abdomen has approximately constant μ;
barium meal has high μ value;
barium meal lines stomach;
so <u>outline</u> of stomach becomes clear; ***[4]***

D4. (a) principle of moments mentioned/stated;
weight-pivot distances > tendon-pivot distance;
force in tendon > weight; ***[3]***

(b) system has large velocity ratio;
only small movement of muscle available but large arm movement possible; ***[2]***

D5. (a) type of radiation;
intensity of radiation;
exposure time; ***[3]***
Do not allow "mass".

(b) (named) suitable shielding material absorbs energy before it reaches worker;
increasing distance from source reduces intensity of radiation at worker; ***[2]***

Option E — The History and Development of Physics

E1. (a) Copernicus $\Rightarrow$ planets move in circle about the Sun
Kepler $\Rightarrow$ planets move in ellipses about the Sun;
Copernicus $\Rightarrow$ hypothesis
Kepler $\Rightarrow$ based on experimental data; ***[2]***

(b) an inverse square law between the Sun and planets;
this force produced the orbital motion of the planets;
and accounted for the elliptical orbits;
able to derive Kepler's law (of periods) theoretically; ***[3 max]***

E2. straight-line as a result of force;
curve as a result of weakening of force;
vertical when no force;
vertical (downward) motion is natural motion; ***[4]***

E3. (a) to determine the equivalence between mechanical energy and thermal energy / *OWTTE*; ***[1]***

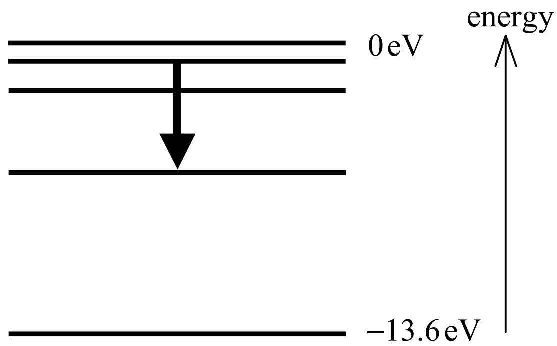
(b) weights raised by turning handle;
then allowed to fall so turning the paddle;
mass of weights and height of fall measured;
mass of water measured;
rise in temperature of water measured;
repeat to obtain measurable temperature; ***[5 max]***

E4. (a) (i) fluorescence glowing;
a shadow (of the cross) opposite to cathode/cross; ***[2]***

(ii) the shadow moved; ***[1]***

(b) (presence of) shadow $\Rightarrow$ rays move along straight-line as light does / rays cast a shadow as light does;
shadow moves $\Rightarrow$ a magnet does not influence light; ***[2]***

E5. (a)



arrow <u>between</u> line 4 and line 2;
arrow points downwards; ***[2]***

(b) uses $c = f\lambda$ to determine wavelength; *(explicit answer not required)*

$R_{\mathrm{H}} = \left\{\left(\frac{1}{2^2}\right) - \left(\frac{1}{4^2}\right)\right\} \div 2.06\times10^6$;

$= 1.1\times10^7\ \mathrm{m}^{-1}$; ***[3]***

(c) only hydrogen / singly-ionized helium predicted;
no relative intensities predicted / no transition probabilities predicted;
no fine structure; ***[2 max]***

(d) electron can be described as a wave;
electron position is undefined;
wave nature determines probability of finding particle;
particle can be represented by <u>standing</u> wave; ***[3 max]***

Option F — Astrophysics

F1. (a) there is an equilibrium;
between radiation pressure and gravitational pressure / *OWTTE*; ***[2]***

(b) *visual binary*:
stars (of system) can be separated through a telescope/binoculars / *OWTTE*;

spectroscopic binary:
(analysis of) light spectrum (from system) reveals two different (<u>classes</u> of) stars; ***[2]***

F2. (a) (class M $\Rightarrow$ low surface temperature $\Rightarrow$) red; ***[1]***

(b) $d(pc) = \frac{1}{p} = \frac{1}{5.0 \times 10^{-3}} = 200\,\text{pc}$;
$200\,\text{pc} \times 3.26 \times 9.46 \times 10^{15} = 6.2 \times 10^{18}\,\text{m}$; ***[2]***

(c) (i) use of $L = b(4\pi d^2)$;
$L = (1.6 \times 10^{-8}) \times (4\pi) \times (6.2 \times 10^{18})^2$;
$L = 7.6 \times 10^{30}\,\text{W}$; ***[3]***

(ii) $T = \frac{2.9 \times 10^{-3}}{\lambda_{\text{max}}} = \frac{2.9 \times 10^{-3}}{935 \times 10^{-9}}$;
$T = 3100\,\text{K}$; ***[2]***

(d) $L = \sigma T^4 (4\pi R^2) \Rightarrow R = \frac{(L)^{\frac{1}{2}}}{(\sigma T^4 4\pi)^{\frac{1}{2}}}$;

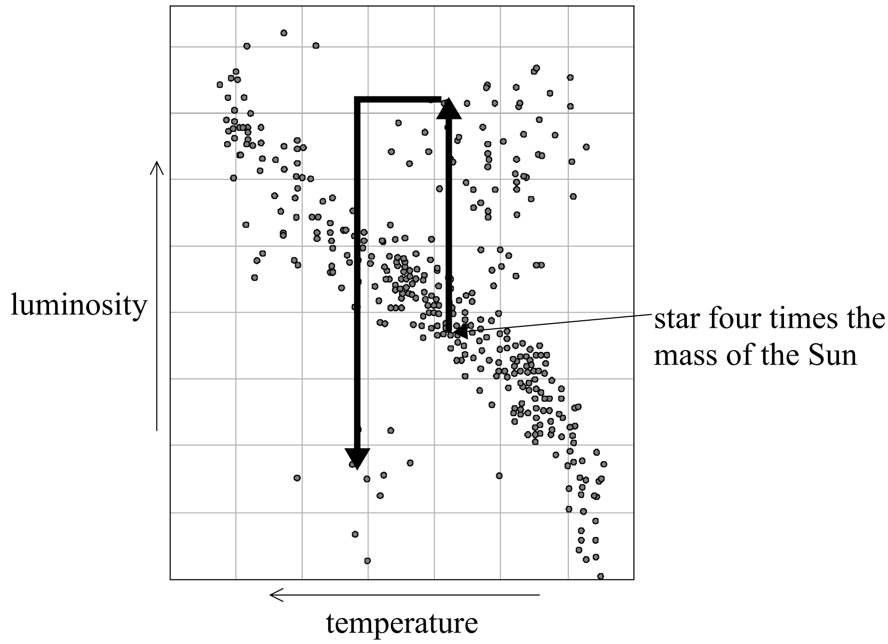
$$R = \frac{(7.6 \times 10^{30})^{\frac{1}{2}}}{\left(5.67 \times 10^{-8} \times (3100)^4\ (4\pi)\right)^{\frac{1}{2}}} ;$$

$\frac{R}{R_s} = \frac{R}{7.0 \times 10^8} = 500$; ***[3]***

F3. (a) the intensity of illumination falls off as $1/r^2$;
(since stars uniformly distributed) the number of stars seen from Earth increases as r^2;
therefore, the sky should be equally bright in any direction / *OWTTE*; ***[3]***
*Award **[1]** for "in any direction, the line of sight will encounter the surface of a star $\Rightarrow$ sky as bright as sun".*

(b) the BB model leads to the idea of the expansion of the universe;
the BB model leads to the idea that the observable universe is not infinite; ***[2 max]***
*Award **[1]** for "because the universe (stars) is not infinitely old" (universe far younger than necessary for us to see a star in every direction. Finite speed of light means that we are not receiving light from all sources) / OWTTE.*

F4. (a) (i)



line to red giant area;
line to white dwarf area; ***[2]***

(ii) white dwarf; ***[1]***

(b) (i) helium fusion; ***[1]***

(ii) carbon formed; ***[1]***

F5. (a) (relative) <u>recessional</u> speed v <u>between galaxies</u>;
at separation distance of d; ***[2]***

(b) conversion of parsec to metres ($1\text{ parsec} = 3.08\times10^{16}\text{ m}$);
$1/H_0 =$ age of universe;
$\left(\dfrac{3.08\times10^{16}}{6.5\times10^{-2}}\right) = 4.7\times10^{17}\text{ s}$; ***[3]***

Option G — Relativity

G1. (a) proper time is the time measured in a FR at rest with respect to events;
clock is at rest with respect to muon; ***[2]***

(b) calculated value of gamma, $\gamma = 5.0$;

$$T_m = \frac{T_g}{\gamma} = \frac{10.2}{5.0} = 2.0\,\mu\text{s};$$ ***[2]***

G2. c is constant in all FR / *OWTTE*;
shorter path length to L for Nino;
so flash on L seen first by Nino; ***[3]***

G3. (a) transformations made under the assumptions that time measurements (and space measurements) are independent of the observer; ***[1]***
Accept "absolute".

(b) (i) $u_x = u'_x + v = 0.9800c + 0.9800c = 1.9600c$; ***[1]***
Accept –1.9600c corresponding to – values of v and u'_x.

(ii) $$u_x = \frac{u'_x + v}{1 + \frac{u'_x v}{c^2}} = \frac{0.9800c + 0.9800c}{1 + \frac{0.9800c\,(0.9800c)}{c^2}};$$

$u_x = 0.9998c$; ***[2]***
Accept – 0.9998c corresponding to – values of v and u'_x.

(c) in (b)(i) $v > c$;
since this is not possible, then the Galilean transformation equation is not applicable; ***[2]***

G4. (a) *RME*: rest mass times c^2;
TE: sum of RME + kinetic energy (assuming no potential energy); ***[2]***

(b) $938\ \text{MeV}$; ***[1]***

(c) $\gamma m_0 c^2 = m_0 c^2 + Ve$;
$Ve = \gamma m_0 c^2 - m_0 c^2$
$Ve = m_0 c^2 (\gamma - 1)$;
$Ve = 938(4.0)$;
$V = 3750\ \text{MV}$; ***[4]***

G5. (a) far away from any other mass;
constant velocity; ***[2]***

(b) (i) diagram showing large mass and distant light source, light bends round mass;
mass warps space-time so that it is curved;
shortest path is now curved not straight; ***[3]***

(ii) describes observed effect when mass between observer and source;
describes observed effect when mass not present;
clear statement that star is the same in both observations; ***[3]***

(c) mass too small;
radius too large; ***[2]***

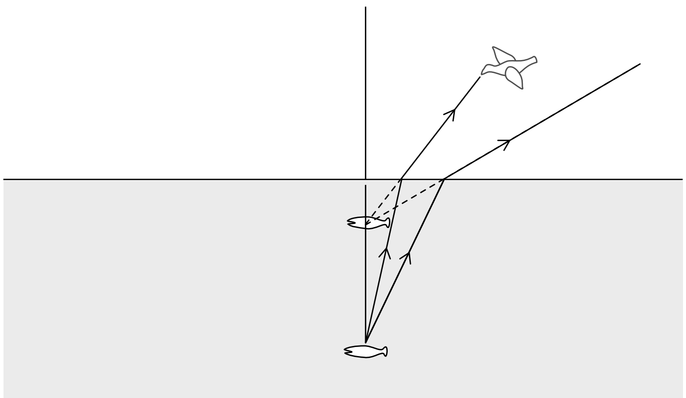
Option H — Optics

H1. (a) oscillating (varying) electric and magnetic fields/electromagnetic waves; ***[1]***

(b) (i) X-rays; ***[1]***

(ii) 10^{14} Hz / 10^{15} Hz; ***[1]***

H2. (a) (i)



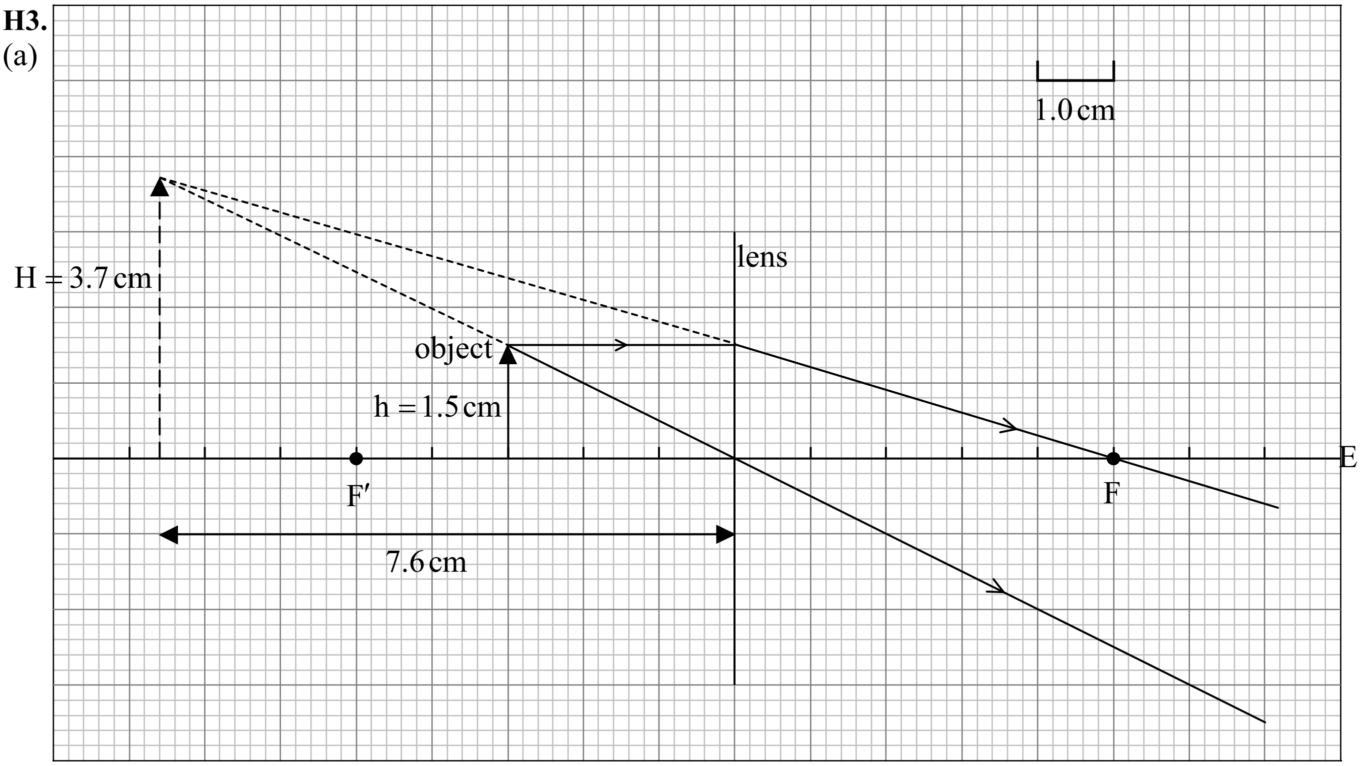
one ray from fish with correct refraction;
2nd ray from fish with correct refraction;
rays backward to give correct position of image; ***[3]***
Here only a qualitative explanation (diagram) is expected, since no numerical values are given. A quantitative solution is asked for in part (a)(iii).

(ii) virtual <u>since</u> extension of rays gives its position / appear to come from fish / *OWTTE*; ***[1]***

(iii) $n = \dfrac{\text{real depth}}{\text{apparent depth}}$;

apparent depth $= \dfrac{48}{1.3} = 37\,\text{cm}$; ***[2]***

H3.
(a)



ray through centre (pole) of lens;
ray parallel to principal axis;
location of image between 6.9 cm and 8.1 cm ; ***[3]***
Accept other suitable ray.

(b) eye to the right of lens; ***[1]***

(c) magnification $= \dfrac{H}{h} = \dfrac{3.7}{1.5}$;
$= 2.5\ (\pm 0.2)$;

or

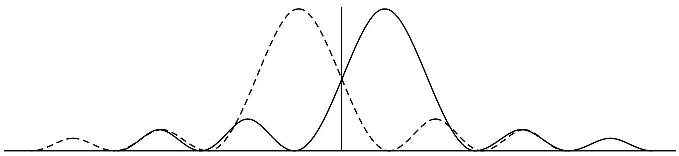
$v = 7.6\,\text{cm}$
$u = 3.0\,\text{cm}$
$m = \dfrac{7.6}{3.0}$;
$= 2.5\ (\pm 0.2)$; ***[2]***

(d) (i) converging (convex) lenses; ***[1]***

(ii) $\dfrac{1}{3.4} + \dfrac{1}{v} = \dfrac{1}{4.0}$;
$v = (-)22.7\,\text{cm}$;
magnification: $\dfrac{22.7}{3.4} = 6.7$;
total magnification: $6.7 \times 24 = 160$; ***[4]***
Allow two sig fig for answer (–)25 cm.
$\Rightarrow$ *magnification = 7.4*
$\Rightarrow$ *total magnification = 180*

H4. identifies correct reflecting surfaces (may be on diagram) *e.g.* reflection from bottom of lens surface interferes with reflection from top of flat surfaces;
reflection at top of flat surface has π (180°) phase change;
describes meaning of "in phase" correctly, *i.e.* simultaneous maxima / *OWTTE*;
two waves superpose to give greater intensity/maximum when arriving in phase; } *Do not allow repeat of "bright fringe" for this mark.* ***[4]***

H5. (a) shape of diffraction pattern acceptable;
central maximum of one pattern falls on first minimum of other;
relative heights of central and first maxima realistic for both patterns; ***[3]***



(b) $\theta = \frac{1.22\lambda}{d} = \frac{1.22 \times 400 \times 10^{-9}}{0.003} (= 1.63 \times 10^{-4}\text{ rad})$;

$\left(\text{woman} - \text{car distance} = \frac{\text{head lamp separation}}{\tan\theta}\right) = \frac{1.2}{1.6 \times 10^{-4}}$;

$= 7.5\,\text{km}$; ***[3]***