IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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MARKSCHEME

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PHYSICS

Higher Level

Paper 3

15 pages

Option D — Biomedical Physics

D1. (a) area scales as $dimension^2$ *Or* L^2;
volume scales as $dimension^3$ *Or* L^3; ***[2]***

(b) surface area of cylinder > surface area of sphere (for same mass);
rate of energy absorption greater for cylinder;
hence {temperature rises more rapidly} for the same mass; ***[3]***

D2. (a) *conductive*: loss occurs in middle ear / damage to membranes / ossicles;
sensory: loss occurs in inner ear / damage within cochlea / auditory nerve; ***[2]***

(b) (i) (changes in) loudness are response of ear to (changes in) sound intensity;
response is (approximately) logarithmic with intensity; ***[2]***

(ii) loss of hearing is selective;
so it is sensory; ***[2]***
Do not award mark if fallacious or no argument.

(iii) $60 = 10 \lg\left(\frac{I}{(1.0\times10^{-12})}\right)$;
$I = 1.0\times10^{-6}\ \text{W m}^{-2}$; ***[2]***

D3. (a) *e.g.* simple scattering;
photoelectric effect;
compton scattering;
pair production; ***[2 max]***
*Allow **[1]** each for any two mechanisms*.

(b) (i) thickness of material required to reduce intensity / photon flux by one half; ***[1]***

(ii) ratio $= 0.5^8$;
$= \frac{1}{256}$ ***or*** 3.9×10^{-3}; ***[2]***

(c) ultrasound (nearly all) reflected by bone (boundary) but X-rays can penetrate;
X-rays show up internal structures; ***[2]***

D4. muscle contracts by (relatively) small amount;
for there to be a much larger movement of bone / load;
force in muscle must be much larger than load;
(and) mechanical advantage is load ÷ effort; ***[4]***

D5. radiation causes direct [*OWTTE*] damage to DNA;
damages cells (indirectly) via ionization of water;
short-term effects include death of cell / failure to replicate;
short-term effects include production of toxins / failure of immune system;
long-term effects include mutations / cancers;
caused by faulty repair / changes to DNA; ***[6]***

Option E — The History and Development of Physics

E1. (a) (precise) positions and times/movements for the (known) planets; ***[1]***

(b) planetary orbits are elliptical rather than circular;
with Sun at one focus; ***[2]***

(c) Newton developed (universal) law of gravitation;
law was used to derive Kepler's laws; ***[2]***

E2. (a) wire carrying a current;
causes deflection of a compass needle / suspended magnet; ***[2]***

(b) used two (parallel) current-carrying conductors;
(mutual) forces when current in wires; ***[2]***

E3. (a) phlogiston / caloric is a fluid;
this flows between bodies when they are at different temperatures; ***[2]***

(b) *e.g.* thermal energy produced as a result of friction / cannot explain change of phase;
further detail regarding stated phenomenon *e.g.* fluid endless / does not cause temp change; ***[2]***

E4. (a) wax blocks placed in neutron beam;
protons ejected from wax blocks;
emergent radiation examined in cloud chamber; ***[3]***

(b) energy / speed of protons measured;
in a cloud chamber / by absorption in aluminium;
momentum of protons measured;
by collision with nitrogen atoms; ***[4]***

E5. (a) permittivity of free space; ***[1]***

(b) (i) angular momentum is quantized ***or*** is $\frac{nh}{2\pi}$;

each quantum is $\frac{h}{2\pi}$ (where h is the Planck constant) ***or*** n is an integer; ***[2]***

(ii) angular momentum $= mvr$;

so, $mvr = \frac{nh}{2\pi}$;

squaring and substituting for v^2 made clear;

gives $r = \frac{\varepsilon_0 h^2 n^2}{\pi m e^2}$ ***[3]***

(c) using $n = 1$

$r = \frac{8.85\times10^{-12}\times(6.63\times10^{-34})^2}{\pi\times9.1\times10^{-31}\times(1.6\times10^{-19})^2}$;

$= 5.3\times10^{-11}\,\text{m}$;

this is about the experimentally measured diameter of an atom / *OWTTE*; ***[3]***

(d) *e.g.* electrons shield nucleus; ***[1]***

Any other sensible suggestion.

Option F — Astrophysics

F1. (a) *constellation*: Pattern of stars;
Candidate must indicate that stars are not close together.

stellar cluster: group of stars bound by gravitation / in same region of space; ***[2]***

(b) $d = \frac{1}{0.0077}$;
$= 130\,\text{pc}$ ***[1]***

(c) no atmospheric turbulence / irregular refraction; ***[1]***

(d) (i) red/red-orange; (not orange)
blue / blue-white / white; ***[2]***

(ii) Betelgeuse looks brighter; ***[1]***

(iii) $L = 4\pi bd^2$;
Rearrangement of formula on data sheet required.
$d = 4.0 \times 10^{18}\,\text{m}$;
$L = 4\pi \times 2.0 \times 10^{-7} \times (4.0 \times 10^{18})^2$;
$L = 4.0 \times 10^{31}\,\text{W}$;

(iv) $L = 4\pi bd^2$
luminosity of Rigel is about half that of Betelgeuse (or ecf from (iii));
brightness of Rigel is about 0.1 times that of Betelgeuse;
so Rigel is more distant (must be a consistent conclusion from statements about luminosity and brightness); ***[3]***
Do not allow mark for fallacious or no argument.
*Mere statement that luminosity and brightness are less so Rigel is more distant scores **[1 mark]** only*.

F2. (a) universe is infinite; ***[1]***

(b) number of stars in shell increases as R^2;
intensity decreases as $\frac{1}{R^2}$;
brightness of shell is constant;
adding all shells to infinity;
sky would be as bright as Sun / uniformly bright; ***[5]***
*Award **[2 max]** for argument based on any line of sight lands on a star*.

F3. high temperatures / high K.E of nuclei;
so that nuclei/atoms come close to each other;
high density/pressure;
so that chance of collision is high; ***[4]***

F4. *e.g.* very distant / moving away at speeds near *c* / (comparatively) young / large Doppler shift;
some are radio sources;
very high luminosity;
centred in galaxies; ***[2 max]***
Do not allow "small".

F5. (a) $v = H_0 d$ or Hd; ***[1]***

(b) $d = \frac{5\times10^{8}}{3.1\times10^{22}} = 1.6\times10^{-14}$ Mpc **or** 0.04 m $\text{yr}^{-1} = 1.27\times10^{-12}$ km s^{-1};
$v = 60\times1.6\times10^{-14} = 9.6\times10^{-13}\ \text{km s}^{-1} = 0.03$ metres per year so no **or** $d = 6.6\times10^{8}$ m;
Any sensible comment.
e.g. this is inconsistent with stated value.
e.g. value of H_0 not known with certainty **or** it is consistent because values known to 1 sf only; ***[3]***

Option G — Relativity

G1. (a) means of locating an object in space; ***[1]***

(b) (i) *observer O*: light from flashes arrives simultaneously at O;
because takes same time, as measured by O, to reach O / because O is at rest with respect to A and B;

observer C: flash from A reaches C before flash from B;
because speed of light independent of reference frame; ***[4]***

(ii) $\gamma = \frac{9.0}{7.2} = 1.25$;

$\left(1 - \frac{v^2}{c^2}\right)^{-0.5} = 1.25$;

$v = 0.6c$; ***[3]***

*Award **[0]** if use of $\gamma = 0.8$.*

G2. (a) (i) $1.8c$; ***[1]***

(ii) recognize use of $u'_x = \frac{(u_x - v)}{\left(1 - \frac{u_x v}{c^2}\right)}$;

Allow equation with + in numerator and denominator.

$u'_x = \frac{(c + 0.8c)}{\left(1 - \left\{\frac{-0.8c^2}{c^2}\right\}\right)}$;

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

*Award **[1 max]** if substitution gives – sign in numerator or denominator.*
*Award **[2 max]** for a statement "c is same in all frames so $u'_x = c$".*

(b) (according to Maxwell), speed of light independent of speed of source / depends on permittivity and permeability which are constants;
this is shown by answer in (a)(ii); ***[2]***

G3. (a) *rest mass energy*: $E = m_0 c^2$ where m_0 is the rest mass;

total energy: sum of rest mass energy and kinetic energy; ***[2]***

(b) energy $= 2 \times 0.51 = 1.02\,\text{MeV}$;
estimate because only rest-mass energy considered / k.e. not considered; ***[2]***

(c) curved line through origin always "above" given line after about $0.4c$;
asymptotic at $v = c$; ***[2]***

G4. (a) frame of reference <u>far from all masses</u> having acceleration a;
is equivalent to frame of reference (at rest) in gravitational field of strength a;

Or

impossible to distinguish between accelerating reference frame;
and a gravitational field; ***[2]***

(b) (i) ray from star A to observer deviated when near Sun;
straight-line from star B to observer; ***[2]***
Do not award credit where curvature shown at distances greater than two Solar diameters from the Sun.

(ii) observation made when no Sun and when Sun is eclipsed;
star A moves relative to background stars; ***[2]***

G5. (a) if object is dense/massive enough it will cause <u>severe</u> warping of space-time;
such that light entering the space-time surrounding the object cannot escape; ***[2]***
Do not accept "light cannot escape".

(b) use of $R_{\text{SCH}} = \dfrac{2GM}{c^2}$

$= \dfrac{2 \times 6.67 \times 10^{-11} \times 2 \times 10^{31}}{(3 \times 10^8)^2}$;

$= 3 \times 10^4$ m; ***[2]***

Option H — Optics

H1. (a) (i) correct position by eye but within $\pm 5\,\text{mm}$; ***[1]***

(ii) ray parallel to principal axis through F_2;
ray undeviated through pole of lens;
correct extrapolation to marked image; ***[3]***
Do not allow unless image lies between L_1 and right-hand F_1.

(b) virtual because rays only appear to come from it; ***[1]***

(c) (compound) microscope; ***[1]***

(d) (i) L_1 unchanged;
L_2 moved (to right) so that I_1 is at F_2; ***[2]***

(ii) angle (subtended) at eye by image is larger than that (subtended) by object; ***[1]***

H2. (a) light must be incident on boundary from the more (optically) dense medium;
angle of incidence must be greater than the critical angle; ***[2]***

(b) (i) $i = 22^\circ$;
$\sin r = 1.5 \times \sin 22$
$r = 34^\circ$; ***[2]***

(ii) ray at correct angle (by eye); ***[1]***

(c) *e.g.* refractive index between core and covering constant;
so that refraction in fibre independent of medium in which fibre is placed;

e.g. core of fibre would not become scratched;
(so that) light would not be scattered out of fibre; ***[2 max]***
*Award **[1]** for a sensible reason and **[1]** for the explanation.*

(d) *e.g.* monochromatic;
so that all light has same speed in fibre;

e.g. can be switched very rapidly;
so that more information can be carried;

e.g. light can be directed;
so that less light losses / less need for amplification; ***[4 max]***
*Award **[1]** each for two sensible reasons and **[1]** for each explanation.*
Do not allow coherence without explanation.

H3. (a) wider slit gives narrower single-slit diffraction pattern;
so fewer fringes observed; ***[2]***

(b) greater amplitude/intensity from both slits;
bright fringes are brighter;
dark fringes are unchanged; ***[3]***

H4. (a) π / same phase change on reflection at upper and at lower surfaces;
for destructive, path difference must be $\frac{1}{2}\lambda$;

$d = \frac{\lambda}{4}$; ***[3]***

(b) destructive interference for one colour/wavelength/green only;
other colours / red and blue still reflected giving colouring / purple colour; ***[2]***