IB DIPLOMA PROGRAMME
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MARKSCHEME

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PHYSICS

Standard Level

Paper 3

13 pages

Option A — Mechanics Extension

A1. (a) total $= \frac{1}{2} \times 0.44 \times 22^2$;
$+0.44 \times 9.8 \times 32$;
$= 240\,(244)\,\text{J}$; ***[3]***
Award only 2 out of 3 if $g = 10\ ms^{-2}$.

(b) energy at sea level $= 244 \times 0.66 = 160\,(161)\,\text{J}$;
$v^2 = \frac{(2 \times 161)}{0.44}$
$v = 27\,\text{m s}^{-1}$; ***[2]***

A2. (a) gravitation / gravity; ***[1]***

(b) gravitational force $= \frac{GM_1M_2}{(R_1 + R_2)^2}$;
centripetal force $= \frac{M_1R_1 \times 4\pi^2}{T^2}$;
gravitational force provides centripetal force
$\frac{GM_1M_2}{(R_1 + R_2)^2} = \frac{M_1R_1 \times 4\pi^2}{T^2}$;
$T^2 = \frac{R_1(R_1 + R_2)^2 \times 4\pi^2}{GM_2}$ ***[3]***

(c) from formula, $\frac{R_1}{M_2}$ is a constant;
(so if R_1 is smaller) then M_2 is smaller / M_1 is larger; ***[2]***
Do not award second mark if no reasoning given or argument is fallacious.

A3. (a) *e.g.* weight of object <u>or</u> reaction force (not mass);
nature of surfaces;
whether stationary / moving (velocity arguments must include zero); ***[3]***
Award any other sensible suggestions.

(b) (i) R shown acting upwards and normal to slope; ***[1]***

(ii) F shown acting upwards and parallel to slope; ***[1]***
Lines of action not important as long as they pass through block.

(c) (i) (resolving normal to slope) $W \cos\theta = R$;
(resolving along to slope) $W \sin\theta = \mu R$;
<u>working</u> to show $\tan\theta = \mu$; ***[3]***

(ii) maximum value of μ is 1.0 and $\tan^{-1} 1.0 = 45^\circ$; ***[1]***

Option B — Quantum Physics and Nuclear Physics

B1. (a) V_S gives a measure of (maximum) kinetic energy of electrons;
intensity determines rate of production / emission (not energy); ***[2]***

(b) photon energy = work function + maximum kinetic energy of electron;
$V_S = \frac{hc}{\lambda e} - \frac{\varphi}{e}$;
gradient is $\frac{hc}{e}$;
gradient is $1.24(\pm 0.02)\times 10^{-6}$;
$h = \frac{(1.24\times 10^{-6}\times 1.6\times 10^{-19})}{(3\times 10^{8})}$; } *Award mark for final answer only if this marking point is clear.*
$= 6.6(\pm 0.1)\times 10^{-34}\,\text{J s}$; ***[6]***

B2. (a) used to compare / measure nuclear / atomic masses; ***[1]***

(b)

Bainbridge type		***Or***	Aston type
collimated beam;			collimated beam;
velocity selector;			region of electric field;
region of magnetic field and vacuum;			region of magnetic field and vacuum;
suitably placed detector;			suitably placed detector; ***[4]***

(c) fraction x of mass $35u$; *(i.e. some clear explanation of working)*
$35x + 37(1-x) = 35.5$;
$x = 0.75$;
ratio is $\frac{0.75}{0.25} = 3.0$; ***[4]***

B3. (a)

baryon numbers	+1	+1	0	0;
lepton numbers	0	0	+1	−1; ***[2]***

(b) mass-energy / charge / spin / momentum / parity / time conjugation; ***[1]***
Do not allow either "mass" or "energy".

Option C — Energy Extension

C1. (a) (i) CA; ***[1]***

(ii) $V \propto T$ and $T = 290\,\text{K}$;
temperature $= 3 \times 290 = 870\,\text{K}$; ***[2]***
*Award **[0]** for 51C.*

(iii) $p \propto T$;
temperature $= \left(\frac{12.5}{2}\right) \times 290 = 1800\,\text{K}$; ***[2]***
*102C scores **[1]** out of **[2]**.*

(b) external work done $= p\Delta V$;
$= 2.0 \times 10^5 \times 6.0 \times 10^{-4}$
$= 120\,\text{J}$;
change in internal energy $(= 300 - 120) = 180\,\text{J}$; ***[3]***

(c) energy supplied to gas $(= \text{A} \rightarrow \text{B} + \text{B} \rightarrow \text{C}) = 550\,\text{J}$;
work done going through cycle $= 120\,\text{J}$ / representing the area under the pressure volume graph;
transfer in stage $\text{C} \rightarrow \text{A}$ $(= 550 - 120) = 430\,\text{J}$; ***[3]***

C2. (a) organic/living matter;
(partial) decomposition;
under conditions of "high"(temperature) and pressure; ***[3]***

(b) (i) *e.g.* renewable energy source;
no CO_2 emissions; ***[2]***
Do not allow "pollution free"/cost.
*Award **[1]** each for any two sensible suggestions.*

(ii) *e.g.* large number of turbines required;
covering large area of land;

e.g. output dependent on wind speed;
so unreliable;

e.g. change in local climate;
as a result of turbulence; ***[4 max]***
*Award **[1]** each for any two sensible suggestions and **[1]** for each explanation.*

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]***

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]***

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.
$d = 4.0 \times 10^{18}\,\text{m}$;
$L = 4\pi \times 2.0 \times 10^{-7} \times (4.0 \times 10^{18})^2$;
$L = 4.0 \times 10^{31}\,\text{W}$; ***[4]***

(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.*

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 $= 2 \times 0.51 = 1.02$ 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]***

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.