MARKSCHEME

May 2006

PHYSICS

Standard Level

Paper 3

15 pages

Option A — Mechanics Extension

A1. (a) $v^2 = 30^2 - 2 \times 10 \times s$;
$v^2 = 0$;
$s = 45\,\text{m}$;

or

$t = 3.0\,\text{s}$;
$s = 30 \times 3.0 - \frac{1}{2} \times 10 \times 3.0^2$;
$s = 45\,\text{m}$; ***[3]***
Accept valid alternative methods.

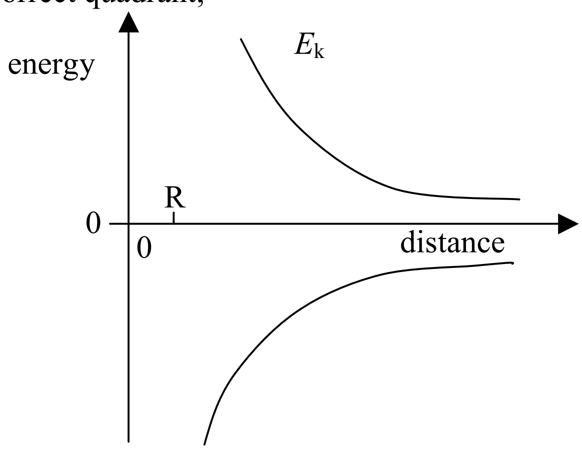
(b) $X = 20 \times 6.0$;
$X = 120\,\text{m}$; ***[2]***

A2. (a) (i) (deceleration due to) gravitational pull of Earth; ***[1]***

(ii) $a = \frac{\Delta v}{\Delta t} = \frac{5100 - 5370}{600}$;
$a = -0.45\,\text{m s}^{-2}$; ***[2]***

(iii) *ECF from (ii)*:
$E = \frac{F}{m}$;
$E = a$;
$E = -0.45\,\text{N kg}^{-1}$; ***[3]***
Accept ms^{-2} *as correct units.*

(b) general shape ($1/r$);
correct quadrant;

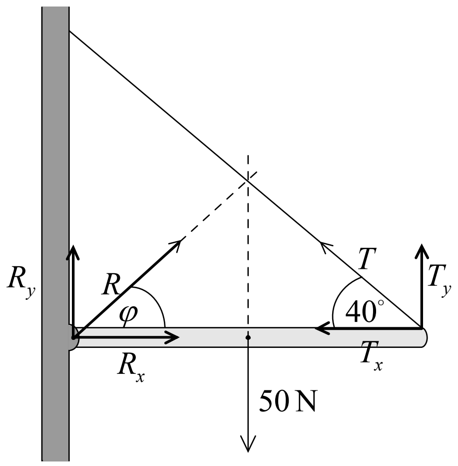


[2]

No need to show the curve further away from the distance axis to achieve full marks.

A3. (a) general direction upward at an angle to wall and beam;
direction through point of intersection of wire and line of action of *W*; ***[2]***
Accept line of action of R within 3 mm of point of intersection.

(b)



resolve horizontally:

$T_x = 39\cos 40° = 30\,\text{N}$

$|R_x| = |T_x| = 30\,\text{N}$;

resolve vertically:

$T_y = 39\sin 40° = 25\,\text{N}$;

$|R_y + T_y| = 50 \Rightarrow |R_y| = 25\,\text{N}$;

$Tan\ \varphi = \dfrac{R_y}{R_x} = \dfrac{25}{30} \Rightarrow \varphi = 40°$;

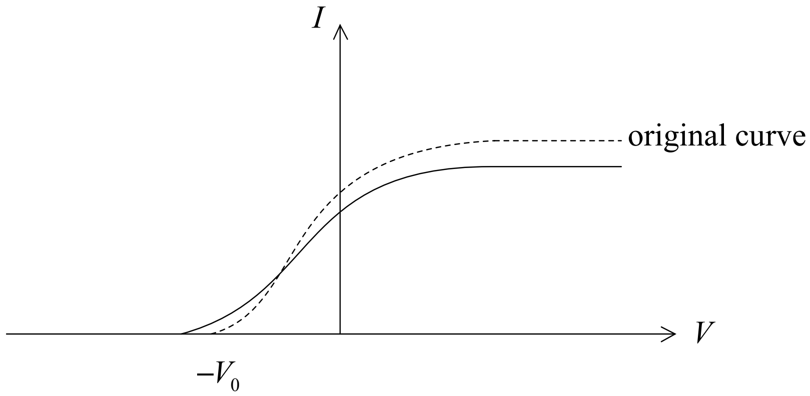
$R = \sqrt{30^2 + 25^2} = 39\,\text{N}$; ***[5 max]***

*Award **[1]** for the direction of R (angle φ). Allow argument using symmetry.*

Option B — Quantum Physics and Nuclear Physics

B1. (a) light consists of photons;
number of photons/sec determines intensity of light;
each photon extracts an electron (from metal);
therefore, current is proportional to intensity of light; ***[4]***

(b)



V_0 is lower / more negative;
general shape of curve (same);
saturation current smaller; ***[3]***

B2. $\lambda = \dfrac{hc}{\Delta E}$;

$\Delta E = 2.88 \times 10^{-15}$ J;

$\lambda = \dfrac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{2.88 \times 10^{-15}}$

$\lambda = 6.9 \times 10^{-11}$ m; ***[3]***

B3. (a) (i) activity $= (-)\lambda N$;

$$\lambda = \frac{4.25\times10^{2}}{8.90\times10^{19}} = 4.78\times10^{-18}\ \mathrm{s}^{-1};$$ ***[2]***

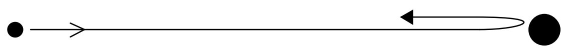
Allow $1.51\times10^{-10}\ \mathrm{yr}^{-1}$.

(ii) $$T_{\frac{1}{2}} = \frac{\ln 2}{4.78\times10^{-18}} = 1.45\times10^{17}\ \mathrm{s};$$

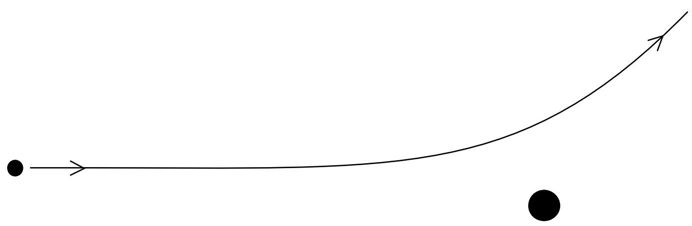
$= 4.60\times10^{9}$ years ; ***[2]***

(b) *e.g.* activity would change during analysis to find *N* / rate of change of activity is too great to allow N(t) to be determined / *OWTTE*; ***[1]***

B4. (a)



path A must show recoil;



path B must show reasonable curvature in correct position (hyperbolic); ***[2]***

Line should show symmetry about nucleus.

(b) α-particle comes to rest when $E_{\mathrm{K}} = E_{\mathrm{P}}$ / all KE is converted to (electrostatic) PE;

$$\mathrm{EPE} = \frac{2Ze^{2}}{4\pi\varepsilon_{0}r} = E_{\mathrm{K}};$$

therefore, *r* can be estimated; ***[3]***

Option C — Energy Extension

C1. (a) *internal energy*: (random translational) kinetic energy of atoms/molecules; ***[1]***

(b) (i) 546 K; ***[1]***

(ii) temperature doubled but pressure remains constant;
<u>hence</u> volume doubled to $44.0\,\text{m}^3$;

or

$V \propto T$;
therefore, volume doubled to $44.0\,\text{m}^3$; ***[2]***

(c) (i) $W = 0$; ***[1]***

(ii) $\Delta W = p_\text{A}(V_\text{C} - V_\text{A})$
$= 1.01 \times 10^5 \times 22.0$;
$= 22.2 \times 10^5$ J; ***[2]***
Note the ECF from (b)(ii).

(iii) work done on the gas;
because the volume is decreasing; ***[2]***
*Award **[0]** for a bald statement without any attempt at reasoning.*

(iv) total work done by gas in cycle is
$\Delta W = 0 + 31.5 \times 10^5 - 22.2 \times 10^5$;
work output $= 9.3 \times 10^5$ J; ***[2]***

C2. (a) (i) $P = \dfrac{\rho \pi r^2 v^3}{2} = \dfrac{1.3 \times \pi \times 7.5^2 \times 9.0^3}{2}$;
$P = 8.4 \times 10^4$ W; ***[2]***

(ii) the speed of air (mass) cannot drop to zero / *OWTTE*; ***[1]***

(iii) 1. idea of less KE available for the next turbine;
2. idea of turbulence; ***[2]***

(b) *advantage*:
statement: wind is a renewable source of energy / clean source of energy;
comment: any relevant comment re statement;

disadvantage:
statement: number of turbines required is very large (about 270) / noise / ugly site / ecological impact;
comment: any relevant comment re statement; ***[4 max]***
*Award **[1]** for each statement and **[1]** for each comment re statement.*
N.B. *some aspect(s) might be considered to be an advantage or disadvantage (e.g. ugliness/beauty of site), accept both.*

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 $I_0 = 1.0\times10^{-12}\ \mathrm{W\,m^{-2}}$; ***[2]***

(b) intensity at eardrum $= \dfrac{2.8\times10^{-7}}{1.9\times10^{-5}} = 1.5\times10^{-2}\ \mathrm{W\,m^{-2}}$;

$IL = 10 \lg\left(\dfrac{1.5\times10^{-2}}{1.0\times10^{-12}}\right)$;
$= 100\,\mathrm{dB}$; ***[3]***
Accept 102 dB.

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

D3. (a) (i) $3.0(\pm0.1)\,\mathrm{mm}$; ***[1]***

(ii) $\mu = \dfrac{\ln 2}{t_{½}}$;

$\mu = \dfrac{\ln 2}{3.0\,\mathrm{mm}} = 0.23\,\mathrm{mm}^{-1}$; ***[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]***

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]***

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 (classes of) stars; ***[2]***

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

(b) $d(pc) = \frac{1}{p} = \frac{1}{5.0\times10^{-3}} = 200\,\text{pc}$;
$200\,\text{pc}\times3.26\times9.46\times10^{15} = 6.2\times10^{18}\,\text{m}$; ***[2]***

(c) (i) use of $L = b(4\pi d^2)$;
$L = (1.6\times10^{-8})\times(4\pi)\times(6.2\times10^{18})^2$;
$L = 7.6\times10^{30}\,\text{W}$; ***[3]***

(ii) $T = \frac{2.9\times10^{-3}}{\lambda_{\text{max}}} = \frac{2.9\times10^{-3}}{935\times10^{-9}}$;
$T = 3100\,\text{K}$; ***[2]***

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

$R = \frac{(7.6\times10^{30})^{\frac{1}{2}}}{\left(5.67\times10^{-8}\times(3100)^4\ (4\pi)\right)^{\frac{1}{2}}}$;

$\frac{R}{R_s} = \frac{R}{7.0\times10^{8}} = 500$; ***[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.*

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 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]***

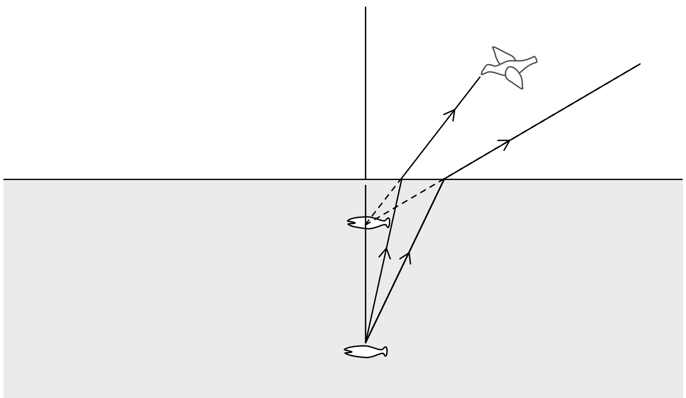
Option H — Optics

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)



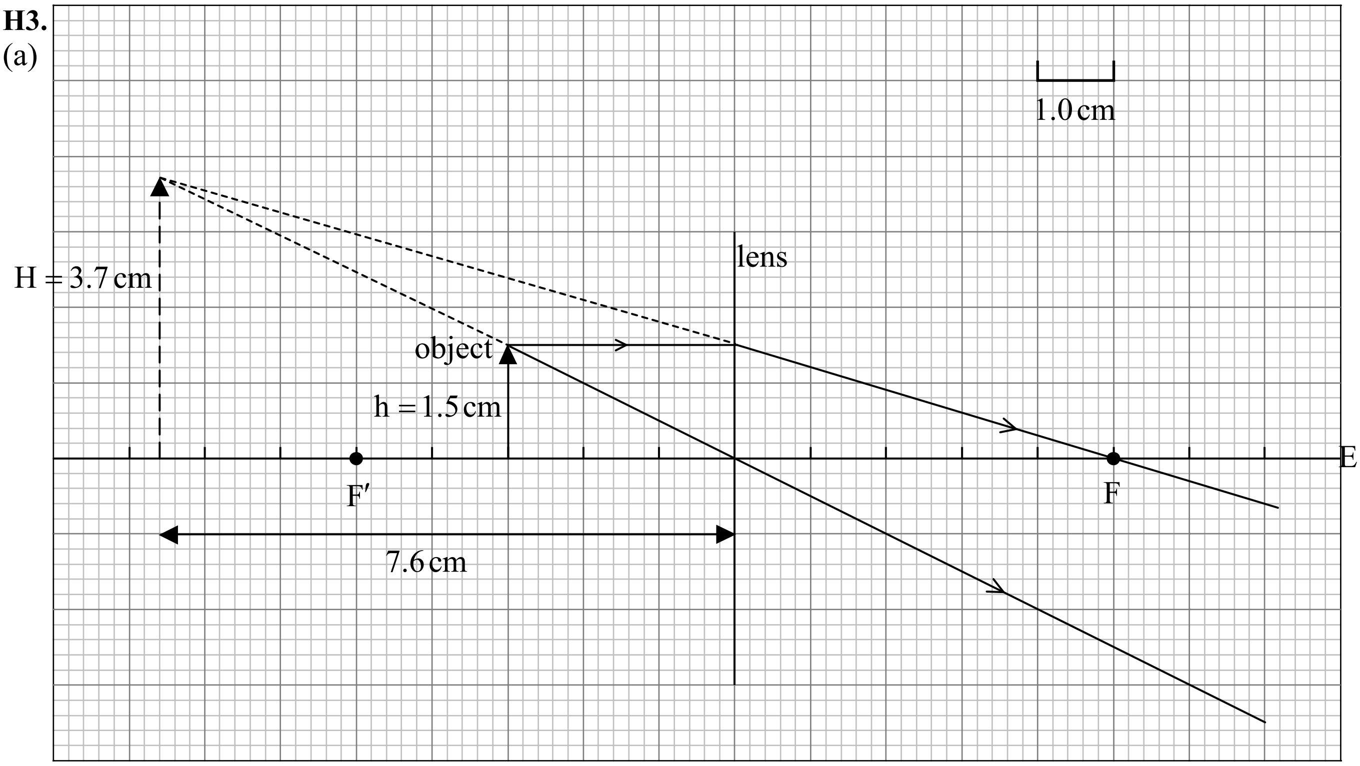
one ray from fish with correct refraction;
2nd ray from fish with correct refraction;
rays backward to give correct position of image; *[3]*
Here only a qualitative explanation (diagram) is expected, since no numerical values are given. A quantitative solution is asked for in part (a)(iii).

(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* $= 180$