INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

N03/430/S(3)M+

MARKSCHEME

November 2003

PHYSICS

Standard Level

Paper 3

19 pages

Subject Details: Physics SL Paper 3 Markscheme

General

A markscheme often has more specific points worthy of a mark than the total allows. This is intentional. Do not award more than the maximum marks allowed for part of a question.

When deciding upon alternative answers by candidates to those given in the markscheme, consider the following points:

- Each marking point has a separate line and the end is signified by means of a semicolon (;).
- An alternative answer or wording is indicated in the markscheme by a "/"; either wording can be accepted.
- Words in (…) in the markscheme are not necessary to gain the mark.
- The order of points does not have to be as written (unless stated otherwise).
- If the candidate's answer has the same "meaning" or can be clearly interpreted as being the same as that in the mark scheme then award the mark.
- Mark positively. Give candidates credit for what they have achieved, and for what they have got correct, rather than penalizing them for what they have not achieved or what they have got wrong.
- Occasionally, a part of a question may require a calculation whose answer is required for subsequent parts. If an error is made in the first part then it should be penalized. However, if the incorrect answer is used correctly in subsequent parts then **follow through** marks should be awarded.
- Units should always be given where appropriate. Omission of units should only be penalized once. Ignore this, if marks for units are already specified in the markscheme.
- Deduct **1 mark in the paper** for gross sig dig error *i.e.* for an **error of 2 or more digits**.

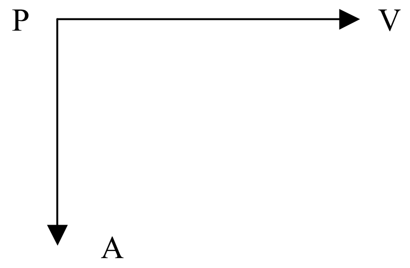
e.g. if the answer is 1.63:

2	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

However, if a question specifically deals with uncertainties and significant digits, and marks for sig digs are already specified in the markscheme, then do **not** deduct again.

OPTION A — MECHANICS EXTENSION

A1. (a)



(i) acceleration; ***[1 max]***

(ii) velocity; ***[1 max]***

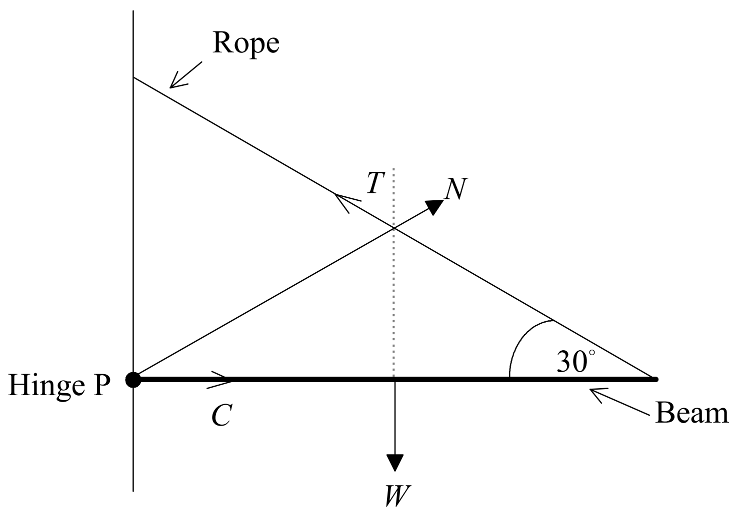
(b) (i) $KE = \frac{1}{2}mv^2 = 0.08 \times 225 = 18\ \text{J}$; ***[1 max]***

(ii) 18 J; ***[1 max]***

(iii) loss in $PE = mgh = 40$ J; ***[1 max]***

(iv) total $KE = 58$ J;
$v = \sqrt{\dfrac{116}{0.16}} = 27\ \text{m s}^{-1}$; ***[2 max]***

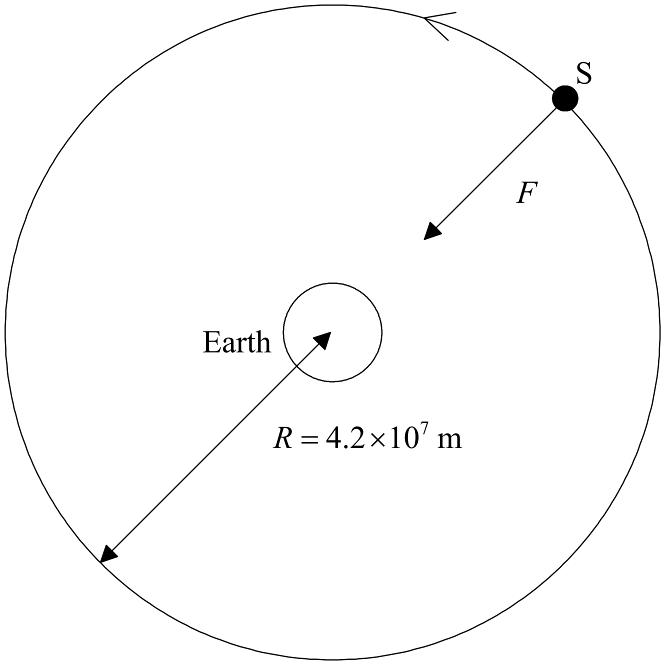
A2. (a)



any arrow in the first quadrant;
correct position of N with respect to W and T; ***[2 max]***

(b) resolve horizontally $C = T\cos 30$;
to give $C = 17$ N; ***[2 max]***

A3. (a)



F – towards centre of Earth; ***[1 max]***
*Award **[0]** if any other forces are drawn.*

(b) (i) $\frac{GM}{R^2} = \frac{v^2}{R}$

so $v^2 = \frac{GM}{R}$; ***[1 max]***

(c) $v = \frac{2\pi R}{T}$;

so $v^2 = \frac{4\pi^2 R^2}{T^2} = \frac{GM}{R}$;

so $T^2 = \frac{4\pi^2 R^3}{GM}$; ***[3 max]***

(d) $T^2 = \frac{4\pi^2 R^3}{g_0 {R_E}^2}$;

to give $T \approx 85000\text{ s} \approx 24$ hours; ***[2 max]***

(e) (i) decreases; ***[1 max]***

(ii) increases; ***[1 max]***

OPTION B — ATOMIC AND NUCLEAR PHYSICS EXTENSION

B1. (a) that all particles can behave as waves / *OWTTE*;
their wavelength λ given by $\lambda = \frac{h}{p}$
where $h \Rightarrow$ Planck's constant and $p \Rightarrow$ is the momentum of the particle; ***[2 max]***
i.e. ***[1]*** *for the idea of matter waves,* ***[1]*** *mark for the mathematical statement and the definition of the terms.*

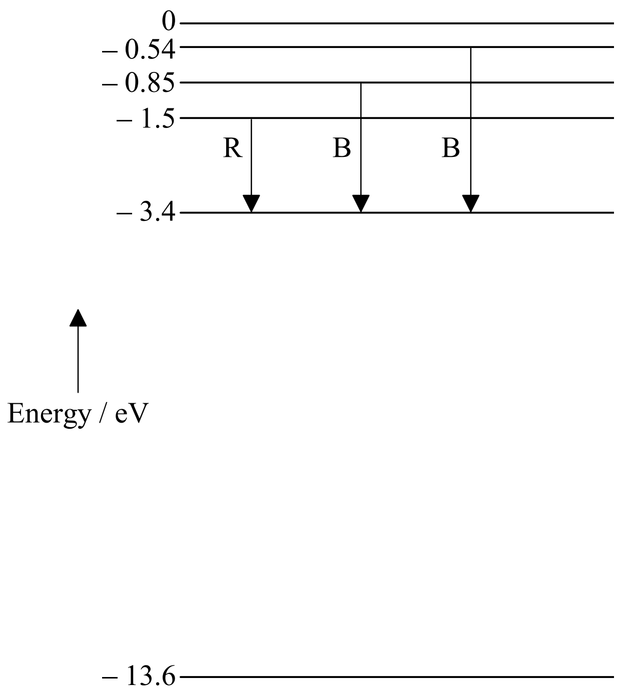
(b) combine $\lambda = \frac{h}{p}$ and $E_k = \frac{p^2}{2m}$;
to get $\lambda^2 = \frac{h^2}{2mE_k}$;
$E_k = 75.0 \times 1.6 \times 10^{-19}$ J;
correct substitution to get $\lambda = 1.4 \times 10^{-10}$ m; ***[4 max]***
Allow ***[3]*** *for calculating the velocity and then the momentum and* ***[1]*** *for final correct value.*

(c) the wavelength of the electrons can be determined from the positions of max and min;
the wavelength can be calculated from de Broglie;
this value of this wavelength is in agreement with the value determined from the experiment / *OWTTE*; ***[3 max]***

Alternatively:
The max and min suggest interference between wave ***[1]****. The interference is consistent with the wavelength determined by the de Broglie hypothesis* ***[2]****. i.e. Look for the tie-up between theory and experiment.*

B2. (a) $E = \dfrac{hc}{\lambda}$;
to give $E = 3.0 \times 10^{-19}$ J;
$= \dfrac{(3.0 \times 10^{-19})}{(1.6 \times 10^{-19})}$ eV $= 1.9$ eV; ***[3 max]***
*The answer must **show** how the value in eV is calculated in order to receive **[3]**.*

(b)



(i) correct placement of R as shown; ***[1 max]***

(ii) any one of the B's shown; ***[1 max]***

B3. (a) positron (β+, positive electron);
neutrino; ***[2 max]***
*Award **[1]** for electron and antineutrino.*

(b) $\lambda = \dfrac{1}{N} \times \dfrac{dN}{dt}$;
$\dfrac{dN}{dt} = \dfrac{16}{60} = 0.27\ \text{s}^{-1}$;
substitution gives $\lambda = 1.8 \times 10^{-17}\ \text{s}^{-1}$; ***[3 max]***

(c) $\approx 4 \times 10^{16}$ s; ***[1 max]***

OPTION C — ENERGY EXTENSION

C1. (a) (i) mass of water $= 1.2 \times 10^3$ kg ;
energy required $= 1.2 \times 10^3 \times 4.2 \times 10^3 \times 30 = 1.5 \times 10^8$ J ; ***[2 max]***

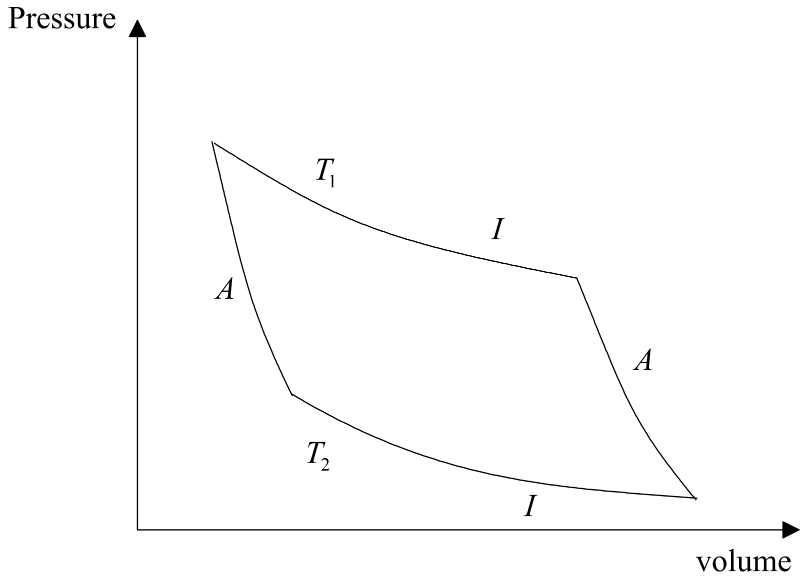
(ii) energy provided in 2 hours $= 7\,200 \times 800 \times A$;
therefore, $A = \dfrac{(1.5 \times 10^8)}{7\,200 \times 800)} \approx 26\ \text{m}^2$; ***[2 max]***

(iii) this is a large area;
appropriate relevant detail *e.g.* a lot of space needed; ***[2 max]***
Look for a plausible argument for or against e.g. if the space is available then could be a viable proposition. Or the response may argue that in reality a greater area than this will be needed.

(b) (i) power $P = \frac{1}{2}\rho A v^3 = \frac{1}{2}\rho \pi r^2 v^3$ where r is the blade radius;
therefore, $r = \sqrt{\dfrac{2P}{\pi \rho v^3}}$;
$= \sqrt{\dfrac{800}{3.14 \times 6^3}} = 1.1\ \text{m}$; ***[3 max]***

(ii) *Look for any sensible reason in support or against.* ***[1 max]***

C2. (a)



correct labelling of the axes;
two sensible isotherms;
two sensible adiabatics; ***[3 max]***
*Use judgement for drawing of cycle. Award **[2]** for a good diagram, **[1]** for a reasonable diagram and **[0]** for a poor diagram.*

(b) (i) two correct I's; ***[1 max]***

(ii) two correct A's; ***[1 max]***

(iii) correct T_1; ***[1 max]***

(iv) correct T_2; ***[1 max]***

(c) (i) efficiency $= 1 - \left(\frac{300}{1000}\right) =$ 0.7 (70 %); ***[1 max]***

(ii) input power $= \frac{\text{(output power)}}{\text{efficiency}}$;

$\frac{(10 \times 75)}{7} = 110\text{ kW}$; ***[2 max]***

OPTION D — BIOMEDICAL PHYSICS

D1. (a) (i) energy loss $\propto L^2$;
mass $\propto L^3$;
therefore, $Q \propto \frac{1}{L}$;
ratio $\frac{small}{large} = \frac{4}{2\times10^{-2}} = 2\times10^2$; ***[4 max]***

(ii) *Anything sensible such as:*
shape of the mammals can be approximated to cubes / spheres / same fur covering / speciality losses ignored such as very large ears; ***[1 max]***

(b) (i) energy loss per unit mass becomes too great;
to be sustained by metabolism / *OWTTE*;
or *difficult* to maintain constant body temperature in a sudden cold snap / *OWTTE*; ***[2 max]***
*Award state **[1]** and explanation **[1]**.*

(ii) the leg bones would not be able to support larger mammals;
mass increases with r^3 so breaking stress of bones soon reached / *OWTTE*;
or energy production is so large;
that mammal will overheat / *OWTTE*; ***[2 max]***
*Award state **[1]** and explanation **[1]**.*

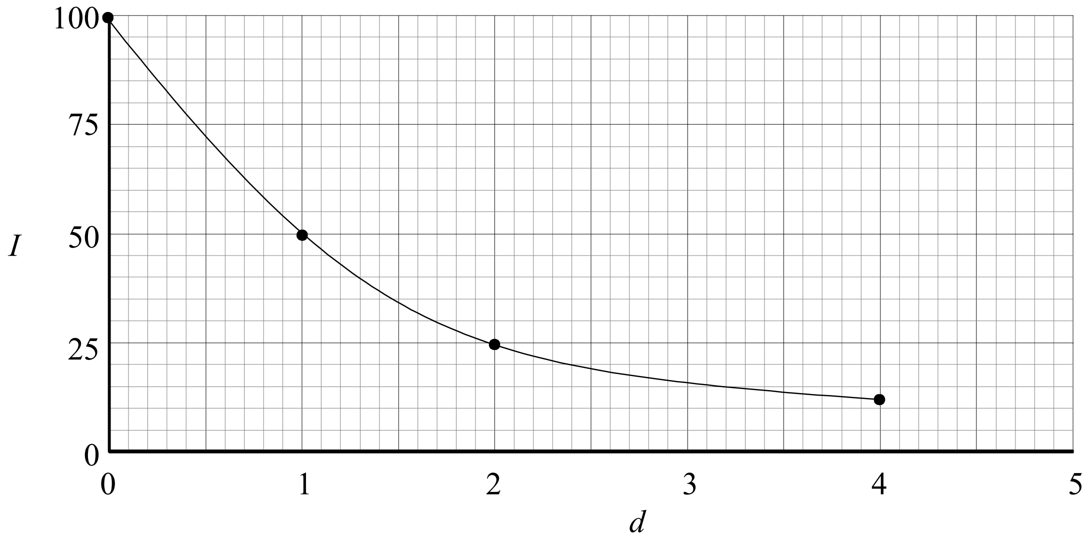
D2. (a) intensity $\propto A^2$;
therefore, ratio of amplitudes $= 10^{-3}$; ***[2 max]***

(b) difference in dB between Carmen and Jorge $= 10 \log\left(\frac{10^{-12}}{10^{-6}}\right)$;
= 60 dB; ***[2 max]***

(c) 3 000 Hz;
since at this frequency she can detect sound at 5 dB below 0 dB / *OWTTE*; ***[2 max]***

(d) 60 ($\pm$5) dB; ***[1 max]***

D3. (a)



Award general shape ***[1]****.*
A graph that clearly shows exponential dependency receives ***[2]****.* ***[2 max]***

(b) 30 keV
is less attenuated by the muscle;
but is still likely to be well attenuated by the bone; ***[2 max]***
30 KeV on its own does not gain any credit. Award ***[1]*** *for each relevant point in the explanation up to* ***[2 max]****.*

OPTION E — THE HISTORY AND DEVELOPMENT OF PHYSICS

E1. (a) (i) acceleration of the Moon at surface of the Earth is given by $M_{moon}g = \dfrac{K}{{R_E}^2}$;

acceleration of Moon in orbit is given by $M_{moon}g_{orbit} = \dfrac{K}{(60R_E)^2}$;

therefore, $\dfrac{g_{orbit}}{g} = \dfrac{1}{3600}$;

therefore, $g_{orbit} = 10 \times 2.8 \times 10^{-4} = 2.8 \times 10^{-3}\ \text{m s}^{-2}$; ***[4 max]***

(ii) acceleration $= \dfrac{v^2}{R} = \dfrac{v^2}{60R_E}$;

$= \dfrac{4\pi^2(60R_E)}{T^2}$;

$= \dfrac{40 \times 60 \times 6.4 \times 10^6}{(2.4 \times 10^6)^2}$;

$= 2.7 \times 10^{-3}\ \text{m s}^{-2}$; ***[4 max]***

(iii) *A statement that the two values are sufficiently close to make Newton's assumption correct.* ***[1 max]***

(b) that the force that causes object to fall to the ground;
is the same as that force that the Earth exerts on all bodies in the Universe; ***[2 max]***
Alternatively*, a clear statement that the law is true for the force between any two bodies. Accept ("or all bodies") in the universe. Award* ***[1]*** *for some idea.*

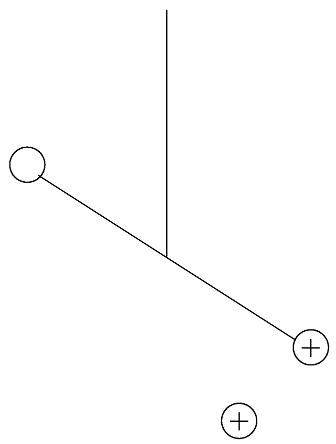
E2. (a) $= \dfrac{kQ^2}{4d^2}$ or $F = \dfrac{Q^2}{16\pi\varepsilon_0 d^2}$; ***[1 max]***

(b) $\dfrac{F}{4}$; ***[1 max]***

(c) the spheres can be assumed to be point charges; ***[1 max]***

(d) each time the charge is shared it halves in value on each sphere;
if F is proportional to the product of the charges then F will be reduced by $\frac{1}{4}$ each time / *OWTTE*; ***[2 max]***
i.e. Look for the halving in value of the charge and the effect is has on F.

(e)



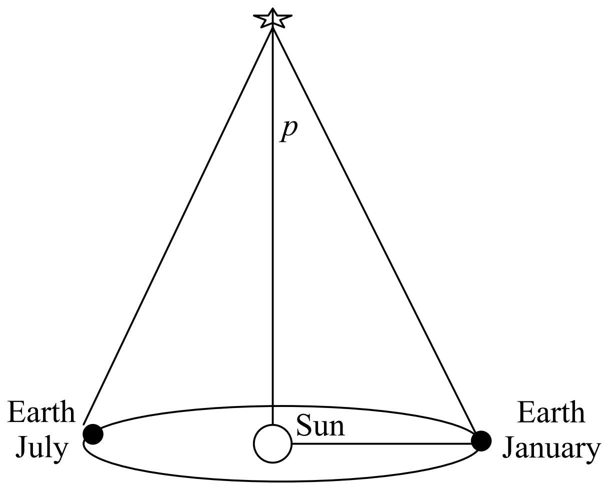
Mark diagram and description together looking for these points:
unlabelled diagram;
description / labelling;
force between the charges produces a twist in suspension;
amount of twist is a measure of the force; ***[4 max]***
*Award good answers **[4 max]** and weak answers **[1 max]**.*

OPTION F — ASTROPHYSICS

F1. (a) Earth → Mars → Jupiter → Pluto; ***[2 max]***
*All correct **[2]**, two in the wrong place **[1]**.*

(b) Pluto → Mars → Earth → Jupiter; ***[2 max]***
*All correct **[2]**, two in the wrong place **[1]**.*

F2. (a)



Mark the definition of p and description of its measurement along with the diagram.
Essentially diagram should:
show p;
position of Sun;
position of Earth;
then definition of $p = \dfrac{\text{(distance of Earth from Sun)}}{\text{(distance of star from Sun)}}$;
diagram should show Earth positions separated by about six months;
then description should mention that angle of sight is measured at these two positions such that the difference between these two angles is equal to $2p$; ***[6 max]***
*Award **[6 max]** for a clear description and diagram, **[3]** for an average and **[1]** for some rudimentary idea. Mark diagram and description together.*

(b) $d = \dfrac{1}{p} = \dfrac{1}{0.549} = 1.82\text{ pc}$;
$= 1.82 \times 3.26 = 5.94\text{ ly}$; ***[2 max]***

(c) (i) the radiant power from a star;
that is incident per m^2 of the Earth's surface;
Alternatively, define from $b = \dfrac{L}{4\pi d^2}$ *but terms must be defined to obtain the mark.*
definition of L;
definition of d; ***[2 max]***

(ii) $L = 4\pi d^2 b$;
therefore, $\dfrac{L_B}{L_S} = \dfrac{d_B{}^2 b_B}{d_S{}^2 b_S}$;
$d_S = 1\ \text{AU}, d_B = 3.8 \times 10^5\ \text{AU}$;
therefore, $\dfrac{L_B}{L_S} = (3.8)^2 \times 10^{10} \times 2.6 \times 10^{-14} = 3.8 \times 10^{-3}$; ***[4 max]***
Allow any answer between (3.0 and 4.0)$\times 10^{-3}$.

(d) (i) temperature too low for it to be a white dwarf; ***[1 max]***

(ii) luminosity too low for it to be a red giant; ***[1 max]***

OPTION G — RELATIVITY

G1. (a) (i) *proper length*
the length of an object as measured by an observer at rest with respect to the object / *OWTTE*; ***[1 max]***

(ii) *proper time*
the time interval between two events measured in the reference frame in which the two events occur at the same place; ***[1 max]***

(iii) *inertial observer*
an observer who is in a reference frame that is moving with constant velocity / in a reference frame in which Newton's 1st law is valid; ***[1 max]***

(b) (i) half-life $= \dfrac{1370}{0.95\,c}$;
$= 4.8 \times 10^{-6}$ s; ***[2 max]***

(ii) from $\gamma = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}$, $\gamma = 3.2$;
$T = \dfrac{T_0}{\gamma} = 1.5 \times 10^{-6}$ s;
Alternatively, from length contraction $= \dfrac{1370}{3.2} = 430$ m;
half-life of muons $= \dfrac{430}{9.5\,c} = 1.5 \times 10^{-6}$ s; ***[2 max]***

(iii) $L = \dfrac{L_0}{\gamma} = 430$ m; ***[1 max]***

(c) *Mark the answers for **time dilation** and **length contraction** together such that a good answer for one can receive **[3 max]** with **[1 max]** for the other answer. Answers will be open-ended but look for these main points:*
the muons regarding themselves at rest measure the proper time for half of them to decay;
to the laboratory observers, the muons will take a longer time to decay;
and this is the time that to them, it takes the muons to travel between the counters;
the laboratory observers measure the proper length since the counters are at rest in their reference frame;
to the muons it will seem that counter 2 is travelling towards them;
and in the time that it takes half of them to decay they will measure counter 2 as having travelled a contracted distance 430 m; ***[4 max]***

(d) (i) $m = \dfrac{m_0}{\sqrt{1 - \dfrac{v^2}{c^2}}}$ ***or*** $m = \gamma m_0$; ***[1 max]***

(ii) if the muon were to reach the speed of light the bottom line of equation would be zero;
showing that the mass would be infinite. This is clearly not possible; ***[2 max]***
*i.e. To receive **[2]** some reference must be made to the equation, otherwise just award **[1]**, e.g. "the mass would be infinite".*

(e) (i) $110\,(\pm 10)\ \text{MeV}\,\text{c}^{-2}$; ***[1 max]***

(ii) $340\,(\pm 50)\ \text{MeV}\,\text{c}^{-2}$; ***[1 max]***

(f) $340\,(\pm 50)$ MeV ; ***[1 max]***

(g) $E_{\text{tot}} = Ve + m_0c^2$;
to give $V = 340 - 110 = 230\,(\pm 60)$ MV; ***[2 max]***

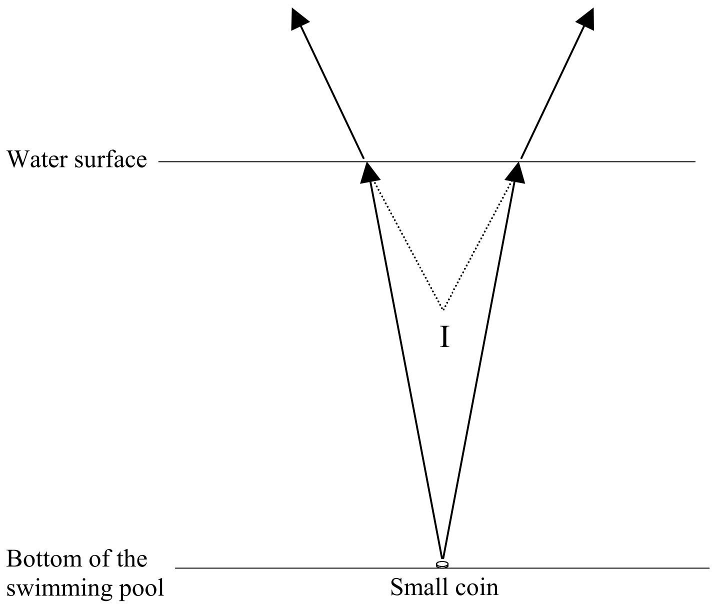
OPTION H — OPTICS

H1. (a) for blue, from the graph $v = 1.9455\ \ (\pm 0.0005) \times 10^8\ \text{m s}^{-1}$;

$n = \frac{c}{v} = \frac{2.9979}{1.9455} = 1.5409\ \ (\pm\ 0.0005)$; ***[2 max]***

(b) white light contains light of different wavelengths;
each wavelength is deviated by a different amount as it passes through the prism / the refractive index of the prism is dependent on the wavelength / *OWTTE*;
the refractive index is larger for blue light, therefore the refractive angle is smaller;
and so blue light is bent more towards the normal / *OWTTE*; ***[2 max]***
Alternatively, the response may use the aid of a diagram.

H2. (a)



two rays from the coin showing refraction into the air;
extrapolated back to locate the labelled image **I**; ***[2 max]***

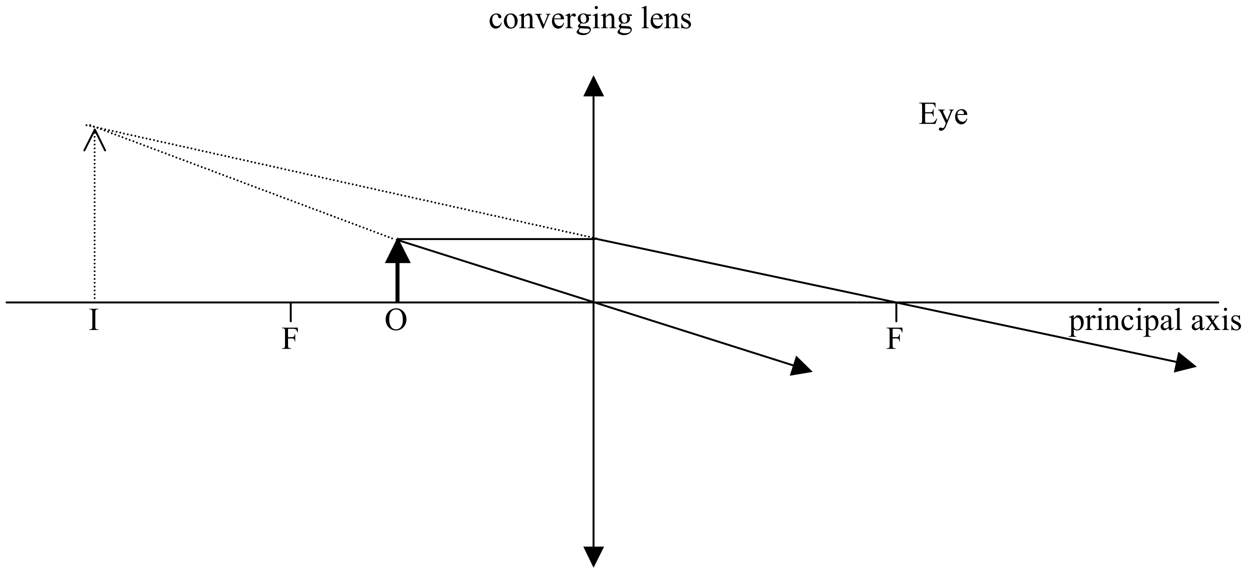
(b) virtual, since the rays form the coin to not come to a focus / *OWTTE*; ***[1 max]***
*Correct answer with wrong or weak or no explanation would receive **[0]**.*

(c) $a = \frac{d}{n}$;

$= \frac{3.0}{1.3} = 2.3\ \text{m}$;

distance from bottom of pool $= 0.7$ m; ***[3 max]***

H3. (a)



(i) two appropriate rays; ***[1 max]***

(ii) correct image position; ***[1 max]***

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

(b) (i) if the object is nearer than this to the eye then the eye cannot focus it clearly / *OWTTE*; ***[1 max]***

(ii) $\frac{1}{u} = -\frac{1}{v} + \frac{1}{f}$;
$v = -(25-3)\ \text{cm} = -22\ \text{cm}$;
$\frac{1}{u} = \frac{1}{22} + \frac{1}{10}$;
to give $u = 6.9$ cm; ***[4 max]***
*Alternatively for scale drawing award **[1]** for scale, **[2]** for rays, **[1]** for position of image and **[1]** for subtraction.*

(iii) at the focal point;
the far point is at infinity; ***[2 max]***