MARKSCHEME

May 2004

PHYSICS

Standard Level

Paper 3

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 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 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. Indicate this with **"ECF"**, error carried forward.
- 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*

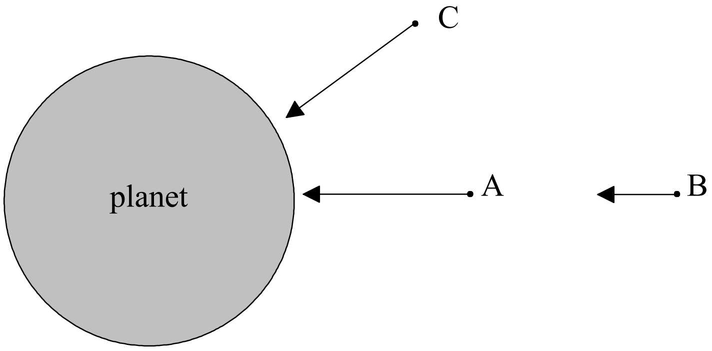
However, if a question specifically deals with uncertainties and significant digits, and marks for sig digs are already specified in the markscheme, then do **not** deduct again.

Option A — Mechanics Extension

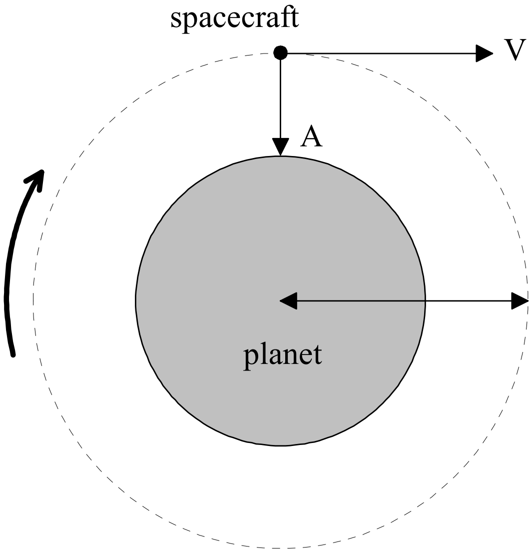
A1. (a) $g = \dfrac{F}{m}$

F is the gravitational force;
exerted on/experienced by a small/point/infinitesimal mass m; ***[2]***

(b) *Award **[1]** for each correct arrow. The one at B points in the same direction as that at A and is shorter. The one at C has the same length as that at A and points toward the centre of the planet.* ***[2]***



(c)



(i) velocity is tangent to path; ***[1]***

(ii) acceleration is normal to velocity toward centre; ***[1]***

(d) for realizing that $g = a$;

$a = \dfrac{v^2}{r} = \dfrac{(6.5\times10^3)^2}{7.5\times10^6}\,\mathrm{N\,kg^{-1}}$;

$g = 5.6\,\mathrm{N\,kg^{-1}}$; ***[3]***

A2. (a) block will not move unless F exceeds the maximum possible frictional force;
maximum possible frictional force $= \mu_s N$;
since $N = mg = 50\,\text{N}$, maximum frictional force is $0.60 \times 50 = 30\,\text{N}$; ***[3]***
Allow use of $g = 9.81\,m\,s^{-2}$ *in which case* $N = 29.4\,N$.

(b) net force $= F - f$;
net force $= 70 - 0.50 \times 50 = 45\,\text{N}$;
So acceleration $= \dfrac{45\,\text{N}}{5\,\text{kg}} = 9.0\,\text{m}\,\text{s}^{-2}$; ***[3]***
Allow use of $g = 9.81\,m\,s^{-2}$ *in which case Net force* $= 45.5\,N$ *and* $a = 9.1\,m\,s^{-2}$.

A3. (a) $N_1 + N_2 = 900\,\text{N}$ (883 N if $9.81\,\text{m}\,\text{s}^{-2}$ is used); ***[1]***

(b) let x be the distance (in meters) of the girl from the end marked X;
when beam is about to tip over, $N_1 = 0\,\text{N}$;
taking torques about the support to the right, $400 \times 5 = 500 \times (5 - x)\,\text{m}$;
solving for x gives $x = 1\,\text{m}$; ***[4]***

Option B — Quantum Physics and Nuclear Physics

B1. (a) *aspect*:
electrons will not be emitted unless the frequency of light exceeds a certain minimum value / electrons are emitted almost instantaneously with the light falling on the surface even if light is of very low intensity / the energy of the electrons emitted is not affected by the intensity of light falling on the surface; ***[1]***

corresponding e*xplanation*:
light consists of photons whose energy is *hf* hence no electrons are emitted unless *hf* is larger than the energy needed to escape the metal / an electron is emitted as soon as it absorbs a photon. If the photon has sufficient energy no delay is required / the intensity of light plays no role in the energy of the electron only the frequency of light does; ***[1]***

(b) (i) the threshold frequency is found from the frequency axis intercept;
to be $3.8(\pm 0.2)\times 10^{14}$ Hz ; ***[2]***

(ii) a value of the Planck constant is obtained from the slope;
to be $6.5(\pm 0.2)\times 10^{-34}$ J s ; ***[2]***
*Award **[0]** for "bald" answer of* 6.63×10^{-34} *J s .*

(iii) the work function of the surface is found from the intercept with the vertical axis;
to be 1.5(±0.1) eV; ***[2]***

(c) straight-line parallel to the first;
intersecting the frequency axis at 8.0×10^{14} Hz ; ***[2]***

B2. (a) (i) muon lepton number / electron lepton number; ***[1]***

(ii) Baryon number; ***[1]***

(iii) Baryon number / electric charge; ***[1]***

(b) there are eight gluons involved in the strong interaction; ***[1]***
Accept just the name gluons or just mesons.

B3. (a) $qvB = m\frac{v^2}{r}$;

hence $r = \frac{mv}{Bq}$; ***[2]***

(b) $\frac{16.5}{15} = \frac{\frac{m_{16.5}v}{Bq}}{\frac{m_{15}v}{Bq}} = \frac{m_{16.5}}{m_{15}}$;

hence $\frac{16.5}{15} = \frac{m_{16.5}}{20} \Rightarrow m_{16.5} = 22u$; ***[2]***

(c) atoms on 15 cm path: 10 protons and 10 neutrons;
atoms on 16.5 cm path: 10 protons and 12 neutrons; ***[2]***

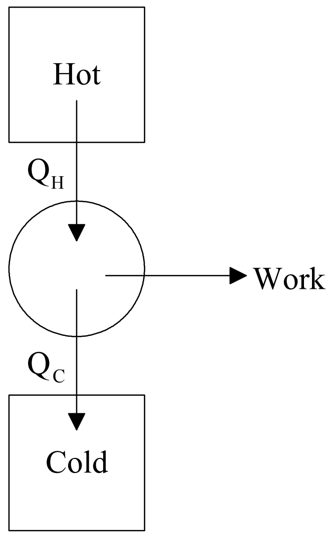
Option C — Energy Extension

C1. (a) area swept out by blades (diameter);
wind speed;
density of air; ***[2 max]***

(b) $P = \frac{1}{2}\rho A v^3$;
$= \frac{1}{2}(1.1)\pi(20)^2(8)^3$
$= 3.54 \times 10^5$ W ;
$E = Pt$;
$= 3.54 \times 10^5 \times 3.2 \times 10^7$
$= 1.12 \times 10^{13}$ J ;
so number of generators needed $= \frac{5 \times 10^7 \times 3.6 \times 10^6}{1.12 \times 10^{13}}$
≈ 16 ; ***[5]***

(c) not all wind goes into turning blades;
average wind speed could be wrong;
wind not always directed at 90° to blades;
not all mechanical energy converted to electrical energy; ***[3 max]***
i.e. turbines not 100 % efficient or frictional losses.

C2. (a)



for each correctly drawn and labelled energy transfer; ***[3 max]***

(b) (i) D→A; ***[1]***

(ii) C→D; ***[1]***

(iii) D→A, A→B; ***[1]***

(iv) B→C, D→A; ***[1]***

(c) the area enclosed by the cycle; ***[1]***

(d) max theoretical efficiency given by $\frac{T_H - T_C}{T_H}$;

river colder in winter therefore T_C lower, therefore efficiency greater; ***[2]***

Option D — Biomedical Physics

D1. (a) (i) mass of water stored $\propto L^3$; *[1]*

(ii) rate of water loss $\propto L^2$; *[1]*

(b) (i) rate of water loss $\times T =$ mass of water stored;
hence $L^2T \propto L^3 \Rightarrow T \propto L$; *[2]*

(ii) $\frac{T_{child}}{T_{adult}} = \frac{L_{child}}{L_{adult}}$;
$\frac{L_{child}}{L_{adult}} \approx \frac{1.20}{1.75} = 0.69$;
so $T_{child} \approx 0.69 \times T_{adult} = 2$ days; *[3]*

Accept any other reasonable estimates of heights and hence time.

D2. (a) (i) X-rays;
because they can easily distinguish between flesh and bone to get a clear image of the fracture; *[2]*

(ii) ultrasound;
because it gives reasonably clear images in the womb without harmful radiation; *[2]*

(b) (i) the half-value thickness is that thickness of lead which (for this particular beam);
will reduce the intensity of the (transmitted) beam by 50 %; *[2]*

(ii) the half-value thickness corresponds to an intensity of 10 units;
and so equals 4 mm; *[2]*

(iii) the transmitted intensity must be $20\% \times 20 = 4$ units;
corresponding to a thickness of lead of about 9.3 (±0.2) mm; *[2]*

(iv) the transmitted intensity must be $(1-0.8)\times 20 = 4$ units;
using $4 = 20(0.5)^{x/8} \Rightarrow (0.5)^{x/8} = 0.20$;
we find a thickness of 18.6 (±1) mm; *[3]*
or
the transmitted intensity must be $(1-0.8)\times 20 = 4$ units;
by drawing a second graph corresponding to the half-value thickness of 8 mm;
and finding the thickness corresponding to a transmitted intensity of 4 units of about 18.6 (±1) mm; *[3]*

Option E — The History and Development of Physics

E1. (a) the apparent reversal of direction of a planet's motion;
with respect to the "fixed" background of stars; ***[2]***

(b) Mars (being further away from the sun than the earth) orbits slower;
explanation / suitable diagram; ***[2]***

E2. (a) *glass*: electric fluid of one type (vitreous) is produced/created; ***[1]***
amber: electric fluid of other type (resinous) is produced/created; ***[1]***

(b) *glass*: electrons leave glass; ***[1]***
amber: electrons move to amber; ***[1]***

E3. (a) (i) movement implies cathode rays have electric charge;
electromagnetic waves do not have charge; ***[2]***

(ii) deflection implies charge;
hence particles; ***[2]***

(b) (i) because cathode rays ionized the air between the plates;
the ions produced neutralized the plates / shielded the cathode rays; ***[2]***

(ii) Thompson evacuated the region between plates of all air; ***[1]***

(c) (i) $q\ v\ B = eE$

$\Rightarrow v = \frac{E}{B}$;

$= 6.1 \times 10^7\ \mathrm{m\,s^{-1}}$; ***[2]***

(ii) $q\ v\ B = \frac{mv^2}{r}$;

$\frac{q}{m} = \frac{v}{Br}$;

$= 1.8 \times 10^{11}\ \mathrm{C\,kg^{-1}}$; ***[3]***

Option F — Astrophysics

F1. (a) (i) luminosity is the total power radiated by a star/source; ***[1]***
Do not accept $L = \sigma A T^4$.

(ii) apparent brightness is the power from a star received by an observer on Earth per unit area of the observer's instrument of observation; ***[1]***
Accept $b = \frac{L}{4\pi d^2}$ *if L and d are defined.*

(b) the surface area/size of the star changes periodically (due to interactions of matter and radiation in the stellar atmosphere); ***[1]***

(c) (i) at two days the radius is larger / point A;
because then the luminosity is higher and so the area is larger; ***[2]***
Award ***[0]*** *if no explanation is provided.*

(ii) *Award* ***[1]*** *for each relevant and appropriate comment to the process of using Cepheid variables up to* ***[3 max]*** *e.g.*

Cepheid variables show a relationship between period and luminosity;
hence measuring the period gives the luminosity and hence the distance (through $b = \frac{L}{4\pi d^2}$);
distances to galaxies are then measured if the Cepheid can be ascertained to be within a specific galaxy; ***[3]***
Marks can be back credited from answer (d) (ii).

(d) (i) $b = \frac{L}{4\pi d^2} \Rightarrow 1.25\times10^{-10} = \frac{7.2\times10^{29}}{4\pi d^2}$;
$d = \sqrt{\frac{7.2\times10^{29}}{4\pi\times1.25\times10^{-10}}}$;
$d = 2.14(\pm0.2)\times10^{19}\ \text{m}$; ***[3]***

(ii) *Award* ***[1]*** *for each relevant and appropriate comment to the phrase "standard candles" up to* ***[2 max]*** *e.g.*

the phrase *standard candle* means having a source (of light) with known luminosity;
measuring the period of a Cepheid allows its luminosity to be estimated / other stars in the same galaxy can be compared to this known luminosity"; ***[2]***

F2. (a) cosmic background radiation is microwave radiation;
"filling" the universe / from all directions; ***[2]***
Award other relevant and appropriate comments e.g. "at a temperature of about 3K or left over from the Big Bang".

(b) the Big Bang predicts an expanding universe that had a very high temperature at the beginning;
during the expansion the universe is cooling down and the temperature of the radiation should fall to its present low value, (which is precisely what the cosmic background radiation measures); ***[2]***
or
Big Bang producing initially very short wavelength photons/em radiation;
as the universe expands, the wavelengths become redshifted / longer (to reach current value); ***[2]***

(c) the redshift in the light observed from distant galaxies (indicating that they are moving away from each other) / the helium abundance in the universe which is about 25 % and is consistent with a hot beginning of the universe; ***[1]***
Note: *question asks for evidence so do not accept "universe is expanding" unless the answer mentions redshift etc.*

(d) the student is wrong;
space is created as the universe expands / there is no outside to the universe; ***[2]***
*Award **[0]** if no explanation or incorrect explanation.*

Option G — Relativity

G1. (a) *postulate 1*: the speed of light in vacuum is the same for all inertial observers;
postulate 2: the laws of physics are the same for all inertial observers; ***[2]***

(b) (i) $\gamma = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}} = \dfrac{1}{\sqrt{1-0.8^2}} = \dfrac{10}{6}(=1.7)$;
interval on earth $= \gamma \times$ interval on spacecraft;
interval on earth $\dfrac{10}{6} \times 6$ years = 10 years; ***[3]***

(ii) the interval measured by the spacecraft observers is the proper time because it represents the interval between two events taking place at the same place; ***[1]***
Accept an answer that correctly defines proper time and applies this to the time measured by the Earth observers on the Earth observers' clock. A plain answer that it is the spacecraft that shows proper time should not be accepted.

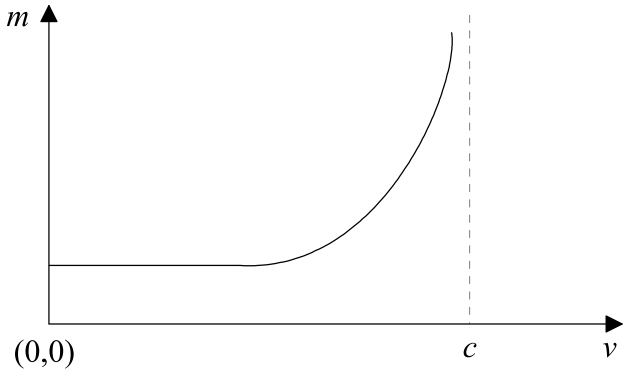
(iii) both observers are inertial observers;
and both are equally valid and correct in their measurements; ***[2]***

(iv) the spacecraft has been travelling for 10 years as far as the Earth observers are concerned;
so the distance travelled according to the Earth observers is
$x = vt = 0.8c \times 10$ years $= 8.0$ light years $(= 7.57\times10^{16}\,\text{m})$; ***[2]***
Watch for ecf from (b) (i).

(v) Earth moves away at $0.80c$ and so is at a distance of $6\times0.80c = 4.8\,\text{ly}$ when signal is emitted;
signal reaches earth in time *T* where $cT = 4.8 + 0.80cT$;
T = 24 years; ***[3]***
or
the signal arrives on Earth after $\dfrac{(10\times0.80c)}{c} = 8$ years *i.e.* 18 years after departure according to Earth clocks;
the events "Earth and spacecraft coincide" and "signal arrives on Earth" occur at the same place according to Earth and so 18 years is a proper time interval;
spacecraft clocks show $\gamma\times18 = 30$ years *i.e.* 24 years after sending the signal; ***[3]***

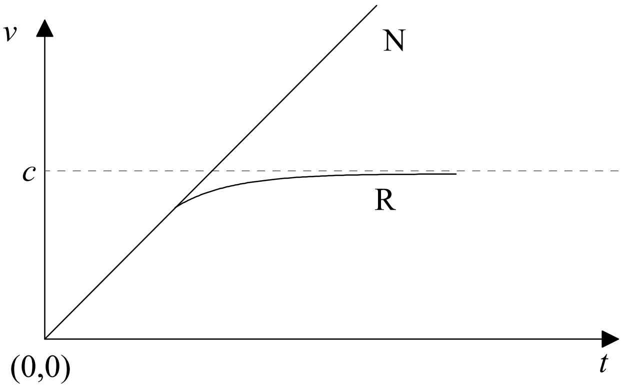
G2. (a) rest mass is the mass of a body as measured in the body's rest frame / alternative correct and unambiguous definition; ***[1]***

(b) graph begins essentially straight and horizontal starting above (0,0);
and approaches infinity asymptotically as the speed approaches the speed of light; ***[2]***



(c) (i) *Newtonian physics*:
graph is a straight-line increasing without limit;

(ii) *Relativistic physics*:
graph starts essentially identical to N but approaches the speed of light asymptotically; ***[2]***



*Award **[2]** for correct graphs without N and R labels. Graphs do not need to start at zero.*

(iii) the mass in Newtonian Physics is constant and so a constant force produces a constant acceleration;
the mass in Relativistic Physics increases and so a constant force produces a decreasing acceleration that never allows the body to reach the speed of light; ***[2]***
*Explanations that are just statements e.g. "nothing travels faster than the speed of light" should be awarded **[0]**. An explanation in terms of mass increase is required.*

Option H — Optics

H1. (a) light incident from glass;
emergent ray along boundary;
c marked correctly; ***[3]***

(b) $\sin c = \frac{1}{1.5}$;
for every 1.0 mm length, light travels 1.5 mm;
path length $= 1.2 \times 10^8 \times 1.5$
$= 1.8 \text{ km}$; ***[4]***
*Award **[4]** for any correct calculation that leads to 1.8 km.*

(c) (i) $\text{time} = \frac{1200}{2.0 \times 10^8} = 6.0\ \mu\text{s}$; ***[1]***

(ii) $\text{time} = 9.0\ \mu\text{s}$; ***[1]***

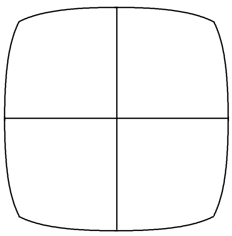
H2. (a) 18 cm; ***[1]***

(b) (i) rays only appear to go to X / *OWTTE*; ***[1]***

(ii) $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$
$u = -6 \text{ cm}$;
$f = -24 \text{ cm}$;
hence distance of image from lens $= 8.0 \text{ cm}$; ***[3 max]***

(c) parallel rays focused further from P;
so focal length is longer; ***[2]***

H3. (a)



straight-line cross;
four outersides curving outwards; ***[2]***
Accept curving of lines in the opposite way or fuzzy in centre and focussed at edges or vice versa.

(b) basic statement *e.g.* use two thin lenses / "stop" down to use only paraxial rays;
further detail *e.g.* same f as the fatter lens; ***[2]***