MARKSCHEME

May 2004

PHYSICS

Higher Level

Paper 3

General Marking Instructions

After marking a sufficient number of scripts to become familiar with the markscheme and candidates' responses to all or the majority of questions, Assistant Examiners (AEs) will be contacted by their Team Leader (TL) by telephone. The purpose of this contact is to discuss the standard of marking, the interpretation of the markscheme and any difficulties with particular questions. It may be necessary to review your initial marking after contacting your TL. **DO NOT BEGIN THE FINAL MARKING OF YOUR SCRIPTS IN RED INK UNTIL YOU RECEIVE NOTIFICATION THAT THE MARKSCHEME IS FINALIZED.** *You will be informed by e-mail, fax or post of modifications to the markscheme and should receive these about one week after the date of the examination. If you have not received them within 10 days you should contact your Team Leader by telephone. Make an allowance for any difference in time zone before calling.* **AEs WHO DO NOT COMPLY WITH THESE INSTRUCTIONS MAY NOT BE INVITED TO MARK IN FUTURE SESSIONS.**

You should contact the TL whose name appears on your "Allocation of Schools listing" sheet.

Note:
Please use a personal courier service when sending sample materials to TLs unless postal services can be guaranteed. Record the costs on your examiner claim form.

1. Follow the markscheme provided, do **not** use decimals or fractions and mark in **RED**.

2. Where a mark is awarded, a tick (✓) should be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark.

3. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases write a brief annotation in the **left hand margin** to explain your decision. You are encouraged to write comments where it helps clarity, especially for moderation and re-marking.

4. Unexplained symbols or personal codes/notations on their own are unacceptable.

5. Record subtotals (where applicable) in the right-hand margin against the part of the answer to which they refer next to the mark allocation. Do **not** circle subtotals. **Circle the total mark for the question in the right-hand margin opposite the last line of the answer.**

6. Where an answer to a part question is worth no marks, put a zero in the right-hand margin.

7. For each Option: Add the totals for each question in the Option and write it in the Examiner column on the front cover.
   Total: Add the marks awarded and enter this in the box marked TOTAL in the Examiner column.

8. After entering the marks on the front cover check your addition to ensure that you have not made an error. Check also that you have transferred the marks correctly to the front cover. **We have script checking and a note of all clerical errors may be given in feedback to examiners.**

9. Every page and every question must have an indication that you have marked it. Do this by **writing your initials** on each page where you have made no other mark.

10. If a candidate has attempted more than the prescribed number of Options within the paper, mark only the required number of Options in the order in which they are presented in the paper, **unless the candidate has indicated the Options s/he wants to be marked, on the front cover**.

11. A candidate can be penalized if he/she clearly contradicts him/herself within an answer. Make a comment to this effect in the left hand margin

Subject Details: Physics HL 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 markscheme 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.
- Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
- 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. Indicate this by **"U-1"** at the first point it occurs. 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*

Indicate the mark deduction by **"SD-1"**. 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 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 $L^2 T \propto L^3 \Rightarrow T \propto L$; ***[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 $T_{child} \approx 0.69 \times T_{adult} = 2.1$ 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]***

D3. (a) Basal metabolic rate is the rate (power) at which internal energy in the body is converted into mechanical work;
in order to support the functions of the basic organs (brain, heart, lungs *etc.*) of a resting, awake person; ***[2]***

(b) *Look for basic descriptions of* ***two*** *mechanisms. Award* ***[1]*** *for each sensible and relevant comment up to* ***[2 max]*** *for each method e.g.*

radiation:
thermal energy/heat is lost as (electromagnetic or IR) radiation;
the heat lost is proportional to surface area/temperature difference between skin and surroundings;

convection:
air in contact with skin warms up;
the air rises and is replaced by cooler air;

evaporation:
heat loss through sweating;
the heat required to evaporate the sweat is taken from the body;

expiration:
warm airs expelled from the lungs;
taking thermal energy/heat with it;
moisture in the air in the lungs is evaporated by heat in the body;

conduction:
loss of heat when body is in direct contact with colder bodies/surroundings;
molecules in the skin pass on kinetic energy to the molecules of the surroundings; ***[4 max]***

D4. (a) taking torques about an axis through the pivot gives
$45 \times (7.0 + 4.0\cos 50^{\circ}) = M \times 40\cos 50^{\circ}$;
$M = 168\text{ N}$; ***[2 max]***
Award ***[0]*** *for an attempt at moments but with errors e.g. without cos factor.*

(b) the closer the teeth are to the back of the jaw the shorter the arm of the force about the pivot;
thus to provide the necessary torque for a given muscle force a larger force will be exerted by the teeth; ***[2]***
OR *mathematically:*
for a given muscle force *M*, the force *F* exerted by the teeth a distance *d* from the back of the jaw is given by $F \times (d \times 4.0\cos 50^{\circ}) = M \times 40\cos 50^{\circ}$;

hence $F = \dfrac{M \times 4.0\cos 50^{\circ}}{(d \times 4.0\cos 50^{\circ})}$ and so the smaller the *d* the larger the force *F*; ***[2]***

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*: <u>electrons</u> leave glass; ***[1]***
amber: <u>electrons</u> 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;
<u>hence</u> 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) $q\,v\,B = eE$
$\Rightarrow v = \frac{E}{B}$;
$= 6.1\times10^{7}\,\mathrm{m\,s^{-1}}$; ***[2]***

(ii) $q\,v\,B = \frac{mv^2}{r}$;
$\frac{q}{m} = \frac{v}{Br}$;
$= 1.8\times10^{11}\,\mathrm{C\,kg^{-1}}$; ***[3]***

E4. (a) the Bohr model predicts the electrons in the hydrogen atom exists in discrete energy levels;
an electron emits a photon every time a transition to a lower energy level is made;
the photon has an energy given by the difference of the energy levels involved in the transitions;
photon frequency determined by its energy / each transition gives rise to a single/discrete wavelength (as observed in spectrum); ***[4]***
*Award **[1]** for any other relevant and appropriate comments up to **[4 max]**.*

(b) it cannot be applied to many electron atoms / it does not predict the intensity of different lines; ***[1]***

(c) (i) Bohr's model has the electron in specific orbits of specific radius;
Schrödinger's theory attaches to the electron a probability wave; ***[2]***
Accept any sensible and appropriate comparison.

(ii) the Schrödinger theory attaches to an electron a probability wave;
and hence the electron cannot be pinpointed with absolute certainty at any one point;
which is what the Heisenberg principle demands since Δx (the uncertainty in position) is always $\neq 0$; ***[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 $b = \dfrac{L}{4\pi d^2}$ *if L and d are defined.*

(b) the surface area/size of the star changes periodically; ***[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 $b = \dfrac{L}{4\pi d^2}$);
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) $b = \dfrac{L}{4\pi d^2} \Rightarrow 1.25 \times 10^{-10} = \dfrac{7.2 \times 10^{29}}{4\pi d^2}$;
$d = \sqrt{\dfrac{7.2 \times 10^{29}}{4\pi \times 1.25 \times 10^{-10}}}$;
$d = 2.14(\pm 0.2) \times 10^{19}$ 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.*

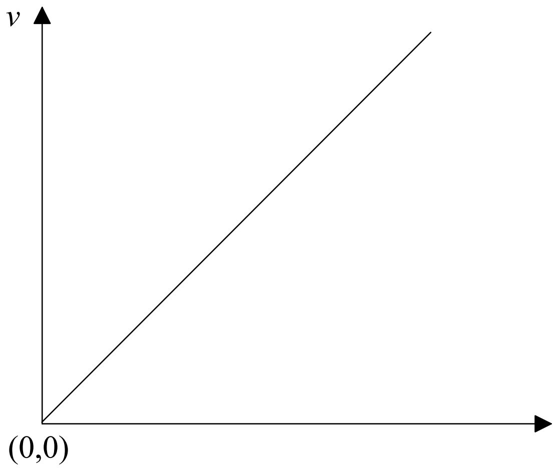
F3. (a) *Diagram should show*
spiral arms;
central disc;
the solar system on one of the arms about a third of the way from the centre; ***[3]***
Be generous in the position - accept between $\frac{1}{4}$ and $\frac{3}{4}$.

(b) $\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c} \Rightarrow \frac{670-658}{658} = \frac{v}{c}$;

hence $v = \frac{670-658}{658}c = 0.018c = 5.47\times10^3\ \text{km s}^{-1}$; ***[2]***

*Award **[1 max]** for $\frac{670-658}{670} = 0.0179$.*

(c) (i) straight-line;
through origin; ***[2]***



(ii) relative speed of two points in the universe separated by distance d is $v = \frac{d}{T}$ where T is the age of the universe / argument to show $v = \frac{d}{T}$;

$v = \frac{d}{T} = H_0 d$ therefore $T = \frac{1}{H_0}$;

*Award **[0]** for answers that just show that $T = \frac{1}{H_0}$ has the right units.* ***[2]***

(iii) the Hubble constant is obtained from the slope of the graph; ***[1]***

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) $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-0.8^2}} = \frac{10}{6}(=1.7)$;
interval on earth $=\gamma\times$ interval on spacecraft;
interval on earth $\frac{10}{6}\times 6$ 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.

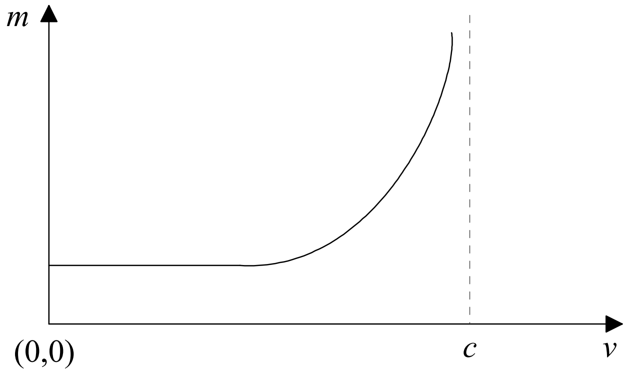
(iii) both observers are inertial observers;
and both are equally valid and correct in their measurements; ***[2]***

(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 $(= 7.57\times 10^{16}\,\text{m})$; ***[2]***
Watch for ecf from (b) (i).

(v) Earth moves away at $0.80c$ and so is at a distance of $6\times 0.80c = 4.8\,\text{ly}$ 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 $\frac{(10\times 0.80c)}{c} = 8$ 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 $\gamma\times 18 = 30$ years *i.e.* 24 years after sending the signal; ***[3]***

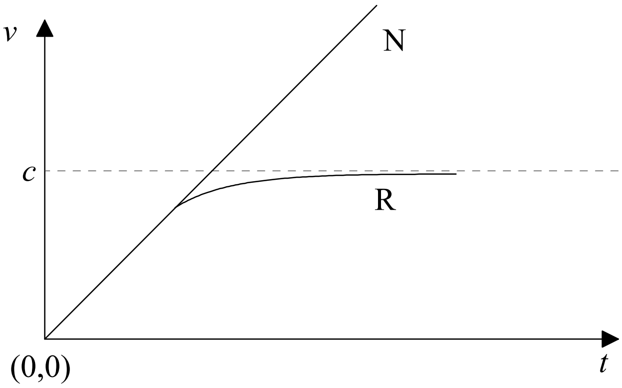
G2. (a) rest mass is the mass of a body as measured in the body's rest frame / alternative correct and unambiguous definition; ***[1]***

(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.*

(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.*

G3. (a) a frame of reference accelerating far from all masses with acceleration a;
is completely equivalent to a frame of reference at rest in a gravitational field of field strength equal to a; ***[2]***
Accept "the impossibility of distinguishing gravitational from inertial effects" for full marks.

(b) (i) B;
because the scale reads the weight of the mass; ***[2]***

(ii) C;
because the scale reads a force F where $F = mg + ma$; ***[2]***

(iii) A;
because there is no acceleration and no gravitational force on the mass; ***[2]***

(c) B;
because by the equivalence principle the accelerating frame is equivalent to a frame at rest on Earth's surface; ***[2]***
Allow ecf for full marks if same answer as (b) (i).

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]***

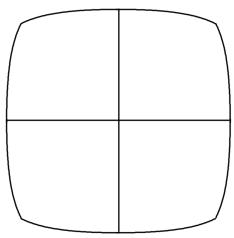
H2. (a) 18 cm; ***[1]***

(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]***

H4. (a) (i) diffraction at the lens; ***[1]***

(ii) circular patch – bright;
circular bright ring/darkness between patch and ring; ***[2]***

(b) (i) $\alpha = \dfrac{4.0 \times 10^{-6}}{17 \times 10^{-3}}$;
$= 2.4 \times 10^{-4}$ rad; ***[2]***

(ii) $1.22\dfrac{\lambda}{d} = 2.4 \times 10^{-4}$ therefore $d = \dfrac{1.22 \times 550 \times 10^{-9}}{2.4 \times 10^{-4}}$;
$d = 2.8$ mm; ***[2]***
*Award **[2]** even if factor 1.22 is missing.*

H5. light gets reflected from oil/air and oil/water interfaces;
these reflected rays interfere, because there is a path difference between them;
caused by the thickness of the oil film/the different index of refraction for different wavelengths (dispersion);
the colour seen is white light minus that colour which suffers destructive interference / the colour seen is that which suffers constructive interference;
*Award **[3 max]** for any three points above.* ***[3 max]***