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MARKSCHEME

May 2011

PHYSICS

Higher Level

Paper 3

16 pages

General Marking Instructions

Subject Details: Physics HL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer questions from **TWO** of the Options **[2 × 30 marks]**.
Maximum total = **[60 marks]**.

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

2. Each marking point has a separate line and the end is signified by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/). Either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

5. Words that are <u>underlined</u> are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by writing ***OWTTE*** (or words to that effect).

8. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized.

9. Only consider units at the end of a calculation.

10. Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** for an **error of 2 or more digits** unless directed otherwise in the markscheme.

e.g. if the answer is 1.63:

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

Option E — Astrophysics

E1. (a) (i) a collection of stars that form a recognizable group (as viewed from Earth);
that need not be/are not close to each other/gravitationally bound; ***[2]***

(ii) stars that are gravitationally bound/forming an open arrangement/close to each other (in space); ***[1]***

(b) (i) $5.1+[0.60]=5\lg\left[\frac{d}{10}\right]$;

$(d=138\,\text{pc})$

$1\,\text{pc}=3.1\times10^{16}\,\text{m}$;

$138\times3.1\times10^{16}=4.3\times10^{18}$;

$\approx 4\times10^{18}\,\text{m}$ ***[3]***

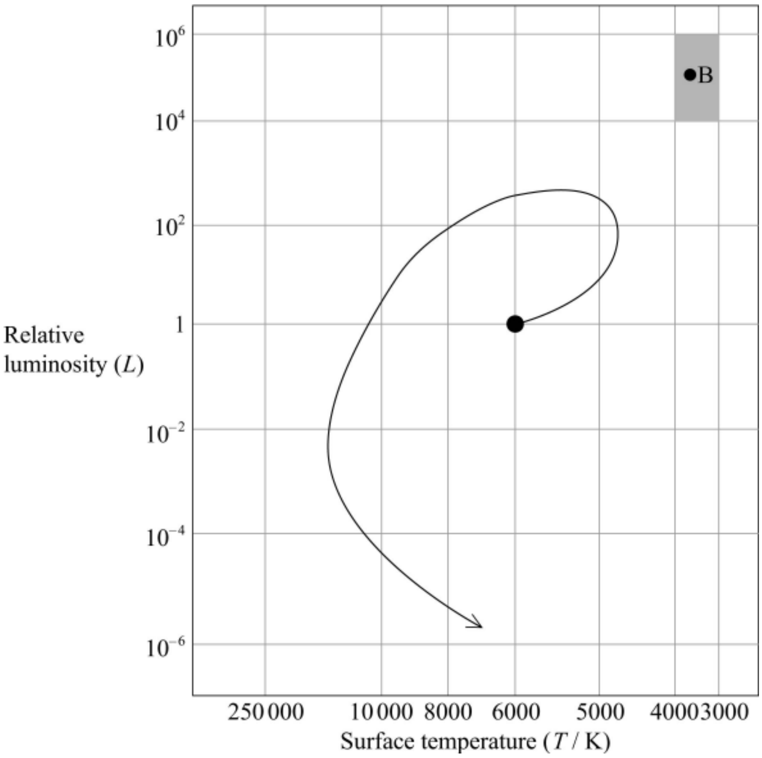
(ii) $L=\frac{1.6\times10^{-7}\times4\times\pi\times\left[4.3\times10^{18}\right]^2}{3.8\times10^{26}}$;

$9.8\times10^{4}\,L_{\text{Sun}}$ ***or*** $8.4\times10^{4}\,L_{\text{Sun}}$ *(if 4.0 used)*; ***[2]***

(iii) $T=T_{\text{Sun}}\sqrt[4]{9.8\times10^{4}\times\left(\frac{1}{790}\right)^{2}}$;

3600 K ***or*** 3500 K; ***[2]***

(c)



(i) position labelled B within shaded area; ***[1]***
*Award **[1]** if label B is missing but point is clear.*

(ii) generally the correct shape; ***[1]***

(d) over time spectral lines regularly split into two lines and then recombine;
as one star approaches observer the other recedes;
leading to Doppler shifts in opposite directions; ***[3]***

E2. (a) if less than critical density, universe expands without limit;
if equal to critical density universe stops expanding after an infinite amount of time;
if greater than critical density, universe expands first then contracts; *[3]*
*Award **[1 max]** if terms open, flat and closed are used and not defined.*

(b) there is matter that cannot be detected;
which is likely to consist of dark matter/neutrinos; *[2]*

or

difficulty of measuring volume accurately;
because of difficulty of measuring distances accurately;

or

matter is not evenly distributed;
so density may vary from place to place;

E3. (a) (i) sets upper limit on mass of white dwarf; *[1]*

(ii) sets upper limit on mass of neutron star; *[1]*

(b) (if in the supernova phase) the mass blown leaves behind a mass of $1.4 M_{\text{Sun}}$ / less than the Chandrasekhar limit;
the star will evolve to a white dwarf;
mass greater than about $1.4 M_{\text{Sun}}$, but less than the O–V limit, will evolve (because of the O–V limit) into a neutron star; *[3]*

E4. (a) red shift used to measure recessional speed of galaxies;
named measurement to yield distance to galaxies (*e.g.* Cepheid variable, Supernova);
repeat for many galaxies/clusters of galaxies;
Hubble constant is gradient of speed–distance graph; *(any symbols used must be defined)* *[3 max]*
*To award **[3]** reference must be made to galaxies in at least one of the marking points.*

(b) $v = 60 \times \frac{6.0 \times 10^8}{3.26 \times 10^6}$;
$= 1.1 \times 10^4 \text{ km s}^{-1}$; *[2]*

Option F — Communications

F1. (a) amplitude/frequency of wave is modified;
to carry information; ***[2]***

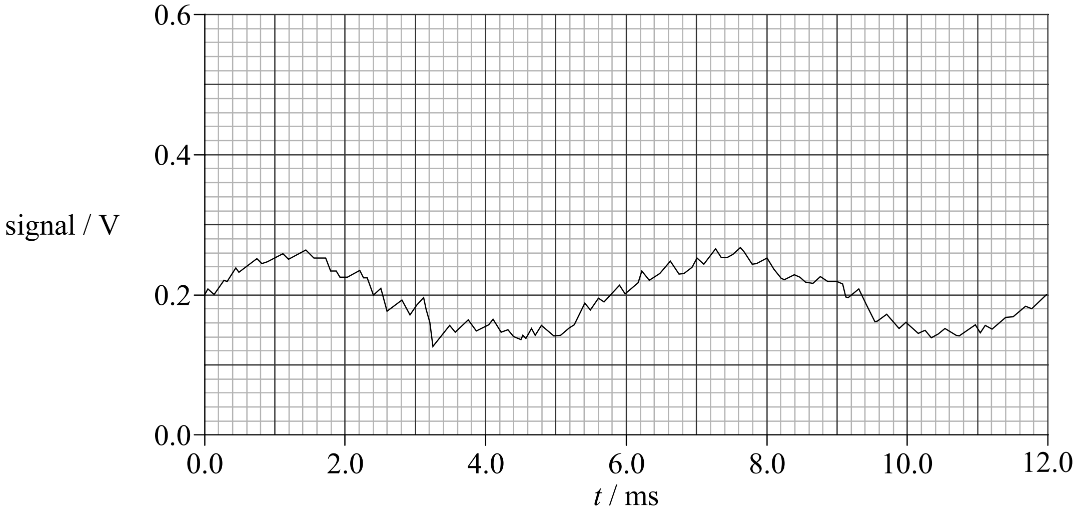
(b) (i) amplitude modulation/AM; ***[1]***

(ii) 40 kHz; ***[1]***

(iii) 16 kHz; ***[1]***

F2. cellular exchange receives signal from base stations;
computer monitors signal strength;
selects base station with strongest signal;
routes call from base station to PSTN; ***[4]***

F3. (a)



waveform: lower mean signal/power/voltage;
smaller amplitude;
noise on waveform; ***[3]***

(b) (i) so that each bit can be transmitted simultaneously; ***[1]***

(ii) parallel-to-serial converter / serial-to-parallel converter; ***[1]***

(c) (i) need at least 22 levels;
(so) 5 bits required; { *(allow ECF from wrong number of levels or bald correct answer)* ***[2]***

(ii) sampled every 0.5 ms;
(so) frequency = 2.0 kHz; { *(allow ECF from wrong time or bald correct answer)* ***[2]***

(d) *advantage*: simpler circuitry / lower cost;
disadvantage: more noisy / shorter uninterrupted length; ***[2]***

F4. (a) use of ratio/dB $= 10\lg\left(\frac{P_2}{P_1}\right)$;

$25 = 10\lg\left(\frac{P}{2.5\times10^{-18}}\right)$;

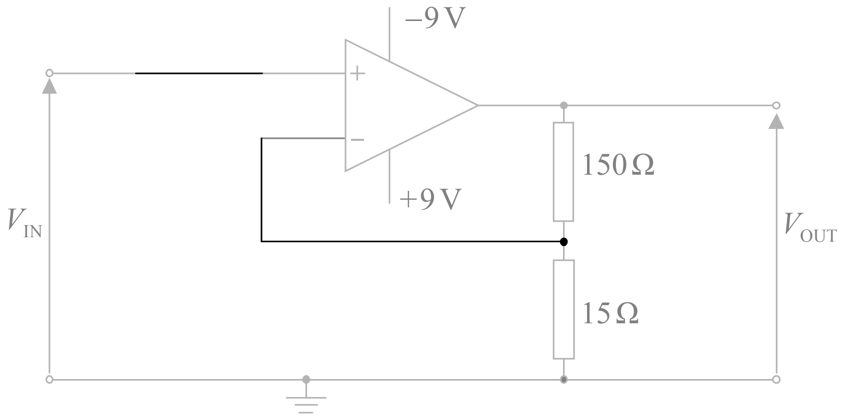
$P = 7.9\times10^{-16}$ W **[2]**

(b) total attenuation $= 2.7\times48 = 130\,\text{dB}$;

$130 = 10\lg\left(\frac{P}{7.9\times10^{-16}}\right)$

$P = 7.9$ mW; **[2]**

F5. (a) V_{IN} connected to non-inverting input;
inverting input connected to point between resistors; **[2]**



(b) (i) gain $= 1 + \frac{150}{15}$;

gain $= 11$; **[2]**

(ii) for saturation, $V_{\text{OUT}} = 9\,\text{V}$;

$V_{\text{IN}} = \frac{9}{11} = 0.82\,\text{V}$; **[2]**

Option G — Electromagnetic waves

G1. (a) transverse;
can be polarized;
all have same speed in a vacuum; ***[2 max]***

(b) each colour/wavelength has different refractive index;
different focal lengths/amount of diffraction for each wavelength/colour;
so all coloured images do not overlap completely/not at same place; ***[3]***

(c) light is scattered by <u>molecules</u>;
greater scattering effect for shorter wavelengths/blue end of spectrum;
so it appears blue ***[2]***

G2. (a) ratio of angle subtended by image and angle subtended by object;
angles measured at eye; ***[2]***

(b) (i) $\frac{1}{u} - \frac{1}{24} = \frac{1}{4.5}$;
distance $= 3.8\,\text{cm}$ ***[1]***

(ii) angular magnification $= \frac{h_I}{D} \div \frac{h_O}{D}$;
$=$ linear magnification;
$= \frac{v}{u}$;
$= \frac{24}{3.8}$
$= 6.3$; ***[4]***
*Award **[2 max]** for use of linear magnification alone.*

(c) less spherical/chromatic aberration (than single lens);
greater aperture can be used/greater light-collecting ability (than single lens); ***[2]***

G3. (a) constant phase difference; ***[1]***

(b) path difference between beams $= n\lambda$, where n is an integer/is one wavelength; ***[1]***

(c) (i) wavelength decreases; ***[1]***

(ii) (effective/optical) path/phase difference changes; ***[1]***

G4. (a) characteristic wavelength produced when electron in target atom de-excites;
wavelength depends on energy change;
energy change depends on energy levels in atom; ***[3]***

(b) (i) $d = \frac{n\lambda}{2\sin\theta}$;

$= \frac{1 \times 1.54 \times 10^{-10}}{2\sin 15.9}$;

$d = 2.81 \times 10^{-10}$ m; ***[3]***

(ii) when $n = 2$, $\theta = 33.2°$;
when $n = 3$, $\theta = 55.3°$;
($n = 4$ not possible) ***[2]***

(c) one angle does not enable *n* (and *d*) to be determined;
need several angles to match up *n* with $\sin\theta$; ***[2]***

Option H — Relativity

H1. (a) (i) proper length is measured by observer at rest relative to object / Carrie is at rest relative to spaceship; ***[1]***

(ii) $\gamma = \left(\frac{100}{91} =\right) 1.1$;

evidence of algebraic manipulation *e.g.* $\frac{v^2}{c^2} = 1 - \frac{1}{1.1^2}$ to give $v = 0.42\,\text{c}$;

$\approx 0.4\,\text{c}$ ***[2]***

(b) travel time measured by Peter $= (10 \times \gamma =)\, 11$ years;
4.6 ly ***or*** 4.4 ly *(if 0.4 c used)*; ***[2]***

(c) moves away at 0.42 c so is 4.2 ly away when signal emitted; *(allow ECF from (a)(ii))*
signal travel time t where $ct = 4.2 + 0.42\,ct$;
7.2 y ***or*** 7 y *(if 0.4 c used)*; ***[3]***

(d) speed of light is independent of speed of source;
so (because of acceleration) source appears to move away from Louise / *OWTTE*;
Doppler effect predicts a red-shift;
Louise measures a lower frequency; ***[4]***

or

accelerating spaceship is equivalent to being at rest in a gravitational field / *OWTTE*;
photons leaving the source therefore gain potential energy and lose kinetic energy;
since $E = hf$;
Louise will measure a lower frequency;

H2. (a) $3m_pc^2 =$ kinetic energy gain $+ m_pc^2$;
kinetic energy gain $= 2 \times 938\,\text{c}^2\,(\text{MeV c}^{-2})$;
1900 MV; ***[3]***

(b) $9{m_p}^2c^4 = p^2c^2 + {m_p}^2c^4$;
$p^2c^2 = 8{m_p}^2c^4$;
$p = 2700\,\text{MeV c}^{-1}$; ***[3]***

or

$\gamma = 3$;
to give $v = 0.943\,\text{c}$;
$p = \gamma m_p v = 3 \times 938 \times 0.943 = 2700\,\text{MeV c}^{-1}$;

H3. (a) (i) to measure the Earth's motion through "ether"; ***[1]***

(ii) 90° rotation exchanges beam directions relative to Earth's motion through "ether";
to produce a shift in the interference pattern (if "ether" exists); ***[2]***

(b) no shift;
means no change in optical path difference/optical lengths of two beams;
so time taken by light independent of path/speed of light is invariant / "ether" has no effect; ***[3]***
*Award **[0]** for a bald statement such as "ether does not exist".*

H4. (a) a coordinate system;
in which time is at right angles to space coordinates / consisting of three dimension of space and one of time; ***[2]***

(b) (i) straight line; ***[1]***

(ii) curve/circle/ellipse; ***[1]***

(c) (general relativity suggests that) Earth warps spacetime;
the satellite follows shortest path in spacetime which is an orbit about Earth; ***[2]***

Option I — Medical physics

I1. (a) (i) power/rate of incident energy per unit area; *[1]*

(ii) minimum intensity at which sound is heard;
at about 3kHz ***or*** $10^{-12}\ \text{W m}^{-2}$; *[2]*

(b) (i) use of intensity level $=10\lg\left(\frac{\text{intensity}}{1\times10^{-12}}\right)$;
$98=10\lg\left(I\times10^{12}\right)$;
$I=6.3\times10^{-3}\ \text{W m}^{-2}$; *[3]*

(ii) $108=10\lg\left(I\times10^{12}\right)$;
$I=0.063\ \text{W m}^{-2}$;
$N=\frac{0.063}{0.0063}=10$; *[3]*

or

$108=10\lg\left(NI\times10^{12}\right)$;
$108=10\lg N+10\lg\left(I\times10^{12}\right)$;
$98=10\lg\left(I\times10^{12}\right)$ so $N=10$;

I2. (a) use of $Z=\rho c$;
$7.8\times10^{6}=\rho\times4.1\times10^{3}$
$\rho=1900\ \text{kg m}^{-3}$; *[2]*

(b) (i) $F=\frac{\left(1.4\times10^{6}-4.3\times10^{2}\right)^{2}}{\left(1.4\times10^{6}+4.3\times10^{2}\right)^{2}}$;
$F\approx1$; *[2]*

(ii) $F=\frac{\left(1.5\times10^{6}-1.4\times10^{6}\right)^{2}}{\left(1.5\times10^{6}+1.4\times10^{6}\right)^{2}}$;
$F=0.0012$; *[2]*

(c) for air-muscle boundary, very little ultrasound is transmitted;
gel permits almost complete transmission; *[2]*

I3. X-ray image taken of slice/section through body;
from many different angles;
these are processed to form an image of the section;
repeated for many sections;
these images are "added";
to form a 3D image;
that can be rotated; ***[5 max]***

I4. (a) exposure can be measured directly;
absorbed dose is calculated from exposure; ***[2]***

(b) (i) exposure is charge deposited per unit mass in air;

$$\text{exposure} = \frac{4.8\times10^{-7}\times90}{3.6\times10^{-6}};$$
$$=12\,\text{C}\,\text{kg}^{-1};$$ ***[3]***

(ii) $$\text{number of ion pairs per second} = \frac{4.8\times10^{-7}}{1.6\times10^{-19}};$$
$$=3.0\times10^{12}$$
$$\text{power} = 3.0\times10^{12}\times34\times1.6\times10^{-19};$$
$$=1.6\times10^{-5}\,\text{W};$$ ***[3]***

Option J — Particle physics

J1. (a) A: π^+ meson;
B: antimuon neutrino; ***[2]***

(b) rest mass is non-zero for W, zero for photon;
range of photon is infinite, not for W;
photon carries electromagnetic force, W weak force;
photon is uncharged, W is charged; ***[2 max]***

(c) $m = \dfrac{6.63\times10^{-34}}{4\pi\times10^{-18}\times3\times10^{8}}$;
$=1.76\times10^{-25}\text{ kg}$; ***[2]***

J2. (a) electric fields / potential differences between drift tubes / *OWTTE*;
to change linear speed of beam/to increase KE of beam/to accelerate beam;
(varying) magnetic fields to provide centripetal acceleration;
to keep beam at correct radius; ***[4]***

(b) (i) assume particle moving close to speed of light;
$m = \dfrac{Bqr}{c}$;
$\dfrac{0.95\times1.6\times10^{-19}\times4900}{3.0\times10^{8}}$;
$= 2.5\times10^{-24}\text{ kg}$; ***[4]***

or

recognize that $m = \dfrac{E}{c^2}$;
$\text{mass} = 1.4\times10^{12}\text{ eV c}^{-2}$;
$= \dfrac{1.4\times10^{12}\times1.6\times10^{-19}}{9\times10^{16}}$;
$= 2.5\times10^{-24}\text{ kg}$;

(ii) as quarks separate the force between them is constant;
(so) energy required to release single quark increases with distance;
these energies exceed the threshold for meson (pair) production; ***[3]***

(c) individual machines are too expensive/complex for one nation to design/build;
international co-operation leads to international understanding / historical example of co-operation / co-operation always allows science to proceed;
large quantities of data are produced that are more than one institution/research group can handle;
co-operation allows effective analysis; ***[2 max]***

J3. (a) property that is conserved in strong nuclear force interaction;
property not (always) conserved in weak/electroweak force; ***[2]***

(b) baryon $(1+0 \rightarrow 0+0)$ not conserved and strangeness $(0+0 \rightarrow -1+0)$ not conserved;
so interaction not possible; ***[2]***

J4. (a) scattering of leptons by hadrons; ***[1]***

(b) deep inelastic scattering transfers large energies/momenta to hadrons; *(award this marking point in part (a) or part (b))*
asymptotic freedom means that energy increases, interaction decreases (so quarks are effectively free particles); ***[2]***

J5. (a) $T=\frac{2E}{3k}$;
$=\frac{2}{3}\times\frac{500\times1000\times1.6\times10^{-19}}{1.38\times10^{-23}}$;
$=4\times10^{9}\text{ K}$ ***[2]***

(b) (time is short) as universe is cooling rapidly;
after this time not enough energy to form heavier elements; ***[2]***