M09/4/PHYSI/HP3/ENG/TZ2/XX/M+

International Baccalaureate
Baccalauréat International
Bachillerato Internacional

MARKSCHEME

May 2009

PHYSICS

Higher Level

Paper 3

17 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. Effective communication is more important than grammatical accuracy.

9. 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. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded.

10. Only consider units at the end of a calculation. Unless directed otherwise in the markscheme, unit errors should only be penalized once in the paper.

11. 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) *red supergiant*: ***[3 max]***
appears red in colour;
(has a very) large luminosity;
(relatively) low (surface) temperature;
(very) large mass;
(very) large surface area;

constellation: ***[1 max]***
a group of stars that form a recognizable pattern (as viewed from Earth) / *OWTTE*; ***[4 max]***

(b) (i) apparent magnitude is a measure of how bright a star appears from Earth/observer;
absolute magnitude is the apparent magnitude of a star at a distance of 10 pc from Earth / how bright a star would appear if it were at a distance of 10 pc from Earth; ***[2]***

(ii) $5\lg\left[\frac{d}{10}\right]=(1.1+5.3=)6.4$;
$d=190\,\text{pc}$;
$=\frac{190\times3.26\times9.46\times10^{15}}{1.5\times10^{11}}$;
$(=3.9\times10^{7}\text{ AU})$ ***[3]***

(iii) stellar/spectroscopic parallax; ***[1]***

(c) (i) the power per square meter received at the surface of Earth/observer; ***[1]***

(ii) use of $L=4\pi bd^2$;
$\frac{L_{\text{Antares}}}{L_{\text{Sun}}}=\frac{b_{\text{Antares}}d^2_{\text{Antares}}}{b_{\text{Sun}}d^2_{\text{Sun}}}$;
$L_{\text{Antares}}(\times L_{\text{Sun}})=4.3\times10^{-11}\times3.9^2\times10^{14}$;
$(=6.5\times10^{4})$ ***[3]***

(d) (lower limit) $\lg\left[6.5\times10^{4}\right]=4\lg\text{M}$; *(M = 16)*
(upper limit) $\lg\left[6.5\times10^{4}\right]=3\lg\text{M}$; *(M = 40)* ***[2]***

(e) the mass limit for a star to become a white dwarf $=1.4\,M_{\text{S}}$;
in its evolution Alnitak will become a supernova;
(even in this phase) its initial mass is so large that it could not blow away/lose enough mass to reach $1.4\,M_{\text{S}}$ / to become a white dwarf / *OWTTE*; ***[3]***

(f) neutron star / black hole; ***[1]***

E2. (a) Newton's model states that the universe is infinite (static) and uniform;
this means that stars are uniformly spaced;
and that if it is infinite there must be a star at every point in space / a star along every line of sight;
since there are regions without stars, Newton's model must be inadequate; ***[3 max]***

(b) both space and time originated with the Big Bang;
the universe is expanding (and not infinite);
due to the expansion, light from the Big Bang is red-shifted to the microwave region so regions between stars will not appear bright;
light from very distant stars will not have reached us yet;
the universe has not existed for all time; ***[3 max]***

E3. (a) very difficult to measure *d* precisely / experimental uncertainties in $\frac{d}{v}$;
when the recession speed is large / when the galaxies are at great distances; ***[2]***

(b) use $H_0 = 60\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$;
use $T = \frac{1}{H_0}$ to give $T = 5\times10^{17}\,\mathrm{s}$; *(ECF if incorrect value of H_0 is chosen)* ***[2]***

Option F — Communications

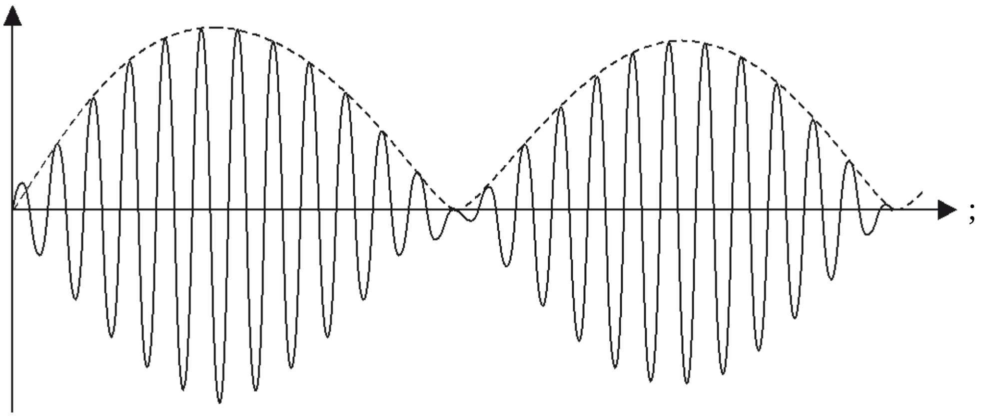
F1. (a) (i) a signal wave carries information / *OWTTE*;
the carrier wave is modulated by the signal wave / is an electromagnetic radio wave; ***[2]***

(ii) *amplitude modulation*: amplitude of <u>carrier</u> is altered;

frequency modulation: frequency of <u>carrier</u> is altered / amplitude stays the same (at the source); ***[2]***

(b) 12 to 13;
one cycle of the signal wave gives one loop of the modulated wave form, there are 12/13 oscillations in each loop of the modulated wave; ***[2]***

(c)



[1]

(d) *advantage*:
long range;
some justification *e.g.* waves reflected from ionosphere / no need for communication satellites / no need for sub-transmitters;

or

power requirements of transmitter can be reduced;
by use of sidebands;

disadvantage:
attenuation of carrier wave amplitude / restricted bandwidth / more susceptible to noise / *OWTTE*; ***[3]***

F2. (a) *X*: parallel to serial converter;
converts the binary word into a sequence of separate digital pulses;

Y: serial to parallel converter converts pulses back to the binary word; ***[3]***

(b) when control pulse is at 0/is at 1 switch connects to input 1 allowing input data 1 to be transmitted;
when control pulse is at 1/is at 0 switch connects to input 2 allowing input data 2 to be transmitted; ***[2]***
If the first marking point specifies 0 second marking point must specify 1 or vice versa.

(c) (i) the loss in power/intensity of the input signal;
due to scattering/absorption/dispersion; ***[2]***

(ii) power loss $= 10\lg\left[\frac{5.0\times10^{-3}}{8.2\times10^{-19}}\right]$;
$= 160\,\text{dB}$;
separation of amplifiers $= 79\,\text{km}$; ***[3]***
*Accept 80 km **do not apply** –1(SD).*

F3. (a) (i) very high/infinite open loop gain;
very high/infinite input resistance; ***[2]***

(ii) -10; ***[1]***

(b) (i) potential across $R_2 = (10+2=)\,12 = 150I$;
(to give $I = 0.08\,\text{mA}$) ***[1]***

(ii) potential across $R_1 = V_{\text{in}} - 2.0 = IR_1$;
$V_{\text{in}} = 0.08\times47 + 2.0$;
$(= 5.8\,\text{V})$ ***[2]***

F4. (a) (the country is divided into) a large number of small geographical regions called cells; ***[1]***

(b) each cell has its own transmitter;
the small separation of the cells means that the transmitter can be low power making for smaller sized receivers / *OWTTE*; ***[2]***

(c) invasion of privacy / download of illegal material / harassment of individuals / cheating in examinations / providing independence for young people / allowing parents to keep in touch / find out where their children are / any other sensible issue; ***[1]***

Option G — Electromagnetic waves

G1. the light from the sun is scattered by the molecules in the Earth's atmosphere;
blue light is scattered most;
on the moon, there is no atmosphere and no scattering; ***[3]***

G2. (a) the phase between the two sources is changing all the time;
there is interference/superposition between the beams of light;
the interference pattern is changing too rapidly to be observed; ***[3]***
*Award **[2 max]** for a response stating that sources are not coherent so no interference pattern.*

(b) (i) stimulated emission of a group of atoms with a population inversion;
(a single stimulus triggers the) spontaneous production of many other photons simultaneously / *OWTTE*;
photons emitted have same wavelength / phase; ***[2 max]***

(ii) coherence; ***[1]***

(c) laser scans the barcode / the laser light is not reflected where the ink is dark;
the reflected light is detected; ***[2]***

(d) distance between maxima is $(100\times 5) = 500\,\text{m}$;

$L = \frac{xd}{\lambda}$;

$L = \left(\frac{500\times 200}{5} = \right) 2.0\times 10^{4}\ \text{m}$; ***[3]***

G3. (a) $\frac{\text{image height}}{\text{object height}}$ ***or*** $\frac{\text{image distance}}{\text{object distance}}$; ***[1]***

(b) (i) $\frac{1}{x} = \frac{1}{f} - \frac{1}{v}$;
substitute to get $x = 13\text{cm}$; ***[2]***

(ii) 3.5; ***[1]***

(c) rays striking different parts of the lens are focused to different points / *OWTTE*;
spherical aberration may be reduced by using non-spherical lenses / by using more than one lens / reduce aperture / use centre part of lens only; ***[2]***

G4. $\lambda = \dfrac{2dn}{\left[m+\frac{1}{2}\right]}$;

$= \dfrac{692}{m+\frac{1}{2}}$;

$m=0,\ \lambda=1383\,\text{nm},\ m=1,\ \lambda=461\,\text{nm},\ m=2,\ \lambda=276\,\text{nm}$;

therefore blue as $m=1$ gives the only value in the visible range; ***[4]***

*Award **[3 max]** if $\frac{1}{2}$ is omitted and answer is red $\lambda = 692\,nm$.*

G5. (a) *Labelled diagram showing the following elements.*

source of electrons / electron beam;

method of accelerating electrons / evacuated glass tube;

target / emission of X-rays upon collision; ***[3]***

(b) (accelerated) electrons remove electrons in the inner shells of the target atoms;

electrons in shells of higher energy occupy the space left / *OWTTE*;

and emit a photon of energy equal to the difference in the two energy levels; ***[3]***

Option H — Relativity

H1. (a) the speed of light in a vacuum/free space is the same for all observers; ***[1]***

(b) according to Barbara, Tom receives light from L_1 and L_2 simultaneously;
but Tom moves away from L_2;
hence light from L_2 was emitted first; ***[3]***

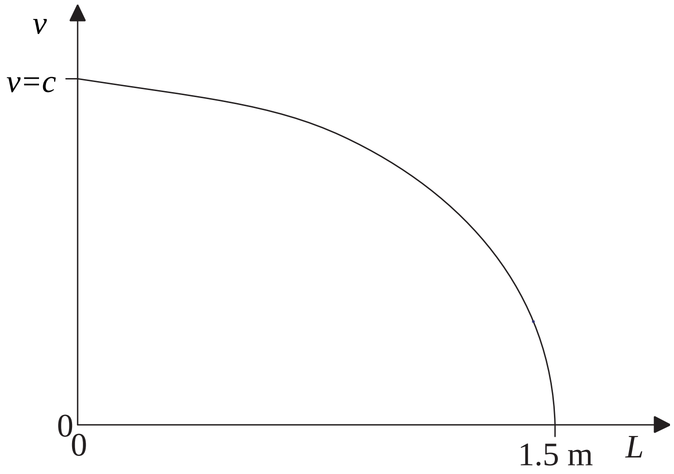
(c) (i) Tom
proper length is the length between objects as measured by the observer at rest with respect to the objects; ***[1]***

(ii) $\gamma = 3$;

$$9 = \frac{1}{1 - \frac{v^2}{c^2}};$$

to give $v = 0.94c$; ***[3]***

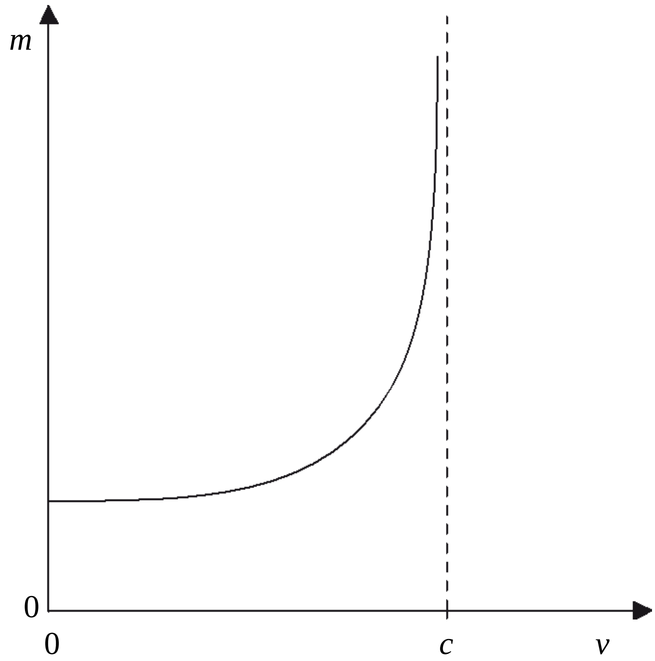
(iii)



data point 1.5, 0;
data point 0, *c*;
smooth curve (by sight); ***[3]***

(d) according to Tom, Barbara's clock will appear to run slower than his;
according to Tom, when Barbara returns she will not have aged as much as him / *OWTTE*;
but according to Barbara, Tom is moving away from her so he is the one that has not aged / *OWTTE*; ***[3]***
*Award **[3 max]** for any order for the description if idea of symmetry is clearly present and correctly acknowledged.*

H2. (a)



non-zero start;
reasonably linear at start – judge by eye;
asymptotic to *c*; ***[3]***

(b) (i) $E = m_0c^2 + Ve$;
$= 938 + 850$;
$= 1790\,\text{MeV}$; ***[3]***

(ii) $\gamma = \dfrac{m}{m_0} = 1.91$;
$= \dfrac{1}{\left[1 - v^2\right]^{\frac{1}{2}}}$;
(to give $v = 0.852\text{c}$) ***[2]***

(c) correct substitution into relative velocity equation $\left(0.987 = \dfrac{0.852 + u}{1 + 0.852u}\right)$;
correct working *e.g.* $0.987 + 0.840u = 0.852 + u$;
(to give $u = 0.849\text{c}$) ***[2]***
Accept other correct mathematical methods that eventually show the speed of the antiproton to be about the same e.g. $0.852 + 0.852 = 0.987$ *via equation.*

H3. (a) (i) is the increase in wavelength (or decrease in frequency) of light;
(when measured) for light moving from stronger to weaker gravitational field; ***[2]***
Accept "climbing uphill" type of response.
Do not award marks for responses along the lines "light in a region of intense gravity is red-shifted".

(ii) spacetime is a coordinate/reference system consisting of (three) dimensions of space and (one of) time; ***[1]***

(iii) matter warps spacetime;
a black hole produces a region of such <u>extreme curvature in spacetime</u> that not even light can escape the region/black hole; ***[2]***

(b) $\Delta t = \dfrac{10}{\left[1-\frac{1}{3}\right]^{\frac{1}{2}}}$;
$(=12\,\text{s})$ ***[1]***

Option I — Medical physics

I1. (a) ossicles / hammer, anvil and stirrup / malleus, incus and stapes; ***[1]***

(b) (i) small displacements/movements of the bone in contact with the eardrum;
result in larger displacements/movements of the bone in contact with the oval window; ***[2]***

(ii) the area of the eardrum is greater than that of the oval window;
since $P \propto \frac{1}{A}$;
area is less so pressure is increased; ***[3]***

(c) impedance matching / *OWTTE*;

(d) $20 = 10\lg\frac{I}{10^{-12}}$;
$I = (1.0\times)10^{-10}\ \mathrm{W\,m^{-2}}$;
$\text{power} = (10^{-10} \times 2.0\times10^{-6} =)\ 2.0\times10^{-16}\ \mathrm{W}$; ***[3]***

I2. (a) $\mu = -\frac{\Delta I}{I\Delta x}$;
where ΔI equals the decrease in intensity of a beam of intensity I after passing though a distance Δx of the material;

or

$I = I_0 e^{-\mu x}$
where I_0 = intensity of incident beam;
I = intensity of passing through distance x of the material; ***[2]***

(b) intensity after passing through bone $= I_0 e^{-0.62\times8.0}$;
$= 7.0\times10^{-3} I_0$;
intensity after passing through tissue $= 0.19 I_0$;
reduction by bone much greater than by tissue so good contrast between bone and tissue; ***[4]***

(c) fetus less likely to be damaged;
much better contrast;
shows motion of fetus; ***[2 max]***

(d) acoustic impedance $(Z) = \text{density}\times\text{speed}$ (of sound);
for air $Z = (330\times1.3) = 430$ for tissue $Z = (1.5\times10^3 \times 1.1) = 1.7\times10^3$;
because of the difference of impedance sound will be reflected;
the gel has the same impedance as tissue to ensure that sound is transmitted/ not reflected at skin; ***[4]***

I3. (a) physical half-life is the time for the activity to halve;
biological half-life is the time for half the isotope to leave the body by natural processes; ***[2]***

(b) (short physical half-life means that) although it remains in the body for the same time as I-131;
it quickly loses its activity so less chance of harming healthy tissue / *OWTTE*;
shorter physical half-life also means smaller dose can be used (to give same activity as a dose of I-131);
(both emit gamma radiation but) beta emission from I-131 is more damaging; ***[3 max]***

(c) $\lambda = \left[\frac{0.69}{13}\right] = 0.053$;

activity of $5.0\,\text{ml}$ after $0.50\,\text{hours} = 2.5\times10^{5}e^{-0.053\times0.50} = 2.4\times10^{5}\,\text{Bq}$;

total volume of blood $= \dfrac{5\times2.4\times10^{5}}{210}$;

(≈ 6) ***[3]***

*Award **[3 max]** if response clearly states that activity change in 0.50 hours can be neglected and therefore 2.5×10^{5} instead of 2.4 is used.*

Option J — Particle physics

J1. (a)

Interaction	*Exchange particle(s)*
Electro-weak	photon, $W^{\pm}$, Z^{0};
Strong	gluon;

[2]

All particles needed for electro-weak.

(b) they have no internal structure / not made out of smaller particles / cannot be divided into smaller particles; ***[1]***

(c) (i) $\Delta t = \dfrac{h}{4\pi\Delta E}$;

$= \dfrac{6.6\times10^{-34}}{4\times3.14\times90\times10^{9}\times1.6\times10^{-19}}$;

$\approx 4\times10^{-27}$ s; ***[3]***

(ii) $m = \left(90\times10^{9}\times1.6\times10^{-19}\times\dfrac{1}{9}\times10^{-16}\right) = 1.6\times10^{-25}$ kg;

substitute in $R \approx \dfrac{h}{4\pi mc}$ to get $R \approx 10^{-18}$ m; ***[2]***

(d) (i) (green-antiblue) gluon; ***[1]***

(ii) so that three particles/quarks $\left(\text{with spin } \frac{1}{2}\right)$ can exist in the same state;
and not violate the Pauli exclusion principle; ***[2]***

J2. (a) the mass m of a particle is given by $m = \frac{E}{c^2}$ where E is its total energy;
if m is large then E must be large; ***[2]***

(b) (i) north pole bottom magnet-south pole top magnet; ***[1]***

(ii) across the gap of the "D's"; ***[1]***

(c) frequency of orbit of the protons is independent of the radius;
(no field inside D's so) protons are accelerated by the field each time they pass the gap;
frequency of p.d. must be synchronized with that of proton orbit; ***[2 max]***

(d) frequency changes/decreases due to relativistic mass/energy increase of protons;
the alternating potential is frequency modulated; ***[2]***

or

(as protons move faster) their orbital radius increases but frequency stays the same;
so frequency of p.d. is kept constant;

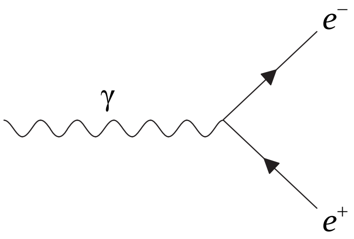
(e) recognize that $E_{\mathrm{a}} \approx \left[E 2 m_{\mathrm{p}} c^2\right]^{\frac{1}{2}}$;
$E_{\mathrm{a}} = \left[2 \times 0.938 \times 28\right]^{\frac{1}{2}}\ \mathrm{GeV}$;
$(\approx 7\,\mathrm{GeV})$ ***[2]***
*Award **[2 max]** for use of complete equation.*

(f) to conserve momentum in a stationary collision kinetic energy must be carried away;
in opposite direction collision total momentum is zero / *OWTTE*;
so all kinetic energy available (for particle formation); ***[2 max]***

J3. (a) (i) the electrons interact via the weak interaction;
with the exchange of a Z^0 boson; ***[2]***

(ii) the standard model predicts weak interactions processes involving the exchange of the Z^0 boson;
the Z^0 boson has been detected experimentally in high energy particle experiments; ***[2]***

(b)



all correct for the mark; ***[1]***

(c) $E_K = 1.02\,\text{MeVc}^{-2} = \frac{3}{2}kT$ ***or*** $T = \frac{2E_K}{3k}$;
to give $T = 10^{10}$ K; ***[2]***