M13/4/PHYSI/HP3/ENG/TZ1/XX/M

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

MARKSCHEME

May 2013

PHYSICS

Higher Level

Paper 3

18 pages

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.

2. Each marking point has a separate line and the end is shown 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 ***OWTTE*** (or words to that effect).

8. Remember that many candidates are writing in a second language. 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. When marking indicate this by adding **ECF** (error carried forward) on the script.

10. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.

Option E — Astrophysics

E1. (a) minor planet / rocky/icy/metallic body; ***[1]***

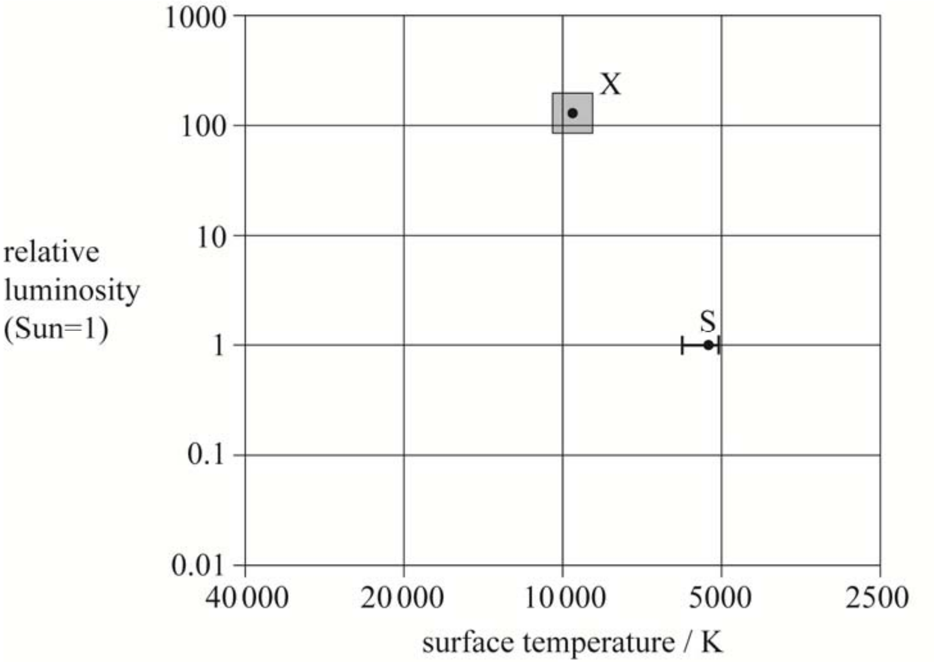
(b) situated between (orbits of) Mars and Jupiter; ***[1]***
Allow answers in terms of near-Earth asteroids or Trojan asteroids.

E2. (a) $T = \dfrac{2.9\times10^{-3}}{3.0\times10^{-7}}$;
9700 K; ***[2]***

(b) (i) $\dfrac{L_X}{L_S} = \dfrac{\sigma r_X{}^2 T_X{}^4}{\sigma r_S{}^2 T_S{}^4}$;
$= \dfrac{4.5^2 \times 9700^4}{5700^4}$;
$= 170$; ***[3]***
Accept answers that use $T = 10\,000\,\text{K}$ *to give an answer of 190.*

(ii) $\dfrac{M_X}{M_S} = \left[\dfrac{L_X}{L_S}\right]^{\frac{1}{3.5}}$;
$= [170]^{\frac{1}{3.5}}$;
$= 4.3$; ***[3]***
Award ***[3]*** *for a bald correct answer.*

(c)



(i) X marked correctly within range shown; ***[1]***

(ii) S marked correctly within range shown; ***[1]***
Allow ECF from (b)(ii).

(d) Chandrasekhar limit below which white dwarf stars can exist is 1.4 solar masses;
X is not going to form a white dwarf / X will not form a white dwarf if its final core/remnant mass is greater than the Chandrasekhar limit; ***[2]***
Allow ECF from (b)(ii).

E3. (a) (i) object of known luminosity/power; ***[1]***

(ii) luminosity varies with time in a regular way;
(average) luminosity related to period of variation;
high luminosity so visible from great distances; ***[2 max]***

(b) the period of the variation of luminosity/apparent brightness/apparent magnitude is measured;
the luminosity/absolute magnitude is determined from the period;
apparent magnitude/brightness is measured (on Earth);
$m - M = 5\lg\left(\frac{d}{10}\right)$ ***or*** $b = \frac{L}{4\pi d^2}$ is used to compute d; ***[3 max]***

E4. *infinite:* cosmic microwave background is observed consistent with cooling from a finite beginning / use of the Hubble constant to find universe age / bright universe not observed whereas an infinite universe would be completely bright;
uniform: significant empty distances visible between galaxies / reference to galactic clusters/super clusters / the greater the observed distance of galaxies, the greater the red-shift;
static: red-shift indicates expansion of universe / galaxies observed to be moving relative to Earth; ***[3]***

E5. (a) $v = 0.0094c$;
$2800\,\mathrm{km\,s^{-1}}$; ***[2]***

(b) $13 - [-20] = 5\lg\left[\dfrac{d}{10}\right]$;

$10^{6.6} = \dfrac{d}{10}$;

39.8 Mpc; ***[3]***

(c) age of universe $= \dfrac{1}{H_0}$;

$\left(= \dfrac{d}{v} = 40 \times 10^{6} \times \dfrac{3.1 \times 10^{13}}{2.8 \times 10^{3}}\right) = 4.4 \times 10^{17}\,\mathrm{s}\ \left(= 1.4 \times 10^{10}\ \mathrm{yr}\right)$; ***[2]***

Option F — Communications

F1. (a) (i) 0.0006 MHz ***or*** 600 Hz; ***[1]***

(ii) 0.0012 MHz ***or*** 1200 Hz; ***[1]***

(b) amplitude is constant in FM transmission;
noise/interference tends to affect the amplitude of the carrier wave only;
receiver compensates for any changes in the (received) signal; ***[3]***

(c) FM has shorter range than AM;
higher frequencies required;
equipment has higher cost (because more elaborate circuitry);
wider bandwidth needed / fewer channels possible; *(not "higher bandwidth")* ***[2 max]***

F2. (a) A: clock;
B: analogue-to-digital converter / C: parallel-to-serial converter; ***[2]***

(b) (i)

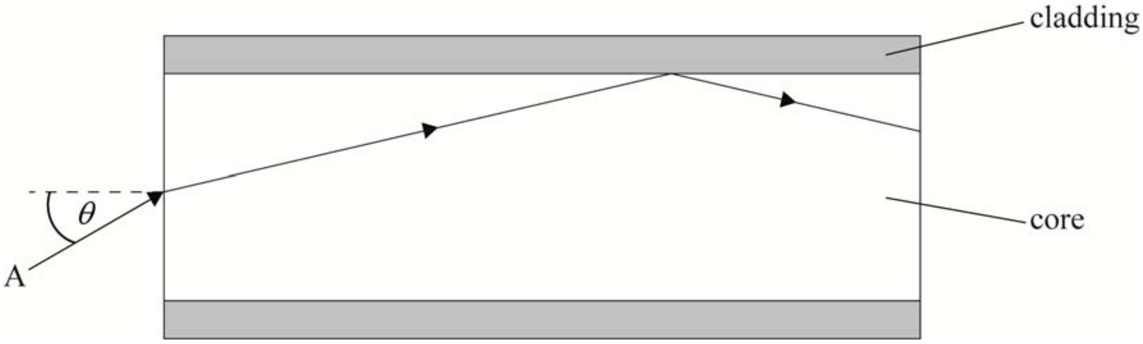
Time / ms	**Digital output equivalent**
3.5	010
4.0	011

times both correct;
digital values both correct; ***[2]***

(ii) can more closely conform to variation in analogue / closer to rounded values / final output more faithful reproduction of input; ***[1]***

F3. (a) refracted angle inside core $= 20^\circ$;
$\sin\theta = \sin 20^\circ \times 1.62$;
34°; ***[3]***

(b)



refraction angle on entering core sensible and smaller than incidence angle;
equal angles of reflection at cladding; *(judge by eye)* ***[2]***

(c) different path lengths so different times of travel;
ray 1 light will arrive first;
if successive pulses from different routes overlap then interference / *OWTTE*;
limit to the transmission rate/bandwidth of fibre; ***[3 max]***

(d) less interference;
more difficult to tap/break into; ***[2]***

F4. (a) infinite/very high gain;
infinite/very high input resistance; ***[2]***

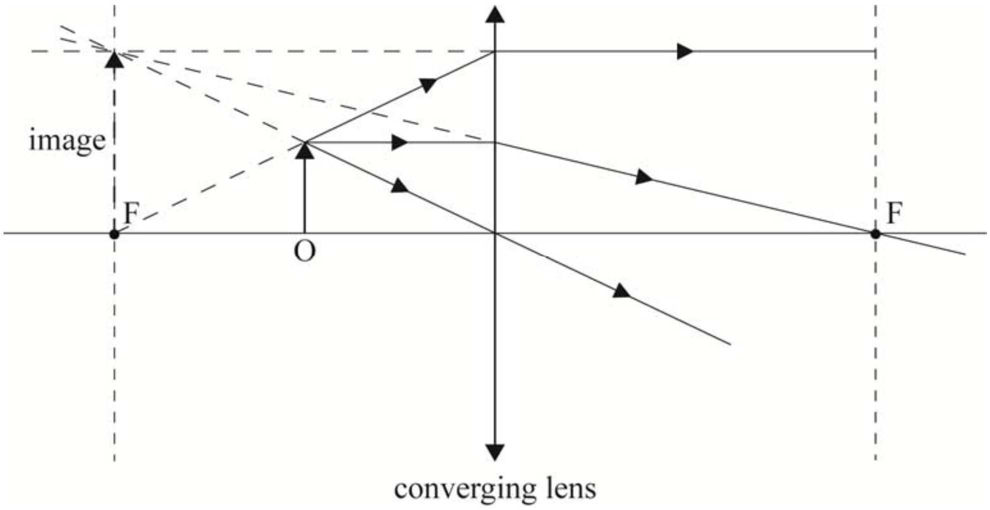
(b) (i) $V_P = -15 + \dfrac{30 \times 100}{[50+100]}$ / other suitable working;
states that potential at midpoint of resistor chain = potential at P; ***[2]***

(ii) +5 V; ***[1]***

(iii) an op-amp amplifies the difference between the inputs (P and Q) (with a large gain);
if A less than V then Q is also less than V (and P);
so output will be driven strongly negative;
R will be at –15 V and pd across buzzer is 30V (so it sounds); ***[3 max]***

Option G — Electromagnetic waves

G1. (a) (i)



any correct ray out of the three shown above;
second ray correct;
image correctly located and labelled; ***[3]***
Accept rays without arrows and solid construction lines back to image.

(ii) virtual because no rays pass through the image / image cannot be formed on a screen; ***[1]***

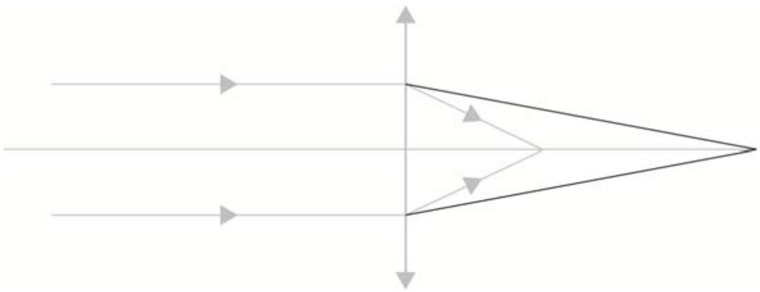
(b) (i) $\frac{1}{v} = \frac{1}{0.20} - \frac{1}{0.40} \left(= 2.5\,\text{m}^{-1}\right)$;
$\Rightarrow v = 0.40\,\text{m}$; ***[2]***

(ii) $m = -\frac{v}{u}$;
$m = -1$; ***[2]***

(c) (i) answer in range 320 – 480 nm; ***[1]***

(ii) answer in range 620 – 780 nm; ***[1]***

(d)



the refracted rays converge on the principal axis farther from the lens than for blue; ***[1]***

G2. (a) (i) single frequency/wavelength / narrow range of frequencies/wavelengths; ***[1]***

(ii) in phase;
constant phase difference/relationship; ***[2]***
*Award **[2]** for any correct reference to constant phase difference.*

(b) $\theta = \tan^{-1}\left[\frac{0.65}{2.0}\right]\left(=18^\circ\right)$;
recognition that $n=1$;
$d = \frac{1}{600}\left(=0.0017\,\text{mm}\right)$;
$\lambda\left(=d\sin\theta = 0.0017\times\sin 18^\circ\right) = 520\,\text{nm}$; ***[4]***

G3. (a) (monochromatic) X-rays illuminate the crystal;
X-rays are scattered by atomic layers in crystals;
giving maxima in the reflection when rays scattered from the (first two) layers are in phase;
measurement of angle of reflection/scatter leads to determination of spacing; ***[3 max]***
Accept a fully labelled diagram with comments/explanations.

(b) $\lambda = \left(\frac{hc}{eV} = \right)\frac{6.63\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times1.5\times10^{4}}$;
$\lambda = 8.3\times10^{-11}\,\text{m}$; ***[2]***

(c) use of Bragg equation $2d\sin\theta = n\lambda$;
recognition that $n=1$;
$\lambda = 5.6\times10^{-10}\,\text{m}$; ***[3]***

G4. (a) $180^{\circ} / \pi$; ***[1]***

(b) path difference must be $\frac{\lambda}{2}$;

physical thickness must be $\frac{\lambda}{2n}$;

so, maximum wavelength $\left(\text{is} \left[2nt = \left[m + \frac{1}{2} \right] \lambda \right] \rightarrow \lambda = 4n_c d \right) = 528\,\text{nm}$; ***[3]***

Allow any valid alternative method.

Option H — Relativity

H1. (a) a coordinate system / set of rulers / clocks;
in which measurements of distance/position and time can be made; ***[2]***

(b) (i) $1.25c$; ***[1]***

(ii) $v' = \dfrac{c+v}{1+\dfrac{cv}{c^2}}$;

$= \dfrac{1.25c}{1+0.25}$;

shows that fraction $= c$; ***[3]***

Award ***[2 max]*** *if signs incorrect* $= \dfrac{0.75c}{1-0.25}$.

(c) light travels at same speed for both observers;
during transit time Officer Sylvester moves towards point of emission at front/away from point of emission at back;
light from front arrives first as distance is less / light from back arrives later as distance is more;
Officer Sylvester observes the front lamp flashes first; ***[4]***

or

time between lights arriving at Speedy is zero (according to Speedy) – (this is a proper time) so Sylvester (indeed all inertial observers) sees lights reaching Speedy simultaneously;
front lamp moving away from Speedy (according to Sylvester);
speed of light constant for all observers;
light from front lamp has to travel further to reach Speedy so must have flashed first (according to Sylvester);

(d) (i) the two events occur at the same place (in the same frame of reference) / shortest measured time; ***[1]***

(ii) $\gamma = \left(\dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}} = \right) 1.15$;

$\Delta t = 1.15 \times \Delta t_0$;

1.48×10^{-8} s; ***[3]***

H2. $\gamma m_0 c^2 = m_0 c^2 + eV$;
$\gamma = 1.81$;
7.6×10^8 V ; ***[3]***

H3. (a) the speed of light is constant / the speed of light does not depend on the speed of the source (relative to the observer);
the gamma source appears to be moving towards the observer / *OWTTE*;
so the frequency will be blue-shifted / have higher frequency / frequency will increase; ***[3]***
Accept answers that state equivalence principle and correctly relate to this situation.

(b) principle of equivalence relates acceleration (of frame of reference) to (frame in a) gravitational field / *OWTTE*;
situation is same (*ie* blue-shifted) as source falling under gravity towards observer; ***[2]***

H4. spacetime is warped by matter;
moving objects follow the shortest path/metric/geodesic between two points in spacetime;
the shortest path for Earth is a (closed) curve around Sun (this is what we call gravitational attraction); ***[3]***

H5. experiment measured path difference/interference effects between two light beams;
and these did not vary with the time of year / times six months apart / orientation of apparatus;
experiment confirmed speed of light is invariant / that there is no ether / there is no absolute reference frame; ***[3]***

H6. $\mathrm{R}_{\mathrm{s}} = \frac{2GM}{c^2} = 2.96\,\mathrm{km}$;
$\rho = 1.8 \times 10^{19}\,\mathrm{kg\,m^{-3}}$; ***[2]***

Option I — Medical physics

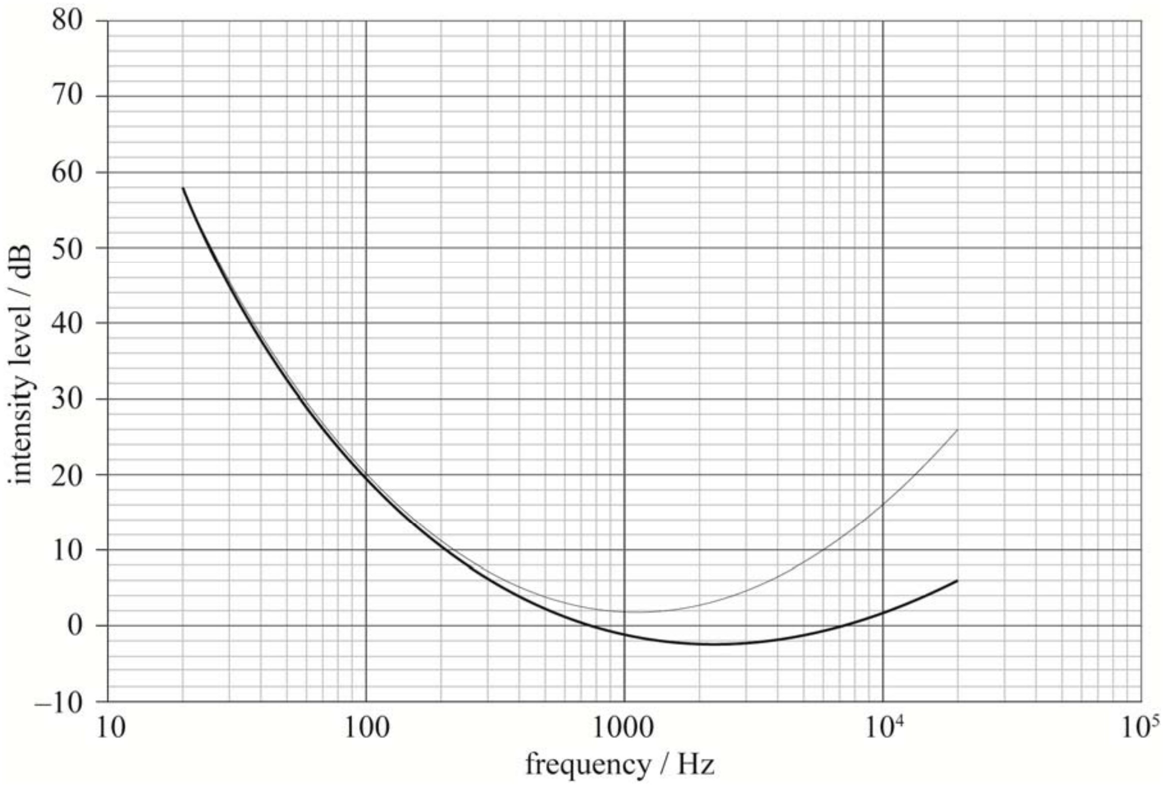
I1. (a) (i) A: eardrum;
B: oval window; ***[1]***
Both needed for ***[1]****.*

(ii) levers (ossicles) amplify force (and so pressure);
area of piston B smaller than piston A, so pressure (further) amplified;
since $\text{Pressure} = \frac{\text{Force}}{\text{Area}}$; ***[2 max]***

(b) since density/speed of sound/acoustic impedance are so different;
most sound would be reflected; ***[2]***

(c) intensity is power per unit area (as measured by an instrument);
loudness takes the frequency response of the human ear into account / *OWTTE*; ***[2]***
For first marking point accept formula only if symbols defined.

(d) continuous graph with line close to or on given line up to 1 kHz;
15 dB loss at 10 kHz shown; ***[2]***



I2. (a) (i) X-rays are absorbed more by bone as it is denser / X-rays are transmitted more by muscle as it is less dense;
denser material/bone leads to less exposure / less dense material/muscle leads to more exposure (on the photographic plate); ***[2]***

(ii) $I_b = I_0 e^{-0.53 \times 10} = 0.0050 \times I_0$;
$I_m = I_0 e^{-0.30 \times 10} = 0.0498 \times I_0$;
$\frac{I_b}{I_m} = \frac{0.0050 \times I_0}{0.0498 \times I_0} = 0.10$; ***[3]***

(iii) low energy X-rays cause less damage to tissue;
but do not penetrate as deeply; ***[2]***

(b) (i) no exposure to radiation / *OWTTE*; ***[1]***

(ii) for impedance matching / *OWTTE*; ***[1]***

(iii) $y = \frac{vt}{2}$;
$y = \frac{1600 \times 12 \times 10^{-5}}{2} = 0.096\,\text{m}\,(= 9.6\,\text{cm})$; ***[2]***

I3. (a) the energy absorbed per unit mass (unit Gy) from any radiation / $D = \frac{E}{m}$ with symbols defined; ***[1]***

(b) $E = mD = \frac{mH}{Q_\gamma} = mH$ for X-rays;
$E = 70\,\text{kg} \times 500 \times 10^{-6} = 35\text{mJ}$;
$E^\alpha = \frac{E}{20} = 1.75\,\text{mJ}$; ***[3]***

(c) (i) the time required for the activity of a radioactive substance in the body to drop by 50 %/half;
by physical and biological means / *OWTTE*; ***[2]***

(ii) use of $\frac{1}{T_E} = \frac{1}{T_P} + \frac{1}{T_B}$;
$T_E \left(= \frac{6 \times 12}{6 + 12}\,\text{h} \right) = 4\,\text{h}$;
time required $= 2T_E = 8\,\text{h}$; ***[3]***

(d) ionization; ***[1]***

Option J — Particle physics

J1. (a) (i) particle with no internal structure / cannot be broken down further; ***[1]***

(ii) electron / neutrino / any lepton / any named exchange particle; ***[1]***

(b) (i) pion/meson/gluon; ***[1]***

(ii) $m = \frac{h}{4\pi Rc}$;
1.8×10^{-28} kg; ***[2]***

J2. (a) -3;
$+\frac{3}{2}$; ***[2]***

(b) (i) anti u (quark) / $\bar{\mathrm{u}}$; ***[1]***

(ii) W^-; ***[1]***

(c) states or uses Pauli exclusion principle;
Ω^- has (three) identical (strange) quarks;
there must be a (further) property that distinguishes them (this is colour); ***[3]***

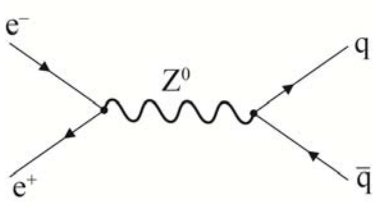
(d) (i) particles pass through superheated liquid;
ionization caused by particles;
which gives rise to formation of (gas) visible bubbles along track; ***[3]***

(ii) sign of charge from track direction;
momentum from track radius (assuming known charge);
rate of energy loss from density of bubbles;
mention that magnetic field is required; ***[2 max]***

J3. (a) confinement means that quarks are not observed as isolated particles;
other quarks will be created (if necessary to form hadrons);
so only quarks combined to make hadrons will emerge; ***[3]***

(b) interaction involving Z^0 particle; ***[1]***

(c) (i)



correct incoming and outgoing particles with correct arrow direction;
Z^0 shown correctly; ***[2]***
Allow any consistent labelling for quark pair.

(ii) Z^0 can also produce an electron–positron pair (by reverse process);
these can therefore be detected from the second Z^0 interaction; ***[2]***

J4. total energy of pair $= 1.02\,\text{MeV}$;

this energy $= \frac{3}{2}kT$;

$8 \times 10^9\,\text{K}$; ***[3]***

J5. attempts to provide quantum field theory of gravitation/to reconcile gravitation and quantum have failed;
top quark mass has not been determined in present theories;
strings are (very much) smaller than particles;
mass is thought to be result of oscillation of strings/membranes in extra dimensions; ***[2 max]***