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MARKSCHEME

May 2012

PHYSICS

Higher Level

Paper 3

21 pages

General Marking Instructions

Assistant Examiners (AEs) will be contacted by their team leader (TL) by e-mail (or telephone) – if by e-mail, please reply to confirm that you have downloaded the markscheme from IBIS. The purpose of this initial contact is to allow AEs to raise any queries they have regarding the markscheme and its interpretation. AEs should contact their team leader by e-mail at any time if they have any problems/queries during the marking process.

Note:

The DHL courier service must be used to send assessment material to your team leader/senior moderator and to IB Assessment Centre. (However, this service is not available in every country.) The cost is met directly by the IB. It is vitally important that the correct DHL account number is used.

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1. Follow the markscheme provided, award only whole marks and mark only in **RED**.

2. Make sure that the question you are about to mark is highlighted in the mark panel on the right-hand side of the screen.

3. Where a mark is awarded, a tick/check (✓) **must** be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark. **One tick to be shown for each mark awarded.**

4. Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases use Scoris™ annotations to support your decision. You are encouraged to write comments where it helps clarity, especially for re-marking purposes. Use a text box for these additional comments. It should be remembered that the script may be returned to the candidate.

5. Personal codes/notations are unacceptable.

6. Where an answer to a question or part question is worth no marks but the candidate has attempted the part question, enter a zero in the mark panel on the right-hand side of the screen. Where an answer to a question or part question is worth no marks because the candidate has not attempted the part question, enter an "NR" in the mark panel on the right-hand side of the screen.

7. If a candidate has attempted more than the required number of questions within a paper or section of a paper, mark all the answers. Scoris™ will only award the highest mark or marks in line with the rubric.

8. Ensure that you have viewed **every** page including any additional sheets. Please ensure that you stamp "seen" on any page, in the Options attempted by the candidate, that contains no other annotation.

9. 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 got wrong. However, a mark should not be awarded where there is contradiction within an answer. Make a comment to this effect using a text box or the "CON" stamp.

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 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) O class; ***[1]***

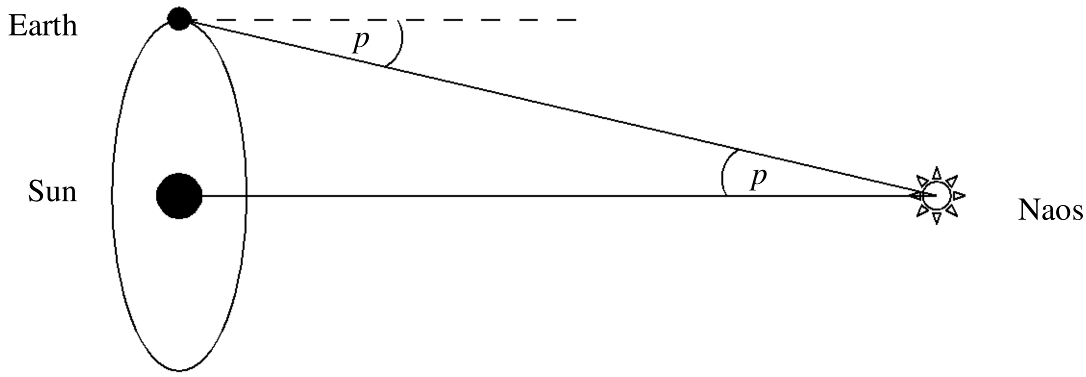
(b) apparent magnitude is a measure of the (apparent) brightness of a star (on a logarithmic scale); ***[1]***

(c) (i) $d = \left(\frac{1}{p} = \frac{1}{3.36 \times 10^{-3}} = \right) 298\,\text{pc}$; ***[1]***

(ii) $2.21 - M = 5 \times \lg \frac{298}{10}$;

$M = \left(2.21 - 5 \times \lg \frac{298}{10} = \right) -5.16$; ***[2]***

(d) (i) either angle p as shown; ***[1]***



(ii) the star's position is observed at two times, six months apart;
the shift in the star's position relative to the distant stars is (twice) the parallax angle; ***[2]***
Accept correct answers which are clear from annotations on the diagram.

(e) (i) $L = 5.67 \times 10^{-8} \times 4\pi \times (7.70 \times 10^{9})^2 \times (42\,400)^4$;
$L = 1.37 \times 10^{32}$ W; ***[2]***

Award ***[1 max]*** *for use of* πr^2 *giving* $\frac{1}{4}$ *of answer.*

(ii) $\lambda = \left(\frac{2.90 \times 10^{-3}}{42\,400} = \right) 6.84 \times 10^{-8}$ m; ***[1]***

(f) most of the energy emitted by Naos is in the ultraviolet/outside visible region;
and hence not detectable by the naked eye; ***[2]***

E2. (a) universe is infinite in extent;
has no beginning/infinite age;
stars uniformly distributed in space / universe is homogeneous in space;
universe is static / universe is homogeneous in time; ***[2 max]***
*Award **[1 max]** for bald "homogeneous".*

(b) number of stars in a thin shell a distance d from Earth is proportional to d^2;
since apparent brightness of each star varies as $\frac{1}{d^2}$, the stars in each shell contribute a constant amount of brightness;
since the number of stars is infinite/since there is an infinite number of shells, the brightness should be infinite; ***[3]***

(c) the universe has a finite age/a definite beginning;
so light from very distant stars has not yet reached us; ***[2]***

or

the number of stars is finite;
the total energy emitted is finite;

or

Universe is expanding;
radiation is red-shifted to lower energy/becomes invisible;

E3. (a) (i) any line from the sun to red giants (anywhere above and right of the sun) and then anticlockwise to white dwarfs (anywhere below and left of the sun); ***[1]***

(ii) after the planetary nebula stage/red giants stage;
the remnant mass/core mass of the star will be less than the Chandrasekhar limit (and so will end up as a white dwarf); ***[2]***

(b) (i) $\frac{M_X}{M_\odot} = \left[\frac{L_X}{L_\odot}\right]^{\frac{1}{3.5}}$;

$\frac{M_X}{M_\odot} = (10^{\frac{4}{3.5}} =)13.9$; ***[2]***

Evidence of calculation required for second mark (i.e. 3 sf or more showing).
*Award **[2 max]** for valid alternative route to this answer.*

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

E4. (a) (i) galaxies move away from each other/from Earth with a speed that is proportional to their separation/distance from Earth; ***[1]***
Accept answer in terms of equation with symbols defined.

(ii) it gives age of the universe/time since the Big Bang; ***[1]***

(b) $\frac{v}{c} = \left(\frac{\Delta\lambda}{\lambda_0} = \frac{504 - 434}{434} = \right) 0.161$;

$d = \left(\frac{v}{H} = \frac{0.161 \times 3 \times 10^5}{72} = \right) 672\,\text{Mpc} \approx 670\,\text{Mpc}$; ***[2]***

Alward ***[1]*** *for 578(Mpc) if 504 used in the denominator.*

Option F — Communications

F1. (a) (i) 456 kHz; *[1]*

(ii) 2 kHz ***or*** 2.0 kHz; *[1]*

(iii) 4 kHz; *[1]*

(iv) use of 2 or 1.5 in the dB equation;
$P_c = 10^{0.2} \times P_0$ ***or*** $P_s = 10^{0.15} \times P_0$;
ratio carrier to signal power = $1.12 \approx 1.1$; *[3]*
Expect variety of approaches, so award ***[3]*** *for bald correct answer.*

(b) (i) *X:* tuning circuit/tuner;
Y: AF amplifier; *[2]*

(ii) *X:* isolates the particular carrier frequency one wants to tune to;
Y: amplifies the electrical signal so loudspeaker can be driven; *[2]*

(c) FM has less distortion;
is less susceptible to interference from buildings;
carries more information;
has less interference between neighbouring stations;
has less radiated power;
for given transmitter power, has clear reception region;
AM has less attenuation;
low frequencies reflected back by ionosphere therefore can travel farther distances;
much smaller band width; ***[3 max]***

F2. (a) (i) (in any time interval) there are (approximately 5.5) more samples;
giving much higher quality reproduction; ***[2]***

(ii) higher sampling means more data stored/more memory needed; ***[1]***

(b) (i) period = 0.2 ms;
lines or points at 0.2, 0.4; ***[2]***
Award first marking point if it is implicit in the lines/points drawn.

(ii) 0101;
0100; ***[2]***
Allow ECF from (i).

(c) (TDM is the) process in which available bandwidth is shared by different users;
signal is divided into samples/data blocks;
time for sample/data block (of a signal) is (very) short compared to the time in between samples;
different signals can be fed into the "dead time" in between samples of one signal;
at reception the different signals are read sequentially to separate into separate signals/channels; ***[3 max]***

F3. (a)

input impedance	infinite
output impedance	zero
(open loop) gain	infinite

[2]

Award ***[2]*** *for all correct and* ***[1 max]*** *for two correct.*

(b) $V_+ = V_- = V_{IN}$;

$I = \frac{V_{OUT}}{(R + R_F)}$ $\quad I = \frac{V_{IN}}{R}$;

equate giving $\frac{V_{OUT}}{V_{IN}} = \frac{R_F + R}{R}$; ***[3]***

(c) –2.5 (gain);
–7.5 V; ***[2]***
Award ***[1 max]*** *if negative sign is missing.*

Option G — Electromagnetic waves

G1. (a) (i) ratio of angle subtended by image at eye to angle subtended by object at the near point; ***[1]***

(ii) $\theta_o = \frac{h_o}{25}$;

$\theta_i = \frac{h_o}{f}$;

$M = \frac{\theta_i}{\theta_o} = \frac{h_o}{f} \times \frac{25}{h_o} = \frac{25}{f}$; ***[3]***

*Award **[3]** for use of symbol (e.g. D) to represent distance to near point (25 cm).*

or

realizes object is at f;

obtains at least 1 correct angle as either $\frac{h}{25}$ or $\frac{h}{D}$, or $\frac{h}{f}$;

shows that $M = \frac{D}{f}$ or $\frac{25}{f}$;

(b) (i) $\left(\frac{1}{f} = \frac{1}{v} + \frac{1}{u}\right)$

$\frac{1}{15} = \frac{1}{v} + \frac{1}{8}$;

$v = (-)17.1\text{cm}$; ***[2]***

(ii) 2.14 or –2.14; ***[1]***

(iii) virtual; ***[1]***

G2. (a) (i) laser coherent (bulb incoherent);
laser is monochromatic; ***[2]***

(ii) requirement of metastable energy level;
pumping of optical medium;
population inversion;
mechanism of stimulated emission;
all excited atoms de-excite together; ***[4 max]***
Also look for these marks within a possible diagram.

(b) (i) equally spaced;
(red) spots/maxima/bright fringes;
and wide minima/dark fringes; ***[2 max]***

(ii) use of diffraction grating equation;
correct use of number of lines per mm or calculation of grating spacing;
one angle correctly calculated (angles are 22.3° and 49.3°);
27°; ***[4]***

G3. (a) (i) power supply connected between anode and cathode with positive terminal connected to anode and negative to cathode; ***[1]***

(ii) bombarding electron ejects inner/K electron;
outer electron fills vacancy;
emits X-ray photon of energy equal to difference between energy levels; ***[3]***

(iii) conversion of 25 keV to J $\left(=4.0\times10^{-15}\right)$;
4.97×10^{-11} m; ***[2]***

(b) (i) interference from beams scattered by different atomic planes;
path difference = $n\lambda$ for constructive interference;
reflection from the same plane leads to intense reflected beam where angle of incidence = angle of reflection; ***[2 max]***

(ii) use of Bragg equation;
4.50×10^{-11} m; ***[2]***

Option H — Relativity

H1. (a) only T measures the proper time interval;
for T the pendulum is (a single clock) at rest/same point in space; *[2]*
Do NOT simply allow that the pendulum is in the same frame as T.

(b) $\gamma = \left(\frac{1}{\sqrt{1-0.95^2}} = \right) 3.20$;

$T = (\gamma T_0 = 3.20 \times 0.85 =) 2.72\,\text{s}$; *[2]*

(c) (i) the arrivals at T of the light from the two strikes occurs at the same point in space for T and are simultaneous for T;
so the arrivals of the light are simultaneous for all other observers as well; *[2]*

or

T measures a zero proper time interval for the arrivals of the light;
so G measures a time interval equal to $\gamma \times 0 = 0$ also;

(ii) according to G, T is moving away from the light from the left strike and yet receives the light at the same time as the light from the right strike;
since <u>the speed of light is the same</u> for light from both strikes;
the left strike occurred first *[2]*
No marks for just stating left strike is first. Given.

(d) (i) the distance between the marks at the ends of the train is the (Lorentz) contracted train length;

i.e. $\left(\frac{160}{3.20} \right) = 50\,\text{m}$; *[2]*

(ii) for T, 160m is the (contracted) distance between the marks on the ground;
so for G the proper length is $\gamma \times 160 = 510$m; *[2]*

(e) $u' = \frac{-0.950\text{c} - 0.950\text{c}}{1-(-0.950)(0.950)}$;
$u' = -0.999\text{c}$; *[2]*
Accept calculation with left as positive to give $+0.999c$.

H2. (a) special relativity rests on the postulate that the speed of light (c) is independent of the speed of its source / speed of light is constant;
both photons were measured to have a speed equal to c with respect to the lab thus verifying the postulate; ***[2]***

(b) (i) the gamma factor is $\gamma = \left(\dfrac{1}{\sqrt{1-0.80^2}} = \right)\dfrac{5}{3} = 1.67$;

so the total energy of the pion is $\left(\dfrac{5}{3}\times 135\right) = 225\,\text{MeV}$; ***[2]***

(ii) $p = (\gamma m v) = \dfrac{5}{3}\times 135\times 0.80c$;

$= 180\,\text{MeV}\,\text{c}^{-1}$; ***[2]***

or

use of $E^2 = p^2c^2 + m^2c^4$

$p = \sqrt{(225^2 - 135^2)}$;

$= 180\ \text{MeVc}^{-1}$;

(iii) (since the momentum of a photon is $\dfrac{E}{c}$) by <u>momentum conservation</u>

$\dfrac{E_R}{c} - \dfrac{E_L}{c} = 180\,\text{MeV}\,\text{c}^{-1}$;

hence the right photon has the greater energy; ***[2]***

or

the total momentum before the decay is directed towards the right;
by <u>momentum conservation</u> the momentum after the decay is also to the right, hence the right photon has the greater energy;
*Award **[1]** for "right photon has greater energy" with wrong or missing explanation.*

H3. (a) a frame of reference that is freely falling in a gravitational field is equivalent to an inertial frame of reference far from all masses; ***[1]***

or

inertial and gravitational effects are indistinguishable;

or

a frame of reference accelerating in empty space is equivalent to a frame of reference at rest in a gravitational field;

(b) (i) $\left(\frac{\Delta f}{f_0} = \frac{g\Delta h}{c^2} \text{ and so}\right) \Delta f = \left(\frac{1.2\times10^{13}\times250\times4.8\times10^{14}}{9\times10^{16}} =\right)\ 0.16\times10^{14}$ Hz;

$f = (4.8\times10^{14} + 0.16\times10^{14} =)\ 5.0\times10^{14}$ Hz; ***[2]***

ECF applies only if the wrong value of Δf is added to f_0.

(ii) as light travels away from a massive body it is red-shifted/frequency decreases/time period increases;
hence closer to the body the time period is shorter / time runs slower (than higher up) – this is (equivalent to) time dilation; ***[2]***

(c) (i) a point of infinite curvature / a point of infinite space / a singularity of spacetime / a region from which nothing can escape / escape velocity $\geq c$; ***[1]***

(ii) matter falling into the black hole radiates;
the (gravitational) influence on other objects;
by observing its gravitational lensing effect;
emission of Hawking radiation; ***[2 max]***

Option I — Medical physics

I1. (a) minimum sound intensity that is detectable by the ear; ***[1]***
*Award **[0]** for intensity level.*

(b) (i) $I = \frac{5}{4\pi \times (8.4)^2}$;
evidence of a calculation *e.g.* 0.0056 W m^{-2}; ***[2]***

(ii) use of log and 1.0×10^{-12};
98 (dB) or 97 (dB) or 100 (dB) as 1sf is ok; ***[2]***

(c) (i) accept between 2 and 4kHz; ***[1]***

(ii) intensity is less than 10^{-12} W m^{-2}; ***[1]***

(iii) 20Hz – 20kHz; ***[1]***

(iv) reduced range at each end or just high f;
curve raised; ***[2]***

I2. (a) apply alternating pd across crystal;
at the resonant frequency of the crystal;
frequency must be greater than 20 kHz; ***[2 max]***

(b) (i) kg $\text{m}^{-2}\text{s}^{-1}$; ***[1]***

(ii)

	Velocity of sound/ms^{-1}	**Density/kg m^{-3}**	**Acoustic impedance/kg $\text{m}^{-2}\text{s}^{-1}$**
Air	*330*	*1.3*	4.3×10^{2}
Gel	*1420*	*980*	1.4×10^{6}
Muscle tissue	*1580*	*1080*	1.71×10^{6}

[2]

*Award **[2]** for all correct and **[1 max]** for 2 or 1 correct.*

(iii) $\left(\frac{1.71\times10^6 - 4.3\times10^2}{1.71\times10^6 + 4.3\times10^2}\right)^2$;
$0.999 \approx 1.0$; ***[2]***

(iv) from (iii) most ultrasound is reflected at air–skin boundary;
gel (replaces air) has impedance similar to skin so decreases reflection (coefficient)/increases transmission; ***[2]***

I3. (a) diagnostic radiography involves the use of radiation to create images for medical diagnoses;
therapeutic radiology involves medical use of radiation as part of (cancer) treatment; ***[2]***

(b) (i) factor which depends upon the radiation type;
reflects the effect equal doses of radiation have on cells; ***[2]***

(ii) absorbed dose $= \left(\frac{48\times10^{-3}}{15}\right)3.2\times10^{-3}\,\text{Gy}$;
time for absorption $(= 45\times35\times3600) = 5.67\times10^{6}$ s;
absorbed dose rate = ratio of these values $= 5.6\times10^{-10}$;
Gy s^{-1}; ***[4]***

(c) *Aspects might include:*
discussion of various alternative therapeutic techniques;
always some risk of harming healthy cells with ionizing radiation;
risk needs to be balanced between not treating and treatment;
as low level of exposure as possible which will harm cancerous cells whilst limiting damage to healthy cells;
isolation from others after receiving certain radiation treatments; ***[3 max]***

Option J — Particle physics

J1. (a) exchange particles are virtual particles/bosons;
that mediate/carry/transmit the weak/strong/em force between interacting particles / *OWTTE*; ***[2]***
Award first marking point for named bosons also, e.g. photons, W, Z, gluons.

(b) (i) anti-blue; ***[1]***

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

(c) strangeness in initial state is –1 and zero in the final;
hence it is not conserved; ***[2]***
*Award **[0]** for unsupported second marking point.*

(d) $\Delta t \approx \left(\frac{h}{4\pi\Delta E}=\right)\frac{6.63\times10^{-34}}{4\pi\times1.2\times10^{9}\times1.6\times10^{-19}}$;

$\Delta t \approx 3\times10^{-25}$ s; ***[2]***

(e)

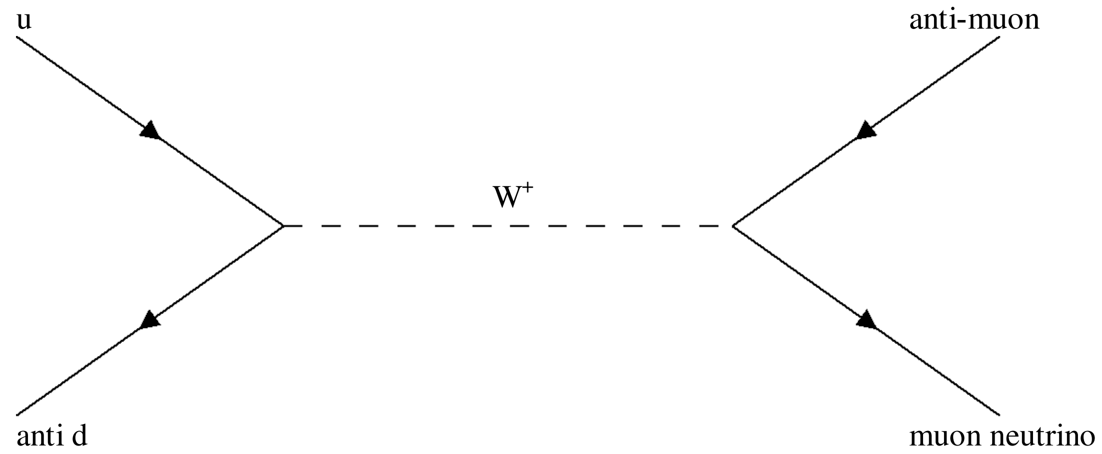


diagram as above;
correctly labelled W^{+}; ***[2]***
Allow time to run vertically. Allow particle symbols. Ignore missing or wrong arrow directions.

J2. (a) (i) to avoid any collisions with air molecules that would slow down the particles; ***[1]***

(ii) since v is increasing, B must be variable;
for permanent magnets B is not variable / only for electromagnets is B variable; ***[2]***

(iii) a lot of the energy is wasted/emitted as synchrotron radiation/bremsstrahlung; ***[1]***

(b) (i) energy that can be used to create particles; ***[1]***

(ii) 60 GeV; ***[1]***

(c) (i) $E_A = \sqrt{2 \times 0.938 \times 60 + 2 \times 0.938^2}$;
$E_A = 11\,\text{GeV}$; ***[2]***

(ii) in collider collisions the available energy can all be used to create the rest energies of new particles without giving them any kinetic energy / in stationary collisions some of the energy must be used for kinetic energy (in order to satisfy momentum conservation); ***[1]***

J3. (a) muon neutrino;
electron antineutrino;
so that (family) lepton number is conserved; ***[3]***
Do not accept particle symbols only.

(b) it is responsible for giving masses (to quarks, leptons and the exchange particles of the weak interaction); ***[1]***

J4. (a) photons in the very early universe had enough energy to excite atoms to higher energy states and so could not penetrate matter;
as the temperature dropped (so did the energy of the photons) no excitation was possible and the photons were transmitted through; ***[2]***

(b) $T = \dfrac{2 \times 0.40 \times 1.6 \times 10^{-19}}{3 \times 1.38 \times 10^{-23}}$;

$T = 3 \times 10^3\ \text{K}$; ***[2]***

J5. (a) the basic constituents of string theory are (one dimensional) strings rather than (point) particles;
they are (consistently) defined in more than four dimensions;
interactions are over a region of space (rather than at a point);
quantum gravity appears naturally in string theories;
string theory attempts to reconcile quantum mechanics and general relativity;
string theory attempts to unify the four fundamental forces; ***[2 max]***

(b) particles appear as (massless) excitations/modes of vibration of the strings; ***[1]***
