N14/4/PHYSI/SP3/ENG/TZ0/XX/M

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MARKSCHEME

November 2014

PHYSICS

Standard Level

Paper 3

16 pages

Subject Details: Physics SL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer questions from **TWO** of the Options **[2 x 20 marks]**.
Maximum total = **[40 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 underlined 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 A — Sight and wave phenomena

1. (a) cones are sensitive to colour while rods provide black and white vision;
cones provide photopic vision while rods provide scotopic vision;
cones work under bright/normal light conditions while rods function under low light conditions; ***[2 max]***

(b) accommodation is the process by which the eye can focus on objects at different distances;
this is accomplished by changes in the lens shape (as a result of changes in tension in the suspensory ligaments and the ciliary muscle); ***[2]***

2. (a) (longitudinal)
the standing wave is formed of (travelling) sound waves (which are longitudinal); ***[1]***
Do not allow responses that focus only on travelling waves.

(b) the frequency is $f = \frac{1}{1.25 \times 10^{-3}} (= 800\,\text{Hz})$;

and the wavelength is $\lambda = \frac{v}{f} = \frac{340}{800} (= 0.425\,\text{m})$;

the fourth harmonic corresponds to 2 wavelengths in the tube, thus $L = 2\lambda = 0.85\,\text{m}$; ***[3]***

(c) the length of the tube closed at one end corresponds to $\frac{\lambda}{4}$, while the length for the tube open at both ends corresponds to $\frac{\lambda}{2}$; ***[1]***

3. (a) as the mosquito approaches the wavelength perceived by Georgia is shorter and therefore the perceived frequency is higher;
as the mosquito is moving away, the wavelength perceived is longer than the emitted and therefore the perceived frequency is lower;
due to the Doppler effect; ***[2 max]***

(b) approaching $751 = f \times \frac{340}{340 - u}$;
moving away $749 = f \times \frac{340}{340 + u}$;
to produce $u = 0.45\,\text{m s}^{-1}$; ***[3]***

or

emitted frequency is $\frac{751 + 749}{2} = 750\,\text{Hz}$;
applying the Doppler effect for approach (or recession), $751 = 750\frac{340}{340 - u}$ ***or*** $749 = 750\frac{340}{340 + u}$;
to produce $u = 0.45\,\text{m s}^{-1}$;

4. (a) light is said to be (plane) polarized if the electric field (vector) lies on one plane;
when light is unpolarized, the electric field (vector) lies on many planes/does not lie on a specific plane; ***[2]***

(b) (i) *correct position of polarizers*: polarizer-glass-liquid crystals-glass-polarizer;
correct position of mirror: at the rightmost end of the system; ***[2]***

(ii) $\frac{I}{I_0} = \frac{1}{2}$;
a correct explanation for why only one polarization occurs; ***[2]***

eg:
$\frac{I}{I_0} = \frac{1}{2}$;
the light is rotated by the crystals to match the outgoing polar;

Option B — Quantum physics and nuclear physics

5. (a) a particle with momentum has a wavelength ;
where $\lambda = \frac{h}{p}$ and wavelength is λ, momentum is p and Planck's constant is h; ***[2]***

(b) (i) $p = \sqrt{2m_e \times eV} = \sqrt{2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 54}$ $(= 3.97 \times 10^{-24}\ \text{kg m s}^{-1})$;

$\lambda = \left(\frac{h}{\sqrt{2m_e \times eV}} = \frac{6.63 \times 10^{-34}}{3.97 \times 10^{-24}} = \right) 1.7 \times 10^{-10}\ \text{m}$; *(must see 2+ significant figures to award this mark)* ***[2]***

(ii) electrons scatter off the periodic structure of the nickel lattice;
separation of ions/atoms is such that diffraction occurs (leading to a maximum in the intensity of scattered electrons); ***[2]***

6. (a) an atom will only absorb a photon if the photon energy corresponds to an energy difference between two of its energy states;
the absorption of energy takes places in discrete quantities (quanta); ***[2]***

(b) arrow drawn downwards from –0.54 level to –3.40 level; ***[1]***

7. (a) (i) (${}^{11}_{6}\text{C} \rightarrow {}^{11}_{5}\text{B} + {}^{0}_{+1}\beta^{+} + \text{v}$ (or neutrino))

${}^{11}_{6}\text{C} \rightarrow {}^{11}_{5}\text{B} + {}^{0}_{+1}\beta^{+}$;

v (or neutrino); ***[2]***

*Award **[1]** for all the correct numbers and **[1]** for the neutrino.*

(ii) positron / antielectron / lepton; ***[1]***

(b) (i) measure activity as a function of time;

create a graph of activity with time, and estimate half-life from the graph;

make at least three estimates of half-life from the graph and take mean; ***[3]***

or

measure activity as a function of time;

create a graph of ln(A) with time, find the decay constant λ from the gradient;

estimate the half-life using $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$;

(ii) the rate of decay is proportional to the amount of (radioactive) material remaining;

the number of undecayed nuclei at time t is given by $N = N_0 e^{-\lambda t}$, where N_0 is the number of undecayed nuclei at time $t = 0$ and λ is the decay constant; ***[1 max]***

(iii) $\frac{N_0}{2} = N_0 e^{-\text{T}\frac{1}{2}}$;

$\ln(\tfrac{1}{2}) = -\lambda \text{T}_{\frac{1}{2}}$ so $\text{T}_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$; ***[2]***

(iv) $\lambda = \frac{\ln 2}{60 \times 20.3} (= 5.69 \times 10^{-4}\,\text{s}^{-1})$;

$\frac{A}{\lambda} = \frac{4.2 \times 10^{20}}{5.69 \times 10^{-4}} = 7.4 \times 10^{23}$; ***[2]***

Option C — Digital technology

8. (a) (i) more information can be stored in the same amount of space;
more portable;
the information is more easily manipulated/shared/copied/searched; ***[1 max]***

(ii) DVDs are digital (and cassette tapes are usually analogue);
cassette tapes use the magnetic alignment of (ferro- magnetic) particles while DVDs use lands and pits on a(n etched) surface; ***[2]***

(b) (i) pit depth $=\frac{1}{4}\lambda$;
reflection from edge gives path difference of $\frac{1}{2}\lambda$;
this leads to destructive interference; ***[2 max]***

(ii) $\frac{4.38\times10^9\times8}{192\times10^3\times2\times24}$;
$=3800\text{ s}$ ***or*** 63 minutes; ***[2]***

9. (a) the ratio of the height/length of the image to the height/length of the object; ***[1]***

(b) (i) $1.5\times10^{-4}\text{ m}\times0.14$;
$2.1\times10^{-5}\text{ m}$ ***or*** 0.021 mm; ***[2]***

(ii) area of one pixel $=\left(\frac{864\text{ mm}^2}{13.7\text{MP}}=\right)6.3\times10^{-5}\text{ mm}^2$;
length of each pixel $=\left(\sqrt{6.3\times10^{-5}}=\right)0.0079\text{ mm}$;
hence the spots are able to be resolved as they are more than 2 pixels apart on the image; ***[3]***

(c) the potential difference across each pixel;
the position of each potential difference/pixel; ***[2]***

10. (a) as temperature decreases, potential difference across the thermistor increases;
voltage at the inverting input of the op-amp decreases; ***[2]***

(b) to control/to set the temperature at which some action/signal is given; ***[1]***
Allow logical, specified actions such as turning on heaters, closing vents.

(c) potential difference across the thermistor $=\left(30\times\frac{193}{193+300}=\right)11.74\text{ V}$;
the voltage at the inverting input of the op-amp will be $15\text{ V}-11.74\text{ V}=3.26\text{ V}$; ***[2]***
(so the voltage of the non-inverting input of the op amp is around 3 V)

Option D — Relativity and particle physics

11. (a) beam X will reach the mirror first;
the speed of light of each beam is constant for all inertial observers;
the left mirror moves towards the beam X while the right mirror moves away from the beam Y; ***[3]***

(b) the beams returning to Daniela occur at one point in space;
if this is simultaneous to Daniela, the event will also be simultaneous to Jaime; ***[2]***

or

beam X has less to go to the mirror and then longer to Daniela, whilst beam Y has longer to the mirror and less to Daniela;
the sum of the times are the same because Daniela is in the middle so they arrive at the same time;

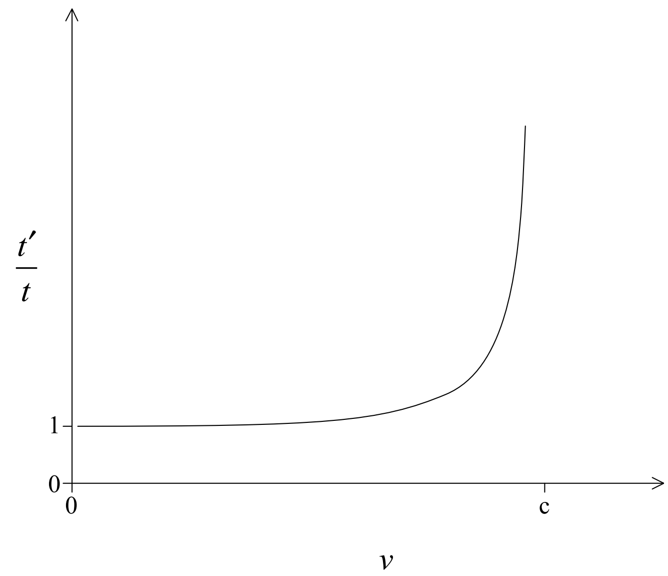
12. (a) the laws of physics are the same for all inertial observers; ***[1]***

(b) (i) $t = \frac{2d}{c}$ and $t' = \frac{d'}{c} = \frac{2}{c}\sqrt{\left(\frac{vt'}{2}\right)^2 + d^2} = \frac{2}{c}\sqrt{\left(\frac{vt'}{2}\right)^2 + \left(\frac{ct}{2}\right)^2}$;

$\frac{c^2t'^2}{4} = \frac{c^2t^2}{4} + \frac{v^2t'^2}{4}$ which gives $t'^2 = t^2 + \left(\frac{v}{c}\right)^2 t'^2$;

$t'^2\left[1 - \left(\frac{v}{c}\right)^2\right] = t^2$; ***[3]***

(ii) line begins at $\frac{t'}{t} = 1$ when $v = 0$;
line fairly flat until around $v = 0.6$ and then asymptotically approaches $v = c$; ***[2]***



13. (a) (i) electromagnetic;
strong; *[2]*

(ii) they are composed of more than one quark; *[1]*

(b) (i) W^+; *[1]*

(ii) u has a baryon number of $\frac{1}{3}$ and $\bar{\text{d}}$ has a baryon number of $-\frac{1}{3}$;

μ^+ and v_μ both have a baryon number of 0; *[2]*

(iii) (conversion of mass into kg:)

$$100\,\text{MeV}\,\text{c}^{-2} = \left(\frac{100\times10^6\times1.6\times10^{-19}}{9\times10^{16}} = \right)1.78\times10^{-28}\,\text{kg};$$

$$R = \left(\frac{h}{4\pi mc} = \frac{6.63\times10^{-34}}{4\pi\times1.78\times10^{-28}\times[3\times10^8]} = \right)9.9\times10^{-16}\,\text{m};$$ *[2]*

At least 2 significant figures required for the second mark.

(iv) the range is comparable to the separation between adjacent nucleons / *OWTTE*; *[1]*

Option E — Astrophysics

14. (a) stars of stellar cluster are close together (in space)/bounded gravitationally;
stars of constellations are not bounded gravitationally/appear to be close together (from Earth); ***[2]***

(b) the stars rise in the east/northeast/southeast and set in the west/northwest/southwest (moving in an arc across the sky) / a description of arcs (as if rotating) in clockwise/anticlockwise direction / *OWTTE*; ***[1]***
An answer such as "move like Sun" is not sufficient for the mark.
Accept answers based in either hemisphere.

15. (a) (i) Alnilam must be further away from Earth than Bellatrix;
Alnilam has greater luminosity with a more negative absolute magnitude / absolute magnitude is a measure of how bright the star is if it is positioned 10 pc away from Earth (and apparent magnitude is a measure of how bright the star is from Earth) / *OWTTE*; ***[2]***

(ii) $\frac{L_A}{L_B} = \frac{275000}{6400}$ ***or*** $\frac{L_A}{L_B} = \frac{\sigma A_A T_A^4}{\sigma A_B T_B^4} \left(= \frac{4\pi R_A^2 T_A^4}{4\pi R_B^2 T_B^4} = \frac{R_A^2 T_A^4}{R_B^2 T_B^4} = \frac{275000}{6400} \right)$;

$\frac{[24R_o]^2}{[6R_o]^2} \times \frac{27000^4}{T_B^4} (= 42.96)$;

$T_B = \left(\sqrt[4]{\frac{24^2}{6^2} \times \frac{27000^4}{42.96}} = \right) 21100\,\text{K}$; ***[3]***

(b) (i) the position of the star (relative to the fixed background) is measured six months apart/January to July;

the parallax angle *p* can be used to determine the distance using $d = \frac{1}{p}$; ***[2]***

(ii) $\left(m - M = 5 \log \frac{d}{10} \right)$

$d = 10 \times 10^{\frac{m-M}{5}} = 10 \times 10^{\frac{1.68-(-6.37)}{5}}$;

$= 407$ (pc);

the distance of Alnilam cannot be determined (from Earth) using stellar parallax as it is further than 100 pc / the distance to Alnilam could be determined by parallax due to recent improvements (in astrophysics); ***[3]***
Do not accept value less than 100 pc, accept any value from 100 pc to 1000 pc.

16. (a) (an infinite) universe can be split into an infinite number of thin shells with diameter of r (with Earth in the centre);
the number of stars in each shell is proportional to r^2 and the brightness of each star is inversely proportion to r^2;
this means that each shell is equally bright (as seen from Earth); ***[3]***

(b) the temperature has cooled considerably since the Big Bang / the Big Bang model predicted cooling and the present temperature;
this cooling was caused by the expansion of the universe/the stretching of spacetime; ***[2]***

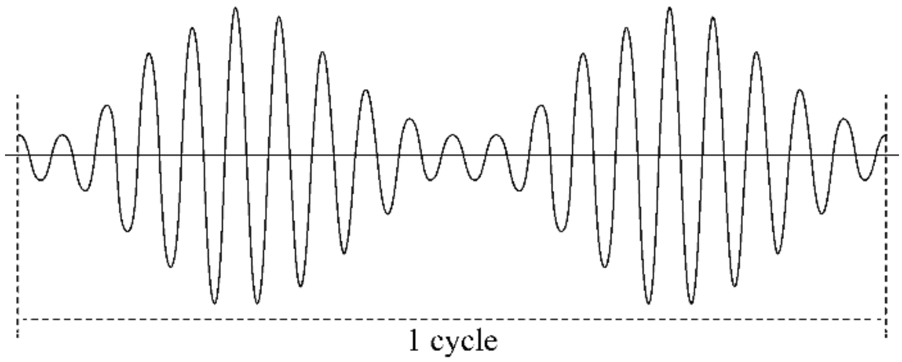
(c) the Big Bang suggests that the universe had a starting point in time;
light from distant stars has been red-shifted beyond the visible spectrum;
light from distant stars has not yet reached us;
the universe has a finite number of stars; ***[2 max]***

Option F — Communications

17. (a) (i) AM: the amplitude of the carrier wave is changed when modulated by the signal wave / *OWTTE*;
FM: the frequency of the carrier wave is changed when modulated by the signal wave is / *OWTTE*; ***[2]***

(ii) for information to be carried by a wave; ***[1]***

(iii) carrier frequency constant and at least one cycle of carrier wave shown;
amplitude of carrier frequency to fit within the envelope of the audio signal; ***[2]***



(b) *advantage*: ***[1 max]***
simpler circuitry;
narrow bandwidth;
large range;

disadvantage: ***[1 max]***
more susceptible to noise;
poorer quality signal;
noise cannot be reduced; ***[2 max]***
Do not allow "expensive".

18. (a) (4 samples every 2 ms/any other correct combinations of points) = 2000 Hz; ***[1]***

(b) 1011; ***[1]***

(c) increase the sampling rate;
more samples taken per unit time so the digital output is smoother / *OWTTE*; ***[2]***

or

increase the number of bits;
smaller changes between each quantum level in the digital signal so the output is smoother / *OWTTE*;

19. (a) (i) $\left(\sin C = \frac{1}{n} = \frac{1}{1.62} \Rightarrow C = \right) 38(.1)^{\circ}$ ***or*** 0.665 rad; ***[1]***

(ii) rays with an angle of greater than 38° shown with total internal reflection;
normal drawn onto diagram for at least one point;
pairs of angles of incidence and reflection the same; ***[2 max]***
Judge by eye.

(b) $\text{attenuation/dB} = \left(10\log \frac{I_1}{I_2} = \right) 10\log \frac{3\,\text{mW}}{150\,\text{mW}}$ ***or*** $-17.0\,\text{dB}$;

$\text{length} = \left(\frac{\text{attenuation}}{\text{attenuation per unit length}} = \frac{-17.0}{12} = \right) 1.42\,\text{km}$; ***[2]***

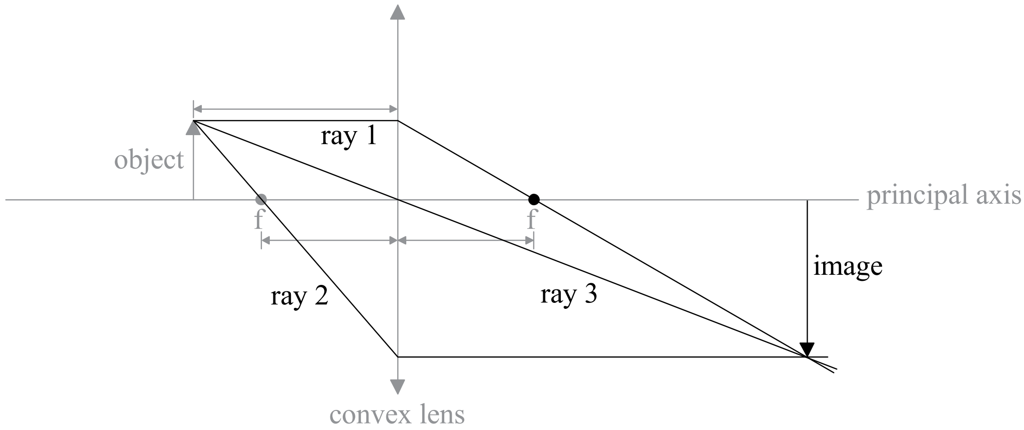
(c) (i) the width of the output signal is wider than that of the input signal;
due to material dispersion / different frequencies travel at different speeds; ***[2]***
Do not accept "reduced power".

(ii) reshapers reduce the spread of the output signal;
amplifiers increase the power of the signal; ***[2]***

Option G — Electromagnetic waves

20. (a) (i) one point on axis identified – centre of curvature/focus/centre of lens and second point on axis identified – centre of curvature/focus/centre of lens/perpendicular to flat side of lens; *[1]*
It is acceptable to choose 2 foci, 2 centres of curvature or a mixture.

(ii) one ray drawn correctly;
a second ray drawn correctly;
image correctly located and shown; *[3]*



(iii) real/inverted/magnified; *[1]*
Allow ECF from (a)(ii).

(b) (i) central cross shown straight;
sides curved (inwards or outwards); *[2]*

(ii) rays passing through the edge of the lens are brought to a different focal point than those passing through the centre;
by covering the outer edge of the lens/reducing the aperture (only the centre of the lens is used) bringing the light to one focus; *[2]*

21. (a) (i) (the waves) all have the same/narrow interval of frequency/wavelength; *[1]*
Do not accept "one colour".

(ii) more electrons are in the higher state than in the ground/lower state; *[1]*

(b) any sensible suggestion; *(eg eye surgery, cancer treatment)*
brief description given; *[2]*

eg eye surgery;
laser burns tissue to control leakage of blood vessels in the eye / laser used to destroy cells (to reshape the cornea) to improve eyesight;

22. (a) the waves are coherent so interference occurs;
high intensity sound corresponds to a position where sound constructively interferes/superposes / low/zero intensity sound corresponds to a position where sound destructively interferes/cancels;
high intensity is where the path difference is an integral number of wavelengths;
low/zero intensity of sound is where the path difference is $n+\frac{1}{2}$ wavelengths; ***[3 max]***

(b) $\lambda = \frac{330}{2500} = 0.132\,\text{m}$;
$x = \left(\frac{n\lambda D}{d} = \frac{1.0 \times 0.132 \times 8.0}{1.5} = \right) 0.70(4)\,\text{m}$; ***[2]***

(c) distance doubles so fringe width is halved;
so fringes are encountered at the same rate, no change; ***[2]***