Semester 2 Examination, 2022
Question/Answer booklet

PHYSICS
Units 3 & 4

MARKING KEY

Time allowed for this paper

Reading time before commencing work:	ten minutes
Working time:	three hours

Materials required/recommended for this paper

To be provides by the supervisor
This Question/Answer booklet
Formulae and Data booklet

To be provided by the candidate

Standard items:	pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid, eraser, ruler, highlighters.
Special items:	up to three non-programmable calculators approved for use in the WACE examinations, drawing templates, drawing compass and a protractor.

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of Questions	Questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One Short Response	10	10	50	54	30
Section Two Problem Solving	6	6	90	90	50
Section Three Comprehension	2	2	40	36	20
			Total	180	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 11 Information Handbook 2022: Part II Examinations.* Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer booklet preferably using a black/blue pen. Do not use erasable or gel pens.

3. You must be careful to confine your answers to the specific questions asked and follow any instructions that are specific to a particular question.

4. When calculating or estimating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning.

   In calculations, give final answers to three significant figures and include appropriate units where applicable.

   In estimates, give final answers to a maximum of two significant figures and include appropriate units where applicable.

5. Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate in the original answer where the answer is continued, ie – give the page number.

6. The Formulae and Data booklet is not to be handed in with your Question/Answer booklet.

Section One: Short Response **30% (54 marks)**

This section has ten (10) questions. Answer **all** questions. Write your answers in the spaces provided.

Suggested working time: 50 minutes.

Question 1 **(5 marks)**

a) Calculate the mass of this kaon, in kilograms, if its mass was due only to its constituent quarks. (3 marks)

$\text{Expected Mass} = 4.8 + 95 = 99.8\ \text{Mev/c}^2$	1 mark
$\text{Expected Mass} = \frac{99.8 \times 1.60 \times 10^{-13}}{(3.00 \times 10^8)^2} = 1.77 \times 10^{-28}\ \text{kg}$ (must be 1.77)	1-2 mark

b) Calculate the electric charge on a Kaon meson. (2 marks)

$Q = \left(-\frac{1}{3}\right) + \left(\frac{1}{3}\right)$	1 mark
$Q = 0$	1 mark

Question 2 **(6 marks)**

a) Calculate the velocity of spaceship 'X' relative to 'Y' and 'Z'. (3 marks)

$u' = \frac{u - v}{1 - \frac{vu}{c^2}}; u = 0.800c; v = -0.700c$	
$u' = \frac{0.700c - (-0.800c)}{1 - \frac{(-0.700c)(0.800c)}{c^2}}$	1 mark
$u' = 0.962c$	1 mark
3 sf	1 mark

b) State and explain which observer or spaceship will view the length of Spaceship 'Y' as the longest **and** which will view the length as the shortest.

(3 marks)

Longest: observer on spaceship 'Z' (or 'Y'); shortest: observer on spaceship 'X'.	1 mark
Velocity of spaceship 'Z' relative to spaceship 'Y' is zero; observers on 'Z' will observe proper length of 'Y'. OR 'Y' is at rest with itself and will observe the proper length.	1 mark
Velocity of spaceship 'X' relative to spaceship 'Y' is the highest value; hence, will observe the greatest length contraction. Do not pay Earth, even if they get a value below 0.700 C for part a.	1 mark

Question 3 **(6 marks)**

Calculate 'ϴ' and, hence, the period (T) of the object's circular motion. Show all working.

$\sin\theta = \frac{1.10}{4.00}$; $\theta = 16.0°$	1 mark
$\frac{F_c}{W} = \tan 16.0°$; $\therefore F_c = 2.40 \times 9.80 \times \tan 16.0° = 6.73 \text{ N}$	1 mark
$F_c = \frac{mv^2}{r}$; $v = \sqrt{\frac{F_c r}{m}} = \sqrt{\frac{6.73 \times 1.10}{2.40}} = 1.76 \text{ ms}^{-1}$	1-2 mark
$v = \frac{2\pi r}{T}$; $T = \frac{2\pi r}{v} = \frac{2\pi \times 1.10}{1.76} = 3.93 \text{ s}$	1-2 mark

Question 4 **(5 marks)**

a) State the direction in which conventional current must be flowing in the copper tube.

(1 mark)

Out of the page or West, but not upwards	1 mark

b) Calculate the strength of the magnetic field (B) between the poles of the horseshoe magnet if a current of 1.30 A is flowing in the copper tube.

(4 marks)

$\Sigma F_{UP} = F_B - W;\ F_B = \Sigma F_{UP} + W$	1 mark
$F_B = ma + mg$ $F_B = 0.0233 \times 0.520 + 0.0233 \times 9.80 = 0.240\ N$	1 mark
$F_B = IBl; B = \frac{F_B}{Il} = \frac{0.240}{1.30 \times 0.0510} = 3.63\ T$	1-2 mark

Question 5 **(7 marks)**

An electron in an electron microscope is accelerated by an electric potential to 15.0% of the speed of light.

a) Calculate the de Broglie wavelength for this electron. As part of your answer, calculate the **relativistic** momentum of the electron at this speed.

(4 marks)

Relativistic momentum: $p = \frac{mv}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}} = \frac{9.11\times10^{-31}\times0.150\times3.00\times10^8}{\sqrt{\left(1-\frac{(0.150\times3.00\times10^8)^2}{(3.00\times10^8)^2}\right)}}$	1 mark
$p = 4.15 \times 10^{-23}\ kg\ ms^{-1}$	1 mark
De Broglie wavelength: $\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{4.15\times10^{-23}}$	1 mark
$\lambda = 1.60 \times 10^{-11}\ m$	1 mark

b) Atoms have a size that is on a scale of 10^{-10} metres. Explain how the electron beam in part a) would need to be changed to achieve maximum resolution of objects at this scale.

(3 marks)

The de Broglie wavelength of the electron beam would need to be increased in magnitude.	1 mark
Hence, the relativistic momentum of the electron beam would need to be decreased.	1 mark
This can be achieved by reducing the speed of the electron beam (by reducing the electric potential)	1 mark

Question 6 **(4 marks)**

Calculate the tension (T) in the metal strut.

Let P be pivot: $\Sigma M_c = \Sigma M_A$ (Must show where the pivot is)	1 mark
$T \times 0.320 = 55.0 \times 9.80 \times 2.30 + 25.0 \times 9.80 \times 0.350$	1-2 marks
$T = 4.14 \times 10^3$ N	1 mark

Question 7 **(4 marks)**

A particle interaction called 'electron capture' can be represented by the following incomplete equation:

$$p^+ + e^- \rightarrow n + \_\_\_\_\_$$

a) Write the name and symbol of the unidentified particle in the spaces provided below. (2 marks)

Electron neutrino	1 mark
υ_e	1 mark

b) Using relevant conservation laws, explain how you determined the unidentified particle in part a). (2 marks)

To conserve electric charge, the particle must have a neutral charge (Q = 0).	1 mark
To conserve baryon number, the particle must have a quantum number B = 0 (Must consider Baryon number); and to conserve lepton number, the particle must have a quantum number L = 1.	1 mark

Question 8 **(5 marks)**

a) The intensity of the incident electromagnetic radiation is slowly increased whilst the wavelength remains constant. Explain what happens to the current measured in the ammeter.

(2 marks)

Increasing the intensity of the incident electromagnetic radiation will increase the number of photons incident on the metal surface.	1 mark
This will increase the rate of production of photoelectrons and, hence, increase the reading on the ammeter.	1 mark

b) The intensity of the incident electromagnetic radiation is returned to its original value and its wavelength is continually increased. Explain what would be observed by the ammeter over time.

(3 marks)

Increasing the wavelength of the incident electromagnetic radiation will decrease its photon energy.	1 mark
The rate of photoelectrons released will decrease as it becomes less likely the photon has enough energy to emit an electron from the metal	1 mark
Eventually, the frequency of the incident radiation will become less than the threshold frequency and zero photoelectric current will be detected in the ammeter.	1 mark

Question 9 **(6 marks)**

a) An electron undergoes a downward transition between n = 6 and n = 4. As a result, a photon of wavelength 548 nm is emitted. Calculate the value (in eV) of energy level n = 6.

(3 marks)

$\Delta E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{548 \times 10^{-9}}$	1 mark
$\Delta E = 3.63 \times 10^{-19}\ J = \frac{3.63 \times 10^{-19}}{1.60 \times 10^{-19}}$	
$\Delta E = 2.27\ eV$	1 mark
$E_6 = E_4 + 2.27 = -4.95 + 2.27 = -2.68\ eV$	1 mark

b) If an electron of energy 5.00 eV bombards a mercury atom in ground state, calculate **all** the possible energies of the electrons after they have been scattered.

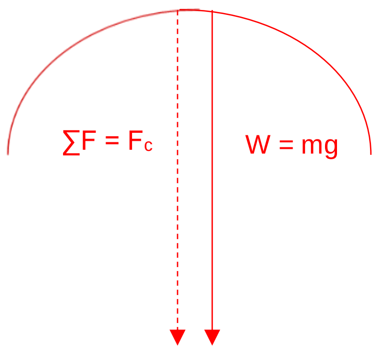
(3 marks)

$E_2 - E_1 = -5.74 - (-10.38) = 4.64\ eV$	1 mark
$E_3 - E_1 = -5.52 - (-10.38) = 4.86\ eV$	1 mark
$0.360\ eV, 0.140\ eV, 5.00\ eV$	1 mark

Question 10 **(6 marks)**

a) Explain how the airplane can create a 'weightless' environment at the top of the vertical circle. Include a diagram showing the force(s) acting on the airplane at this point, including the resultant force.

(3 marks)



Vector diagram shows two (2) vectors: net force/centripetal force ($\sum F$ or F_c) and W (or mg).	1 mark
Both vectors are the same length.	1 mark
If weight = centripetal force, normal force (N) will be equal to zero.	1 mark

b) Calculate the speed 'v' at which this airplane would need to be travelling to simulate a weightless environment at the top of the vertical circle.

(3 marks)

$\text{At top: } N = \frac{mv^2}{r} - mg; \; N = 0; \; v = \sqrt{gr}$	1 mark
$v = \sqrt{9.80 \times 4.13 \times 10^3} = 201 \text{ ms}^{-1}$	1-2 mark

END OF SECTION ONE

Section Two: Problem Solving **50% (90 marks)**

This section contains six (6) questions. Answer **all** questions. Answer the questions in the space provided.

Suggested working time is 90 minutes.

Question 11 **(16 marks)**

a) Explain why the path taken by a bobsled changes on the banked turn as its speed 'v' increases.
(3 marks)

As the velocity increases, the centripetal force required to maintain the motion increases ($F_c \propto v^2$)	1 mark
The inward force provided by the banked turn is a constant ($F = mgcos\theta$)	1 mark
Only by increasing the radius of the path, can the centripetal force be matched by the inward force of the banked turn.	1 mark

Marker's notes:
- Common mistake was not relating the answer to the forces acting on the bobsled.
- Use given information, some students talked about the angle of the bank changing – which it does not, as given in the question.

Using appropriate equipment, the officials gathered the following data.

v (kmh^{-1})	v (ms^{-1})	v^2 (m^2s^{-2})	r (m)
95	26.4	697	193
100	27.8	772	215
105	29.2	853	238
110	30.6	936	264
115	31.9	1020	285
120	33.3	1110	312

a) Complete the table by calculating the missing values in the table above. Show any calculations in the space below.
(2 marks)

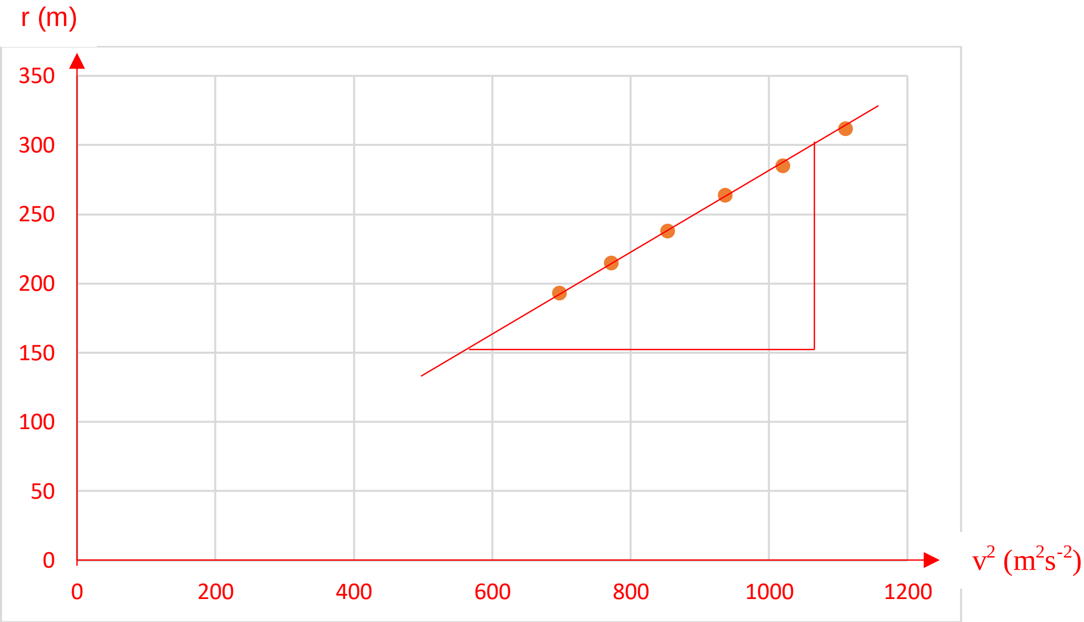
$v = 100 \text{ kmh}^{-1} = \frac{100}{3.6} = 27.8 \text{ ms}^{-1}$	1 mark
$v^2 = (27.8)^2 = 772 \text{ m}^2\text{s}^{-2}$	1 mark

Marker's notes:
- Ensure rounded value for v is **not** used to find v^2 – no penalty in this question

b) On the grid on the next page, plot a graph of 'v^2' against 'r'. Place 'r' on the y-axis. Draw a line of best fit or the data.

(4 marks)

(4 marks)



Axes correctly labelled	1 mark
Correct units (see graph above).	1 mark
Points correctly plotted with scaled axes	1 mark
Line of best fit correctly drawn.	1 mark

Marker's notes:
- Penalty of 1 mark if scale breaks were used in the graph – consistent with past WACE marking

c) Calculate the gradient of the line of best fit. Show clearly how you did this. Include units in your answer.

(4 marks)

Uses points from the line of best fit: E.g. (1070, 300) and (560, 150)	1 mark
$\text{Gradient} = \dfrac{(300 - 150)}{(1070 - 560)}$	1 mark

$\text{Gradient} = 0.29$	1 mark
Units: $s^2\,m^{-1}$	1 mark

Marker's notes:
- Points used to find gradient had to be clearly shown on line of best fit
- Paid follow through for gradient value and units if graph was plotted incorrectly

d) Use the gradient from part d) to calculate an experimental value for 'g' (acceleration due to gravity on the Earth's surface).

(3 marks)

$\tan\theta = \frac{v^2}{gr}; r = \frac{1}{g \times \tan\theta} \times v^2$	1 mark
$\text{Gradient} = 0.29 = \frac{1}{g \times \tan 20.0°}$	1 mark
$g = \frac{1}{0.29 \times \tan 20.0°} = 9.47\ ms^{-2}$	1 mark

Marker's notes:
- Only 1 mark paid if $F_c = \frac{mv^2}{r}$ used

Question 12 **(18 marks)**

a) Explain how the current in the circuit can be measured by the clamp meter.

(4 marks)

The AC current in the conductor creates an alternating magnetic field.	1 mark
Which is directed by the iron clamp into secondary coil	1 mark
Hence, an alternating emf is induced in the coil	1 mark
Which drives a current/signal to the meter	1 mark

Marker's notes:
- For first point, also accepted "changing electric field causes changing magnetic field"
- Common mistake was considering that the meter was reading with its own emf source instead of the induced emf – ensure the diagram is used to explain

b) Calculate the peak current (I_{PEAK}) in the conductor.

(2 marks)

$I_{PEAK} = \pm\sqrt{2} \times 5.00$	1 mark
$I_{PEAK} = \pm 7.07\ A$ (accept a positive value only)	1 mark

c) Calculate the maximum magnitude of the magnetic field strength at the distance where the clamp is positioned.

(2 marks)

$B = \frac{\mu_0}{2\pi}\frac{I}{r} = \frac{4\pi \times 10^{-7} \times 7.07}{2\pi \times 0.0110}$	1 mark
$B = 1.29 \times 10^{-4}\ T$	1 mark

d) Calculate the maximum **change** in flux by the coil if its cross-sectional area is 4.00 cm^2. [If you were unable to calculate an answer for part c), use a value of 1.30 x 10^{-4} T]

(4 marks)

$\Delta B_{MAX} = 1.29 \times 10^{-4} - (-1.29 \times 10^{-4})$	1 mark
$\Delta B_{MAX} = 2.58 \times 10^{-4}\ T$	1 mark
$\therefore \Delta\phi_{MAX} = BA = 2.58 \times 10^{-4} \times 4.00 \times 10^{-4}$	1 mark
$\Delta\phi_{MAX} = 1.03 \times 10^{-9}\ Wb$	1 mark

Marker's notes:

- Maximum change in flux is from B_{max} to - B_{max} - not 0 to B_{max}

e) Hence, calculate the average EMF (Ɛ) generated in the secondary coil during the maximum change in flux if it consists of 250 turns.

(3 marks)

$\Delta\phi_{MAX}$ occurs over half a cycle: $t = \frac{T}{2} = \frac{1/50}{2} = 1.00 \times 10^{-2}\ s$	1 mark
$\varepsilon = -N\frac{\Delta\phi_{MAX}}{t} = 250 \times \frac{1.03 \times 10^{-7}}{1.00 \times 10^{-2}}$	1 mark
$\varepsilon = 2.58 \times 10^{-3}\ V$	1 mark

Marker's notes:

- Can't use 4BANf as the average is only over half a rotation, not a full rotation

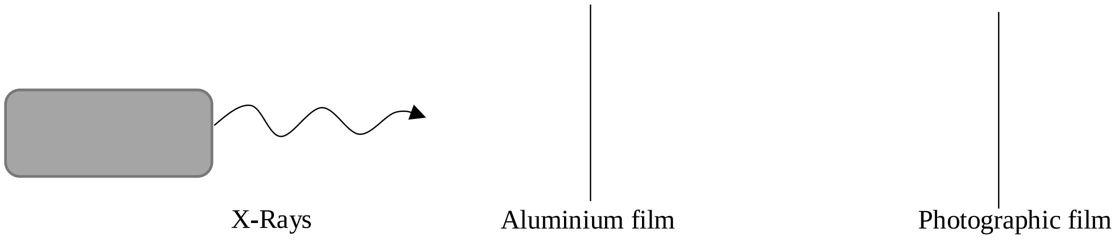
f) Would this particular type of circuit clamp work for a DC circuit? Explain.

(3 marks)

No.	1 mark
A DC power supply would not create a change in flux through the iron clamp.	1 mark
Hence, no change in flux will occur through the secondary coil and zero EMF/current will be induced.	1 mark

Question 13 **(13 marks)**

A beam of X-rays of wavelength 2.50 x10^{-10} m is directed onto a thin aluminium foil as shown in the diagram below. The X-rays scatter from the foil and strike the photographic flim.



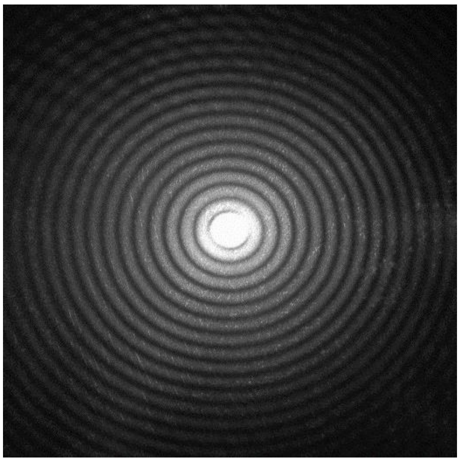
a) Calculate the energy, in keV of these X-rays.

(4 marks)

Description	Total
E = hf, f = c / λ, E = hc / λ	1
$= \frac{6.63 \times 10^{-34}(3.00 \times 10^{8})}{2.50 \times 10^{-10}}$	1
Converts to J = 7.96 x10^{-16} ÷ (1.60 x10^{-19})	1
Converts to keV = 4.97 keV	1
Total	**4**

_______________ keV

After the X-rays pass through the foil, a pattern is formed as shown in the diagram below. In further experiments, the source was replaced with a beam of energetic electrons. Again, a similar pattern was observed.



b) Explain how electrons and X-rays produce these patterns.

(4 marks)

Description	Total
Electrons/matter and X-rays have a wave behavior	1
X-rays and electron waves diffract **around the aluminium atoms/through gaps in the film**	1
The waves can be in phase (constructive) producing light bands on the film	1
or out of phase (destructive) on the film, producing dark bands	1
Total	**4**

c) Assuming the diffraction patterns have identical fringe spacing, (i.e. the wavelength of the electrons is the same as the X-ray photons) calculate the momentum of the electron beam.

(3 marks)

Description	Total
$p = h / \lambda$	1
$= \frac{6.63 \times 10^{-34}}{2.50 \times 10^{-10}} = 2.65 \times 10^{-24}$ kg m s^{-1}	1
Total	**2**

d) The voltage that accelerates the electron beam is gradually increased, providing a higher electrical potential to the electrons. Explain how the wavelength of the electrons are impacted.

(3 marks)

Description	Total
Increasing the voltage results in higher electron energy/velocity	1
Faster electrons have more momentum	1
Larger momentum will decrease the wavelength of the electrons $\lambda \propto \frac{1}{mv}$	1
Common mistake was to use $E = hf$ but as this formula is exclusive to electromagnetic waves, not physical matter, it can't be used in establishing a relationship between energy and wavelength of electrons.	
Total	**3**

Question 14 **(13 marks)**

a) Calculate the horizontal component (u_h) of the athlete's launch velocity 'v'.

(2 marks)

$v = \frac{s}{t};\ u_h = \frac{6.85}{0.847}$	1 mark
$u_h = 8.09\ ms^{-1}$	1 mark

b) Using the vertical displacements shown, calculate the vertical component (u_v) of the athlete's launch velocity 'v'.

(4 marks)

$s = ut + \frac{1}{2}at^2; s =$	1 mark
$s = -(1.05 - 0.42) = -0.630\ m$ $-0.63 = u_v \times 0.847 - \frac{1}{2} \times (-9.8) \times 0.847^2$ (careful of direction!)	1-2 mark
$u_v = 3.41\ ms^{-1}$	1 mark

c) Hence, calculate the magnitude of the launch velocity 'v' and the launch angle 'ϴ'. [If you were unable to calculate answers for parts a) and b), use values of 8.00 ms^{-1} and 3.40 ms^{-1} respectively]

(4 marks)

$v^2 = 8.09^2 + 3.41^2$	1 mark
$v = \sqrt{77.1} = 8.78\ ms^{-1}\ \ (8.69\ ms^{-1}\ \text{OR}\ 8.70\ ms^{-1})$	1 mark
$\tan\theta = \frac{3.41}{8.09}$	1 mark
$\theta = 22.9°\ \ (23.0°\ \text{OR}\ 23.1°)$	1 mark

d) Argue how the high altitude of Mexico City could have contributed to a world record in the long jump event.

(3 marks)

At higher altitudes, the gravitational field strength is smaller	OR	Air is thinner at high altitudes, reducing air resistance	1 mark
Lower acceleration down would allow for an increase flight time		Less resistance to motion allows for a higher average horizontal velocity	1 mark
More time in air allows for a larger horizontal displacement		Giving more horizontal displacement for the time spent in air	1 mark

Question 15 **(17 marks)**

a) Each H-2$^+$ ion achieves a speed of 6.19 x 10^5 ms^{-1}. Calculate the magnitude of the accelerating potential (in Volts). The mass of a H-2$^+$ ion is 3.34 x 10^{-27} kg.

(4 marks)

$\Delta E_K = \frac{1}{2}mv^2 = \frac{1}{2} \times 3.34 \times 10^{-27} \times (6.19 \times 10^5)^2 = 6.40 \times 10^{-16}$ J	1-2 mark
$\Delta E_K = Vq;\ V = \frac{\Delta E_K}{q} = \frac{6.40 \times 10^{-16}}{1.60 \times 10^{-19}} = 4.00 \times 10^3$ V	1-2 mark

b) In Stage 2 (Velocity Selection), the effects of an electric field and a magnetic field combine to ensure the velocity of the H-2$^+$ ions are constant and in a straight line.

(i) Using the diagram as a guide, state the direction of the magnetic field of the STAGE 2 velocity selector by circling the correct option.

(1 mark)

INTO THE PAGE.	1 mark

(ii) Derive an expression showing the relationship between the electric field strength 'E'; the magnetic field strength 'B', and the speed of the H-2$^+$ ions 'v'.

(2 marks)

In STAGE 2, $F_B = F_E$; $Bvq = Eq$	1 mark
$\therefore E = vB$	1 mark

c) (i) Based on the diagram, state the direction of the magnetic field in the chamber.

(1 mark)

Out of the page.	1 mark

(ii) Explain why the chamber is filled with a vacuum. As part of your answer, describe how the path of the beam of H-2^+ ions would change if the chamber was filled with a low-pressure gas.

(3 marks)

If the chamber was filled with a low-pressure gas, the H-2^+ ions would collide with these atoms reducing their E_K and speed 'v'.	1 mark
The radius 'r' of the circular path taken by the ions is given by: $r = \frac{mv}{Bq}$, so, if 'v' decreases, 'r' decreases and a spiral path will result.	1 mark
Therefore, a vacuum ensures a constant speed 'v' and radius 'r'.	1 mark

d) Use the appropriate formulae in your data booklet to derive the following expression for the frequency 'f' of the charged particle's rotation in the field:

$$v = \frac{2\pi r}{T}$$

to show that the following expression can be derived for the frequency 'f' of the charged particle's rotation in the field:

$$f = \frac{Bq}{2\pi m}$$

where B = magnetic field strength (T);
q = electric charge on the particle (C); and
m = mass of the particle (kg).

(4 marks)

$r = \frac{mv}{Bq}; v = \frac{2\pi r}{T}; f = \frac{1}{T}; \therefore v = 2\pi rf$	1 mark
$\therefore r = \frac{m2\pi rf}{Bq}$	1 mark
$1 = \frac{m2\pi f}{Bq}$	1 mark
$f = \frac{Bq}{2\pi m}$	1 mark

e) Hence, calculate the frequency of circular rotation of the H-2^+ ions if the magnetic field strength in the vacuum chamber is 1.20 T.

(2 marks)

$f = \frac{Bq}{2\pi m}$	
$f = \frac{1.20 \times 1.60 \times 10^{-19}}{2\pi \times 3.34 \times 10^{-27}}$	1 mark
$f = 9.15 \times 10^{6}$ Hz	1 mark

Question 16 **(13 marks)**

a) Calculate the transmission current in the line between the AC generator and the substation.

(2 marks)

$P_T = V_T I_T;\ I_T = \frac{P_T}{V_T} = \frac{35.0 \times 10^6}{66.0 \times 10^3}$	1 mark
$I_T = 5.30 \times 10^2\ A$	1 mark

b) Hence, calculate the power lost in the transmission line between the AC generator and the substation.

(2 marks)

$P_{lost} = {I_T}^2 R = (5.30 \times 10^2)^2 \times 5.50$	1 mark
$I_T = 1.54 \times 10^6\ W$	1 mark

c) Calculate the electric power generated at the AC generator.

(2 marks)

$P_{generator} = P_{transformer} + P_{lost}\ 1.54 \times 10^6 + 35.0 \times 10^6$	1 mark
$P_{generator} = 3.65 \times 10^7\ W$	1 mark

d) Determine the voltage at which electric power is generated at the AC generator.

(2 marks)

$V_{generator} = 5.30 \times 10^2 \times 5.50 + 66.0 \times 10^3$ (OR $V_{gen} = \frac{3.65 \times 10^7}{5.50}$)	1 mark
$V_{generator} = 6.89 \times 10^4\ V$	1 mark

e) Calculate the ideal turns ratio in the transformer at the substation.

(2 marks)

$\text{Ideal turns ratio} = \frac{V_P}{V_S} = \frac{66.0 \times 10^3}{240}$	1 mark
$\text{Ideal turns ratio} = 275:1$	1 mark

f) If all other factors were kept equal, would an increase in AC frequency from 50 Hz to 60 Hz increase or decrease the power loss in a transformer due to eddy currents? Explain.

(3 marks)

Increasing the AC power frequency will also increase the rate of change of flux due to the alternating currents in the transformer coils.	1 mark
Increasing the rate of change of flux will increase the size of the eddy currents generated in the iron cores.	1 mark
Hence, as the eddy currents increase, there is more resistive heating and therefore more power loss.	1 mark
Common mistake: Using $\varepsilon\_\max = 2\pi BANf$ to justify an increase in voltage. This is for the generator output – not induced emf inside the transformer core.	

END OF SECTION TWO

Section Three: Comprehension **20% (36 marks)**

This section has two (2) questions. Answer **both** questions. Answer the questions in the spaces provided.

Suggested working time: 40 minutes.

Question 17 **(18 marks)**

a) Using information from the article - and data from your Formulae and Data Booklet – calculate the centripetal force acting on the James Webb Telescope while it is in orbit at L2 La Grange Point. [Note, the distance between the Earth's centre of mass and L2 is 1.5 million kilometres].

(3 marks)

$F_{EARTH} = \frac{Gm_1m_2}{r^2} = \frac{6.67 \times 10^{-11} \times 6200 \times 5.97 \times 10^{24}}{(1.5 \times 10^9)^2} = 1.10\ N$	1 mark
$F_{SUN} = \frac{Gm_1m_2}{r^2} = \frac{6.67 \times 10^{-11} \times 6200 \times 1.99 \times 10^{30}}{(1.50 \times 10^{11} + 1.5 \times 10^9)^2} = 35.9\ N$	1 mark
$\Sigma F_G = F_C = 1.10 + 35.9 = 37.0\ N$	1 mark

b) (i) State the orbital period (T) of the James Webb Telescope around the Sun in seconds.

(2 marks)

$T = 365 \times 24 \times 3600$	1 mark
$T = 3.15 \times 10^7\ s$	1 mark

Paid 1 mark if calculated using Kepler's law

(ii) Hence (or otherwise) calculate the average orbital speed of the James Webb Telescope around the Sun.

(3 marks)

$v = \frac{2\pi r}{T}$	1 mark
$v = \frac{2\pi \times 1.52 \times 10^{11}}{3.15 \times 10^7}$	1 mark
$v = 3.03 \times 10^4\ ms^{-1}$	1 mark
OR	
$F_c = \frac{mv^2}{r}; v = \sqrt{\frac{F_c r}{m}}$	1 mark
$v = \sqrt{\frac{37.0 \times 1.52 \times 10^{11}}{6200}}$	1 mark

$v = 3.01 \times 10^4\ ms^{-1}$	1 mark

c) The James Webb Telescope is tuned to infrared radiation that is emitted by extremely distant luminous objects (eg – galaxies). To be able to detect this faint IR radiation, the telescope needs to be cooled to a very low operating temperature of 50 K. Suggest a reason for this.

(3 marks)

The infrared radiation from different galaxies will be very low intensity.	1 mark
At greater than 50 K, the JWT will emit black body radiation in the infrared region. This will overwhelm the faint incoming infrared signals from distant objects.	1 mark
By cooling the JWT to 50 K or less, the JWT will emit less IR and not interfere with the faint incoming infrared signals.	1 mark

d) The James Webb Telescope's four instruments collect radiation in the 0.5 to 28 micron range. Calculate the corresponding frequency range for these instruments.

(2 marks)

$f_{range} = \frac{3.00 \times 10^8}{28 \times 10^{-6}}$ to $\frac{3.00 \times 10^8}{0.5 \times 10^{-6}}$	1 mark
$f_{range} = 1.1 \times 10^{13}$ Hz to 6.0×10^{14} Hz	1 mark

e) Explain why conducting astronomy in the infrared region of the electromagnetic spectrum will allow the James Webb telescope to view the first stars in the universe. Your answer should refer to principles of redshift.

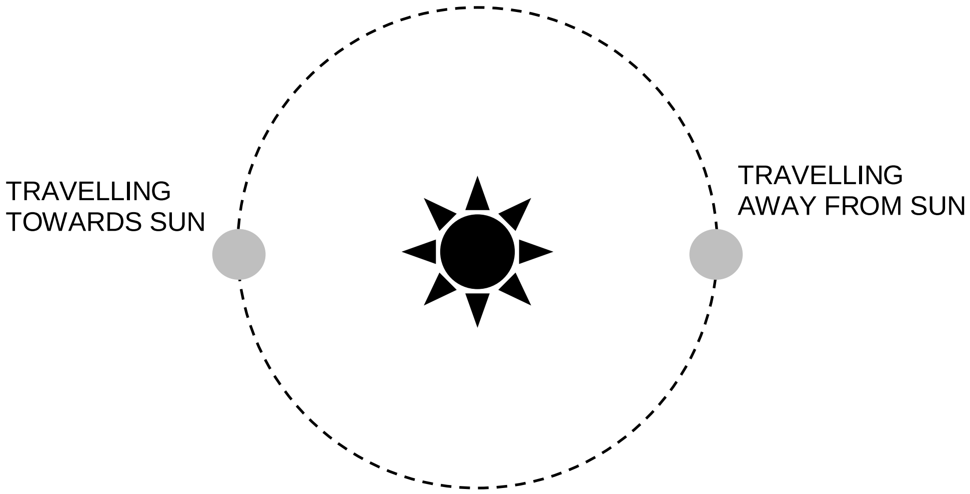
(5 marks)

The universe is expanding.	1 mark
The wavelength of the light emitted in the past is redshifted – caused by the wavelength being stretched by the expansion	1-2 mark
Looking at IR spectrum in deep space is looking at light produced 100-250 million years after the big bang.	1 mark
This has the potential to reveal information about first stars/early universe/early planets etc.	1 mark

Question 18 **(18 marks)**

a) In their famous experiment, Michelson and Morley used the rotation of the Earth on its axis and its revolution around the Sun to measure the speed of sunlight. They took measurements of the speed of sunlight six (6) months part.

One measurement was taken when the observers were travelling AWAY from the Sun. The next measurement was taken so that they were travelling TOWARDS the Sun (see below).



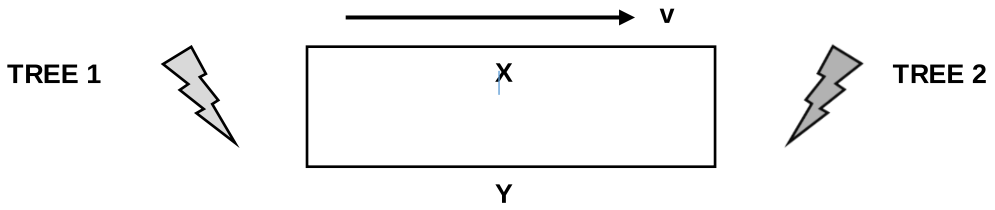
In accordance with Newton's Laws, Michelson and Morley incorrectly hypothesised that the speed of light should be measured to be different values at these two locations. State their hypothesis and explain why they made this prediction.

Travelling towards the Sun: SPEED OF LIGHT > c	1 mark
Travelling away from the Sun: SPEED OF LIGHT < c	1 mark
According to Newtonian Physics, all velocities (including the speed of light) are relative.	1 mark
TOWARDS SUN: speed of light = c + v_{EARTH}; AWAY FROM SUN: speed of light = c - v_{EARTH}	1 mark

b) In his famous train experiment, Einstein imagined a train travelling at speed ‘v’ that was a significant proportion of the speed of light ‘c’. At particular instant of time, the train was situated equidistant between two trees – an observer (X) on the moving train was also positioned at the midpoint between the two trees (see below).

Another observer (Y) is standing in a stationary position on the side of the tracks directly opposite the train. At the same instant, this stationary observer is standing directly opposite the observer in the train and is also equidistant between the two trees (see below).

At this instant in time, the stationary observer sees two bolts of lightning strike the two trees at exactly the same time.



State the order in which the observer on the train (X) sees the lightning bolts. Explain your answer.

(3 marks)

Observer ‘X’ sees TREE 2 first; TREE 1 second.	1 mark
Light travels form both lightning bolts towards observer ‘X’ at the same speed ‘c’.	1 mark
Observer ‘X’ is travelling towards TREE 2 so the light from this tree reaches him before that of TREE 1.	1 mark

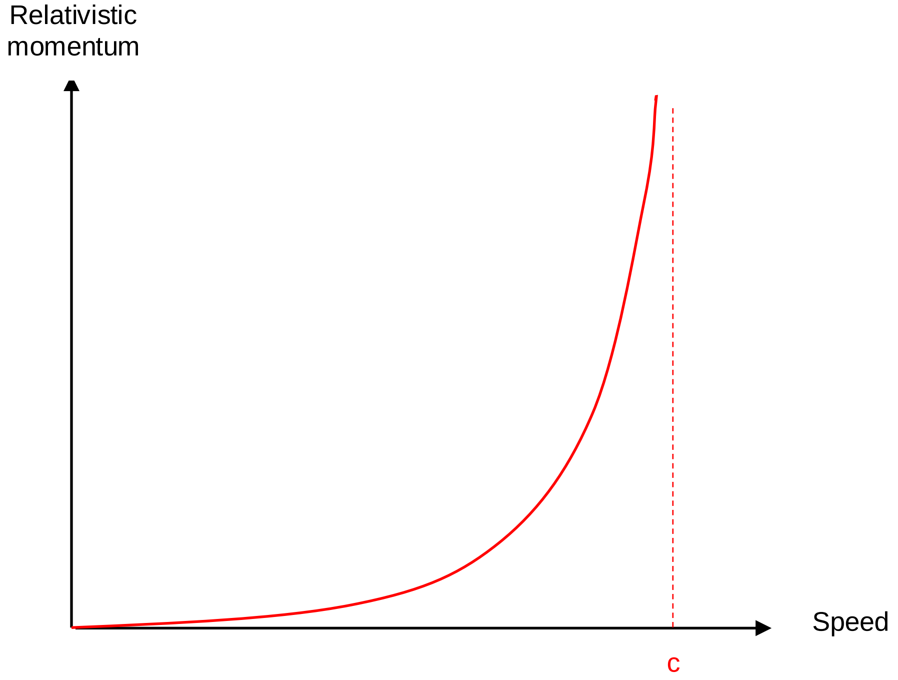
c) (i) Using appropriate formulae from your Data Booklet, explain why objects cannot travel at the speed of light, ‘c’.

(3 marks)

Relativistic energy of an object is given by: $$E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$	1 mark
Hence, as v $\rightarrow \infty$, E$\rightarrow \infty$	1 mark
To reach ‘c’, the energy required would become infinitely large.	1 mark

(ii) On the axes below, sketch a graph showing how the relativistic momentum of an object changes as its speed approaches 'c'.

(3 marks)



Asymptote going to infinity	1 mark
Asymptote labelled with c	1 mark
Starts at 0,0 and slopes upwards	1 mark

d) The following questions relate to the examples of time dilation mentioned in the article. Consider only the effects of **special** relativity

(i) A spaceship travels from Earth to a distant galaxy at 99.5% of the speed of light. The astronaut ages 5.00 years by the time they arrive. Calculate the duration of the astronaut's journey from Earth's reference frame.

(2 marks)

$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}} = \frac{5}{\sqrt{(1 - 0.995^2)}}$	1 mark
$t = 50.1 \text{ years}$	1 mark

(ii) Calculate the average orbital speed of a GPS satellite if it ticks seven (7) microseconds longer in the course of one day than a stationary clock on earth.

(3 marks)

$t_0 = 24 \times 60 \times 60 = 86400\ s; t = 86400.000007\ s$	1 mark
$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$ $86400.000007 = \frac{86400}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$	1 mark
$v = 3819\ ms^{-1}$	1 mark

Paid 2 marks if used time $t_0 = 1$ day and arriving at an answer of 1.12×10^6 (wrong units though)

END OF EXAMINATION