Kennedy
Baptist College

Semester 2 examination, 2023
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	11	11	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 12 Information Handbook 2023*. 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 eleven (11) questions. Answer **all** questions. Write your answers in the spaces provided.

Suggested working time: 50 minutes.

Question 1   **(6 marks)**

a)   Compete the missing value for 'n' on the energy level diagram.

(1)

n = ∞	1 mark

b)   Use the information in the question to calculate the energy value (in eV) for n = 3. Show working.

(5)

$E_3 - E_1 = \dfrac{hc}{\lambda} = \dfrac{6.63 \times 10^{-34} \times 3.00 \times 10^8}{589.6 \times 10^{-9}} = 3.37 \times 10^{-19}$ J	1-2 marks
$= 2.11$ eV	1 mark
$\therefore 2.11 = E_3 - (-5.14); \; E_3 = 2.11 - 5.14$	1 mark
$E_3 = -3.03$ eV (accept 3.03 eV)	1 mark

Question 2   **(3 marks)**

The diagram below shows two negatively charged particles. Particle X has a charge 3 times that of particle Y. On the diagram draw field lines to represent the electric field associated with the two particles.
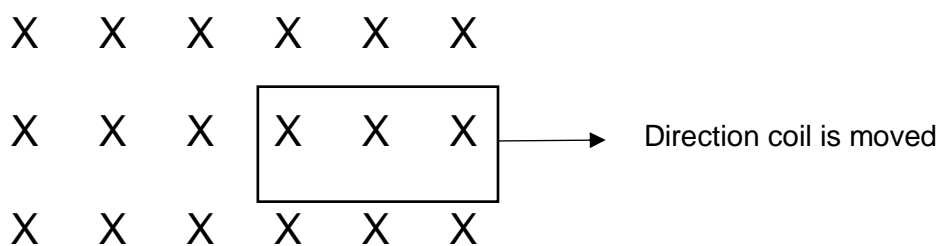
X
- 3

Y
- 1

Shape of field with neutral point closer to Y	1 mark
Direction of field	1 mark
More dense field lines near X than Y	1 mark

Question 3   **(4 marks)**

A coil is withdrawn from the magnetic field as shown in the diagram below.

X   X   X   X   X   X

X   X   X   X   X   X   ⟶   Direction coil is moved

X   X   X   X   X   X

A current is observed flowing in the coil.

a)   State the direction of current as viewed. Draw an arrow on diagram.   (1)
        clockwise

b)   Explain, referring to the Physics principles, why a current will flow and why in this direction.   (3)

The coil experiences a change in flux as it is pulled out inducing an emf in the coil and so a current flows according to Faraday's Law $$Emf = N\frac{\Delta\emptyset}{\Delta t}$$	1 mark
The direction of the current will be in a direction so its flux will oppose the change in flux that induced it.	1 mark
Shrinking B, therefore an increasing B into page induced,this is Lenz's law	1 mark

Question 2   **(7 marks)**

a)   Use the appropriate formulae from the Formula and Data Booklet, to derive the expression below
      relating the rotational period (T) of an object on the liquid's surface; its radius of rotation (r); and
      the centripetal force (F_c) acting on that object.

$$F_c = \frac{4m\pi^2 r}{T^2}$$

(2)

|	
$F_c = \frac{mv^2}{r} ; v = \frac{2\pi r}{T} ; F_c = \frac{m\left(\frac{2\pi r}{T}\right)^2}{r}$	1 mark
$\therefore F_c = \frac{4m\pi^2 r}{T^2}$	1 mark

b)   Compare the centripetal forces acting on the objects at 'X' and 'Y'. Justify your answer using the
      expression in part a).

(2)

$T_X = T_Y; \; r_X < r_Y$	1 mark
$\therefore F_c$ at $X < F_c$ at Y	1 mark

(c)   On each diagram below, draw a free body diagram showing vectors for: (i) the weight force (W);
      (ii) the buoyancy force (B); and (iii) the net force (F_c) acting on each of two objects floating at
      points 'X' and 'Y'.

(3)
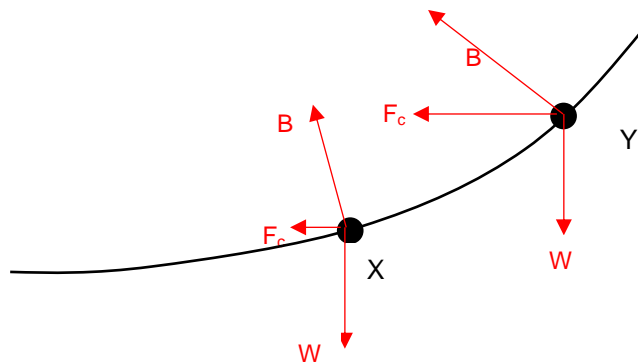
The weight force (W) vectors at 'X' and 'Y' are equal in magnitude, act vertically downward.	1 mark
The net force (F_c) vector at 'X' is smaller than that at 'Y'; act horizontally.	1 mark
The buoyancy force (B) vector at 'X' is smaller than that at 'Y'; acts at a greater angle to the horizontal than at 'Y'.	1 mark

QUESTION 3   **(6 marks)**

a)   Explain why this observation appears to contradict Big Bang Theory.

(3)

Big Bang Theory states that the Universe is expanding.	1 mark
One piece of evidence for Big Bang Theory is that most galaxies outside of our own are redshifted which indicates they are travelling away from the earth.	1 mark
A blue shifted object is travelling towards us – thus contradicting this theory.	1 mark

b)   Calculate an object's distance from the Earth (in light years) when its recessional velocity is equal to 1.03×10^6 ms^{-1}.

(3)

$v = H_o d; d = \dfrac{v}{H_o} = \dfrac{1.03 \times 10^3}{73.8}$	1 mark
$\therefore d = 14.0 \text{ Mpc} = 14.0 \times 3.26 \times 10^6$	1 mark
$d = 4.56 \times 10^7 \text{ ly}$	1 mark

QUESTION 4   **(5 marks)**

Calculate the work function (in eV) for sodium metal.

$E_K = hf - \emptyset = \dfrac{hc}{\lambda} - \phi$	1 mark
$1/2 \times 9.11 \times 10^{-31} \times (3.88 \times 10^5)^2 = \dfrac{6.63 \times 10^{-34} \times 3.00 \times 10^8}{391 \times 10^{-9}} - \phi$	1 mark
$\therefore \phi = 5.09 \times 10^{-19} - 6.86 \times 10^{-20}$	1 mark
$\phi = \dfrac{4.40 \times 10^{-19}}{1.60 \times 10^{-19}}$	1 mark
$= 2.75 \text{ eV}$	1 mark

QUESTION 5   **(4 marks)**

An electron is travelling with a speed of 0.990c. Calculate the kinetic energy of this electron (in Joules).

$E_T = E_K + E_{rest}; \therefore E_K = E_T - E_{rest} = \dfrac{mc^2}{\sqrt{1 - \dfrac{v^2}{c^2}}} - mc^2$	1 mark
$E_K = \dfrac{9.11 \times 10^{-31} \times (3.00 \times 10^8)^2}{\sqrt{1 - (0.990)^2}} - 9.11 \times 10^{-31} \times (3.00 \times 10^8)^2$	1-2 marks
$\therefore E_K = 4.99 \times 10^{-13} \text{ J}$	1 mark

QUESTION 6   **(4 marks)**

a)   On Figure 2, draw five (5) arrows to indicate the direction of the external magnetic field in the region of the conductor.

(1)

Five (5) arrows drawn to the right.	1 mark

b)   Using the information provided, calculate the magnitude of the external magnetic field utilised in this experiment.

(3)

$\Sigma T = 0$; $\Sigma T_C = \Sigma T_A$; $mg \times 0.150 = IBl \times 0.150$	1 mark
$0.050 \times 9.80 = 4.45 \times B \times 0.200$	1 mark
$\therefore B = 0.551$ T	1 mark
OR	
$\Sigma F_V = 0$; $mg = BIl$	1 mark
$0.050 \times 9.80 = 4.45 \times B \times 0.200$	1 mark
$\therefore B = 0.551$ T	1 mark

QUESTION 7   **(4 marks)**

How does the speed at which the protons travel as they pass through the two narrow slits compare to that of the electrons? Explain your answer. Include any relevant formulae as part of your answer.

The internodal distance between successive maxima (bright spots) is determined by the de Broglie wavelengths of the electrons and protons.	1 mark
For the interference patterns formed by the electron and proton beams to be the same, internodal distances and, therefore, their de Broglie wavelengths must be equal.	1 mark
$\lambda = \dfrac{h}{p} = \dfrac{h}{mv}$	1 mark
$m_{proton} > m_{electron}$; $\therefore v_{proton} < v_{electron}$	1 mark

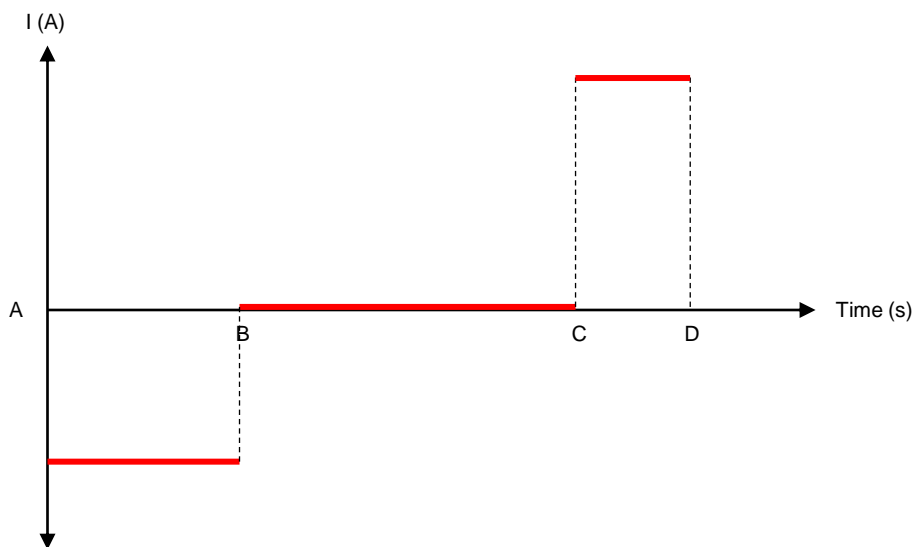## QUESTION 8   (5 marks)

In which direction will the satellite accelerate? Answer this by calculating the ratio between the gravitational forces acting on the satellite due to Jupiter and Ganymede respectively.

$F_J = \dfrac{6.67 \times 10^{-11} \times 1.90 \times 10^{27} \times 2000}{(0.750 \times 628 \times 10^6 \times 10^3)^2} = 1.14 \times 10^{-3} \text{ N}$	1 mark
$F_G = \dfrac{6.67 \times 10^{-11} \times 1.48 \times 10^{23} \times 2000}{(0.250 \times 628 \times 10^6 \times 10^3)^2} = 8.01 \times 10^{-7} \text{ N}$	1 mark
$\dfrac{F_J}{F_G} = \dfrac{1.14 \times 10^{-3}}{8.01 \times 10^{-7}}$	1 mark
$= 1.42 \times 10^3 : 1$	1 mark
Object accelerates towards Jupiter.	1 mark

QUESTION 9   (4 marks)

On the set of axes below, sketch a graph of the current induced in the resistor during the time intervals indicated (ie – A, B, C and D).

Each section is linear.	1 mark
Section BC: $I_{BC} = 0$	1 mark
Section $I_{AB} < 0$; $I_{CD} > 0$	1 mark
Magnitude: $I_{CD} > I_{AB}$	1 mark

QUESTION 10 (5 marks)

a) Calculate the velocity of the missile relative to the observer on Earth.

(4)

Uses consistent sign convention	$v = 0.700c;\ u' = -0.400c$	1 mark
Correctly identifies frame of reference and formula	$u = \dfrac{v + u'}{1 + \dfrac{vu'}{c^2}}$	1 mark
Enters correct data and directions in formula	$u = \dfrac{0.700c + (-0.400c)}{1 + (0.700)(-0.400)}$	1 mark
Correct answer	$u = 0.417c$	1 mark

b) In your own words, describe the direction of the missile's motion as viewed by the observer on Earth.

(1)

The observer will observe the missile travelling in the same direction as the rocket (ie – to the left).	1 mark

QUESTION 11 (4 marks)

a) Will the output voltage be less than or greater than 240 V. Explain.

(2)

Greater than 240 V.	1 mark
This is a step-up transformer; $N_S > N_P$.	1 mark

b) Explain the role of the iron core.

(2)

The iron core increases the efficiency of the transformer.	1 mark
Being a ferromagnetic material, it increases the magnetic flux linkage between the primary and secondary coil.	1 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 12   **(14 marks)**

a)   Calculate the size of the force exerted by the breeze on the chair.

(4)

$\Sigma M = 0$ around the hinge/pivot: $\Sigma M_c = \Sigma M_A$;	1 mark
$2.25 \times 9.80 \times \dfrac{0.440}{2}$ $= F_W \times 0.390 \times \sin 70.5° + 1.55 \times 9.80 \times \dfrac{0.390}{2}$ $\times \sin 19.5°$	1 mark
$F_W = \dfrac{4.85 - 0.989}{0.368}$	1 mark
$F_W = 10.5$ N	1 mark

b)   Hence, calculate the magnitude and direction of the force (to the horizontal) exerted by the ground on the hinge/pivot of the seat. [If you were unable to calculate an answer for part a), use a value of 10.6 N]

(5 marks)

$\Sigma F = 0$; $\Sigma F_{UP} = \Sigma F_{DOWN}$; $F_P = 2.25 \times 9.80 + 1.55 \times 9.80$; $\therefore F_P$ $= 37.2$ N upwards	1 mark
$\therefore \Sigma F_{LEFT} = \Sigma F_{RIGHT}$; $\therefore F_P = 10.5$ N right (10.6 N)	1 mark
$(F_P)^2 = 37.2^2 + 10.5^2$; $\therefore F_P = 38.7$ N (38.7 N)	1 mark
$\tan\theta = \dfrac{37.2}{10.5}$; $\theta = \tan^{-1}(3.54) = 74.2°$ (74.1°)	1-2 marks

c)   Show, via a calculation, that the seat will not tip over regardless of the angle 'θ'.

(5)

As seat tips over, $\Sigma M = 0$.	1 mark
$\Sigma M_C = \Sigma M_{A;}$ $1.55 \times 9.80 \times \dfrac{0.390}{2} \times \sin\theta = 2.25 \times 9.80 \times \dfrac{0.440}{2}$	1 mark
$\sin\theta = \dfrac{4.85}{2.96} = 1.64$	1 mark
$\sin^{-1}(1.64) =$ undefined	1 mark
Hence, no matter the size of 'θ', the anticlockwise moment due to the weight of the back rest will never exceed the clockwise moment due to the weight of the seat.	1 mark

Allow for up to 2 marks total if students CAN'T perform a calculation but give a reasonable explanation as follows:

As the back rest approaches a horizontal flat position, the lever arm for the weight of the back rest approaches a maximum value; hence, total anticlockwise torque acting on the chair approaches a maximum value.	1 mark
The total anticlockwise torque, however, never exceeds the total clockwise torque; hence, chair never tips over.	1 mark

Question 13   (18 marks)

a)   Calculate the vertical component of the rubber ball's speed when it lands on the **middle** step.

(3)

$u_v = 0 \text{ ms}^{-1}$; $a = 9.80 \text{ ms}^{-2}$; $s = 0.30$ m; $v^2 = u^2 + 2as$	1 mark
$v^2 = 0^2 + 2 \times 9.80 \times 0.30 = 5.88$	1 mark
$v = 2.42 \text{ ms}^{-1}$	1 mark

b)   Hence, show that the landing velocity of the rubber ball when it bounces on the **middle** step is approximately 3.5 ms^{-1}, and it is at an angle of approximately 45° to the horizontal.

(4)

$v^2 = 2.42^2 + 2.50^2 = 12.1$	1 mark
$v = 3.48 \text{ ms}^{-1}$ (3.43 ms^{-1})	1 mark
$\tan\theta = \dfrac{2.42}{2.50} = 0.968$	1 mark
$\theta = \tan^{-1}(0.968) = 44.1°$ ($43.2°$)	1 mark

c)   Calculate the distance 'x'.

(4)

$u_v = 0 \text{ ms}^{-1}; a = 9.80 \text{ ms}^{-2}; v = 2.42 \text{ ms}^{-1}; v = u + at$	
$2.42 = 0 + 9.80t$	1 mark
$t = \dfrac{2.42}{9.80} = 0.247 \text{ s}$	1 mark
$x = u_h t = 2.50 \times 0.247$	1 mark
$x = 0.617 \text{ m}$	1 mark

d)   Show with a calculation that the time taken by the rubber ball to reach the top of the cup from the **middle** step is about 0.6 s.

(4)

$s_v = 0.300 - 0.0850 = 0.215 \text{ m}; u_v = -2.42 \text{ ms}^{-1} (2.35 \text{ ms}^{-1});$ $a = 9.80 \text{ ms}^{-2}$	1 mark
$s = ut + {}^1\!/_2\, at^2; 0.215 = -2.42t + 4.90t^2; 4.90t^2 - 2.42t - 0.215 = 0$	1 mark
$t = \dfrac{2.42 + \sqrt{5.86 - 4 \times 4.90 \times -0.215}}{9.80}$	1 mark
$t = 0.571 \text{ s}$	1 mark

e)   Hence, calculate the distance 'y'. It can be assumed that the rubber ball enters the middle of the top of the cup.

(3)

$s_h = u_h t = 2.50 \times 0.571$	1 mark
$s_h = 1.43 \text{ m}$	1 mark
$y = 1.43 - (0.750 - 0.617) = 1.30 \text{ m}$	1 mark

Question 14 (17 marks)

a) Explain how the pattern (ie – the bright and dark fringes) is formed on the screen. Name the phenomenon involved and why this is confirmation of the wave nature of light.

(3)

|	
As the light passes through the double slits, it is diffracted through each slit.	1 mark
Between the double slits and the screen, the diffracted light waves will superposition and interfere.	1 mark
The maxima are points of constructive interference; the minima are points of destructive interference – these confirm wave properties of light.	1 mark

b) Complete the table by calculating the missing values. Show any working below.

(2)

$\dfrac{1}{d}(\times 10^5 \text{ m}^{-1}) = 1.25$	1 mark
$y_{\text{left}} = 0.0186$ m	1 mark

c) On the grid below, plot a graph of average fringe distance (y) against the inverse of double slit filter width ($^1/_d$). Place '$^1/_d$' on the x-axis. Draw a line of best fit for the data.

(4)
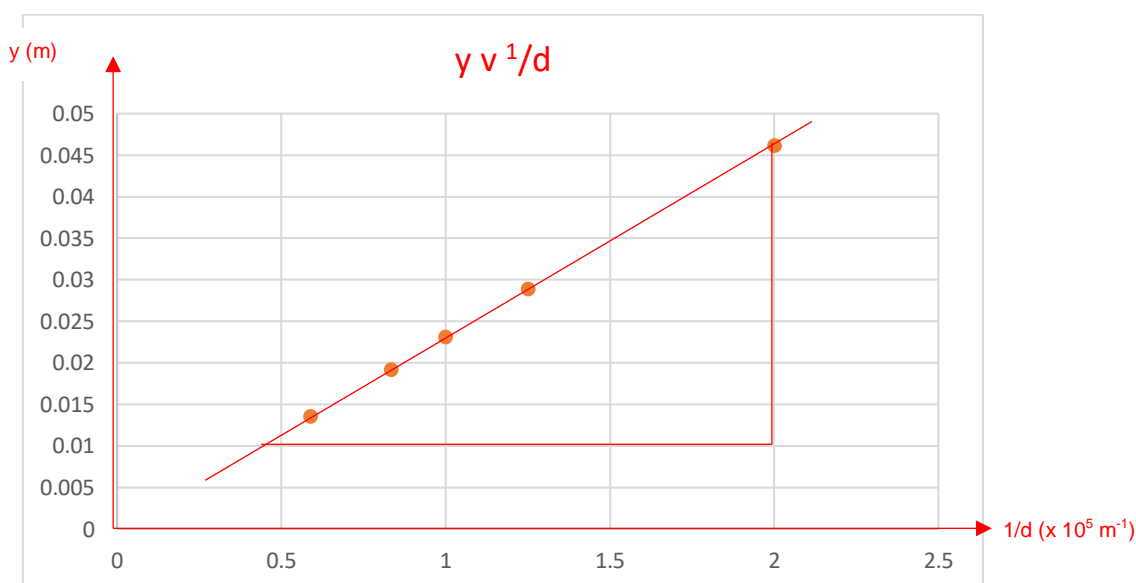
Points plotted correctly.	1 mark
Line of best fit drawn correctly.	1 mark
Axes labelled correctly; 1/d on x-axis.	1 mark
Units correctly labelled.	1 mark

d) Calculate the gradient of the line of best fit. Clearly state the units.

(3)

Uses two points from the line of best fit: eg, (2 x 10^5, 0.046) and (0.4 x 10^5, 0.01)	1 mark
$\text{gradient} = \dfrac{(0.046 - 0.01)}{(2 \times 10^5 - 0.4 \times 10^5)} = 2.2 \times 10^{-7}$ $(2.1 \times 10^{-7} - 2.4 \times 10^{-7})$	1 mark
Units: m^2	1 mark

e) Use the gradient from part d) to calculate an experimental value for the wavelength of the laser's light.

(3)

$\text{Gradient} = \dfrac{y}{\frac{1}{d}} = yd = \lambda mL$	1 mark
$\therefore 2.2 \times 10^{-7} = \lambda \times 3 \times 1.1; \ \lambda = \dfrac{2.2 \times 10^{-7}}{3.3}$	1 mark
$\lambda = 6.7 \times 10^{-8} \ m \quad (6.3 \times 10^{-8} - 7.2 \times 10^{-8})$	1 mark

f) Describe and explain how the interference pattern would change if a laser with light of a higher frequency was used. Explain.

(2)

A higher frequency light (f) will result in a lower wavelength (λ).	1 mark
'y' and 'λ' are directly proportional to each other; hence, y decreases.	1 mark

Question 15   **(14 marks)**

a)   Convert the mass of the neutral pion into kilograms (kg).

(2)

$m(\pi^0) = \dfrac{135.0 \times 10^6 \times 1.60 \times 10^{-19}}{(3.00 \times 10^8)^2}$	1 mark
$= 2.40 \times 10^{-28}$ kg	1 mark

b)   Hence, calculate the energy (in Joules) of each photon.

(2)

$e = mc^2 = 2.40 \times 10^{-28} \times (3.00 \times 10^8)^2 = 2.16 \times 10^{-11}$ J	1 mark
Hence, $E(\gamma) = \dfrac{2.16 \times 10^{-11}}{2} = 1.08 \times 10^{-11}$ J	1 mark

c)   Calculate the wavelength of the photons in part b) and, hence, identify the region in the electromagnetic spectrum from which they originate.

(3)

$E = \dfrac{hc}{\lambda}; \lambda = \dfrac{hc}{E} = \dfrac{6.63 \times 10^{-34} \times 3.00 \times 10^8}{1.08 \times 10^{-11}}$	1 mark
$\therefore \lambda = 1.84 \times 10^{-14}$ m	1 mark
Photons are gamma rays.	1 mark

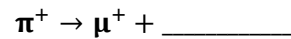d)   Show why the charge on a positive pion (π^+) is equal to +1.

(1)

$\pi^+ = u\bar{d};$ charge $= \left(+\dfrac{1}{3}\right) + \left(+\dfrac{2}{3}\right) = +1$	1 mark

e)   Write the baryon number and lepton number for the positive pion (π^+) in the spaces provided below:

(2)

Baryon number = 0	1 mark
Lepton number = 0	1 mark

f)   Write the following for the unidentified particle in the incomplete particle interaction (π^+ decay) shown above.

$$\pi^+ \rightarrow \mu^+ + \underline{\hspace{2cm}}$$

(4)

Charge = 0;	1 mark
Baryon number = 0	1 mark
Lepton number = +1	1 mark
Name = muon neutrino; Symbol = ν_μ	1 mark

Question 16   **(14 marks)**

a)   Calculate the root-mean square voltage produced by the generator.

(1)

$\varepsilon_{RMS} = \dfrac{\varepsilon_{MAX}}{\sqrt{2}} = \dfrac{0.139}{\sqrt{2}} = 0.0983 \text{ V}$	1 mark

b)   Calculate the strength of the uniform magnetic field (in mT).

(5)

$\varepsilon_{MAX} = 2\pi NBAf; \ 0.139 = 2\pi \times 125 \times B \times 0.065 \times 0.055 \times \dfrac{240}{60}$	1-2 marks
$B = \dfrac{0.139}{8.42}$	1 mark
$= 1.24 \times 10^{-2} \text{ T}$	1 mark
$= 12.4 \text{ mT}$	1 mark

c)   The students apply a force to the handle in such a way that the coil rotates with a constant circular speed. Explain why this force cannot have a constant magnitude. Describe how the magnitude changes as the coil rotates.

(3)

As the coil rotates an EMF is generated that opposes the direction of its rotation (Lenz's Law).	1 mark
When the coil is perpendicular to the field, no EMF is generated in the coil. When the coil is parallel to the field, maximum EMF is generated in the coil.	1 mark
Hence, the magnitude of the force varies from a maximum when the coil is parallel to the field to zero when the coil is perpendicular to the field.	1 mark

d) (i)   On the set of axes below, sketch a graph showing how the brightness of the light globe changes
         while the coil completes one full rotation.

         An accurate scale is provided on the time axis. The brightness axis has no scale and is only
         meant to be qualitative.

         The horizontal dashed line shows the maximum brightness achieved by the light globe as it
         rotates.

(3)
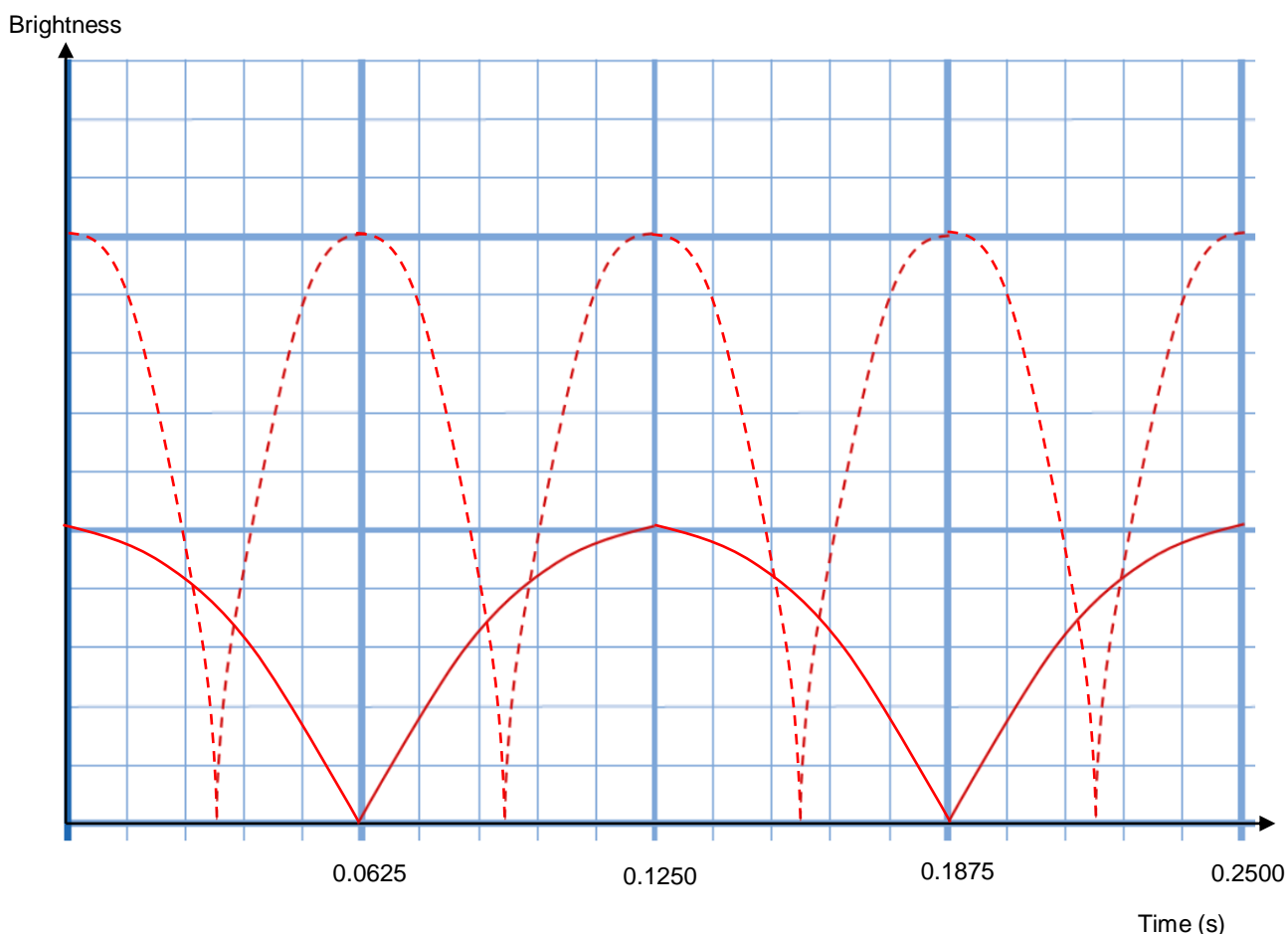
Brightness

Shape of graph oscillates between a maximum value and zero (see solid curve).	1 mark
The graph oscillates between a maximum value and zero every quarter of a turn (ie – every 0.250 s).	1 mark
Graph starts at a maximum value (ie – at t = 0, brightness is at a maximum value).	1 mark

         The students now double the frequency at which they rotate the coil.

(ii)   On the set of axes in part (i), sketch a graph showing how the brightness of the light globe now varies over the same time period of 0.2500 s. Again, assume the coil starts parallel to the magnetic field.

(2)

Maximum intensity is higher than for solid curve (see dashed curve).	1 mark
The graph oscillates between a maximum value and zero every quarter of a turn (ie – every 0.125 s).	1 mark

Question 17   **(13 marks)**

a)   As the cyclist enters the bottom of the loop-the-loop, they observe that they 'feel heavier' than they usually do. Explain.

(4)

Apparent weight is due to the normal force exerted on the cyclist from the track.	1 mark
When entering the vertical loop, a net upward force is required to produce a centripetal force in order to move in a circle.	1 mark
This additional force must be provided by the normal force from the track.	1 mark
Since the normal force from the track increases, so will the apparent weight	1 mark

b)   Calculate the minimum speed the cyclist must attain to navigate the top of the loop-the-loop safely.

(3)

Minimum $'v': N = 0;$ ie $-\dfrac{mv^2}{r} - mg = 0; v = \sqrt{gr}$	1 mark
$v = \sqrt{9.80 \times 2.75}$	1 mark
$v = 5.19 \text{ ms}^{-1}$	1 mark

c)   Does the cyclist make it all the way around the top of the loop-the-loop? Answer this question by
     calculating the minimum speed required at the bottom of the loop for the cyclist to make it all the
     way around. [If you were unable to calculate an answer for part b), use a value of 5 ms⁻¹]

(6)

At top, minimum energy: $E_T = E_k + E_P = \dfrac{1}{2} \times 150 \times 5.19^2 + 150 \times 9.80 \times 2 \times 2.75$	1 mark
$E_T = 1.01 \times 10^4 \text{ J} \qquad (8.84 \times 10^3 \text{ J})$	1 mark
At bottom, minimum speed required: $1.01 \times 10^4 = \dfrac{1}{2} \times 150 \times v^2$	1 mark
$v = \sqrt{\dfrac{2 \times 1.01 \times 10^4}{150}}$	1 mark
$\therefore v = 11.6 \text{ ms}^{-1} \quad (10.9 \text{ ms}^{-1}); \text{ greater than } 10.0 \text{ ms}^{-1}$	1 mark
No, cyclist will not make it around the top of the loop-the-loop.	1 mark

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 18   **(18 marks)**

a)   Chandra's images and extra data gathered from other telescopes indicated that these flares were cooling down over time. In terms of black body radiation, explain how the data illustrates evidence of cooling.

(3)

Over time, the evidence shows that the emissions from the flare moved from the X-Ray region to the infrared and then radio waves regions.	1 mark
This indicates that the peak wavelength of the flare's emissions had increased.	1 mark
An increase in the peak wavelength of black body radiation indicates a decrease in the temperature of the black body.	1 mark

b)   The X-ray emissions from the flare were strongly polarised.

Explain what is meant by the term "polarised" and describe whether this is evidence of the wave or particle nature of light.

(3)

Polarised means that the electromagnetic wave is oscillating in a single plane/orientation.	1 mark
Polarisation confirms that light behaves as transverse oscillations of the electromagnetic fields	1 mark
providing evidence for the wave nature of light.	1 mark

c)   Using the information from the article, show that the hot gas bubble must have an average orbital speed of about 30% of the speed of light.

(4)

$r = 0.4 \times 1.5 \times 10^{11} = 6.0 \times 10^{10}$ m; $T = 70 \times 60 = 4200$ s	1 mark
$v = \dfrac{2\pi r}{T} = \dfrac{2\pi \times 6.0 \times 10^{10}}{4200}$	1 mark
$\therefore v = 8.98 \times 10^7$ m	1 mark
$v = \dfrac{8.98 \times 10^7}{3.00 \times 10^8} = 0.299 \approx 30\%$ of $'c'$	1 mark

d)   Use Kepler's 3rd Law and data from the article to show that the mass of Sagittarius A* is over
        three and half million solar masses.

(4)

Kepler's 3rd Law: $\dfrac{T^2}{r^3} = \dfrac{4\pi^2}{GM}$; $M = \dfrac{4\pi^2 r^3}{GT^2}$	1 mark
$M = \dfrac{4\pi^2 (6.0 \times 10^{10})^3}{6.67 \times 10^{-11} \times (4200)^2}$	1 mark
$\therefore M = 7.25 \times 10^{36} \text{ kg}$	1 mark
$M = \dfrac{7.25 \times 10^{36}}{1.99 \times 10^{30}} = 3.64 \times 10^6 \text{ solar masses } (> 3.5 \times 10^6 \text{ solar masses})$	1 mark

e)   An event lasting 70 minutes occurs in an inertial frame of reference and is viewed by a stationary
        observer on Earth. Relative to the stationary observer, the inertial frame of reference is moving at
        30% of the speed of light. Calculate how long the duration of this event would appear to be to the
        stationary observer on Earth. Show working.

(4)

Uses relativistic time dilation formula to find 't'. Uses $t_o = 70$ minutes and $v = 0.30c$ (Note: $v = 0.299c$ may be used from part c))	1 mark
$t = \dfrac{t_0}{\sqrt{1 - \dfrac{v^2}{c^2}}}$	1 mark
$t = \dfrac{70}{\sqrt{1 - \dfrac{(0.30c)^2}{c^2}}}$	1 mark
$t = 73.4$ minutes	1 mark

Question 19   **(18 marks)**

a)   Calculate the maximum speed that could be achieved by the electron in the CRT in Figure 1. Ignore relativistic effects.

(3)

$\Delta E_K = \frac{1}{2} mv^2 = Vq \therefore v = \sqrt{\dfrac{2Vq}{m}}$	1 mark
$v = \sqrt{\dfrac{2 \times 15000 \times 1.60 \times 10^{-19}}{9.11 \times 10^{-31}}}$	1 mark
$\therefore v = 7.26 \times 10^7 \text{ ms}^{-1}$	1 mark

b)   On Figure 2, show the polarity of the plates to create an upward deflection on an electron. Label the plates with the appropriate symbols.

(1)

Top plate: labelled '+'; Bottom plate: labelled '-'.	1 mark

c)   In the space between the plates on Figure 2, draw and label the direction of a magnetic field that creates a downward deflection.

(1)

Field is drawn into the page.	1 mark

d)   When the cathode ray (ie – electron beam) is undeflected during the second part of the experiment, both electric force and magnetic force are in equilibrium. Derive a formula for the electron beam's speed in terms of the electric field strength 'E' and the magnetic field strength 'B'.

(3)

$F_B = Bvq; E = \dfrac{F_E}{q}, \therefore F_E = Eq; F_B = F_E$	1 mark
$Bvq = Eq$	1 mark
$\therefore v = \dfrac{E}{B}$	1 mark

e)   When the electric field is turned off in the third part of the experiment, the magnetic force from part 2 acts as a centripetal force on the electrons. Hence, use your answer from part d) to show that the derived expression for the charge to mass ratio $\left(\frac{q}{m}\right)$ for the electron is given by:

$$\frac{q}{m} = \frac{E}{rB^2}$$

(3)

$F_B = F_C; Bvq = \dfrac{mv^2}{r}; \dfrac{mv}{r} = Bq$	1 mark
$\dfrac{m\left(\frac{E}{B}\right)}{r} = Bq$	1 mark
$\therefore \dfrac{q}{m} = \dfrac{E}{rB^2}$	1 mark

f)   Thomson calculated the charge to mass ratio for electrons to be 1.76×10^{11} C kg^{-1} – 1800 times larger than that for hydrogen ions. Explain how this experimental finding led him to the conclusion that these particles were subatomic.

(3)

Electrons and hydrogen ions have the same magnitude charge.	1 mark
Hence, this means that electrons must be 1800 time lighter in mass than the hydrogen gas atoms that they originated from.	1 mark
Given they are much smaller than these atoms and appear to originate from them, it can be concluded that they must be sub-atomic.	1 mark

g)   The electron is a 'fundamental' particle; the proton is a 'composite' particle. State the difference between these two types of particles.

(1)

A fundamental particle has no internal structure; a composite particle consists of a combination of fundamental particles.	1 mark

h)   The charge on the electron and proton is the same in magnitude, but opposite in polarity. Explain this statement. As part of your answer describe the quark structure of a proton.

(3)

A proton consists of two up quarks and one down quark (uud).	1 mark
The charge on the proton = $(+^2/_3) + (+^2/_3) + (-^1/_3) = +1$	1 mark
Charge on an electron = -1; therefore, magnitude of charge on a proton and an electron are equal in magnitude.	1 mark

END OF EXAMINATION