ACE

Name: Daniel Bociarski

Subject: Physics

Class: Vonathy

2020 HIGHER SCHOOL CERTIFICATE EXAMINATION

Section I

Multiple Choice Answer Sheet

Instructions

- Write using black pen.
- Answer Questions 1–20 only on this answer sheet.
- Select the alternative A, B, C or D that best answers the question.
- Fill in the response oval completely.
- If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.
- If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer with a labelled arrow.

1	A	B	C	D	11	A	B	C	D
2	A	B	C	D	12	A	B	C	D
3	A	B	C	D	13	A	B	C	D
4	A	B	C	D	14	A	B	C	D
5	A	B	C	D	15	A	B	C	D
6	A	B	C	D	16	A	B	C	D
7	A	B	C	D	17	A	B	C	D
8	A	B	C	D	18	A	B	C	D
9	A	B	C	D	19	A	B	C	D
10	A	B	C	D	20	A	B	C	D

ACE

2020 HIGHER SCHOOL CERTIFICATE EXAMINATION

Name: Daniel Bociarski

Class: Vanathy

Physics

Section II Answer Booklet

80 marks

Attempt Questions 21–31

Allow about 2 hours and 25 minutes for this section

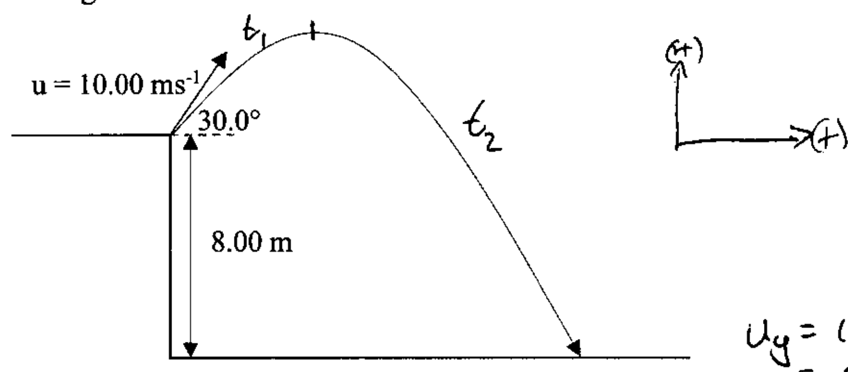
Instructions

- Write your Name and Class at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

Question 21 (7 marks)

A ball labelled A is thrown at a speed of 10.0 ms^{-1} at an angle of 30.0° off an 8.00 m tall cliff, as shown in the diagram below.



$s = ut$
$t = \frac{s}{u}$

$u_y = 10\sin 30$
$= 5$

(a) Calculate the maximum height of the projectile. **3**

~~$s_y = u_y t + \frac{1}{2} g t^2 = u\sin 30 +$~~

$v^2 = u^2 + 2as$

$s_y = \frac{0 - u^2}{2 \times 9.8} = 1.28m$

$v_y^2 = u_y^2 + 2 a s_y$

$s_y = \frac{0 - u_y^2}{2g}$

$= -\frac{(u\sin 30)^2}{2 \times (-9.8)}$

$= \frac{25}{19.6}$

$= 1.28 m$

(b) Show that the time of flight of the projectile is approximately 1.886 s. **3**

~~$0 = u_y + at_1$~~
~~$t_1 = \frac{5}{9.8}$~~
~~$= 0.51s$~~
~~$s_y = -8 = u_y t - 4.9t^2$~~
~~$4.9t^2 - 5t - 9.28 = 0$~~
~~$t = 1.$~~

~~$t_{flight} = t_1 + t_2$~~ ~~$s_y = u_y t + \frac{1}{2} g t^2$~~ ~~$4.9t^2 - 5t - 1.28 = 0$~~

~~$t_1 = \frac{5 \pm \sqrt{25 - 4(4.9)(-1.28)}}{9.8}$~~ ~~$= t(4.9t - 5) = 1.28$~~

~~$v_y = u_y + gt$~~ ~~$t_1 = \frac{-u_y}{-9.8} = 0.5102s$~~

~~$t_2 = \frac{s_y}{u_y} = \frac{8 + 1.28}{5} = 1.856$~~

$S_y = -8 = 5t - 4.9t^2$

$0 = 4.9t^2 - 5t - 8$

$t = \frac{+5 \pm \sqrt{25 - 4(4.9)(-8)}}{9.8}$

$= 1.886s, -0.86s$

Discard -ve

$\therefore t = 1.886s$

(c) Calculate the range of the projectile. **1**

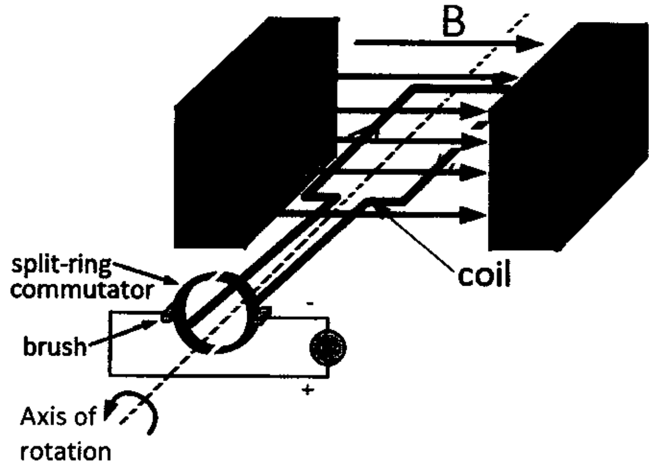
$R = u_x t$

$= 10\cos 30 \times 1.886 = 16.33m$

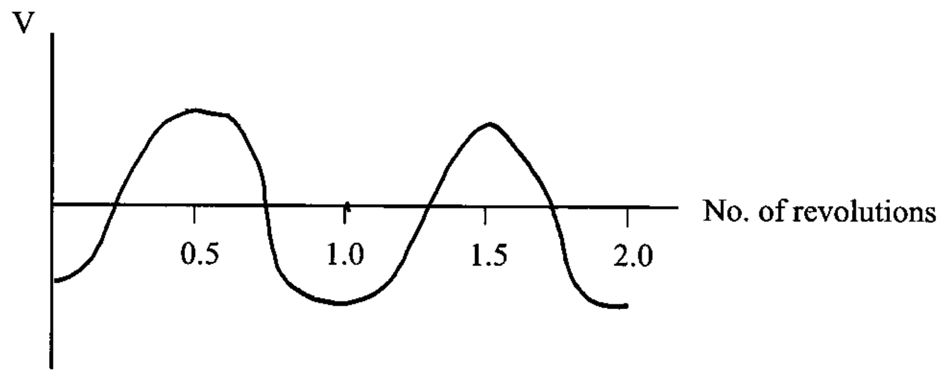
ACE PHYSICS EP 1

Question 22 (4 marks)

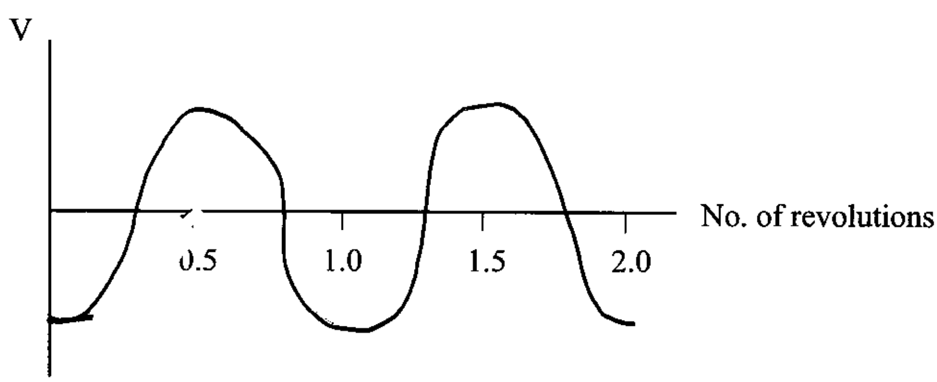
A schematic diagram of a simple DC generator is shown below.



(a) Sketch the output voltage from this generator in the space provided below, for two complete revolutions of the coil. **3**



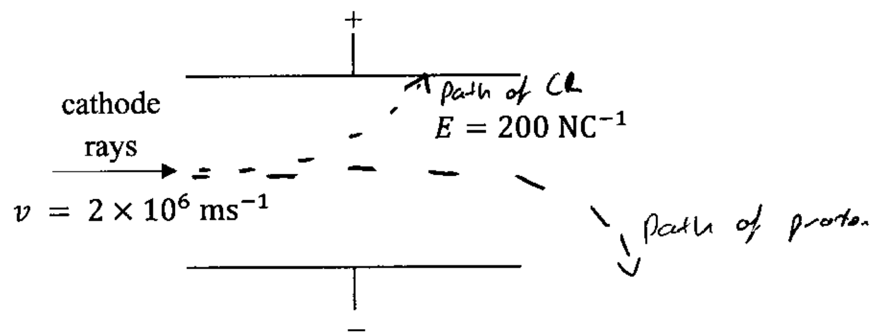
(b) Sketch the output voltage if the single split ring commutator is replaced with a multiple split ring commutator. **1**



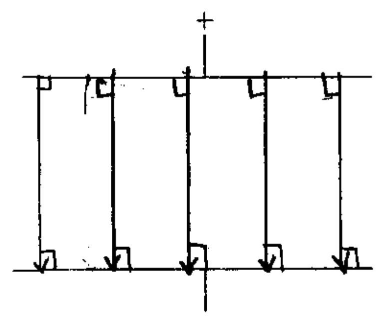
Question 23 (7 marks)

A student attempts to simulate Thomson's charge to mass ratio experiment.

A uniform electric field of magnitude 200 NC^{-1} is generated by a pair of parallel plates as shown in the diagram below.



(a) Draw the electric field lines that are generated by the oppositely charged plates **2**



(b) Determine the direction and magnitude of the applied magnetic field such that the cathode rays remain undeflected. **3**

Into page $\therefore F_{net} = 0 = \cancel{q}E - \cancel{q}VB$

$E = vB$

$B = \frac{E}{v}$

$= \frac{200}{2\times10^6} = 0.0001\ T$ into page

Question 23 continues on page 15

Question 23 (continued)

(c) Explain how your answer to part b) would change if the cathode rays were replaced by a beam of protons with the same initial speed as the cathode rays. **2**

As the protons are positively charged unlike the cathode rays, they will deflect towards the -ve plate initially, this means the applied $\vec{B}$ field would have to be applied out of the page.

$qE = qvB$

~~B~~ $B = \frac{E}{v}$, as v,E is constant magnitude of B field is the same as in b)

End of Question 23

Question 24 (10 marks)

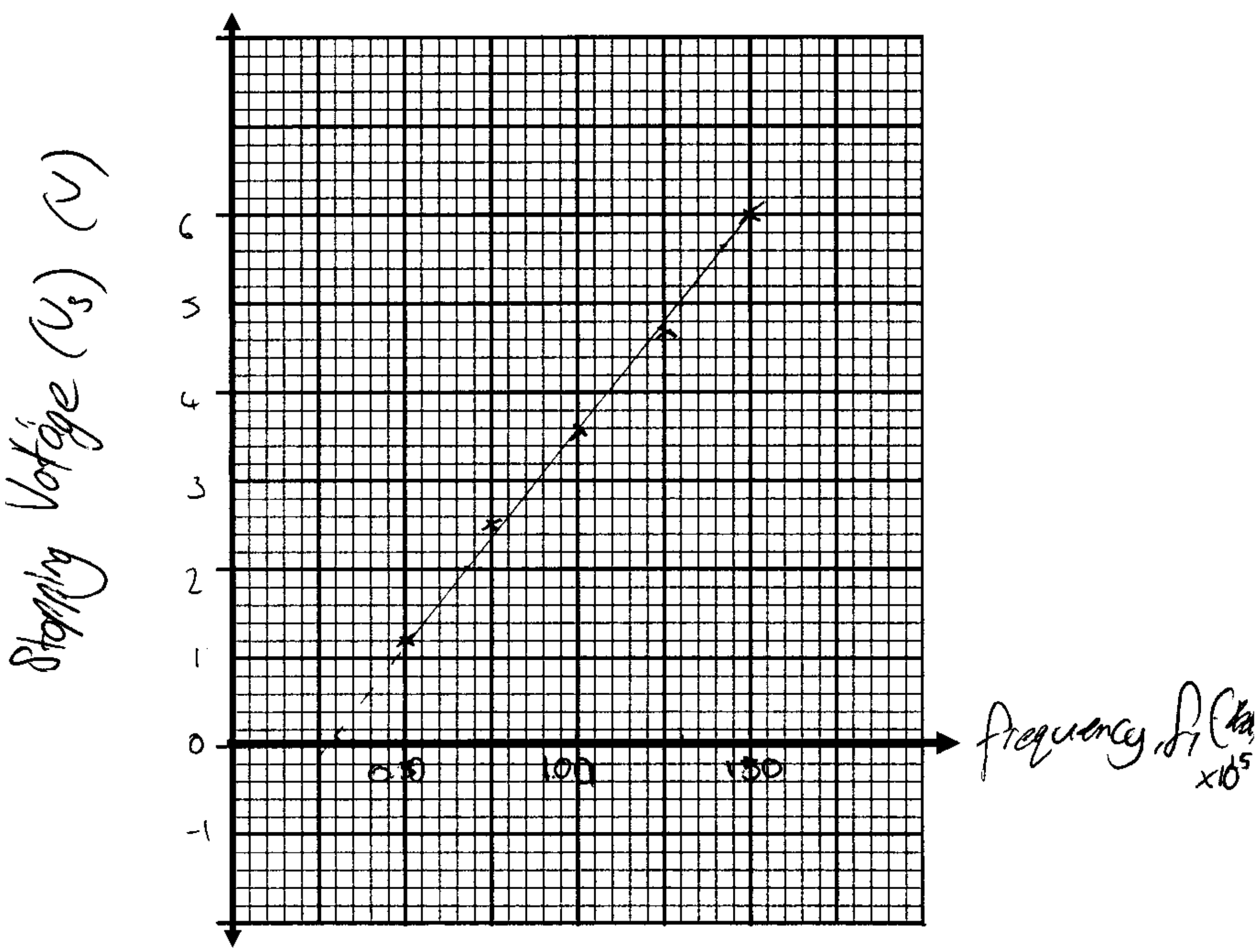
An experiment is designed to confirm the value of Planck's constant.

To do so, it investigates the relationship between stopping voltage and frequency for a photoelectric effect experiment.

The AVERAGE results are shown in the table opposite.

frequency f ($\times 10^{15}$ Hz)	*stopping voltage,* V_s (V)
0.50	1.2
0.75	2.5
1.0	3.6
1.25	4.7
1.50	6.0

(a) Plot a graph of stopping voltage V_s versus frequency f on the grid provided below, including a line of best fit. **3**



Question 24 continues on page 17

Question 24 (continued)

(b) Use your graph from part (a) to estimate the work function of the metal, in eV. **2**

~~$V_s = \frac{hf - \phi}{q_e}$~~ Threshold freq: 0.29×10^{15} Hz

~~$\phi = hf - qV$~~ $\phi = hf_0 = 1.92154 \times 10^{-19}$ J

$= 1.199$ eV

(c) Determine the experimental value of Planck's constant and hence assess the accuracy of this experiment. **3**

$\frac{\Delta y}{\Delta x} = \frac{h}{e}$ $h = \frac{e\Delta y}{\Delta x}$

~~$V_s = \frac{h}{}$~~ Use point $(1.3 \times 10^{15}, 5)$ and $(0.67 \times 10^{15}, 2)$

~~$5 = \frac{h \times 1.3 \times 10^{15}}{q_e} - \phi_{eV}$~~

~~$\frac{6.199 \times 1.602 \times 10^{-19}}{1.3 \times 10^{15}} = h$~~

$= \frac{1.602 \times 10^{-19}(5-2)}{(1.3 - 0.67) \times 10^{15}}$

$= 7.628 \times 10^{-34}$ Js

$h = 7.628 \times 10^{-34}$ Js

$= 7.628 \times 10^{-34}$ Js

The experiment was accurate as it determined Planck's constant to a close degree, where exp. value was 6.626 $\times 10^{-34}$ and the result was only 15% above the expected value. However using such small values in results meant that this was accurate

(d) Comment on the reliability of this experiment. **2**

The experiment was reliable as it was averaged and ∴ repeated with removed outliers, as well as having a consistent value close to the known value of Planck's constant meaning the results were consistent and reliable

End of Question 24

Question 25 (9 marks)

"The scientific method requires constant revision of models as new evidence emerges." **9**

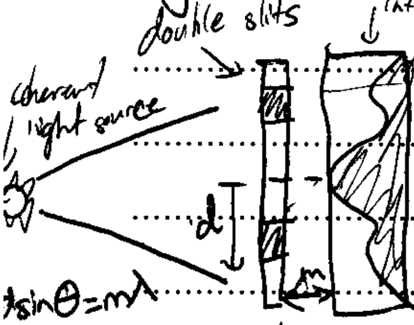
Assess the validity of this statement with reference to our early understanding of light based on the work of Newton, Huygens, Young and Foucault.

The nature of light has been discussed by physicists in depth for centuries. ~~The~~ Newton was the first to majorly define light as something, which he defined as small particles called corpuscles. These particles travelled in straight beams and Newton attempted to explain phenomena with it. For example, he believed that as light was a particle it was attracted to other objects with mass and therefore sped up in mediums such as water and prisms due to gravity. However, Newtons theories could not fully explain diffraction, but due to his fame, his idea gained prevalence in the scientific community. Huygens, on the other hand, proposed light was a wave which needed a medium to travel in. While it explained phenomena such as diffraction and refraction, he was over shadowed by Newtons fame. However, due to Thomas Young, Huygens model was ressurected by Young's double slit experiment. The new evidence from

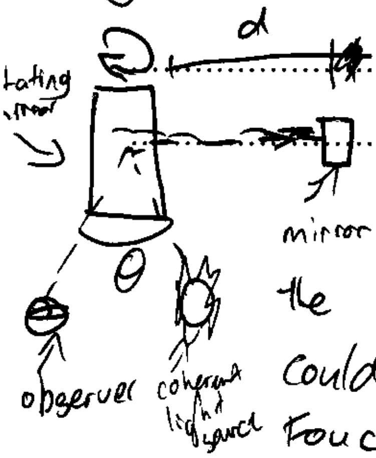
Question 25 continues on page 19

Question 25 (continued)

his double slit experiment showed that when two beams of light were diffracted through small slits (as below), an interference pattern could be seen.



As the superpositioning of waves and destructive/constructive interference were exclusively wave properties, this meant that light was a wave as bars of darkness and light with fuzzy edges overlapped, showing that the light had undergone both constructive and destructive interferences, supporting Huygen's model over Newtons, ~~showing~~ ~~showing~~ showing how scientific method requires constant revision due to new evidence. Furthermore, the work of Foucault ~~that contradicted Newtons~~ also improved the early understanding of light. By shooting a coherent light source on a rotating mirror at x rpm and reflecting it off a ~~rotating~~ mirror at a set distance 1km away and measuring the change in the angle, this meant that the speed of light could be determined by $\omega = \frac{\Delta\theta}{t}$, which Foucault measured to be $3.? \times 10^8 ms^{-1}$ which determined ~~that light had a~~ that light travelled at a finite speed as well as how fast light travelled, showing the progress of scientific thought due to new evidence.

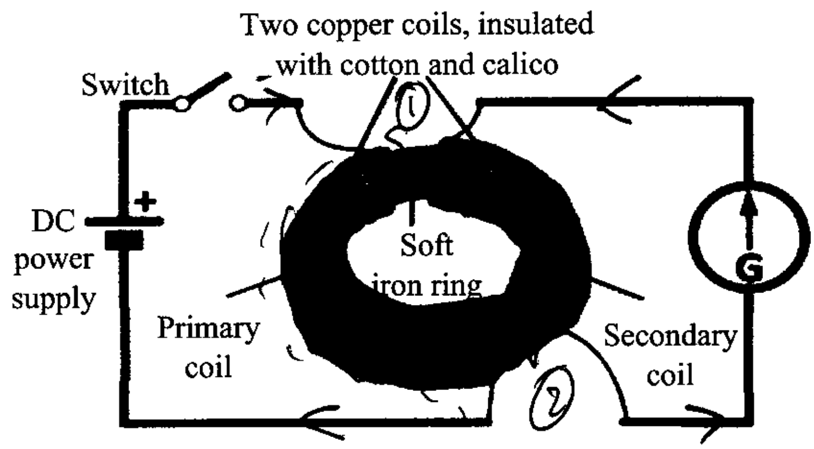


End of Question 25

Question 26 (9 marks)

A physics student attempts to replicate Faraday's iron ring experiment in order to demonstrate the principle of electromagnetic induction.

A diagram of the situation is shown below.



(a) Explain how the soft iron ring improves the sensitivity of this transformer. **4**

As iron is an excellent magnetic conductor as compared to air or wood (like faradays past attemp; due to its eas ~~[illegible]~~ ~~allows~~ alignment of magnetic domains and therefore a higher flow of magnetic flux, ϕ is achieved. This means the coils around the core as well as the entire transformer itself can change more easily and provide lower power losses to ~~[illegible]~~ improve efficiency. This means as more ϕ is carried by the soft iron ring, more ϕ enters the secondary coil, allowing for more power to be transmitted to the secondary circuit, ~~[illegible]~~ improving the quality / sensitivity of the transformer.

Question 26 continues on page 21

Question 26 (continued)

(b) The student closes the switch, waits a few seconds, then opens the switch again.

Explain the observations that the student would make during this process. **5**

As the switch is closed, current flows, causing a Nth pole to develop at the bottom of a circuit due to ~~Faraday's~~ ~~law~~ induction. By Faraday and Lenz's Laws ~~this~~ state that ~~a~~ ~~emf~~ ~~is~~ a $\Delta\phi$ will induce an emf to generate a $\vec{B}$ field to oppose this change. This means a Nth pole is involved at the bottom of the secondary coil. This induces an electrical current by induction causing the galvanometer to swing in one direction. However, due to the DC supply, this $\Delta\phi$ would no longer occur after a few seconds and return to ground state. ~~At~~ When the switch is reopened, the decrease in current at ② means a Sth pole is instigated in the secondary coil at ①, This reverses current direction and the galvanometer swings in the opposite direction to before, then returns to ground state ①

End of Question 26

Question 27 (7 marks)

The following astronomical data shows the period and orbital radius for three of Jupiter's moons.

(a) Fill in the missing columns in the table below (answers to 2 decimal places). **4**

	Orbital radius r ($\times 10^6$ m)	*Orbital radius³* r^3 ($\times 10^{25}$ m³)	*Orbital Period* T (days)	*Orbital Period* T ($\times 10^5$ s)	*Orbital Period²* T^2 ($\times 10^{10}$ s²)
Io	422	7.52	1.75	1.51	2.29
Europa	671	30.21	3.54	3.06	9.35
Ganymede	1070	122.50	7.17	6.19	38.38

(b) Hence, using the data for Ganymede, calculate the mass of Jupiter. **3**

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$M = \frac{r^3 \times 4\pi^2}{6.67\times10^{-11} \times T^2}$$

$$= \frac{122.5\times10^{25}\times 4\pi^2}{6.67\times10^{-11}\times(38.3765\times10^{10})}$$

$$= 1.889380547\times10^{27}\ \text{kg}$$

$$\approx 1.89\times10^{+27}\ \text{kg}$$

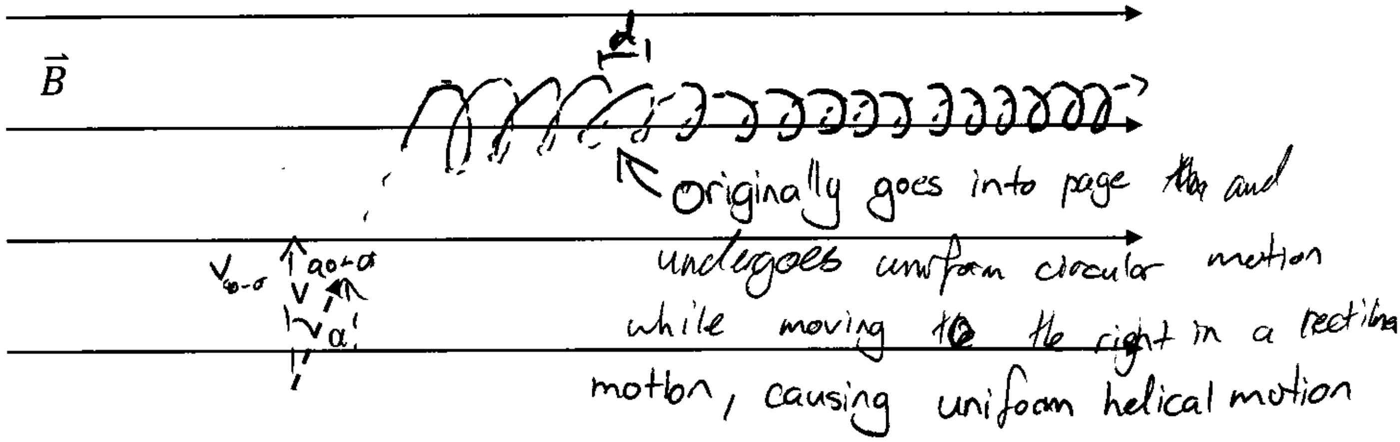
Question 28 (5 marks)

Explain how de Broglie accounted for Bohr's postulated stationary states for an electron in a hydrogen atom. 5

$\lambda = \frac{h}{mv}$, $E = hf$

Question 29 (8 marks)

A proton enters a large, uniform magnetic field region $\vec{B}$ with an initial speed v at an angle α, as shown in the diagram below.



Explain, using relevant physics principles, the motion of the proton whilst it is moving in the uniform magnetic field. **8**

~~A~~ a proton is a charged particle with $q = 1.602 \times 10^{-19}$ C and $m = 1.673 \times 10^{-27}$ kg, it interacts with the $\vec{B}$ field, undergoing uniform circular motion. This means, using the right hand palm rule, it deflects downwards as the $V_{90-\alpha}$ ~~[illegible]~~ is perpendicular to the $\vec{B}$ field meaning this component of the velocity is acted upon, instead of the component of the parallel velocity. This causes an acceleration and force causing uniform circular motion.

Question 29 continues on page 25

Question 29 (continued)

Using $F_c = \frac{mv^2}{r} = qvB$, $r = \frac{mv}{qB} = \frac{m\,v\sin\alpha}{qB}$

$= 1.044 \times 10^{-8}\ \frac{v\sin\alpha}{B}$

However, due to the $v_{\parallel}$ component, there is a constant v directed to the right. This means there is a uniform helical path of the proton from left to right, as drawn on the diagram. Due to no accelleration parallel to the $\vec{B}$ field (no force parallel to B-field on charged objects), the distance between peaks of the helix, d, remains constant and d=vt. The proton will continue in this motion presumably forever, until the proton exits the $\vec{B}$ field. ie undergoes uniform helical motion where the distance between peaks, d, is constant, as well as the pitch of the helix.

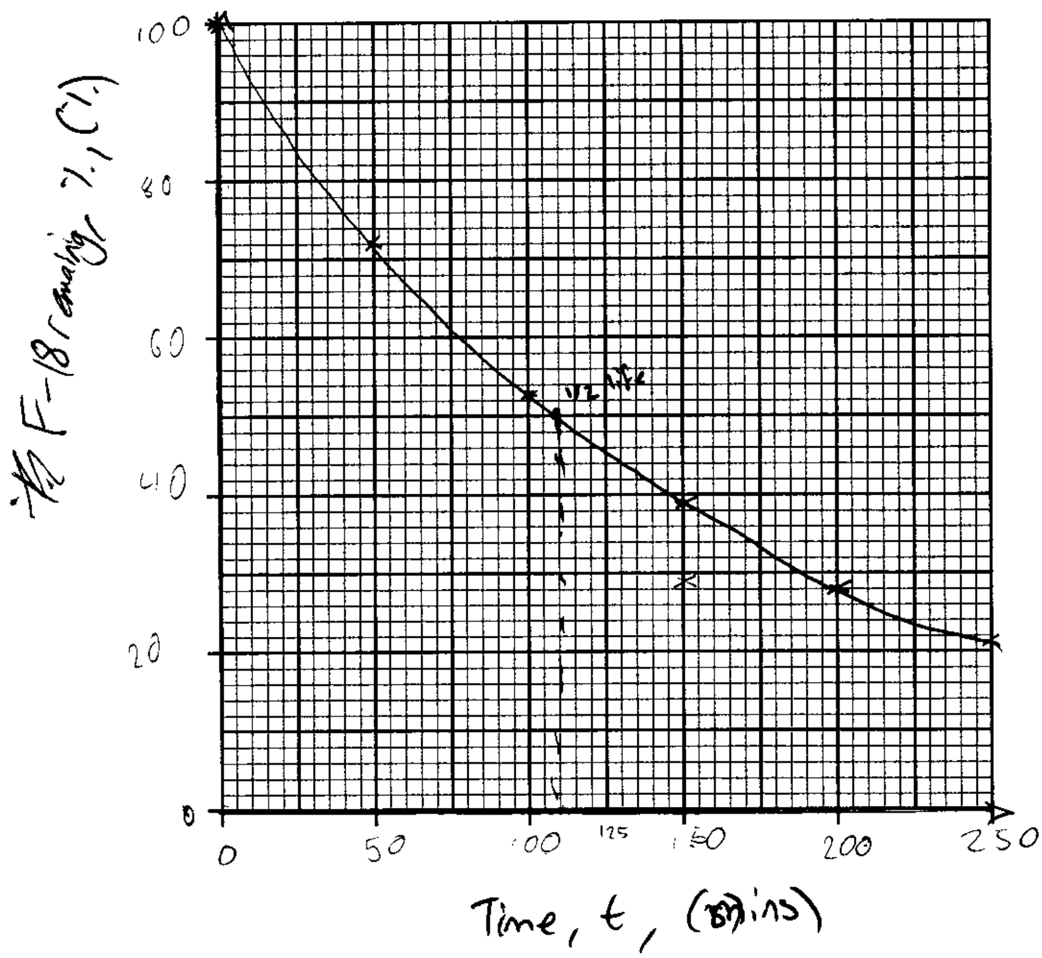
End of Question 29

Question 30 (9 marks)

Positron-emission tomography is a medical imaging technique that relies on nuclear physics. Flourine-18 (F-18) is a commonly used radioactive tracer in medicine and its decay table is shown below.

Time t (mins)	0	50	100	150	200	250
Percent remaining of F-18 (%)	100	72	53	39	28	21

(a) Graph the 'percent remaining of F-18' as a function of time. **3**



(b) Use your graph to estimate the half-life of Flourine-18. **1**

110 mins = 6600s

Question 30 continues on page 27

Question 30 (continued)

(c) In order to reach stability, F-18 usually decays to O-18 via the following equation:

$$^{18}_{9}F \rightarrow {}^{18}_{8}O + {}^{0}_{+1}\bar{e} + {}^{0}_{0}v_e$$

Justify the use of F-18 as a medical diagnostic tool, with particular reference to matter-antimatter annihilation. **5**

In the ~~Beta~~ plus (β^+) decay of F18, it produces ~~an~~ a positron. This anti-electron collides quickly with ~~other~~ electrons close by in antimatter-matter annihilation, producing pure energy. Using $e=mc^2 = (2\times 9.109\times10^{-31})\times(3\times10^8)^2 = 1.63962\times10^{-13}$ J $\approx$ 1 MeV of energy in the form of high energy γ gamma rays is produced. This highly penetrative EMR photon penetrates the body and is uniformly distributed around the collision. By viewing the absorption of γ rays in the body, ~~in~~ objects that should not have the certain absorption of γ rays can be scanned, such as cancerous cells, diagnosing physical illnesses. Also, as F-18 has a longerish halflife, ~~the~~ the F-18 will not decay as fast, meaning less positrons are formed and less energy is released, healthier for the human body than the same mass of a substance with a short wavelength.

End of Question 30

Question 31 (5 marks)

A satellite of mass m is in a Low Earth Orbit (LEO) at a distance r above the centre of the Earth.

(a) Show that the total mechanical energy E of the satellite is given by $E = \frac{-GmM}{2r}$ **3**

$\sum E_M = K_E + U_E = \frac{1}{2}mv^2 + \left(-\frac{GMm}{r}\right) = \frac{mv^2}{2} - \frac{GMm}{r}$

$\cancel{= \frac{rmv^2 - 2GMm}{2r} = \frac{m(rv^2 - 2GM)}{2r}}$

$v = \frac{2\pi r}{T}$, $T = \sqrt{\frac{r^3 4\pi^2}{GM}}$, $\cancel{v = \frac{2\pi r}{T}}$, $\cancel{v = \sqrt{\frac{r^3 4\pi^2}{GM}}}$ $\quad \frac{mv^2}{2} + \frac{-GMm}{r}$

$= m\left(\frac{\cancel{4\pi^2 r^2}}{\cancel{\frac{r^3 4\pi^2}{GM}}} - \frac{GM}{r}\right)$

$= m\left(\frac{GM}{2} - \frac{GM}{r}\right)$

$= GMm\left(\frac{1}{2} - \frac{1}{r}\right)$

$=$

cont next page

Don't be like Dr. Hooper and miss that note so I lose marks like in Y11 yearly

(b) A major limitation of LEO satellites is that they experience atmospheric drag, a friction force, when interacting with the Earth's atmosphere.

Use $E = \frac{-GmM}{2r}$ to help explain why atmospheric drag will cause a LEO satellite to lose altitude. **2**

As $K_E \downarrow$ with increasing drag due to non-elastic collisions with atmospheric particles, E overall decreases. As $E \propto \frac{1}{r}$ this means that for every time $E\downarrow$, $r\uparrow$, ~~however~~ as but this is to remain in equilibrium. As $E\downarrow$, $KE\downarrow$ and $v\downarrow$ meaning there is not enough centripetal force to maintain altitude, causing the radius to decrease as it spirals towards the center, not obeying $E = -\frac{GMm}{2r}$ as that is for uniform circ. motion only.

End of paper

Section II extra writing space

If you use this space, clearly indicate which question you are answering.

Q31a) $v = \frac{2\pi r}{T}$

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

$T^2 = \frac{r^3 4\pi^2}{GM}$

$= \frac{4\pi^2 r^2}{r^3 4\pi^2} \times GM = \frac{GM}{r}$

$\therefore K_E + U = \frac{\frac{GMm}{r}}{2} - \frac{GMm}{r} = \frac{GMm}{2r} - \frac{2GMm}{2r}$

$= -\frac{GMm}{2r}$

Section II extra writing space

If you use this space, clearly indicate which question you are answering.