ACE

Name: Daniel Bociarski

Subject: Physics HSC

Class: Special Normo Physics Leon

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

2020 HIGHER SCHOOL CERTIFICATE EXAMINATION

Name: Daniel Bacborski

Class: Special Normo Class Saturday Leon

Physics

Section II Answer Booklet

80 marks

Attempt Questions 21–34

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 (8 marks)

An astronaut performs an investigation on Mars to determine the acceleration due to gravity on the planet's surface.

The astronaut varies the initial velocity u of a toy rocket and measures it's range, when fired at an elevation angle of 45°.

The range equation used by the astronaut is: $R = \left(\frac{\sin 2\theta}{2g}\right)u^2$

where: θ = initial launch angle; u = initial velocity of rocket; R = horizontal range of rocket

The astronaut's results are tabulated below.

Initial velocity, u (ms^{-1})	*Range,* R (m)	*Initial velocity squared,* u^2 $(m^2 s^{-2})$
1.0	0.17	1.0
2.0	0.50	4.0
3.0	1.10	9.0
4.0	2.05	16.0
5.0	3.20	25.0

(a) Complete the table shown above **1**

(b) Identify the independent and dependent variables and one controlled variable. **1**

Independent variable ....Initial velocity of rocket........

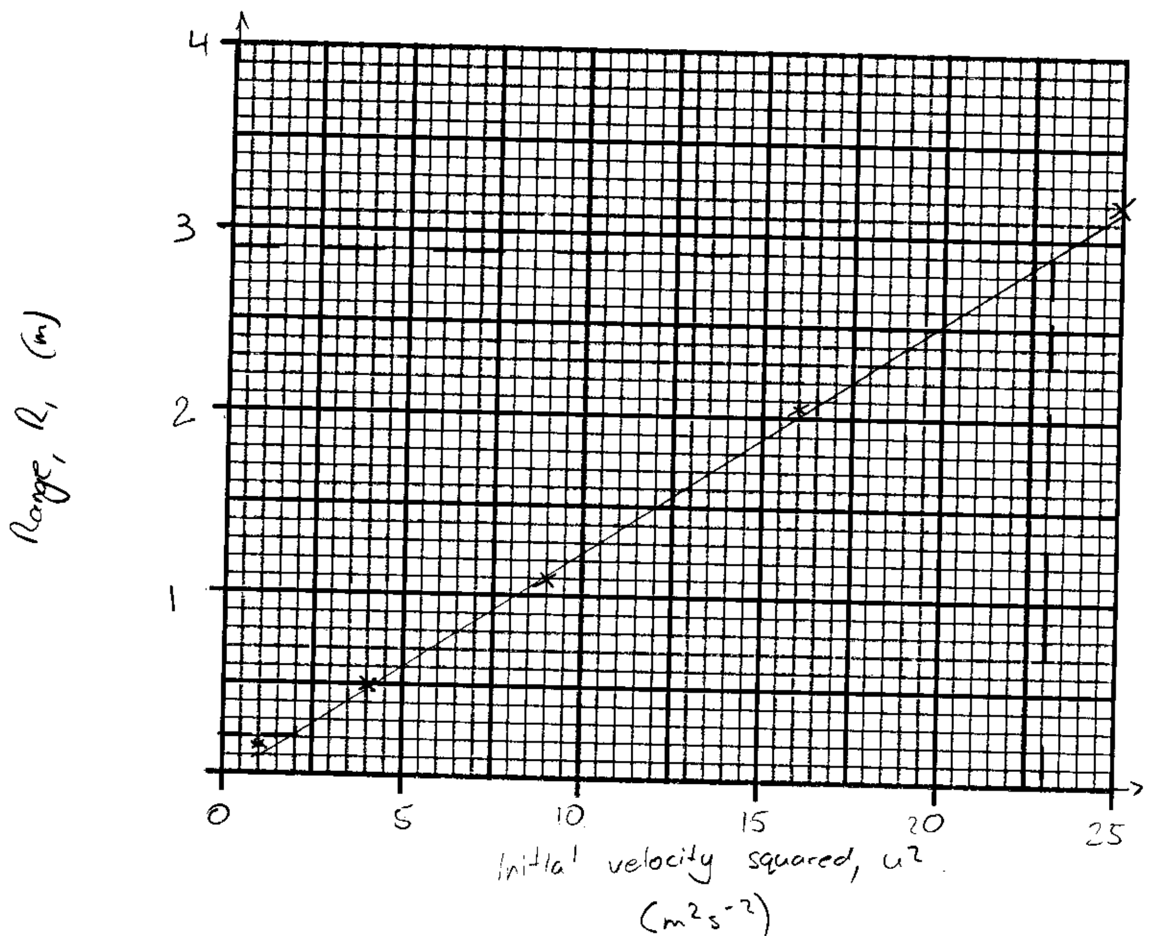
Dependent variable ....horizontal Range of projectile........

Controlled variable ....initial ~~velocity~~ launch angle........

Question 21 continues on page 12

Question 21 (continued)

(c) Plot a graph of R vs u^2 on the grid below, including a line of best fit. **2**



(d) Calculate the gradient of your line of best fit, including units. **2**

Units $\frac{\Delta y}{\Delta x} = \frac{m}{m^2 s^{-2}} = \frac{s^2}{m} = m^{-1}s^2$ Use: (23, 2.9), (2, 0.2)

$m = \frac{\Delta y}{\Delta x} = \frac{2.9 - 0.2}{23 - 2} = 0.1286$

$\approx 0.13\ m^{-1}s^2$

(e) Hence, determine the acceleration due to gravity on Mars. **2**

$g = x\ ms^{-2}$

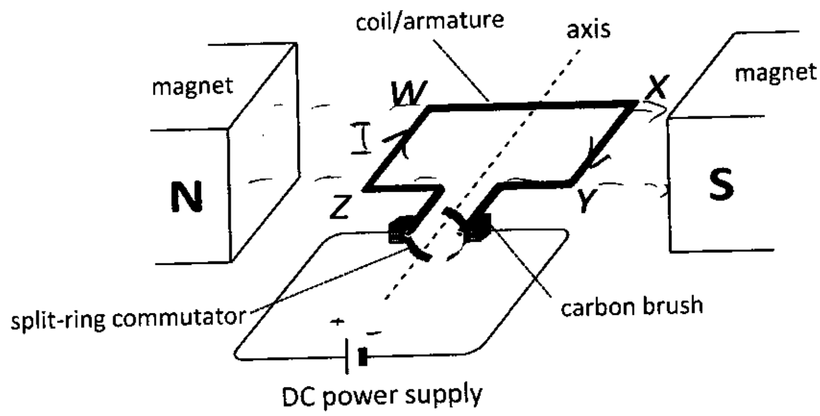
$\therefore g_m = m^{-1}$

$= 7.78 ms^{-2}$

$\approx 7.8 ms^{-2}$

Question 22 (5 marks)

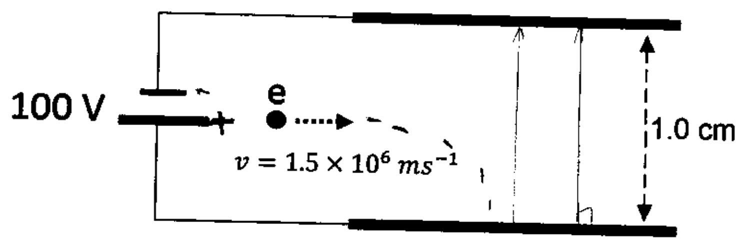
Explain the physics principles behind the operation of the DC motor shown below. **5**



As on the diagram, there is a $\vec{B}$ field directed left to right. This B field threads the area of a current carrying loop of wire, and by the motor effect, each side of the coil experiences a force by $F = ILB\sin\theta$, where I = current in coil, L is length WZ/XY and $\vec{B}$ is $\vec{B}$ field strength and θ is the angle between the B field and coil's area vector. By the Right Hand Rule, This means on WZ there is a downward force, XY has an upwards force and WX/ZY have no force. This means $F_{net} = 0$, but a rotation occurs. Due to the forces acting on opposite directions, a net torque is made by $\tau_{net} = nIAB\sin\theta$, spinning anticlockwise from this view. This rotation means that in order to prevent the wires tangling, a split ring commutator and carbon brushes are used to maintain rotational direction by keeping the current flowing in the same direction keeping direction of rotation constant, as the coil rotates around the axis of rotation. To improve the amount of force and torque, more coils must be added ~~at~~ at different angles, introducing a new pair of commutators every time. By a $\tau = nIAB\sin\theta$, τ is directly proportional to the number of coils. However as a motor rotates, the flux threading the coil is changing meaning an opposing emf is induced by Faraday's and Lenz's law. This back emf produces a high current, and ~~[illegible]~~ causes force and torque in the opposite direction. At this point, rotational speed is constant as $\varepsilon_{back} = \varepsilon_{supply}$ and $\tau_{net} = 0$, $F_{net} = 0$

Question 23 (7 marks)

An electron is fired horizontally between a pair of oppositely charged metal plates, as shown in the diagram below.



(a) What magnetic field $\vec{B}$, would be required to be applied for the electron to travel undeflected between the plates? **4**

$F_{net} = qvB - qE = 0$

~~$v = qE$~~

F_B

F_E

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

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

$= \frac{V}{dv}$

$= \frac{100}{0.005 \times 1.5 \times 10^6}$

$= 0.0133\,T$

$\therefore B = 1.33 \times 10^{-2}\,T$ Out of the page

(b) Assuming the magnetic field in part (a) extends well beyond the length of the plates, determine the trajectory of the electron after it leaves the plates. **3**

Support your answer with an appropriate calculation.

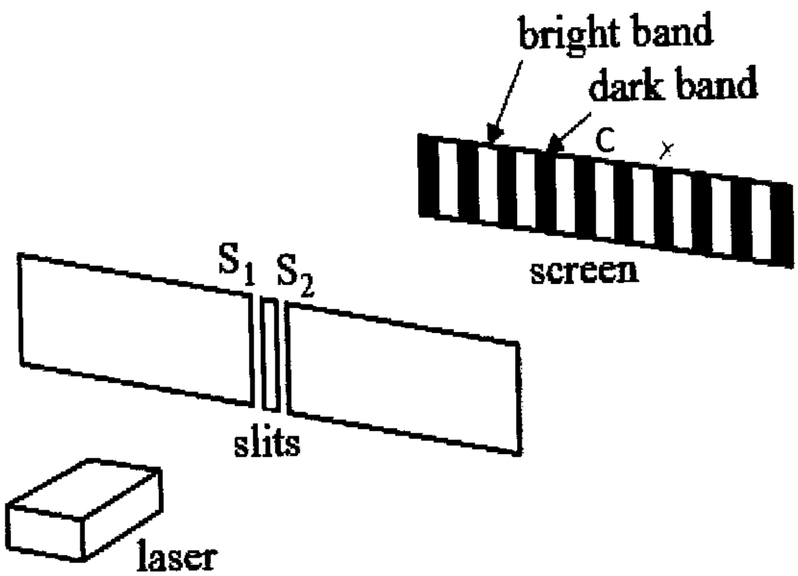
As a $\vec{B}$ field acting on a charged particle causes the particle to undergo uniform circular motion, it would go up the page and exhibit uniform circular motion. By $F_{net} = 0 = \frac{mv^2}{r} - qvB$,

$r = \frac{mv}{qB} = \frac{9.109 \times 10^{-31} \times 1.5 \times 10^6}{1.602 \times 10^{-19} \times 1.3 \times 10^{-2}} = 0.000639\,m$

$\approx 6.4 \times 10^{-4}\,m$ radius.

Question 24 (7 marks)

Louise set up a double slit experiment using a 610 nm laser, as shown in the diagram below.



The light power output of the laser is $5.03 \times 10^{-3}\ Js^{-1}$.

(a) Calculate the number of photons leaving the laser each second. **3**

$E = hf = \frac{hc}{\lambda} = 3.25 \times 10^{-19}$ J per photon

$n = \cancel{\frac{3.25 \times 10^{-19}}{5.03 \times 10^{-3}}}$

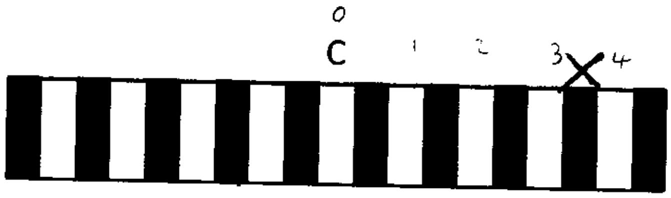
$= \frac{5.03 \times 10^{-3}}{3.25 \times 10^{-19}}$ $\frac{Js^{-1}}{J} = s^{-1}$

$= 1.54 \times 10^{16}$ Photons per second

Question 24 continues on page 16

Question 24 (continued)

(b) A segment of the screen image is shown below. The point C, the centre of the image, is directly above a bright band and is also directly opposite the middle of the two slits S_1 and S_2.



Why is the band below point C a bright band rather than a dark band? **2**

Below C is the central maxima, where the mos constructive interference occurs, as it is equidistant from slits S_1 and S_2. By diffraction, this means more light waves arrive at C in phase, causing more constructive interference, more intense light and therefore brighter light.

(c) Another point, X, to the right of C, is further from S_1 than S_2 by $2.135 \times 10^{-6}\ m$.

Mark this position by writing an X on the diagram in part b) above. **2**

Justify your answer with a calculation.

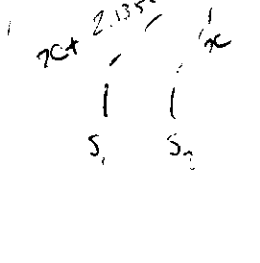
$d\sin\theta = n\lambda$

$f = \frac{c}{\lambda} = \frac{3\times10^{8}}{610\times10^{-9}} = 4.918\times10^{14}$ Hz

$n = \frac{d}{\lambda} = 3.5$

$\therefore$ Destructive interference

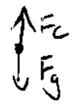
$\therefore$ X is dark



Question 25 (4 marks)

The Earth and Venus orbit the Sun in approximately circular orbits in the same direction.

(a) Derive an algebraic expression for the orbital velocity v_0 of any satellite in a circular orbit of radius r around a mass M. **2**



$F_{net} = 0 = \frac{\cancel{m}v^2}{r} - \frac{GM\cancel{m}}{r^{\cancel{2}}}$

$v_0^2 = \frac{GM}{r}$

$v_0 = \sqrt{\frac{GM}{r}}$

(b) A common theme in science fiction books and movies is for planets to be forced into the same orbit, resulting in the planets colliding with each other.

The Earth and Venus rotate in the same direction whilst orbiting the Sun.

If Venus was successfully moved into Earth's orbit, with no change in its direction of rotation, justify whether the two planets would, in fact, collide. **2**

As v_0 is inversely proportional to $\sqrt{r}$, this means that an increase in r would result in an decrease in v_0. As the r would be the same as the earth, both planet's v_0 would be the same, with the same total energy. This means that as long as Venus was not directly moved into the earth, it would orbit around the Sun at the same radius as the Earth, if the effects of gravity between the Earth and Venus are ignored.

Question 26 (5 marks)

Th-234 is an unstable isotope that is part of the decay series for U-238. It undergoes beta minus decay.

(a) Write the equation for the beta minus decay of a Th-234 nucleus **2**

$^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu} + {}^{0}_{0}\gamma$

(b) A U-238 nucleus commonly undergoes alpha decay to become a Th-234 nucleus. The reaction proceeds by the following equation:

$$^{234}_{92}U \longrightarrow {}^{230}_{90}Th + {}^{4}_{2}He$$

Using the data given in the table below, calculate, to 4 significant figures, the energy, in joules, released in this reaction. **3**

Particle	*Mass (u)*
U-238	238.050788
He-4	4.001506
Th-234	234.0436

$\Delta m = (234.0436 + 4.001506) - 238.050788$

$= 0.005682$ u lost as energy

$= 9.437802 \times 10^{-30}$ kg lost

$E = \Delta m c^2$

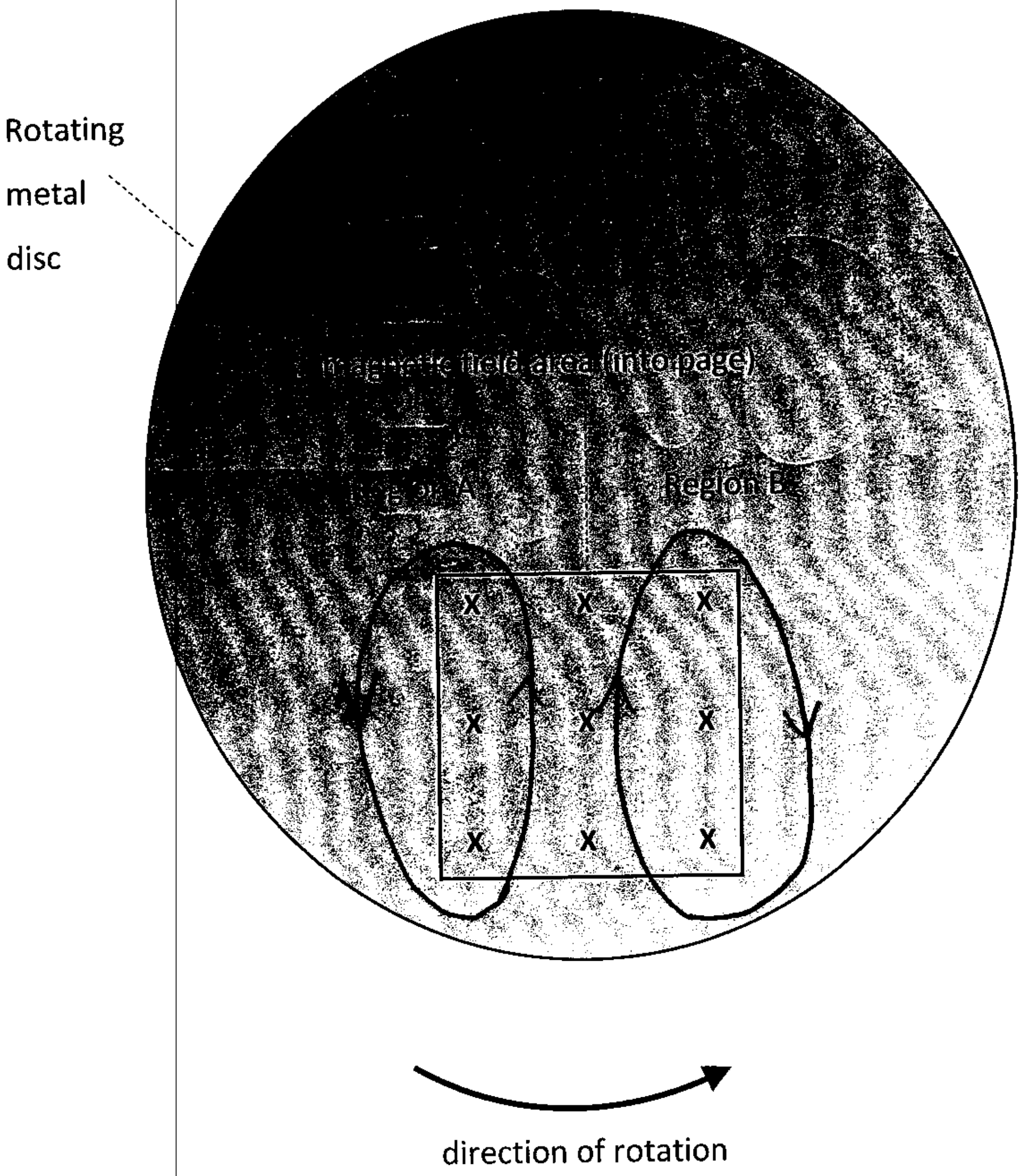
$= 9.437802 \times 10^{-30} \times 9 \times 10^{16}$

$= 8.494 \times 10^{-13}$ J

ACE PHYSICS EP 3

Question 27 (6 marks)

The diagram below shows a metal disc (part of a wheel) that has part of its surface exposed to a magnetic field directed into the page. The disc rotates anticlockwise initially.



As a result of its rotation, currents are induced in the metal disc and the disc slows down.

(a) Annotate the diagram to show these induced currents. 1

Question 27 continues on page 20

Question 27 (continued)

(b) Lenz's Law states that "*if a conductor experiences a change in magnetic flux, an induced magnetic-field B_{ind}, always acts to oppose the change in magnetic flux $\Delta\Phi$ that caused it*".

Justify, using Lenz's Law, the direction of the induced currents drawn in part a). **4**

As ~~the~~ Point X enters the $\vec{B}$ field ~~into the~~ from the left into region A it experiences a change in magnetic flux. By Lenz's law this induces a $\vec{B}$ field out of the page to oppose and minimise this change in flux. Also by Faraday's Law ~~an~~ an induced emf and current arise, meaning by the right hand grip rule, an eddycurrent is induced on the left in an anticlockwise direction. In the middle, X does not experience any $\Delta\phi$ and $\therefore$ no induced eddy currents. As X leaves the B field in region B, however, there is a decrease in ϕ_B, and by Lenz's law, the conductive wheel induces a B field into the page to minimise the change in flux. Hence, by Faraday's law an induced emf and eddycurrent is induced by this change in flux and ~~an~~ an clockwise rotating eddy current is induced in Region B.

(c) Identify the energy transformation the metal disc is experiencing as it slows down. **1**

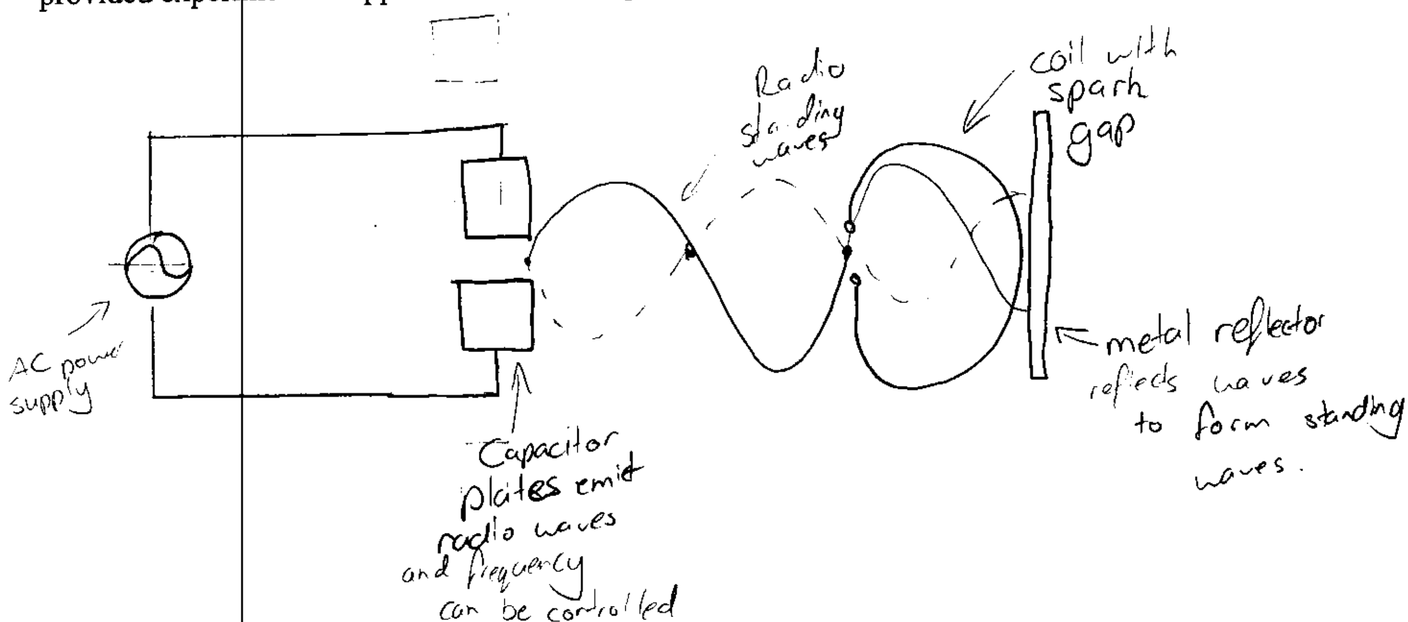
~~Electrical~~ ~~Kinetic energy → electrical pot.~~

Electrical potential from $\mathcal{E}_{ind}$ → Kinetic energy opposing motion.

Question 28 (9 Marks)

In 1873, James Clerk Maxwell's mathematical theory predicted that electromagnetic disturbances should propagate through space at the speed of light and should exhibit the wave-like characteristics of visible light.

Explain, with the aid of an appropriately labelled diagram, how Heinrich Hertz, in 1887, provided experimental support for Maxwell's predictions. **9**



Maxwell used 4 equations to combine the fields of electricity and magnetism, proposing light was a wave made up of varying, perpendicular $\vec{B}$ and $\vec{E}$ fields, and that it required no medium. This did only only apply for light, but all EMR. Giving the speed of light as $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ (which is correct), Maxwell found a theoretical value of the speed of light ~~than~~ in a vaccum. This theoretical value was confirmed later by Hertz in 1887. By setting up the diagram above, the AC power supply meant accelerating charges were in the capacitor plates, a control method that allowed the frequency of the AC current, and therefore EMR produced's ~~wav~~ frequency. By using a silver reflector to

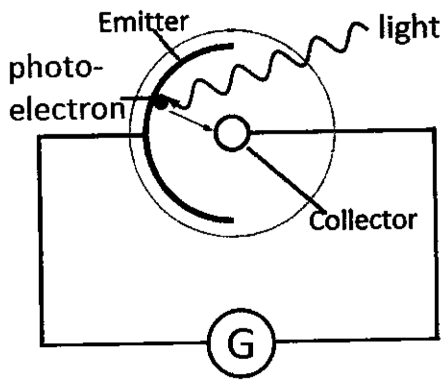
Question 28 continues on page 22

Question 28 (continued)

reflect any waves incident, Hertz set up standing waves with ~~the~~ the radio waves generated by the circuit. By using a copper wire coil with a spark gap, Hertz was able to find the areas with no spark and maximum intensity spark (nodes and antinodes). By measuring gaps between antinodes where there was no spark, Hertz measured the $\frac{\lambda}{2}$ of the wave. By using $v = f\lambda$, Hertz calculated the speed of radio waves to be around $2.8 \times 10^8 \, ms^{-1}$, very close to the expected 3×10^8 predicted by Maxwell. This slowness came from air as the medium, not a vaccuum, and showed that ~~the~~ EMR travel/propagate through space at a fixed speed. Furthermore, this showed that radio waves had wave properties, as particles could not ~~show~~ form standing wave, ~~as~~ confirming Maxwell's work in his unification of electromagnetism. This meant Hertz and other scientists could infer, that like radio waves, visible light was a type of EMR, propagating through space at fixed speeds (speed of light, c) and exhibit wave properties.

Question 29 (4 marks)

Experiments on the photoelectric effect revealed surprising results that contradicted the classical (wave) model of light. 4



Two of these results were the existence of a threshold frequency and the lack of any time delay in photoemission, when it occurred.

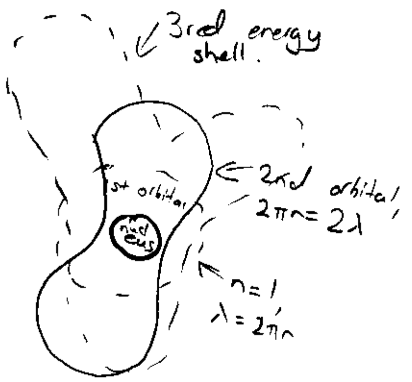
How did Einstein's particle model of light explain these two experimental results?

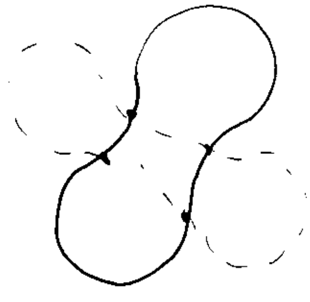
Einstein's hypothesized particle, the photon, carried energy by $E=hf$. Due to the strong coulombic attraction between an electron and a positive nucleus, enough energy was required from a photon to ~~interact~~ collide with the atom and to eject an electron. This energy is equal to the ionisation energy of each electron. If a photon had a too low frequency and ∴ kinetic energy, then that meant that it did not have sufficient energy to force an atom to eject an electron, called the threshold frequency. If light was a wave, then the ~~ele~~ atom would absorb the energy ~~or reflect it~~ and eject an electron ~~by~~ due to the EMR being absorbed, and not predicting a threshold frequency. ~~Tran~~ Furthermore, a wave delivers energy gradually, meaning if a wave interacts a particle, it should have some time to build up energy to release a photoelectron. However, a particle with K_E can ~~eject~~ transfer lots of energy very quickly through elastic collisions, making the photoelectrons emitted the instant the light with a high enough ~~the~~ frequency to be above the threshold by $E=hf-\phi$ to instantly eject an electron.

Question 30 (5 marks)

Describe Louis de Broglie's explanation of stable quantised electron orbits. **5**

After the failures of Rutherford's model to explain issues such as why orbiting electrons did not emit EMR, lose KE and collapse into the nucleus, Bohr postulated that electrons have stable circular orbits, but could not explain why in any of his postulates. De Broglie solved this issue by hypothesizing that in the atom, electrons move around in quantised orbits as waves. Whereas Bohr postulated ~~stated~~ electron orbits were circular, De Broglie stated they were integer multiples of an electron's wavelength, and that electron waves formed standing waves and hence did not emit ~~lose~~ EMR and lose energy. Furthermore, he was able to prove Bohr's 3rd postulate with some revisions, as $2\pi r = n\lambda$, as n is the orbital shell/energy level. By stating the orbits formed standing waves, this showed that electron orbits were quantised by $E=hf$ and $\lambda = \frac{h}{mv}$, proposing that matter (electrons) could act as waves in a wave-particle duality. Furthermore, ~~this explained~~ the explanation of electrons as standing waves meant that each orbital was stable and quantised, and that electrons could exist anywhere on each orbital, found at points of intersection on each level.





Question 31 (5 marks)

(a) Discuss ONE reason why the early universe was radiation dominated. **2**

The early universe was very hot, meaning it was not possible for matter to form, as it would be turned back into energy anyway, meaning that there was lots of radiation.

(b) Approximately 380 000 years after the big bang this radiation was released into the universe around the same time as neutral atoms formed.

Identify what this remnant radiation is known as today and outline why it is so important to our understanding of the universe. **3**

Cosmic ~~Micro~~ Background Microwave Radiation. This wave has been identified as around 2°K above absolute zero and is important in our understanding of the universe as it originally was gamma radiation made when the first atoms formed from the combination of quarks and leptons. Over time, this meant that the gamma rays lost energy and their subsequent wavelength increased, going from γ to microwaves. It ~~is~~ by finding out how long it takes for a wave to lose that much energy, the time and age of this wave can be calculated and shows us when the first neutral atoms were formed.

Question 32 (2 marks)

Calculate the minimum energy, in joules, a photon must have in order to eject an electron from the innermost shell of a hydrogen atom. 2

$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ $f = \frac{c}{\lambda}$

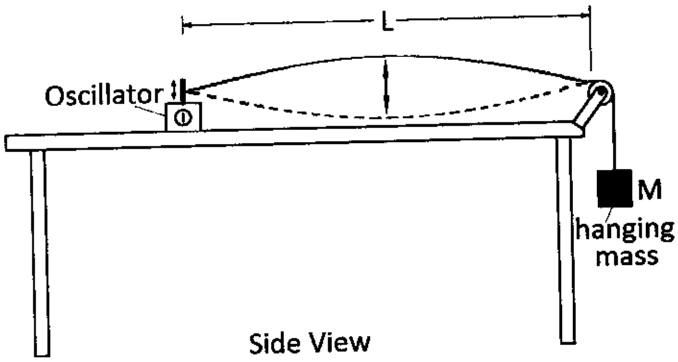
$E = hf = \frac{hc}{\lambda} = hcR\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$= 6.626 \times 10^{-34} \times 3 \times 10^{8} \times 1.097 \times 10^{7} \times \left(\frac{1}{7^2} - \frac{1}{1^2}\right)$

$= 2.136 \times 10^{-18}$ J

Question 33 (7 Marks)

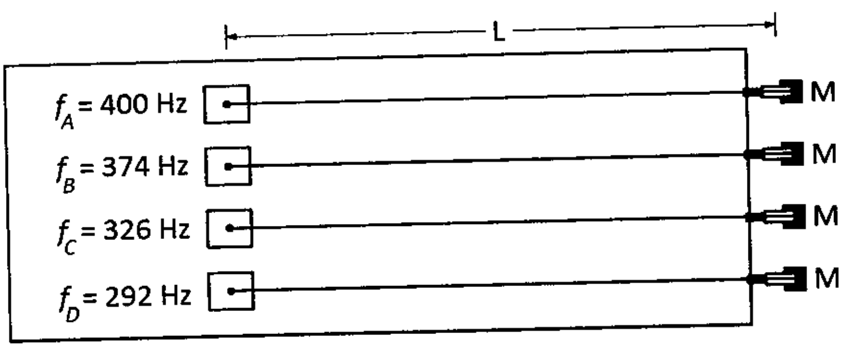
The figure below shows a side view of a student's experimental set-up.



Side View

- A metal wire (wire A) is attached to an oscillator at one end and a hanging mass via a pulley at the other end.
- The wire is set to oscillate at its fundamental frequency f_A, as shown.
- The experiment is repeated for three other wires made of the same metal (wires B -D).
- The distance L between the oscillator and the pulley is kept constant for all experiments involving the four wires A – D. However, each wire oscillates with a different fundamental frequency $f_A - f_D$.

A top view schematic diagram of the experimental set up is shown below.



Top View

The frequency of oscillation of each metal wire is given by the equation: $f = \frac{1}{\lambda}\sqrt{\frac{T}{\mu}}$

where: λ = wavelength of a wave

T = tension in the string

$\mu = \frac{M}{L}$ = mass per unit length of the string.

Question 23 continues on page 28

Question 33 (continued)

Explain, using physics principles and the information given, what would cause the wires to oscillate with different fundamental frequencies. **7**

As ~~freq~~ As frequency and λ vary with each other in an inversely proportional way and are dependent on the other variables, frequency is dependent on something else. This means ~~by~~ that ~~frequ~~ the fundamental frequency ~~is~~ ~~d~~ differs by the factor of $\sqrt{\frac{T}{\mu}}$

As $\mu = \frac{M}{L}$ and L is constant, as the wires are the same material, and L is kept constant, the only other variably is the tension in the string. However, as mass of the blocks are kept constant, This means that the frequency is determined by the tension in the string. These differences in tension do not come from the ~~2~~ masses but can be from other variables.

~~$A2\ 400 = \frac{d}{\lambda}\sqrt{\frac{T}{\mu}}$~~ This means that by $v = f\lambda$

$\therefore v = \sqrt{\frac{T}{\mu}}$

$F = ma$

$= m(v-u)$

$= m(v-0) = mv$

$\therefore mv = m\sqrt{\frac{T}{\mu}}$

$(mv)^2 = \frac{m^2 T}{\mu}$

~~$E = \frac{T}{m\mu}$~~

$\frac{1}{2}mv^2 = \frac{mT}{2m\mu}$

$K_E = \frac{mT}{2m\mu}$

Trust me, its a 7/7 just trust me

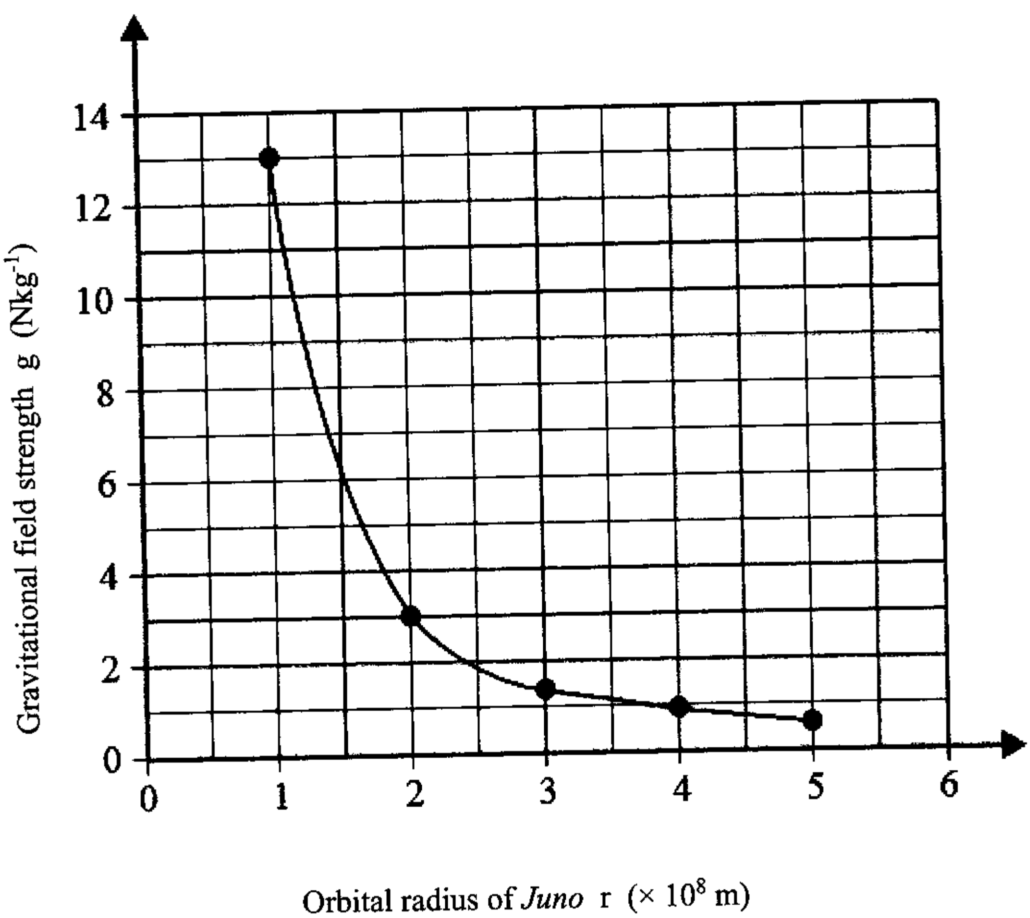
ACE PHYSICS EP 3

Question 34 (6 marks)

The spacecraft *Juno*, which has a mass of approximately 1600 kg, is currently in orbit around Jupiter.

$$U = -\frac{GMm}{r} \qquad g = \frac{GM}{r^2}$$

The graph below shows how the gravitational field strength, g, around Jupiter varies as a function of the orbital radius of *Juno, r* (distance from the centre of Jupiter).



Question 34 continues on page 30

Question 34 (continued)

(a) Use the graph to calculate the magnitude of the gravitational force experienced by *Juno* at an orbital radius of 10^8 m. **2**

This occurs at $(1 \times 10^8, 13)$ or $10^8, 13$

$\therefore$ 13 $N kg^{-1}$

(b) Show that $U = -mgr$ using the equations given. **1**

$GM = gr^2$

$\therefore U = -\frac{g\cancel{r^2}m}{\cancel{r}} = -mgr$

(c) Use the graph given and $U = -mgr$ to estimate the change in gravitational potential energy, ΔU, of *Juno* as it descends from an orbital radius of 4.0×10^8 m to an orbital radius of 2.0×10^8 m. **3**

$\Delta U = U_f - U_i$

$= (-mgr)_f + (mgr)_i$

$= m((gr)_i - (gr)_f)$

$= 1600((1 \times 4 \times 10^8) - (3 \times 2 \times 10^8))$

$= -3.2 \times 10^{11}$ J

End of paper

Section II extra writing space

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

Section II extra writing space

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