STUDENT NUMBER: | | | | | |

PYMBLE LADIES' COLLEGE

2007

TRIAL EXAMINATION

Physics

General Instructions
- Reading time - 5 minutes
- Working time - 3 hours
- Write using black or blue pen
- Draw diagrams in pencil
- Board-approved calculators may be used
- A data sheet, formulae sheets and Periodic Table are provided
- Write your Student Number at the top of this page and other pages where indicated, including the multiple choice answer sheet

Total marks – 100

Section I
75 marks
This section has two parts, Part A and Part B

Part A – 15 marks
- Attempt Questions 1-15
- Allow about 30 minutes for this part

Part B – 60 marks
- Attempt Questions 16 – 26
- Allow about 1 hour and 45 minutes for this part

Section II
25 marks
- Attempt all sections of Question 27
- Allow about 45 minutes for this section

Section I
75 marks

Part A Multiple choice 15 marks
Attempt Questions 1–15.
Allow about 30 minutes for this part

Use the multiple-choice answer sheet.

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

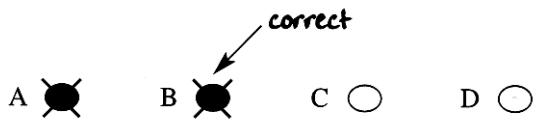
Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

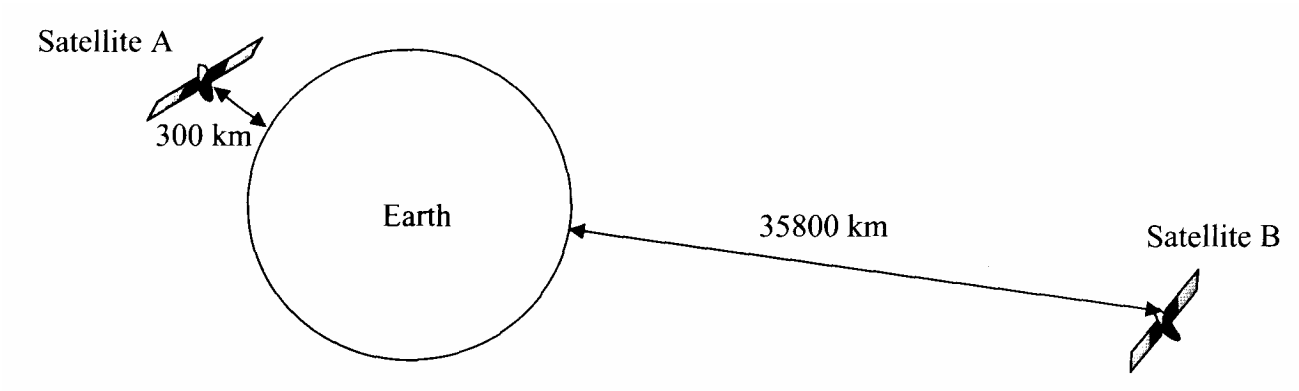
A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.



Question 1

The diagram below shows two satellites (A and B) orbiting the Earth at different altitudes.



Which is the most correct statement?

(A) Satellite A will travel at a faster speed than Satellite B

(B) Satellite A is in a geostationary orbit

(C) The period of Satellite A is equal to times the period of Satellite B

(D) The centripetal force on Satellite A is equal to the centripetal force on Satellite A

Question 2

A spacecraft of mass 5.0 x 10^3 kg is orbiting the Earth at a radius of 6.5 x 10^6 m.

What is the amount of additional energy that must be given to the spacecraft for it to completely escape the gravitational force of the Earth?

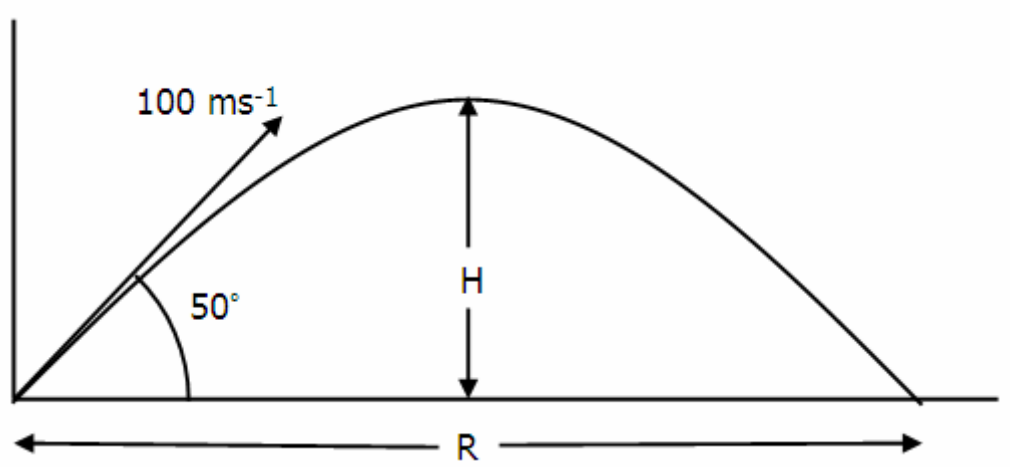
(A) 4.74 x 10^4 J

(B) - 4.74 x 10^4 J

(C) 3.08 x 10^{11} J

(D) - 3.08 x 10^{11} J

Question 3 and 4 refer to the diagram of a projectile's path, shown below:



Question 3

What time does it take for the projectile to reach its maximum height, H?

(A) 6.56 s

(B) 7.82 s

(C) 13.1 s

(D) 15.6 s

Question 4

What is the range, R, of the projectile?

(A) 502.7 m

(B) 782.0 m

(C) 1,004.9 m

(D) 1,560.0 m

Question 5

Before the Michelson-Morley experiment, the ether was proposed as the medium through which light travelled.

Which of the following was a property of the proposed ether?

The ether

(A) was partially transparent

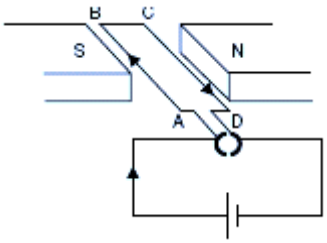
(B) had high elastic stiffness

(C) had high viscosity

(D) had lower density in matter than in free space

Question 6

A rectangular loop of wire carrying a current of 2.5 A is in a uniform magnetic field of 1.0 T.
AB = CD = 0.050 m, BC = 0.010 m



What is the torque when the coil is at 30^{o} to the field?

(A) 1.25×10^{-3} Nm

(B) 1.08×10^{3} Nm

(C) 4.33×10^{-4} Nm

(D) 2.24×10^{-4} Nm

Question 7

Work must be done on an electric generator because:

(A) The generator induces a current which assists the motion

(B) Kinetic energy must be conserved

(C) Momentum must be conserved

(D) The generator induces a current which opposes the motion

Question 8

The figure below shows two parallel wires carrying currents.

A ⟶ 0.5 A

B ⟶ 10 A

Which statement about the forces between the wires is correct?

(A) repulsive, force on A greater than force on B

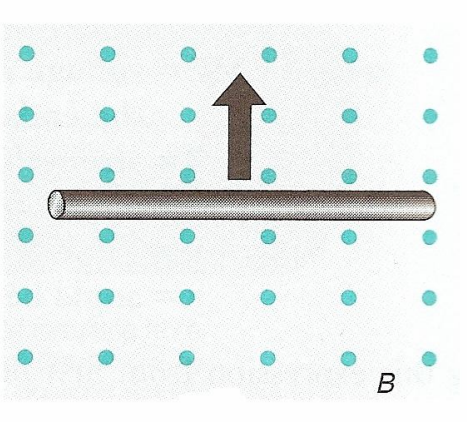
(B) repulsive, force on A and B equal

(C)	**attractive, force on A equal to that on B**

(D) attractive, force on A smaller than that on B

Question 9

Determine the direction of the induced current in the conductor moving in the direction shown by the arrow.



(A) To the left

(B)	**To the right**

(C) Out of the page

(D) Into the page

Question 10

Transmission towers are big and stand out in the landscape and so they are vulnerable to lightning strikes. Which of the following is NOT a feature used to protect transmission towers from lightning strikes?

(A) step down transformers in towers

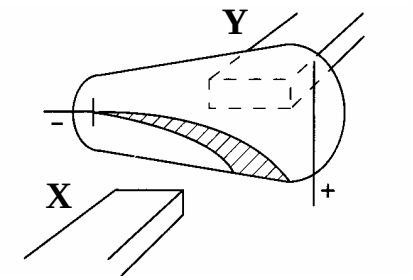
(B) ceramic insulating stacks

(C) metal towers

(D) distance between towers

Question 11

The diagram below shows cathode rays being deflected by two magnets of equal strength.



Which of the following statements about the poles of the magnets (X and Y) is correct?

(A) X and B are both North poles

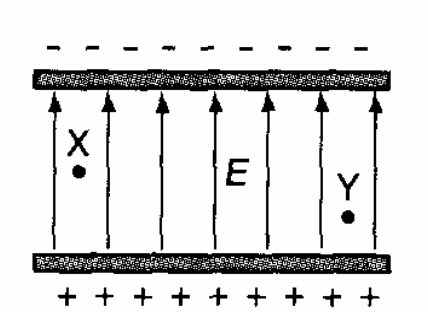
(B) X and B are both South poles

(C) X is a North pole and Y is a South pole

(D) X is a South pole and Y is a North pole.

Question 12

The diagram below shows two negative point charges (X and Y) in an electric field between two parallel plates. The magnitude of the electric charges on X and Y are the same.



Which of the following statements is correct?

(A) The forces on X and Y are both in the upward direction

(B) The force on X is greater than the force on Y

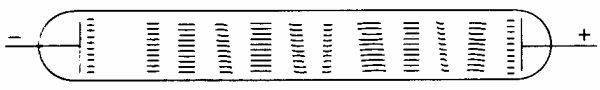
(C) The force on Y is greater than the force on X

(D) The forces on X and Y are equal

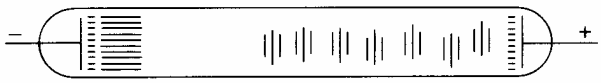
Question 13

The diagrams below show gas discharge tubes containing air at different pressures, when a constant high voltage is passed across their electrodes.

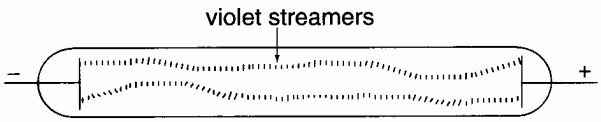
W



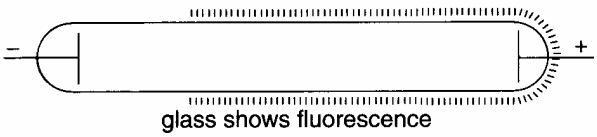
X



Y



Z



Which is the correct order of the tubes, from lowest pressure to highest?

(A) Z X W Y

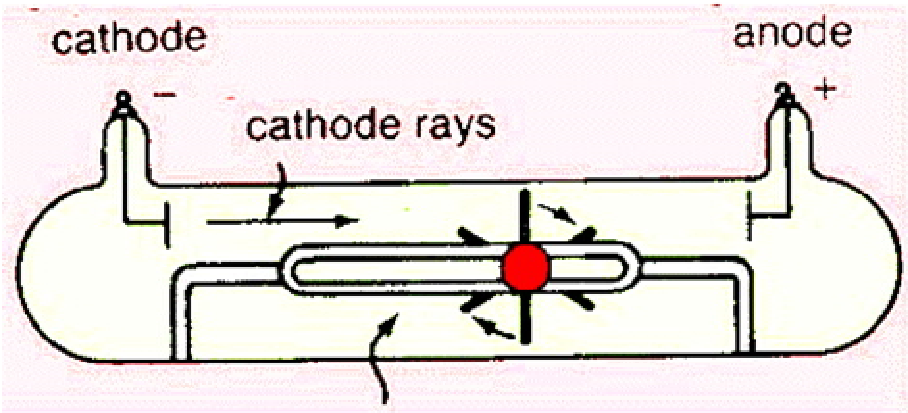
(B) X W Y Z

(C) Y X W Z

(D) Y W X Z

Question 14

The diagram below shows one of the experiments performed by Crookes when he was investigating the nature of cathode rays.



Which property of cathode rays can be deduced from this experiment?

Cathode rays

(A) are negatively charged

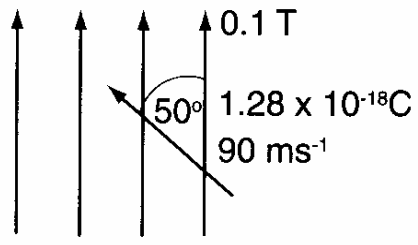
(B) have momentum

(C) travel in straight lines

(D) are deflected by electric fields

Question 15

The diagram below show the path of a charged particle in a magnetic field of strength 0.1 T. The charge on the particle is +1.28 x 10^{-18} C and it is travelling at a speed of 90 ms^{-1}.



What is the force on the particle due to the magnetic field?

(A) 1.15 x 10^{-17} N into the page

(B) 8.82 x 10^{-18} N at an angle of 50° to the magnetic field

(C) 1.15 x 10^{-17} N at an angle of 50° to the magnetic field

(D) 8.82 x 10^{18} N into the page

Section I (Continued)

Part B Extended Answers - 60 marks
Attempt Questions 16 – 26
Allow about 1 hour and 45 minutes for this part

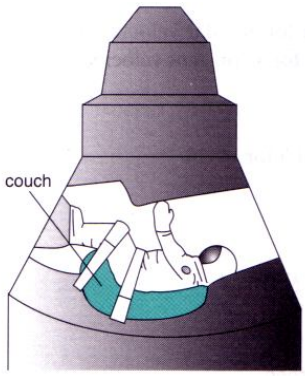
Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Question 16 (9 marks)

Marks

The diagram below shows a 70 kg astronaut during launch in a three stage space craft.



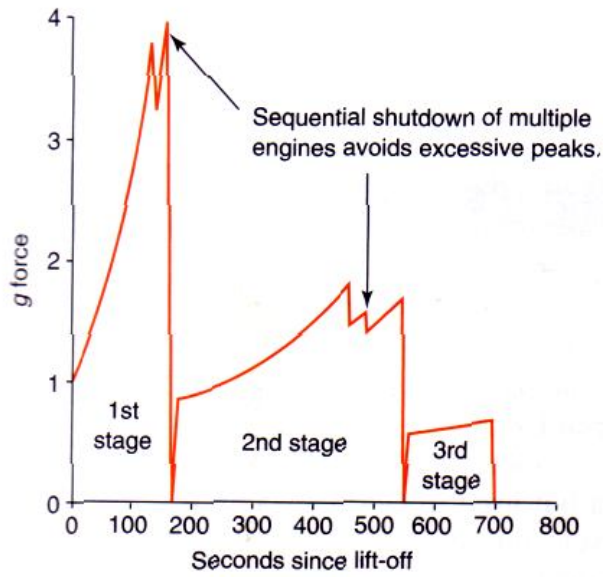
(a) Explain the term 'g force' in terms of the forces acting on an astronaut during launch. **2**

- **'g force' is the ratio apparent weight / true weight (1 mark)**
- **apparent weight = reaction force (R_a) experienced by the astronaut during launch**
- **true weight W = m.(9.8) (always 9.8 ms^{-2} even if g is changing during launch)**
- **g-force for astronaut = R_a/W_a**

(+1 mark for further explanation as shown in dot points)

Question 16 continues

The graph below shows how the g-force experienced by the astronaut changed during the launch.



(b) Account for the g force values shown by the graph between 0 and 100 s since lift-off. **3**

- **At t=0s, 'g force' is equal to 1 because the astronaut & rocket have not yet begun to accelerate, so Ra = Wa. (1/2 mark)**
- **During this phase of the launch, the net force on the astronaut ($\Sigma F_a = R_a - W_a$) is greater than zero, as the rocket & astronaut are accelerating. (1/2 mark)**
- **Therefore, Ra > Wa, so ('g force' is > 1). (1/2 mark)**
- **The 'g force' continues to increase over the time period (0 - 100 s) because the acceleration of the rocket & astronaut continues to increase. (1 mark)**
- **The acceleration increases because the thrust of the rocket engine is approximately constant, but the mass of the rocket is decreasing because the burnt fuel is being expelled to propel the rocket & astronaut. (1 mark)**

(Maximum 3 marks)

Question 16 continues

The third stage rocket was shutdown after 700 s since lift-off, at an altitude of 190 km.
(The radius of the Earth is 6.4×10^6 m)

(c) (i) Calculate the weight of the astronaut at this altitude. **2**

$F_g = GM_EM_a / r_a^2$

$= (6.67 \times 10^{-11})(6.0 \times 10^{24})(70) / (6.4 \times 10^6 + 1.90 \times 10^5)^2$

$= 645$ N (towards the centre of the Earth)

(1 mark for correct substitution; 1 mark for correct answer (-1/2 mark for incorrect unit); no mark for direction)

(ii) Justify the assertion that the astronaut is 'weightless' at this point. **2**

- **i.e. the reaction force experienced by the astronaut is zero (1 mark)**
- **the 'apparent weight' of the astronaut is zero (1/2 mark)**
- **after shutdown, the only force acting on the astronaut is their weight. (1/2 mark)**

(Max. 1 mark)

(d) Identify why g force is an important issue during re-entry of a spacecraft into the Earth's atmosphere. **1**

- **If the angle of re-entry is too steep (greater than about 7° to the surface of the atmosphere), the negative acceleration (and resulting g forces) will be too great for the astronauts to survive.**

(1 mark)

End of Question 16

Question 17 (6 marks) **Marks**

Sometime in the distant future, a rocket may be launched to visit the solar system's nearest star, proxima Centauri. The distance to proxima Centauri is 4.2 light years. Assume that the rocket is able to travel at 0.7 c (0.7 of the speed of light).

(a) Compare quantitatively (calculate values) the time it would take the rocket to reach proxima Centauri as measured by observers on Earth and observers in the rocket. (Ignore any time required to accelerate the rocket after leaving Earth). **4**

Two frames of reference:

Earth observer	**Rocket observer**
v = 0.7 c	**v = 0.7c**
$L_E = L_o$ = 4.2 l.y. = 4.2 c x 1 yr	**$L_R = L_v = Lo \sqrt{(1-v^2/c^2)}$**
$t_E = t_v = t_o / \sqrt{(1 - v^2/c^2)}$ = ?	**$t_R = t_o = tv \sqrt{(1-v^2/c^2)}$**
$t_v = L_o/v$ = (4.2c x 1 y) / 0.7c = 6 yr	**= (6) x $\sqrt{(1 - (0.7c/c)^2)}$**
	= 4.28 yr
(2 marks)	**(2 marks)**

i.e. The rocket observer measures 4.28 yr for the journey, while the Earth observer measures a greater time of 6 yr.

(b) Compare qualitatively (do not calculate values) the distance measured between Earth and proxima Centauri as measured by observers on Earth and observers on the rocket. Justify your answer. **2**

- **As seen from the equations:**

$L_E = L_o$ and $L_R = L_v = Lo \sqrt{(1-v^2/c^2)}$ (1 mark)

- **it can be seen that $L_E > L_R$ (1 mark)**

Question 18 (5 marks)

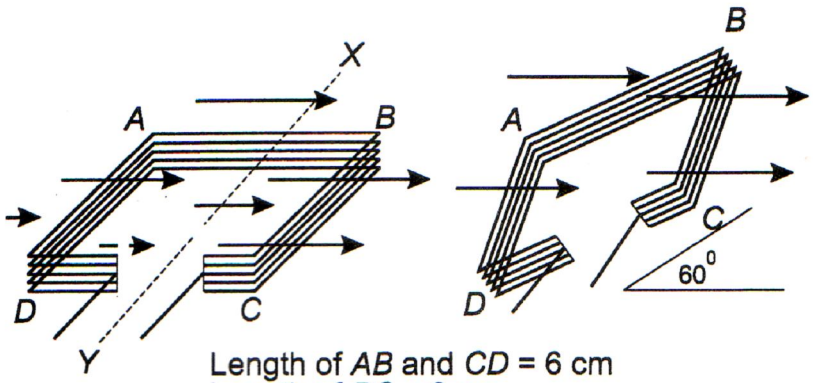
(a) Outline the nature of inertial frames of reference. • **Inertial frames of reference have a constant velocity (zero acceleration) (1 mark)** • **There is no experiment that can be performed that can distinguish between one inertial frame and another (the Principle of Relativity) (1 mark)**	**2**
(b) Discuss the role of Michelson and Morley's experiment, to measure the relative velocity of the Earth through the aether, in making determinations about competing theories that were proposed at the time.	**3**

- **MM experiment found that there was no change in the speed of light when the Earth moved in different directions relative to the 'proposed' aether. (1/2 mark)**
- **This 'null result' suggested that the aether did not exist. (1/2 mark)**
- **Some attempts were made to account for the 'null result' e.g. Lorentz-Fitzgerald equations which implied that lengths of the apparatus used in the measurements (Michelson interferometer) changed as they moved relative to the aether - but these were only empirical (arbitary) without any theoretical basis. (1/2 mark)**
- **i.e. the theory that the aether was the medium through which light travelled was weakened and any theory which did not rely on the aether would be strengthened. (1 mark)**
- **e.g. Maxwell's equations implied that the speed of light would be 3×10^8 m/s, regardless of the motion of the frame of reference OR Einstein's Special Theory of Relativity second postulate is that the speed of light will be the same for all observers, regardless of the relative motion of the source of light and the observer i.e. it had no requirement for an aether. The null result for the MM theory helped in the acceptance of Einstein's theory and in the acceptance that Maxwell's equations applied for all frames of reference. (1 mark)**

(Maximum of 3 marks)

Question 19 (3 marks) **Marks**

A rectangular coil, 3 cm x 6 cm and consisting of 100 turns, is placed in a magnetic field of strength 0.15 T. Initially the coil lies in a plane parallel to the magnetic field. It is then rotated about the axis XY through an angle of 60^o as shown.



Length of *AB* and *CD* = 6 cm
Length of *BC* = 3 cm
Number of turns = 100

(a) Identify the initial magnetic flux through the coil. **1**

- **the magnetic flux is given by** $\Phi = BA\cos\theta = BA\cos 90 = 0$ **(1mk)**

or

- **zero flux**

(b) Calculate the final magnetic flux through the coil. **1**

- $\Phi = BA\cos\theta = 0.15x3x6x\cos 60 = 1.35x10^{-4}T$
- **Correct answer and units (1/2 mk each).**

(c) Faraday's Law states that the induced emf is proportional to the rate of change of magnetic flux through the coil, that is $\varepsilon = -n\dfrac{\Delta\Phi}{\Delta t}$ (where *n* is the number of coils).
Calculate the induced emf if the coil is rotated through 60^o in 0.01s. **1**

- $\varepsilon = -n\dfrac{\Delta\Phi}{\Delta t} = -100x\dfrac{1.35x10^{-4}}{0.01} = -1.35V$ **.**

- **Correct answer and units (1/2 mk each)**

Question 20 (5 marks)

Assess the effects of the development of AC generators on society and the environment. **5**

See all possible answers below; 2 marks for 1 pro and 1 con for society & 2 marks for 1 pro and 1 con for environment.

Positives (1 mk each):

- steam driven engines replaced by electric engines - more efficient and produced less heat into environment, less fuel waste pollutants, cleaner air, cleaner clothes, etc.
- cleaner environment meant better general health in people.
- better health meant greater ability to work, so more reliable income to provide essentials for living.
- more efficient production because of the more efficient machinery in factories meant cheaper produce.
- greater demand for products and thus more employment.
- hydroelectricity schemes provided work for thousands and took pressure off government welfare programs and provided a cleaner source of electricity.
- cheaper electricity, and the ability to transmit it long distances, revolutionised communications, refrigeration and food storage.
- personal comfort improved with air conditioning and electric blankets.
- leisure activities, movies, TV, CDs, hi-fi systems, kitchen appliances, workshop tools.
- the computer revolution has impacted on everybody and almost every thing we do: leisure and work, e.g. banking, buying and selling, keeping accounts or doing school homework.
- more opportunities (which could be traced back to electricity prompted improvements) in cities have drawn more and more people to the suburban sprawl.

Negatives (1mk each):

- however, atmospheric pollution has increased enormously as demand for electrical power increased. Pollution from the burning of fossil fuels has reversed initial gains.
- heat pollution from coolant water into natural streams has affected water quality and water life adversely, affecting peoples' leisure activities, e.g. fishing.
- the development of nuclear power stations to cope with decreasing availability of fossil fuels in some countries has its own side effects - nuclear waste disposal, radiation hazards for thousands of years, accident possibilities and social unrest.
- hydro schemes impacted severely on specific areas of the environment, requiring huge dams, flooding of forests, valleys and even towns.
- ugly power lines cross the countryside and offer impact sites for accidents.
- transformers in substations and polemounted in streets are not visually attractive.
- possible harmful effects from high frequency electromagnetic radiations are associated with high AC voltage transmission.
- longer term effect has been the elimination of many unskilled jobs, impacting government welfare programs, family lifestyle and stability, community stability.
- many country areas are struggling from lack of opportunity, particularly for their younger generations.

1 mark for assessment – ie. any reasonable judgement on the overall value of generators on society

Question 21 (5 marks)

During your course, you performed a first-hand investigation to verify the effect on a generated current when the relative motion between a coil and a magnet is varied.

Outline the method you used and the results you obtained. Include a diagram to illustrate your answer. **5**

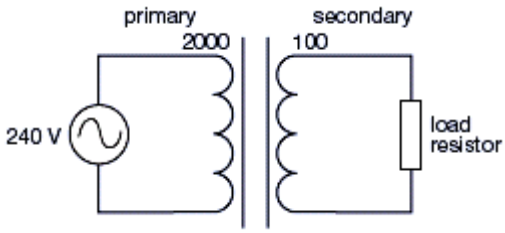
- **labelled diagram containing ammeter, solenoid, magnet, wires (1mark)**

One mark each for mentioning the following (max of 4 marks):

- **distance between coil and magnet affects current generated**
- **strength of magnet affects magnitude of current induced**
- **speed of relative movement between magnet and coil affects the magnitude of the induced current**
- **the number of turns on the solenoid affects the magnitude of the induced current**
- **flow of induced current was indicated by deflection of needle on ammeter**
- **direction of current changed when magnetic poles were reversed**

Question 22 (4 marks)

A transformer has 2000 turns in its primary coil and 100 turns in its secondary coil. Assume the transformer has 100% efficiency. The load resistance is 120 ohms.



(a) Calculate the output voltage when the input voltage is 240 V. **1**

- **Vp/Vs=np/ns → Vs = 12V**
- **correct substitution (1/2 mk)**
- **correct answer and units (1/2 mk);**

(b) Calculate the current that flows through the primary coil. **2**

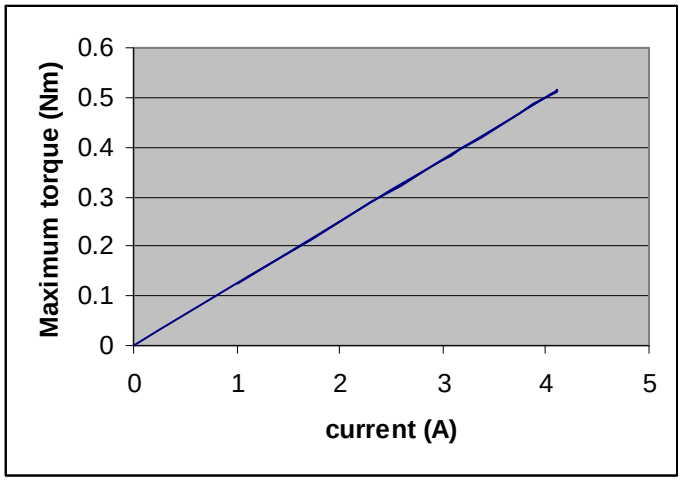
- **for calculating Is and correct units (1 mk each);**
- **for calculating Ip using Is (1mk)**

(c) Identify one reason why, in practice, the power output of the transformer is less than the power input. **1**

- **Some energy is lost as heat (due to e.g. eddy currents in the soft iron core of the transformer) (1 mk)**

Question 23 (3 marks)

A square coil with 5 cm sides is placed in a uniform magnetic field of strength 0.05 T. The figure below shows how the maximum torque on the coil changes with the current through it.



(a) Predict the position of the coil relative to the magnetic field when the torque is at its maximum. **1**

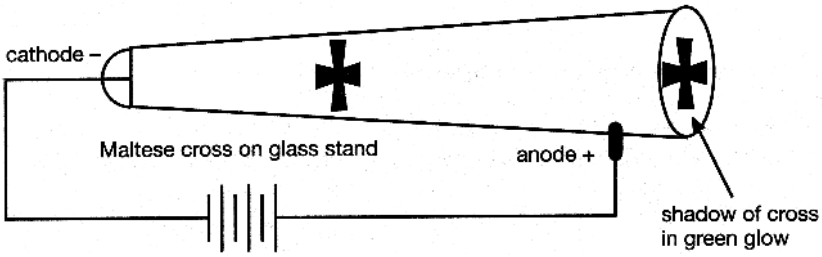
- **area of the coil is parallel to the magnetic field (1mk)**

(b) Calculate the number of turns in the coil. **2**

- **using gradient from torque and current graph (1mk);**
- **correct answer (1 mk); - ½ for units**

Question 24 (5 marks) **Marks**

The diagram below shows one of the experiments performed by Crookes when he was investigating the nature of cathode rays.



(a) Identify two pieces of information about cathode rays that can be gained from this experiment. **2**

- **cathode rays travel in straight lines**
- **cathode rays are emitted from the cathode (negative electrode)**
- **cathode rays can cause fluorescence (i.e. must have some form of energy)**

(1 mark per point up to a maximum of 2 marks)

(b) When cathode rays were first investigated, there was a debate as to whether they were negatively charged particles or electromagnetic waves. Outline one experiment that was interpreted as showing that cathode rays were electromagnetic waves. Include a diagram to illustrate your answer. **3**

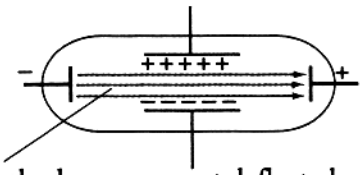
The evidence from Crookes' experiments so far gave no information as to whether the cathode rays were particles or waves.

This is because both particles and waves move in straight lines and cast shadows.
EITHER:

- **In 1883, Heinrich Hertz tried passing the rays between charged plates and observed no deflection as would be expected if they were charged particles. (This observation was later shown to be incorrect by J.J. Thomson, due to inadequacies in the experimental design).**

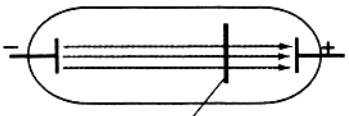
- **In 1892, Hertz also found that they could pass through a thin gold foil without leaving holes, suggesting that they may have no mass and this was interpreted to mean that cathode rays were electromagnetic waves.**

i



Cathode rays are not deflected, and behave in the same way as light

ii



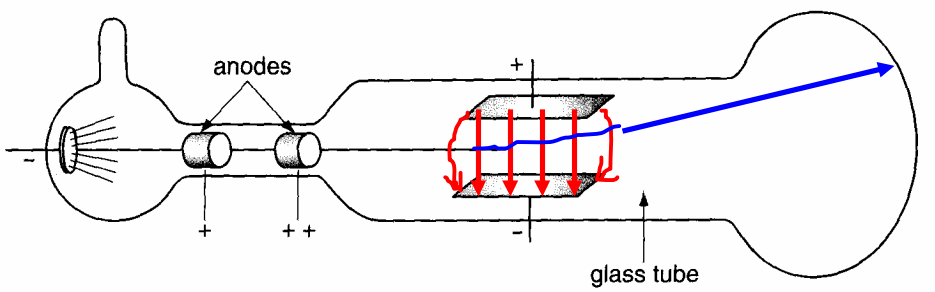
Cathode rays pass through gold foil in the same way as light passes through glass

Question 25 (8 marks) **Marks**

The diagram below shows a cathode ray tube similar to that used by J.J. Thomson in his experiment to determine the charge to mass ratio of cathode rays (electrons).

Initially, the electron beam hit the centre of the front of the cathode ray tube.

Thomson then deflected the electron beam with an electric field produced between two horizontal, parallel plates with a voltage applied across them, as shown.



(a) On the diagram, draw

(i) the electric field produced between the parallel plates. **1**

Electric field is downwards (shape ½ mark; direction ½ mark)

(ii) the path followed by the electron beam. **1**

Electron path moves in upward direction. (1 mark)

The plates are separated by a distance of 15 mm and the voltage across them is 550 V.

(b) Calculate the strength of the electric field between the plates. **2**

$E = V/d = (550)/(15 \times 10^{-3}) = 3.67 \times 10^{4}\ Vm^{-1}$

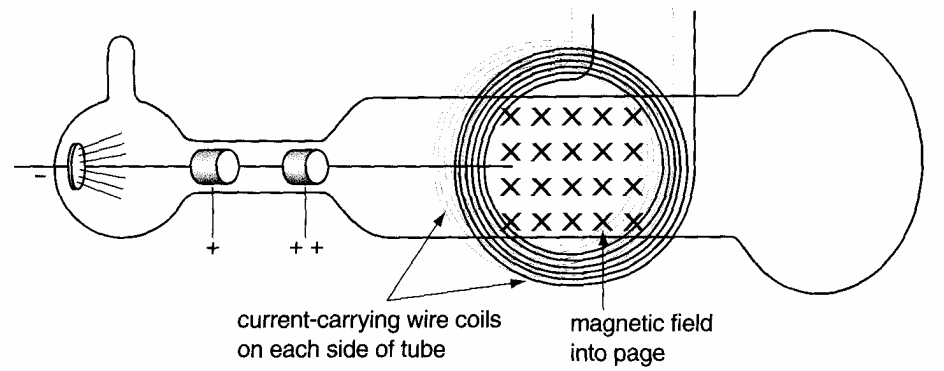
(1 mark for correct substitution; 1 mark for correct answer)

(c) Calculate the magnitude of the force on each electron in the beam as a result of the electric field. **2**

$F = Eq = (3.67 \times 10^{4}) \times (1.6 \times 10^{-19}) = 5.9 \times 10^{-15}\ N$

(1 mark for correct substitution; 1 mark for correct answer)

A magnetic field is now applied across the tube as shown below (with the above electric field still in place).



The strength of the magnetic field is adjusted until the electron beam again hits the centre of the front of the cathode ray tube.

The strength of the magnetic field is now 0.35 T.

(d) Calculate the speed of the electrons in the beam. **2**

When the electrons go straight through $F_B = F_E$ (i.e. the net force on the electrons is zero)

$F_B = 5.9 \times 10^{-15}$ N downwards (1/2 mark)

$F_B = vqB$

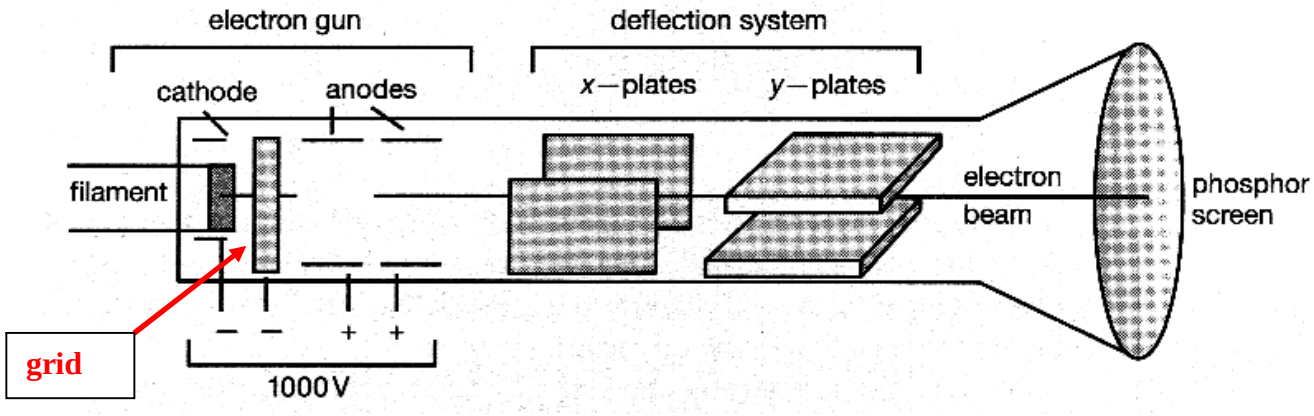
$v = F_B/qB = (5.9 \times 10^{-15}) / (1.6 \times 10^{-19})(0.35) = 1.05 \times 10^5$ ms^{-1}

(1 mark for correct substitution; 1 mark for correct answer)

(Maximum of 2 marks)

Question 26 (7 marks)

The diagram below shows the main components of a cathode ray oscilloscope.



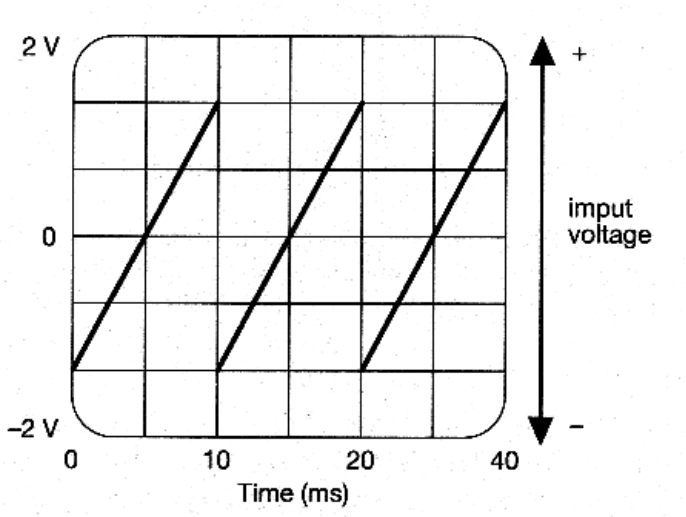
(a) Outline the role of the electrodes in the electron gun. **3**

- **The negative electrode (cathode) is heated by the filament and is the source of electrons, produced by thermionic emission. (The filament provides heat energy to the electrons and so they are more easily removed from the metal electrode.) (1 mark)**
- **(The voltage on the grid (not an electrode) is more negative than the cathode and adjustable, to make the electron beam less or more intense (by 'turning back' some electrons to the cathode))**
- **The positive electrodes (anodes) are at a positive electrical potential relative to the cathode, so electrons are attracted towards them, acquiring kinetic energy as they move towards them. (1 mark)**
- **The positive voltage of anodes can be adjusted to help focus the electrons into a narrow beam. (1 mark)**

(3 marks)

Question 26 continues

The graph below shows the voltage applied between the x-plates of the cathode ray oscilloscope shown above. (Assume that the voltage in the graph indicate the voltage of the front plate relative to the back plate in the diagram).



(b) Describe the path of the electron beam on the phosphor screen during the time shown on the graph. (Assume that the electron beam is in the centre of the phosphor screen before the varying voltage is applied.) **3**

- **The electron beam will move horizontally from the centre to the right (into the page) of the screen (1 mark)**
- **As this plate increases to 0 V and then +2V, the beam will move horizontally towards the centre of the screen and then continue towards the left (out of the page) of the screen by the same distance as it was from the centre to start with. (1 mark)**
- **Then the electron beam will move almost instantaneously back to the right of the screen (1/2 mark) and the repeat the motion back to the left, etc., for a total of 3 times. (1 mark)**

(c) Television sets typically use magnetic coils rather than electric plates to guide the path of the electron beam(s). Identify one advantage of magnetic coils compared with electric plates for television sets. **1**

- **The magnetic field produced by coils (& thus the force on the electrons and their subsequent oscillatory 'sweeping' motion) can be changed more rapidly than can the electric field between electric plates, a feature which produces a higher quality image for televisions.**

(1 mark)

End of Question 26

Section II - From Quanta to Quarks (25 marks)

Answer Question 27 - Sections (a) – (h)

Allow about 45 minutes for this section

Answer the question on the writing paper provided. Extra writing paper is available.

Write your student number on every piece of writing paper.

Show all relevant working in questions involving calculations.

Marks

(a) A photon of visible light is emitted when an electron in hydrogen undergoes a transition from the fifth energy level to the second energy level. **2**

(i) Calculate the frequency of the emitted photon.

From Balmer's equation we have:

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

$$= 1.097x10^7\, x\left(\frac{1}{2^2} - \frac{1}{5^2}\right)$$

$= 2.30x10^6\ m^{-1}$

$v = f\lambda$

$f = v/\lambda = 3.0 \times 10^8 \times 2.30 \times 10^6 = 6.9 \times 10^{14}$ Hz

Correct formula (1mk); answer and units (1/2 mk each)

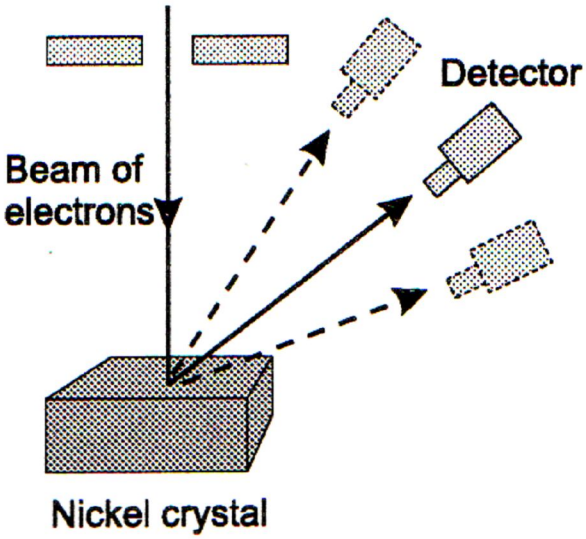
(ii) Calculate the photon's energy. **1**

Energy is given by:

$= 6.6 \times 10^{-34} \times 6.9 \times 10^{14}$ J $= 4.55 \times 10^{-19}$ J

Correct answer (1/2 mk); correct units (1/2mk)

(b) In a series of experiments in the early twentieth century, the Americans Davisson and Germer fired electrons at a nickel crystal as shown in the diagram below and detected the intensity pattern of the reflected electrons.



Identify two characteristics of the electrons that Davisson and Germer were able to deduce from this experiment. **2**

Davisson and Germer were able to show

- **the wave nature of electrons**
- **the wave length of the electron's matter waves**
- **(verifying de Broglie's hypothesis)**

(2 mk)

(c) Following is a quotation from a best selling HSC physics study guide!

> *In 1930 the Austrian physicist Wolfgang Pauli proposed the existence of a particle with properties unlike anything known at the time. It would be a particle with no electric charge, no mass, and no magnetic properties and would have almost no interaction with matter. It would, however, have energy, linear momentum and angular momentum (the momentum associated with a rotating body). As such, it was 'something' rather than 'nothing'!*

(i) Identify the particle which this quote is referring to. **1**

Neutrino (1 mk)

(ii) Explain why Pauli proposed the existence of such a particle. **2**

- **Pauli proposed its existence because there was a discrepancy between the energy and momentum of the atom and beta particles in beta decay (1 mk).**
- **Without it, the laws of conservation of energy and momentum appeared to be violated (1mk).**

(d) Consider the following nuclear reaction:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{b}_{a}X + energy\ \ Q$$

(i) Calculate the numbers represented by *a* and *b* and hence deduce what particle is represented by *X*. **2**

a= 0 ; b = 1 (1 mk); the particle is a neutron $^{1}_{0}n$ (1 mk)

(ii) Calculate the mass of *X* in (i) above, given the following data: **3**

mass $^{2}_{1}H$ = 3.3443 x 10^{-27} kg
mass $^{3}_{1}H$ = 5.0079 x 10^{-27} kg
mass $^{4}_{2}He$ = 6.6460 x 10^{-27} kg
energy Q = 2.82 x 10^{-12} J
speed of light = 3.0 x 10^{8} m.s^{-1}

- $\Delta E = \Delta mc^2$ **(1mk)**

Δm = mass of reactants – mass of products (1mk)
= (3.3443 + 5.0079) x 10^{-27} – (6.6460 x 10^{-27} + mass$_x$)
Therefore:
mass$_x$ = 1.6749 x 10^{-27} kg (1/2 mk each for units and correct answer)

(e) An important component of a nuclear fission reactor is the *moderator*.

(i) Describe the purpose of the moderator. **1**

- **The moderator slows the neutrons down to energies that improve their chances of initiating a fission reaction (1mk)**

(ii) Identify one possible material used as a moderator. **1**

- **One of the following: water, heavy water (deuterium oxide), beryllium and graphite (1mk)**

(f) A significant problem associated with nuclear reactors is the disposal of the radioactive material they produce. One proposal currently under consideration to eliminate this waste is to irradiate it with neutrons. This would convert it into other non-radioactive isotopes. One major waste isotope is technetium-99, $^{99}_{43}Tc$. When irradiated with a neutron, technetium-99 is converted into technetium-100. This technetium-100 has a half-life of 15 s and decays into stable ruthenium-100, $^{100}_{44}Ru$.

(i) Write a nuclear equation showing the *production* of technetium-100. Indicate the nature of any particle involved in the reaction. **1**

- $^{99}_{43}Tc + ^{1}_{0}n \rightarrow ^{100}_{43}Tc + ^{0}_{0}\gamma$ **where $^{0}_{0}\gamma$ is a gamma ray (1mk)**

(ii) Write a nuclear equation showing the *decay* of technetium-100. Indicate the nature of any particle involved in the reaction. **1**

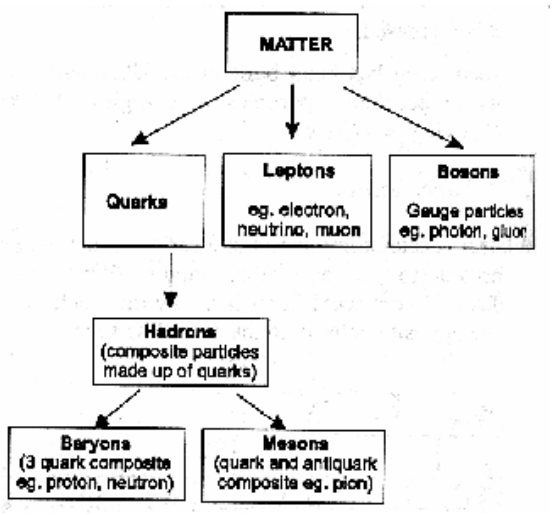
- $^{100}_{43}Tc \rightarrow ^{100}_{44}Ru + ^{0}_{-1}e$ **where $^{0}_{-1}e$ is an electron (beta particle) (1mk)**
  - **½ mk for every mistake**

(g) Neutron scattering is a powerful method for analysing the internal structure and properties of matter. Explain, by referring to two of their properties, why neutrons are useful for this purpose. **4**

- **list any TWO of their properties (2mk) and explain how this property aids in Neutron Scattering (2 mk),**
- **eg.**
  - **their wave nature causes them to scatter from atoms (1mk); the amount and type of scattering depends on the arrangement of the atoms (1mk);**
  - **has magnetic moment (1mk); this makes it ideal for studying magnetic structures and materials (1mk)**

any other

(h) Discuss the key features and components of the standard model of matter. **4**



(Flowchart: the information below could be contained in the flowchart)

Particles can be classified as either: Fermions or Bosons
(1/2 mark)
Fermions:
- obey the Pauli exclusion principle (Bosons don't)
(1/2 mark)
- obey Fermi-Dirac statistics
- two main groups:
Hadrons or Leptons:
(1/2 mark)
- Hadrons
- made of quarks
(1/2 mark)
- 2 main groups:
- Baryons: made of 3 quarks e.g. protons & neutrons.
(1/2 mark)

- Mesons: made of 1 quark and 1 antiquark e.g. pion

(1/2 mark)

- Leptons

- apparently no constituent particles e.g. electrons & neutrinos

(1/2 mark)

Bosons:

- don't obey Pauli exclusion principle

- obey Bose-Einstein statistics

- force carrying particles

(1/2 mark)

Force	Boson
electromagnetic	photon
weak nuclear	W & Z particles
strong nuclear	gluons
gravity	gravitons (speculated)

(1 mark for information in table)

(Maximum of 4 marks for Question)

End of Question

End of Paper