Student Number | | | | | | |

Newington College

Physics

Trial HSC Examination

2015

General Instructions

- Reading time: 5 minutes
- Working time: 3 hours
- Board approved calculators may be used
- Write using black or blue pen only
- Draw diagrams using a sharp pencil and ruler
- A Data Sheet, Formula Sheet and Periodic Table is provided at the back of this paper
- Write your Student Number at the top of each page

Total Marks: 100

Section I
80 marks

This section has two parts, Part A and Part B

Part A – 20 marks
- Attempt Questions 1 – 20
- Allow about 35 minutes for this part

Part B – 60 marks
- Attempt Questions 21 – 33
- Allow about 1 hour and 40 minutes for this part

Section II
20 marks
- Attempt ALL parts of the question
- Allow about 45 minutes for this section

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Section I
80 marks
Part A – 20 marks
Attempt Questions 1 to 20
Allow about 35 minutes for this part

Use the multiple-choice answer sheet for Questions 1-20.

1. A student holds a bag of marbles. Which of the following changes in either motion or position would cause a DECREASE in the apparent weight of the bag of marbles?

(A) Pulling the bag so that it accelerates upwards.

(B) Lowering the bag so that it accelerates downwards.

(C) Changing to a location where there is greater density in the underlying rock.

(D) No change in motion can alter the apparent weight.

2. The value of acceleration due to gravity on three planets, as well as their masses and radii, are given in the table below.

Planet	Acceleration due to gravity at surface ($m\ s^{-2}$)	Radius (m)	Mass (kg)
X	9.8	6.370×10^6	6.00×10^{24}
Y	9.8	3.190×10^6	1.50×10^{24}
Z	? ?	1.274×10^7	1.20×10^{25}

The acceleration due to gravity on the surface of planet Z is closest to:

(A) 2.5 $m\ s^{-2}$

(B) 4.9 $m\ s^{-2}$

(C) 9.8 $m\ s^{-2}$

(D) 19.6 $m\ s^{-2}$

3. A space probe orbits a distant planet at an altitude 100 km above the planet's surface. The planet has a mass equal to Earth; the probe's orbital period is one hour. The radius of this new planet is closest to:

(A) 1.30×10^{20} m

(B) 5080 km

(C) 4980 km

(D) 4100 km

4. A satellite's gravitational potential energy is always increased by…

(A) decreasing its altitude (with respect to surface).

(B) increasing its altitude (with respect to surface).

(C) decreasing its orbital speed.

(D) increasing its orbital speed.

5. The situation which most closely approximates an inertial frame of reference is:

(A) A moving bicycle, leaning into a curve.

(B) A car accelerating away from traffic lights.

(C) Inside an aeroplane cabin while it is maintaining velocity and altitude.

(D) Inside a box, which has just been pushed out of an aeroplane.

6. A group of students carried out a first-hand investigation to determine a value for acceleration due to gravity in their science laboratory. They used a simple pendulum, consisting of a 'bob' mass attached by string to a retort stand. They then measured the period of swing of the pendulum using a stopwatch.

Which of the following would best improve the accuracy of their results?

(A) Using a very light-weight string to suspend the bob.

(B) Making the string as long as possible.

(C) Using a heavier pendulum bob.

(D) Keeping the amplitude of the swing as small as possible.

7. A proton is accelerated so that its mass is measured to be 150% of its rest mass. Its speed is closest to:

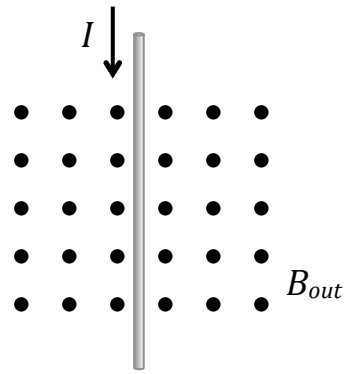
(A) $0.56c$

(B) $0.66c$

(C) $0.75c$

(D) $1.50c$

8. A wire, with current flowing down the page, is located in a magnetic field, which is directed out of the page. Which of the following alternatives will occur?



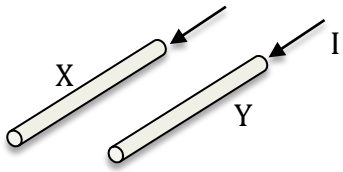
(A) The wire will experience a force out of the page.

(B) The wire will experience a force into the page.

(C) The wire will experience a force to the right of the page.

(D) The wire will experience a force to the left of the page.

9. Two long, straight, parallel wires, labelled X and Y, are 1.0 cm apart. The currents travel in the same direction; X carries 3.0 A while Y caries 5.0 A. What is the force per unit length experienced by wire Y?



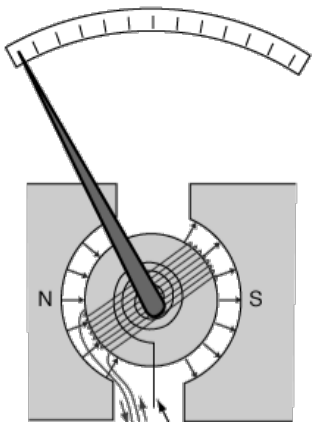
(A) 3.0×10^{-4} N m^{-1} (towards X)

(B) 3.0×10^{-4} N m^{-1} (away from X)

(C) 1.5×10^{-4} N m^{-1} (towards X)

(D) 1.5×10^{-4} N m^{-1} (away from X)

10. A diagram of a galvanometer appears below.



The working principle of such a meter is:

(A) The magnets become stronger as a current moves through the coils.

(B) The greater the current, the faster the needle rotates.

(C) The radial magnets provide a varying force on the current carrying conductor.

(D) A greater torque is produced as the current in the coil increases.

11. The purpose of a soft iron core in a transformer is to …

(A) absorb the excess energy generated by the primary coil.

(B) increase the magnetic flux through the secondary coil.

(C) prevent excessive heat loss from the coils.

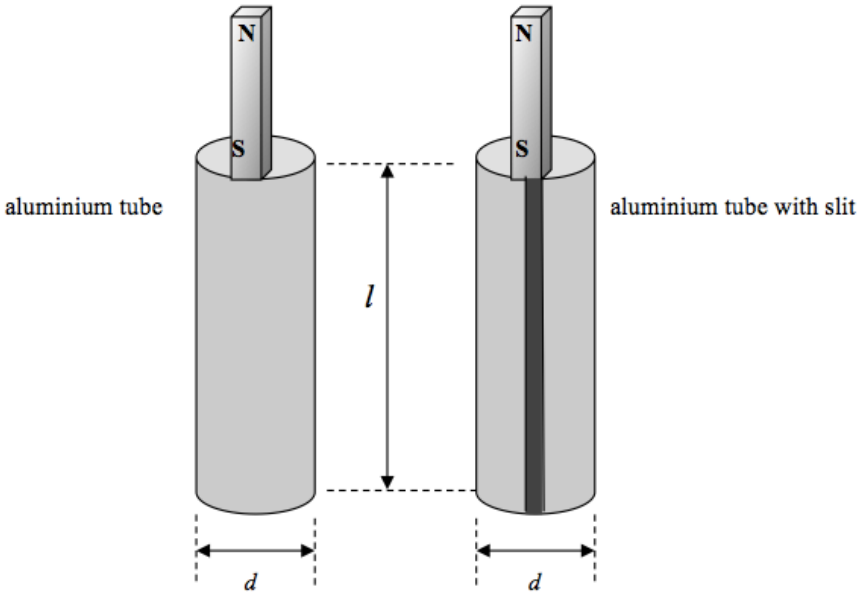
(D) trap electrical current within the transformer, thus increasing efficiency.

12. An ideal transformer has its primary coil of 1200 turns of wire connected to a 240 V AC mains supply. The current through the primary coil is 2.50 A.

Which of the following completes the specifications of this ideal transformer?

	Number turns secondary coil	Secondary voltage (V)	Secondary current (A)
(A)	400	720	0.625
(B)	100	20.0	0.208
(C)	600	120	2.500
(D)	200	40.0	15.00

13. An investigation was performed to compare the rate at which a magnet would fall through two aluminium tubes, identical in every aspect except for one having a slit cut out of it and a length of rubber inserted, as shown.



Initially stationary, the identical permanent bar magnets are released simultaneously. Which of the following will be observed?

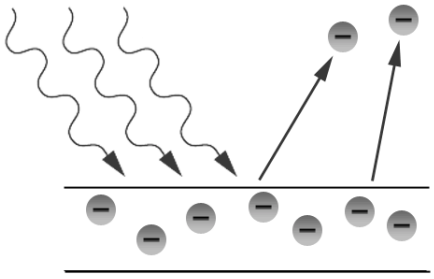
(A) The two magnets would take the same time to fall.

(B) The magnet falling through the full-aluminium tube will fall faster.

(C) The magnet falling through the aluminium tube with the slit will fall faster.

(D) Both magnets will be attracted to the wall of the tubes.

14. Consider the diagram:



This is a representation of which phenomenon?

(A) Reflection of light.

(B) Semiconductor energy-band theory.

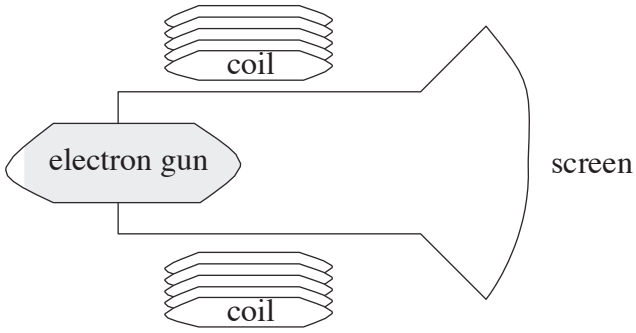
(C) Photoelectric effect.

(D) Cooper pair formation.

15. Which alternative in the table about the types of electrical discharge patterns formed in gas discharge tubes is correct?

	High Pressure	Low Pressure	Very Low Pressure
(A)	Striations	Green glow on gas	Streamers
(B)	Streamers	Striations	Green glow on gas
(C)	Streamers	Green glow on gas	Striations
(D)	Green glow on gas	Striations	Streamers

16. The diagram below represents a cathode ray tube with current carrying coils above and below the tube.



What is the purpose of the current carrying coils in this apparatus?

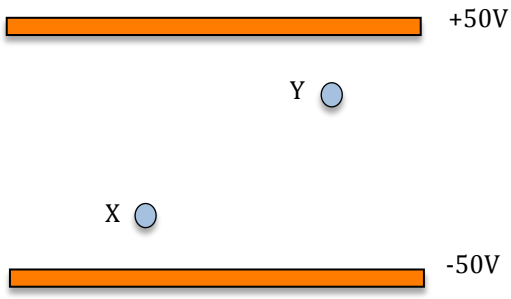
(A) To accelerate the electrons towards the screen.

(B) To deflect the electron beam vertically (i.e. up/down page).

(C) To deflect the electron beam horizontally (i.e. into/out of page).

(D) To control the intensity of the electron beam.

17. Two protons, X and Y, are located between two oppositely charged parallel plates, as shown.



How does the magnitude of the force exerted by the electric field compare for X and Y?

(A) There is no force on either proton since they are stationary.

(B) The magnitude of force on proton X is greater than the force on proton Y.

(C) The magnitude of force on proton Y is greater than the force on proton X.

(D) The magnitude of force on each proton is equal.

18. Which of the following correctly describes what happens when a semiconductor is doped?

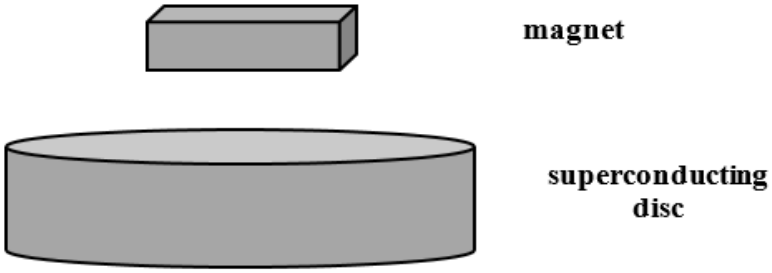
(A) Atoms from a different element replace a small number of the atoms in the semiconductor crystal.

(B) The semiconductor crystal is crammed with excess electrons.

(C) The original atoms in the semiconductor crystal are replaced entirely by atoms from Group IV elements.

(D) The atoms in the semiconductor crystal are replaced entirely by positive holes.

19. A magnet rests on a superconducting material above its critical temperature. When the temperature is lowered below the critical temperature of the superconducting material, the magnet levitates as shown.



Which statement best explains this levitation?

(A) Eddy currents are spontaneously induced in the superconducting material and, by Lenz's Law, repel the magnet.

(B) The movement of the magnet upwards, induces eddy currents in the superconducting material, which increase the upwards force on the magnet.

(C) The superconducting material becomes diamagnetic below its critical temperature and repels the magnet's magnetic field, causing the magnet to levitate on its own field.

(D) According to BCS theory, eddy currents induced in the superconductor produce a second magnetic field that repels the magnet upwards.

20. In what way did Planck contribute to the understanding of black body radiation?

(A) He explained black body radiation in terms of discrete line spectra.

(B) He was able to use Maxwell's theory of Electromagnetism to explain observed black body radiation.

(C) He observed that the nature of radiation leaving the cavity in a heated black body depended on the type of material that the black body was made of.

(D) He proposed the concept of quanta of energy to explain black body radiation.

Section I (continued)

Part A – 60 marks
Attempt Questions 21
Allow about 1 hour and 40 minutes for this part

Answer the questions in the spaces provided. These spaces proved guidance for the expected length of response
Show all relevant working in questions involving calculations.

Question 21 (5 marks) **Marks**

The Earth has a mass of 5.97×10^{24} kg and a radius of 6370 km.

(a) Calculate the energy that must be supplied to launch a rocket of initial mass 5000 kg from the Earth's surface to an altitude of 2000 km. To achieve this orbit, the rocket will consume 3000 kg of fuel. **2**

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(b) Calculate the magnitude of the force between the Earth and the rocket when it is in orbit. **1**

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(c) To maintain this orbit, the rocket must have a substantial tangential velocity with respect to the surface of the Earth. **2**

Calculate the magnitude of this velocity.

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Question 22 (4 marks) **Marks**

The *Newgalistein*, a prototype futuristic spaceship, travels at speeds close to the speed of light. On a test flight, it passes a near-spherical planet whilst maintaining its speed.

(a) Describe the appearance of the planet as observed by the crew on the spaceship. A diagram may aid your answer. **1**

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(b) The planet's atmosphere contains radioactive elements with a half-life of 100 seconds. The crew on the spaceship measures these elements as they pass them: their results show a half-life of 200 seconds. **2**

Calculate the speed of the spaceship relative to the planet.

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(c) The spaceship performs a slingshot manoeuvre around a different planet. **1**

Identify why special relativity CANNOT be used to explain observations made by the crew during this manoeuvre.

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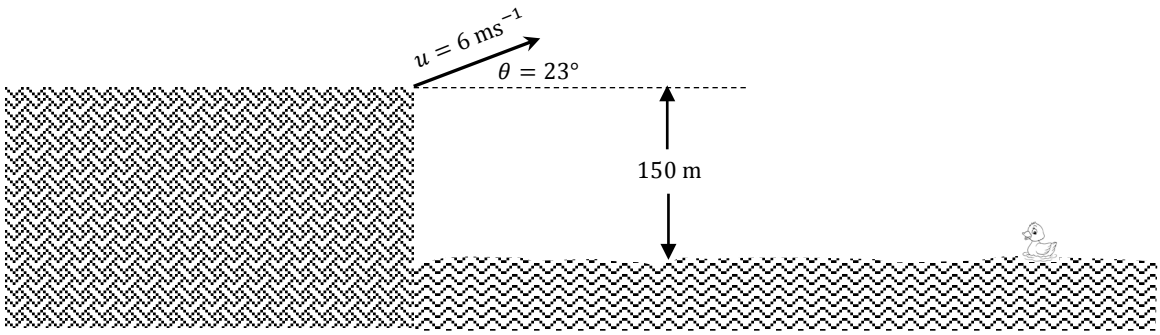
Question 23 (5 marks) **Marks**

A projectile is launched from a cliff towards a duck, resting on a calm sea. The cliff is 150 m above sea level and the projectile has an initial velocity of 6 ms^{-1} at 23° above horizontal.
The projectile hits the duck. (Assume a constant gravitational acceleration, magnitude 9.8 ms^{-2}.)



(a) Calculate the horizontal distance of the duck from the cliff edge at the moment of impact. **3**

*Recall that, for a quadratic equation $ax^2 + bx + c = 0$, the solution is given by: $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

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(b) Describe the claims that Galileo made in his analysis of projectile motion. **2**

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Question 24 (5 marks) **Marks**

During your study of *Motors and Generators*, you performed a first-hand investigation to predict and verify the effect on a generated electric current when the relative motion between the coil (solenoid) and the magnet is varied.

(a) Account for the generated current varying in magnitude, depending on the relative speed of the magnet being moved in and out of the solenoid. **2**

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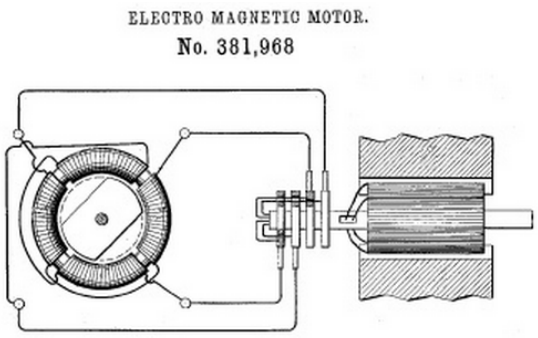
(b) Sketch a diagram of the apparatus you used in the above investigation, labelling all equipment and, for one particular instance of relative motion, indicating clearly the polarity and direction of motion of the magnet and the corresponding direction of the current induced in the solenoid. **3**

Question 25 (5 marks) **Marks**

Motors are used extensively to convert electrical energy into rotational kinetic energy. An early patent for one such type of motor, the AC 'induction' electric motor, is pictured here:



(a) Describe the main features of an AC electric motor **2**

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(b) An AC electric motor relies upon an alternating current supply. In what has become referred to as 'The War of the Currents', two men were each proposing a different system of electricity generation. **3**

Identify these two men, the type of electricity they were favouring, and discuss advantages & disadvantages of AC and DC generators, relating these to the distribution of electrical energy that they each produced.

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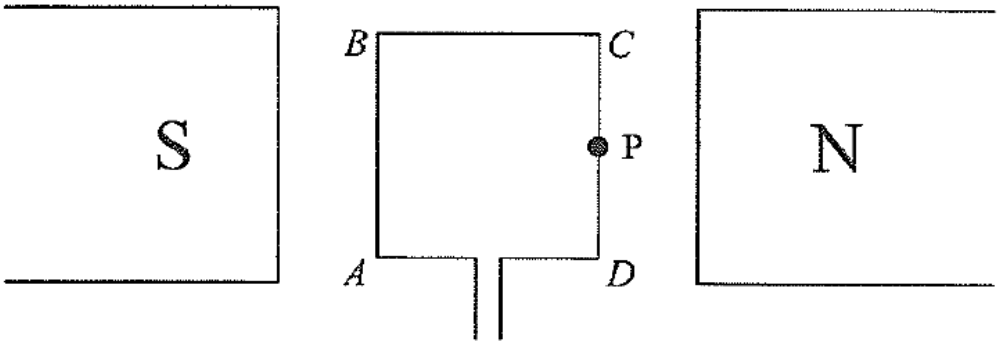
Question 26 (4 marks) **Marks**

Consider a square, single-coil wire (ABCD) of side length 30 cm, which is free to rotate about its central axis. This coil is placed into a uniform magnetic field of magnitude 8.1×10^{-4} T.

The diagram depicts the arrangement, looking down onto the plane of the coil.



When the coil is connected to an external circuit and a current is passed through it, the coil—though wanting to rotate—is held stationary by a 5.0 g mass (attached at point P; the weight force of the mass is directed INTO the page).

Calculate the current (both magnitude and direction) that must exist in the coil in order that the forces are in equilibrium and the coil does not rotate. Show all working. **4**

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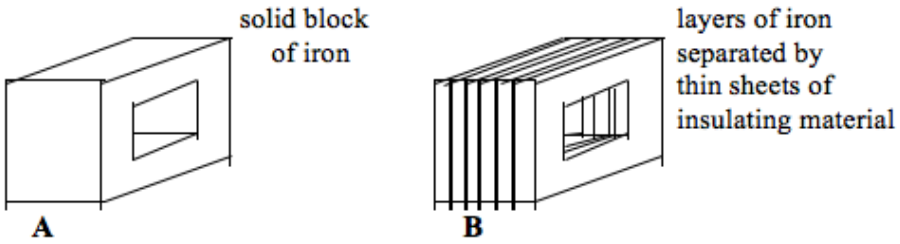
Question 27 (3 marks) **Marks**

Transformers need to be as efficient as possible, however they produce some heat. The iron cores of two transformers are depicted in the diagrams below.



Account for the difference in the heat production between two otherwise identical transformers, one utilising core **A** and the other utilising core **B**. **3**

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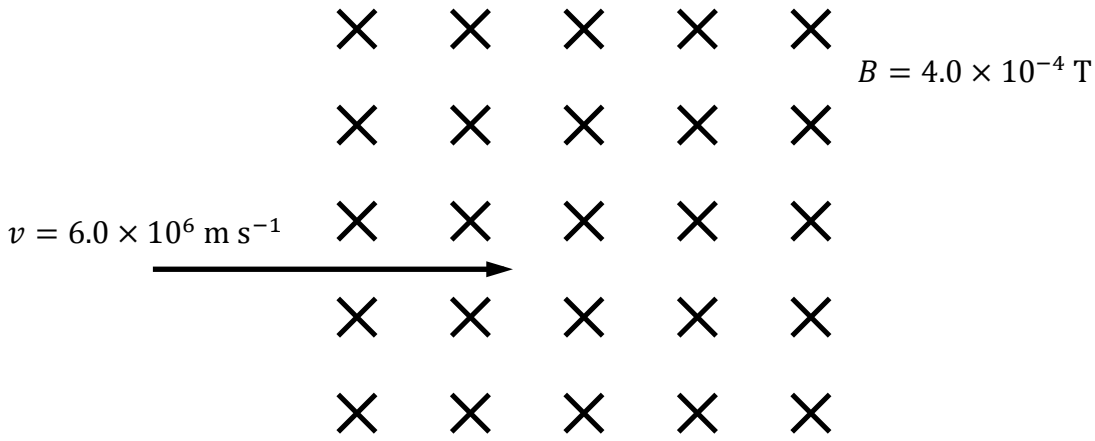
Question 28 (3 marks) **Marks**

A charged particle moves through a uniform magnetic field. Calculate the radius of the curvature of the path of an electron when it enters this field. **3**

The strength of the field is $B = 4.0 \times 10^{-4}$ T and the particle has velocity $v = 6.0 \times 10^{6}$ m s^{-1} perpendicular to the magnetic field, as shown below.

Ignore gravitational effects.



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Question 29 (3 marks) **Marks**

Compare the electrical properties of a pure semiconductor, doped semiconductor and a metal conductor. **3**

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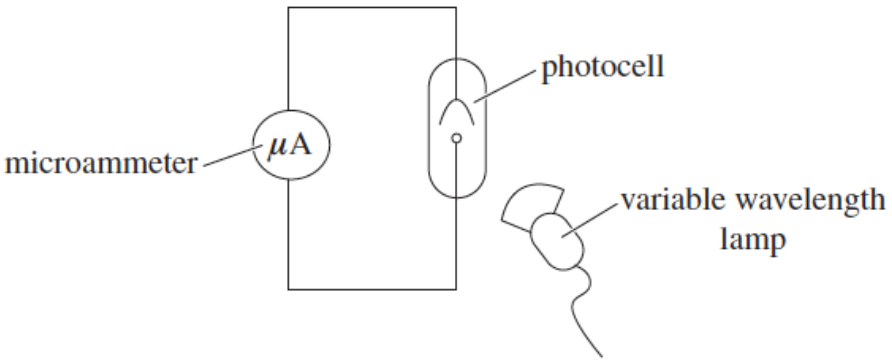
Question 30 (7 marks) **Marks**

The following apparatus is used to investigate the photoelectric effect. Photocells made of different metals are inserted into the circuit.



(a) Using the photon model of light, account for the following observations:

(i) When ultraviolet light is used, the photocurrent increases as the intensity of the light increases. **1**

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(ii) Sodium produces a photocurrent when green light is shone onto it's surface, but copper does not. **1**

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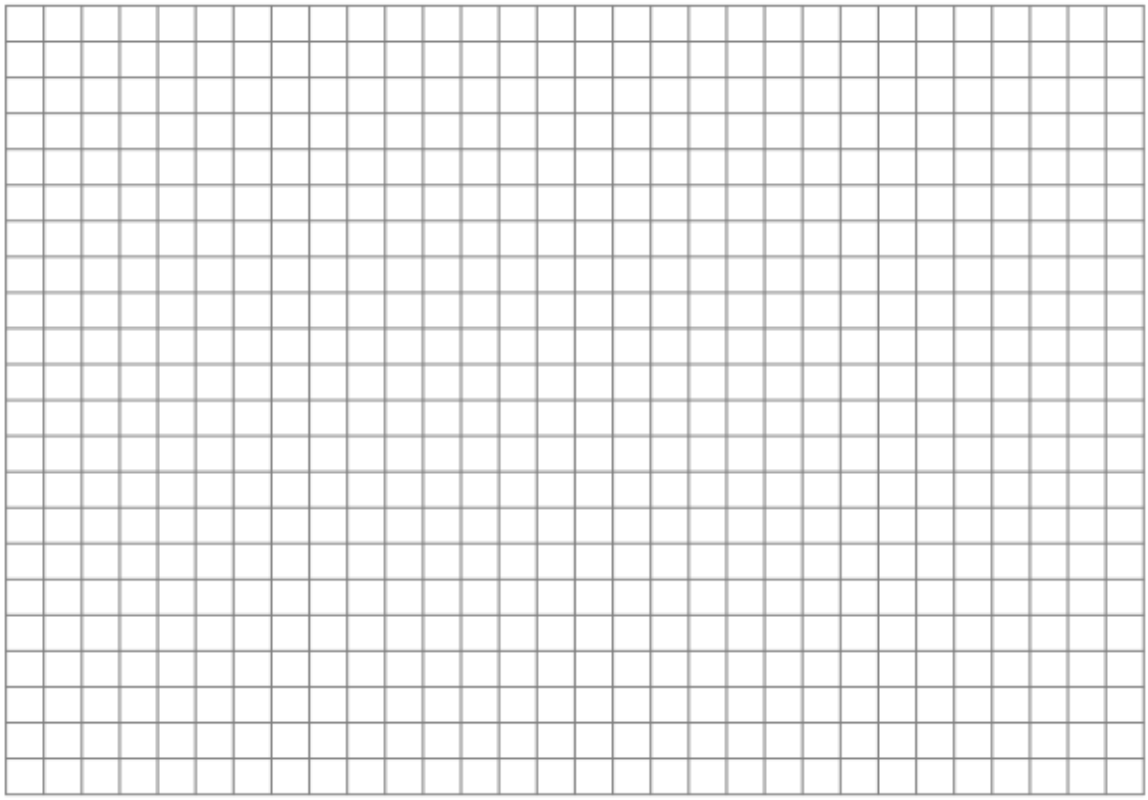
Continued over…

Question 30 *(continued)* **Marks**

(b) A group of students used the apparatus to find the lowest frequency of light that will emit photoelectrons from a range of metals. For each metal, they decreased the frequency of the light until the photocurrent dropped to zero. Their results are shown in the table below.

Metal	*Frequency* ($\times 10^{14}$ *Hz*)	*Work function* ($\times 10^{-19}$ *J*)
sodium	5.6	3.6
calcium	7.1	4.6
zinc	10.5	6.9
copper	11.5	7.5
platinum	15.2	10.0

(i) Plot a graph of the data, with Frequency on the *x*-axis and Work function on the *y*-axis. Include a line of best fit. **3**



(ii) Use the graph to determine a value for Planck's constant. **2**

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Question 31 (6 marks) **Marks**

Superconductors have been developed for use in several potential applications. **6**

Describe TWO of these potential applications and, for each of these, discuss the impact on society that they would have.

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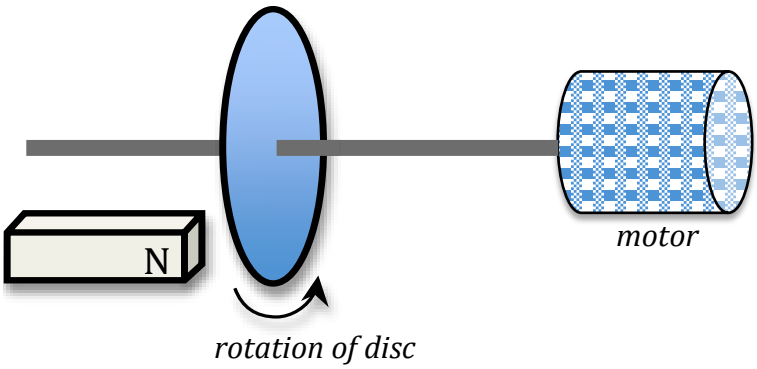
Question 32 (5 marks) **Marks**

An aluminium disc, attached to the axle of an electric motor, is initially spinning with a constant angular speed. A magnet is brought near to the spinning disc, as shown.



(a) Describe the changes to the magnetic flux through the disc, and explain the effect on the motion of the disc as the magnet is brought near. **3**

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(b) With reference to 'back emf', predict what will occur in the electric motor as the magnet is brought close to the spinning disc. **2**

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Continued over…

(c) Distinguish between the definition and units of *magnetic flux* and *magnetic flux density*. **2**

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Question 33 (3 marks) **Marks**

Identify a real life situation in which eddy currents are useful and outline how they work in this situation. **3**

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Section II

20 marks
Attempt ALL parts of the question.
Allow about 45 minutes for this section.

Answer the question in a separate writing booklet.

Extra writing booklets are available.

Show all relevant working in questions involving calculations.

Question 34 **From Quanta to Quarks** (20 marks) **Marks**

(a) When Rutherford proposed his model of the atom, he could not account for the stability of the electrons around the nucleus.

(i) Explain how the Bohr model addressed this limitation. **2**

(ii) Identify ONE other limitation of the Rutherford model of the hydrogen atom that the Bohr model addressed. **1**

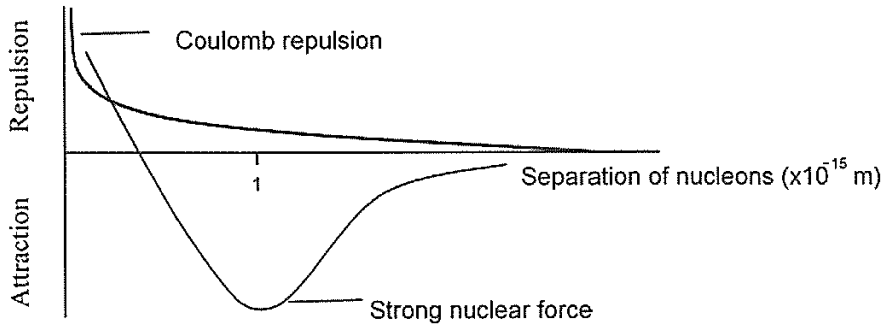
(ii) Calculate the wavelength of a photon which is emitted when an electron in a hydrogen atom moves from energy level $n = 4$ to $n = 2$. **2**

(b) (i) Describe the Davisson and Germer experiment and justify their results as confirmation of de Broglie's proposal that any kind of particle has both wave and particle properties. **3**

(iii) Using a labelled diagram, explain the stability of the electron orbits in the Bohr model of the atom using de Broglie's hypothesis. **2**

(iv) Calculate the de Broglie wavelength of a beta particle travelling at $1.8 \times 10^6 ms^{-1}$ and state whether a particle of this wavelength would be diffracted by a typical crystal lattice. **2**

(c) A graph of the nuclear force versus the separation distance between two nucleons is shown in the figure below. A corresponding plot for the electrostatic force between two protons is also shown. **2**



Using this information, explain the need for the strong nuclear force.

(d) (i) Explain why Chadwick needed to use the laws of conservation of momentum and energy to prove the existence of the neutron. **2**

(ii) Calculate the binding energy for a $^4He_2$ nucleus. ($^4He_2 = 6.64832 \times 10^{-27}$ kg) **2**

(iii) Americium-241 undergoes alpha decay to produce Neptunium-237, as shown below: **2**

$$^{241}_{95}Am \rightarrow {}^{4}_{2}He + {}^{237}_{93}Np$$

Explain how this results in a release of energy.

END OF EXAMINATION

Newington College

IN FIDE SCIENTIAM

2015

HSC PHYSICS

Trial Examination

MARKING GUIDELINES

MARKING GUIDELINES

Section I:

Multiple Choice

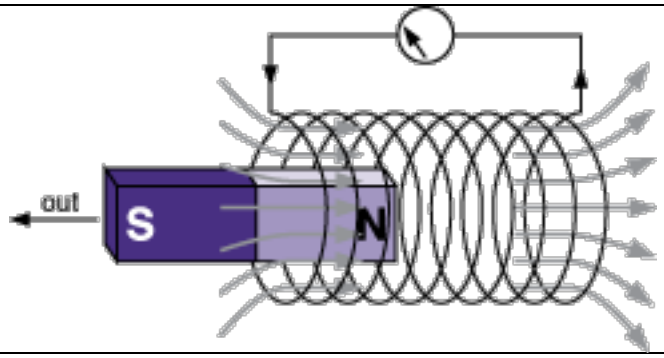
Question	Answer	Question	Answer
1	B	11	B
2	B	12	D
3	C	13	C
4	B	14	C
5	C	15	B
6	D	16	C
7	C	17	D
8	D	18	A
9	A	19	C
10	D	20	D

MARKING GUIDELINES

Short Answer

Question 21 (5 marks)		
(a)	$E = E_2 - E_1$ $= \frac{GMm_2}{r_2} - \frac{GMm_1}{r_1}$ $= \left(\frac{6.67\times10^{-11}\times5.97\times10^{24}\times5000}{6370000}\right) -$ $\left(\frac{6.67\times10^{-11}\times5.97\times10^{24}\times2000}{8370000}\right)$ $= 2.17\times10^{11} J$	2 marks – correctly states formula and substitution AND states correct answer with correct units OR 1 mark – correctly states formula and substitution OR state correct answer with correct units
(b)	$F = \frac{GMm}{r^2}$ $= \frac{6.67\times10^{-11}\times5.97\times10^{24}\times2000}{8370000^2}$ $= 1.14\times10^{4} N$	1 mark – correctly states formula and substitution AND states correct answer
(c)	$F = \frac{mv^2}{r}$ $1.14\times10^{4} = \frac{2000v^2}{8370000}$ $v^2 = 4.77\times10^{7}$ $v = 6.91\times10^{3} ms^{-1}$	2 marks – correctly states formula and substitution AND states correct answer OR 1 mark – correctly states formula and substitution OR state correct answer
Question 22 (4 marks)		
(a)	The length of the planet would be shortened in the direction of travel, so the planet would appear to be elliptical rather than spherical	1 mark – correctly describes appearance of planet
(b)	$t_v = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$ $\sqrt{1-\frac{v^2}{c^2}} = \frac{1}{2}$ $1-\frac{v^2}{c^2} = \frac{1}{4}$ $\frac{v^2}{c^2} = \frac{3}{4}$ $\frac{v}{c} = 0.87$ $v = 0.87c$	2 marks – correctly states formula and substitution AND states correct answer OR 1 mark – correctly states formula and substitution OR state correct answer
(c)	A slingshot manoeuvre involves a change of speed and/or direction; therefore the spaceship is accelerating relative to the planet. Special relativity can only be used for inertial frames of reference that are not accelerating.	1 mark – correctly explains that special relativity does not apply to accelerating frames of reference

MARKING GUIDELINES

Question 23 (5 marks)		
(a)	$\Delta y = u_y t + \frac{1}{2} a_y t^2$ $-150 = (6.0 \sin 23)t - \frac{1}{2} 9.8t^2$ $t = \frac{-(6.0 \sin 23) \pm \sqrt{(6.0 \sin 23)^2 - (4 \times -4.9 \times 150)}}{2 \times -4.9}$ $t = -5.3 or 5.78 s$ $\Delta x = u_x t$ $= (6.0 \cos 23) \times 5.78$ $= 31.9 m$	2 marks – correctly chooses and substitutes data into formula/s to calculate time using correct sign convention 1 mark – correctly substitutes into range formula Allow error carried through (e.c.f)
(b)	For projectile motion, horizontal and vertical components of motion need to be treated **independently**. Vertical motion only influenced by acceleration due to gravity.	2 marks – two correct aspects of Galileo's analysis described OR 1 mark – aspects identified only or only one aspect described
Question 24 (5 marks)		
(a)		1 mark – magnitude of induced current due to rate of change of flux 1 mark – the faster the magnet is moved the greater the change in flux
(b)		1 mark – clear diagram draw showing all necessary equipment 1 mark – diagram labelled with magnet polarity 1 mark – induced current direction identified

MARKING GUIDELINES

Question 25 (a)

Criteria	Marks
• Describes correctly TWO main features of an AC electric motor.	2
• Identifies correctly TWO features of an AC electric motor. OR • Describes correctly ONE feature of an AC electric motor.	1

Marker's comments

- *Many students were confusing the AC electric (induction) motor with an AC generator; only an AC generator has slip-rings to transfer current to an external circuit.*

Sample answer:

- *AC is supplied to sets of stationary coils of wires (stator), which surround the rotating section of the motor (rotor), typically referred to as a 'squirrel-cage'.*
- *The stator windings are arranged such that a rotating magnetic field is established due to the input AC.*
- *The induced current in the squirrel-cage rods subsequently induces magnetic fields surrounding the rotor, and the interaction between the stator and rotor magnetic fields results in a torque applied to the rotor.*

MARKING GUIDELINES

Question 25 (b)

Criteria	Marks
• Identifies correctly Westinghouse (AC) AND Edison (DC). AND • Discusses, with sufficient detail, BOTH advantages AND disadvantages of both AC and DC generators. AND • Clear relation of AC and DC to distribution of electrical energy.	3
• Identifies correctly Westinghouse (AC) AND Edison (DC). AND • Discusses, with sufficient detail, EITHER advantages OR disadvantages of both AC and DC generators. AND • Some relation of AC and DC to distribution of electrical energy.	2
• Identifies correctly Westinghouse (AC) AND Edison (DC). OR • Discusses, with some detail, EITHER advantages OR disadvantages of EITHER AC or DC generators. OR • Some relation of AC and DC to distribution of electrical energy.	1

	Advantages	Disadvantages
AC (Westinghouse)	• AC systems much cheaper and more efficient to operate. • AC is readily transformed to different voltages. • Use of transformers allowed distribution at high voltage (reduced energy loss due to resistance heating) before being stepped-down to safe operating voltage. • AC generators could be located far from where electricity was required.	• Due to constantly changing currents – and therefore change in magnetic flux – currents are induced in any nearby conductor. • More dangerous to biological systems, such as the heart (can cause fibrillation with just a few mA)
DC (Edison)	• Initially, electronic appliances were designed to run on DC and an AC motor had not yet been created. • Less dangerous to biological systems. • Does not cause electromagnetic interference in nearby conductors.	• Generator must be located close to where electricity is required. • DC transformers are inefficient, involving a mechanical make-and-break magnetic switch.

MARKING GUIDELINES

Question 26

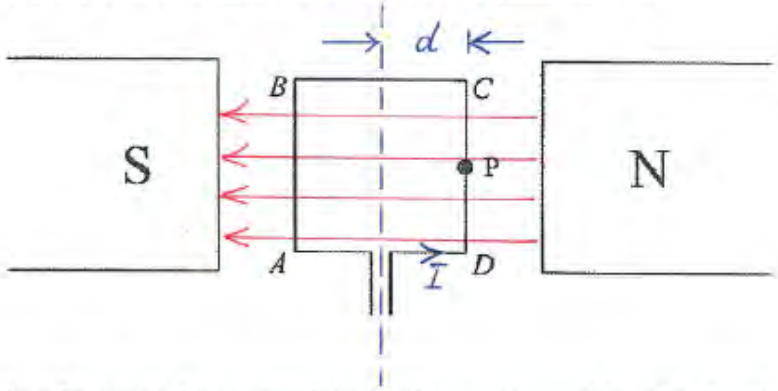
Criteria	Marks
Response includes ALL of: • Identify that the coil will not rotate due to equal and opposite torque from motor effect and torque due to weight of additional mass. • Calculate correctly the weight due to mass at point P. • Correct substitution of SI data into appropriate equation (equate two expressions for torque). • Correctly calculates magnitude AND direction of current. **Omission of units not penalised.*	4
Response includes any THREE of criteria for full marks.	3
Response includes any TWO of criteria for full marks.	2
Response includes any ONE of criteria for full marks.	1

MARKING GUIDELINES

Question 26 (4 marks) **Marks**

Consider a square, single-coil wire (ABCD) of side length 30 cm, which is free to rotate about its central axis. This coil is placed into a uniform magnetic field of magnitude 8.1×10^{-4} T.

The diagram depicts the arrangement, looking down onto the plane of the coil.



When the coil is connected to an external circuit and a current is passed through it, the coil—though wanting to rotate—is held stationary by a 5.0 g mass (attached at point P; the weight force of the mass is directed INTO the page).

Calculate the current (both magnitude and direction) that must exist in the coil in order that the forces are in equilibrium and the coil does not rotate. Show all working. 4

DATA

$B = 8.1 \times 10^{-4}$ T

$m_p = 5.0 \times 10^{-3}$ kg

$d = 0.15$ m

$A_{ABCD} = 0.09$ m^2

$g = 9.8$ m s^{-2}

$n = 1$

In order that the coil does not rotate, the torque due to the motor effect must be exactly opposed by the torque generated by the mass suspended at point 'P'.

$\tau_{mass} = \tau_{coil}$

$(mg)d = nBIA$

$\Rightarrow I = \dfrac{mgd}{nBA}$

$= \dfrac{(5.0 \times 10^{-3})(9.8)(0.15)}{(1)(8.1 \times 10^{-4})(0.09)}$

$\cong 101$ A (counter-clockwise) //

MARKING GUIDELINES

Question 27

Criteria	Marks
• Identify LARGE eddy currents in Core A due to solid conducting material. • Identify SMALL eddy currents in Core B due to thin width of iron layers. • State that Core A will generate more heat (= higher energy loss) than Core B. *NB. Response must make explicit reference to eddy currents (or, at least, "induced" currents).*	3
Response includes any TWO of criteria for full marks.	2
Response includes any ONE of criteria for full marks.	1

Sample answer:

Both cores can be used in a transformer to channel magnetic flux through the primary and secondary coils. Solid core 'A' will generate large eddy currents due to the substantial volume of conducting material, causing significant energy loss due to resistance heating. Laminated core 'B' is prevented from large induced eddy currents because of the thin 'slithers' of conducting material; core 'B' will suffer much lower energy loss due to heating compared to core 'A'.

Marker's comments:

- *Eddy currents are not exclusively a surface phenomenon; a changing magnetic flux will induce eddy currents within the entire volume of a conductor.*
- *Lamination DOES NOT prevent magnetic fields from penetrating the core. Rather, the laminations limit the volume of conductor in which eddy currents can be induced.*
- *There is no 'back emf' in transformers.*

MARKING GUIDELINES

Question 28

Criteria	Marks
• Identify that centripetal force is provided by the magnetic force (i.e. equate these two formulae). • Substitute SI data correctly into equation. • State correct radius of curvature WITH units.	3
Response includes any TWO of criteria for full marks.	2
Response includes any ONE of criteria for full marks.	1

Marker's comments:

- *The number of students who lost marks for calculation errors is very concerning.*
- *Ensure that you ALWAYS show full working, including FULL substitution.*
- *Students are strongly encouraged to write down data in SI units BEFORE attempting to solve the problem.*

Sample answer on following page.

MARKING GUIDELINES

Question 28 (3 marks) **Marks**

A charged particle moves through a uniform magnetic field. Calculate the radius of the curvature of the path of an electron when it enters this field. **3**

The strength of the field is $B = 4.0 \times 10^{-4}$ T and the particle has velocity $v = 6.0 \times 10^{6}$ m s^{-1} perpendicular to the magnetic field, as shown below.

Ignore gravitational effects.

DATA

$B = 4.0 \times 10^{-4}$ T

$v = 6.0 \times 10^{6}$ m s^{-1}

$|q_e| = 1.602 \times 10^{-19}$ C

$m_e = 9.109 \times 10^{-31}$ kg

$\theta = 90°$

$r = ?$

An electron entering a uniform magnetic field will undergo circular motion. The force causing this motion is quantified by two expressions:

$$F_{centripetal} = F_B$$

$$\frac{mv^2}{r} = qvB$$

$$\Rightarrow r = \frac{mv}{qB} = \frac{(9.109 \times 10^{-31})(6.0 \times 10^{6})}{(1.602 \times 10^{-19})(4.0 \times 10^{-4})}$$

$$\cong 0.085 \text{ m} \quad //$$

MARKING GUIDELINES

Question 29 (3 marks)		
		1 mark – identifies delocalised electrons responsible for conduction 1 mark – identifies electron – hole conduction for pure semiconductors 1 mark – identifies excess of electrons or holes for conduction in doped semiconductors
Question 30 (7 marks)		
(a)	(i) Increased intensity of UV light increases the number of photons incident on the metal surface which can each be responsible for the ejection of a photoelectron (ii) Sodium and copper have different work functions, that is the frequency of green light equates to an insufficient energy of photons to release a photoelectron from the surface of copper, as compared to sodium	(i) 1 mark – correctly identifies reason for observations (ii) 1 mark – correctly identifies reason for observations
(b)	(i) Grid set up correctly with both axes labelled, including units and an appropriate line of best fit. (ii) Points taken from the l.o.b.f and the gradient is correctly calculated from data.	(i) 1 mark – appropriate scale with data points plotted correctly 1 mark – appropriate straight line of best fit drawn 1 mark – graph axes correctly labelled with units (ii) 1 mark – gradient calculated 1 mark – gradient used to correctly determine Planck's constant
Question 31 (6 marks) (Holistically marked)		
TWO potential applications of superconductors (correctly) described in some detail. (NOT Maglev) Impacts on society are linked in and are discussed in some detail giving points on both the advantages and disadvantages of each potential application.		5-6 marks
TWO potential applications of superconductors described. At least ONE impact on society is described for each. (Impacts may be listed but not discussed) OR TWO potential applications of superconductors identified. Impacts on society are outlined in detail.		3-4 marks
At least ONE potential application of superconductors identified. An impact on society identified/described.		1-2 marks

MARKING GUIDELINES

Question 32 (5 marks)		
(a)	As magnet is brought near the rotating disc there is an **increase** in flux density through the metal disc; The rotation of the disc will slow; because the change in flux will induce eddy currents which in turn set up a **B** that opposes the original change.	1 mark – increase in flux identified 1 mark – effect on disc rotation identified 1 mark – cause of change rotation described
(b)	As the rotation of the disc slows down back emf is reduced; as the motor is cutting lines of **B** flux less often. This will result in a larger net voltage ($V_{net}=V_{supply}-V_{emf}$) (OR motor burns out as a result of large current);	1 mark – effect on back emf correctly identified 1 mark – correct effect on the motor identified
(c)	Magnetic flux is the magnetic field lines penetrating a given area (perpendicular); Webers or $Tm^{2;}$ Magnetic flux density is the magnetic flux **per** unit area OR the strength of the magnetic field; Tesla or Wbm^{-2}	2 mark – difference between magnetic flux and magnetic flux density identified with correct units associated OR 1 mark - difference between magnetic flux and magnetic flux density identified OR formulae with unit analysis given for both (but not well defined)
Question 33 (3 marks)		
Possible examples: • Induction cooktops • E/m braking – trains, amusement park rides (drops)		3 marks – application identified AND production of eddy currents identified AND description of how they are utilised in the application OR 2 marks – application identified AND: production of eddy currents identified OR description of how they are utilised in the application OR 1 mark – application identified OR brief outline where they may be beneficial
Question 34 (20 marks)		
	Marking guidelines on following pages…	

MARKING GUIDELINES

Q36

a)

(i) Must say: $\bar{e}$ exist in stationary states or fixed energy levels (1)
: in these states they do not emit e.m.r. (1)

(ii) Any one of: → Hydrogen emission spectrum
→ Specifically how the $\bar{e}$ were arranged around the nucleus (orbital radius, possibly)
→ Energy value of $\bar{e}$ at the fixed energy level. (1)
→ Angular momentum (L) of $\bar{e}$
* Can't be the same (overtly or implied) as in (i) above.

(ii) $\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{4^2}\right)$ (1)

$= 1.097 \times 10^7 \left(\frac{1}{4} - \frac{1}{16}\right)$

$= 1.097 \times 10^7 \left(\frac{3}{16}\right)$

$\therefore \frac{1}{\lambda} = 2.06 \times 10^6$

$\therefore \lambda = 4.86 \times 10^{-7}$ m (1)

units not necessary.

MARKING GUIDELINES

6

(i) Describe what D & G did:

→ Fired a beam of e^- onto the surface of Ni crystal.
→ The beam was scattered from the surface of the crystal.
→ A detector was used to 'map' the intensity areas of the scattered electrons. (1)

Justify results as confirmation of matter waves

→ The intensity pattern detected showed successive high / low intensity areas.
→ this pattern conformed to the expected pattern for e/m radiation undergoing diffraction and interference (e.g. Bragg's X-rays) (1)

→ Particles don't show diffraction / interference effects, only waves do this.
→ Therefore, particles have a 'wave' nature as well as a 'particle' nature, confirming the De Broglie proposal. (1)

Note: The best answers (only 1 or 2) referred to the fact that 'λ' calculated using Bragg's $n\lambda = 2d\sin\theta$ gave pretty much the same value as De Broglie's $\lambda = \frac{h}{p}$.

MARKING GUIDELINES

(iii)

Standing wave for $n = 3$. (1)

Stable $\bar{e}$ orbits can only occur whole numbers of wavelengths (n) form perfect standing waves that do not decay due to emr emission resulting from interference effects. (1)

(iv)

$$\lambda = \frac{h}{mv}$$

$$= \frac{6.63 \times 10^{-34}}{9.109 \times 10^{-31} \times 1.8 \times 10^{6}}$$ (1)

$$\lambda = 4.04 \times 10^{-10} \text{ (m)}$$

Yes, diffraction would occur (1)

Note: Typical lattice separation of atoms is of the order of 10^{-10} (m) $\rightarrow 0.5 \times 10^{-10} \Rightarrow 5.0 \times 10^{-11}$

MARKING GUIDELINES

C]

Note:
The graph refers to coulomb repulsion and the strong nuclear force (Not gravitational attraction).

→ Coulomb repulsion occurs between positively charged protons in the nucleus and at normal nucleon separation distances (of the order of 1×10^{-15} m) this would prevent the nucleus from forming and/or remaining stable

(1)

→ At these typical nucleon separation distances it can be seen, from the graph, that the strong nuclear attraction is at a maximum and is far greater than coulomb repulsion forces. This is essential if the nucleus is to form and remain stable.

(1)

MARKING GUIDELINES

d] Why Chadwick NEEDED to use the conservation laws:

(i) Something like this for (1)

→ When Beryllium is bombarded with α-particles it was noticed that a seemingly very penetrating 'radiation' was emitted.

→ This suffered no deflection in $\bar{B}$ or $\bar{E}$ fields but seemed to have too high an energy content to be 'radiation' (eg γ-rays).

⇒ So, if a 'particle' then conventional methods of determining mass by deflection in $\bar{E}$ and $\bar{B}$ fields could not be used.

(1)

In Chadwick's experiment the 'uncharged particles' entered paraffin wax and ejected protons (+ve charge). He used conservation of energy (E_k) and conservation of momentum between the supposed 'neutrons' and ejected protons to determine the mass of the neutron and confirm its' existence.

MARKING GUIDELINES

(ii) ^4_2He has 2 protons + 2 neutrons

Total mass of individual nucleons

$= (2 \times 1.673 \times 10^{-27}) + (2 \times 1.675 \times 10^{-27})$ (1)

$= 6.696 \times 10^{-27}$ kg [OR 4.034 amu]

Mass of $^4_2He = 6.648 \times 10^{-27}$ kg [4.005 amu]

$\therefore$ Mass defect $= (6.696 - 6.648) \times 10^{-27}$ kg

$= 0.048 \times 10^{-27}$ kg [OR 0.029 amu]

$\therefore$ Binding energy $= mc^2$

$= (0.048 \times 10^{-27}) \times (3 \times 10^8)^2$

$= 4.32 \times 10^{-12}$ J (1)

OR $\simeq$ 27 MeV

MARKING GUIDELINES

(iii) There are a number of possible approaches here:

→ Mass defect:

(1) The total mass of all the nucleons making up the $^{241}_{95}Am$ is greater than the total mass of the nucleons making up the products of decay ($^{4}_{2}He + ^{237}_{93}Np$).

(1) There is a loss of mass or mass defect in the nuclear reaction. This 'lost mass' is converted to energy: $E = mc^2$.

OR → An unstable, 'excited' or

(1) high E_p condition of the $^{241}_{95}Am$ nucleus results in radioactive decay.

(1) Energy is released as E_k of the products and γ. The products are more stable than the parent $^{241}_{95}Am$.

OR → You can talk about binding energy being released But you

(1) must say that the binding energy of the nucleons in the products ($He + Np$) is greater (in total) than the binding energy of the parent (Am) and that Δ binding energy is the energy released as both E_k of products and γ-radiation. (1)