Student Number	
Mark / 100	

2014

TRIAL HSC EXAMINATION

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Write your Student Number at the top of this page and on the response sheet on page 12
- Board-approved calculators may be used
- A data sheet, formulae sheets and Periodic Table are provided

Total Marks – 100

Section I Pages 2 - 25

75 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 – 55 marks

- Attempt Questions 21 - 32
- Allow about 1 hour and 45 minutes for this part

Section II

25 marks

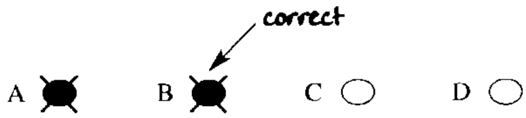
- Attempt Question 33
- Allow about 45 minutes for this section

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

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 by writing the word *correct* and drawing an arrow as follows.



Section I 75 marks

Part A – 20 marks

Attempt Questions 1–20

Allow about 35 minutes for this part

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

1. Two satellites of masses M_1 and M_2 have escape velocities V_1 and V_2 from the surface of a planet of radius *R*, with acceleration due to gravity *g*.

Which of the following is true?

(A) $V_1 / V_2 = (M_2 / M_1)^2$

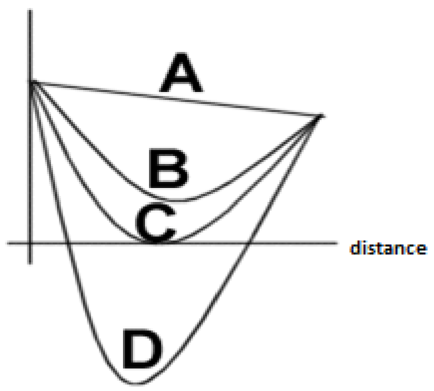
(B) $V_1 / V_2 = M_2 / M_1$

(C) $V_1 / V_2 = M_1 / M_2$

(D) $V_1 = V_2$

2. The gravitational acceleration on a planet is 20 % less than that on the Earth. A rocket takes a man from the Earth to this planet.

On neglecting the effect of all other bodies in the sky, which curve in the figure best describes the change in the man's weight with distance travelled?



(A) A

(B) B

(C) C

(D) D

3. While riding at a constant speed on the train at the Kiddie Park, Victor Velocity playfully tossed Phluffy straight upward. During the time Phluffy was in the air, the train moved forward 1 m.

Where would Phluffy land?

(A) in Victor's loving arms

(B) 1 m in front of Victor

(C) 1 m behind Victor

(D) several metres behind Victor

4. A passenger train travels east at high speed. One passenger is located at the east side of one carriage, another is located in the west side of that carriage. In the train's frame, these two passengers glance up at the same time.

In the Earth's frame, with the observer being equidistant from both passengers, he would notice

(A) they glance up simultaneously.

(B) the passenger at the east side glances up first.

(C) the passenger at the west side glances up first.

(D) the passengers glance sideways.

5. Consider an astronaut during take-off.

Which definition of the g-force on her is correct?

(A) The g-force is a measure of the force acting on her expressed in multiples of her apparent weight.

(B) The g-force is the force on her expressed as a multiple of her weight force.

(C) The g-force measures her apparent weight force in multiples of her weight force on the Earth's surface.

(D) The g-force is the weight force of the astronaut on the surface of the Earth.

6. A beam of light travels at 3.00×10^8 m s^{-1}.

If a moped moving at 20.0 m s^{-1} turns on its headlight, how fast does the light travel?

(A) 20.0 m s^{-1}

(B) 3.00×10^8 m s^{-1} − 20.0 m s^{-1}

(C) 3.00×10^8 m s^{-1}

(D) 3.00×10^8 m s^{-1} + 20.0 m s^{-1}

7. The Michelson–Morley experiment established that:

(A) the aether moves at *c* as Earth travels in its orbit.

(B) the aether is an elastic solid that streams over Earth.

(C) Earth does not move with respect to the Sun.

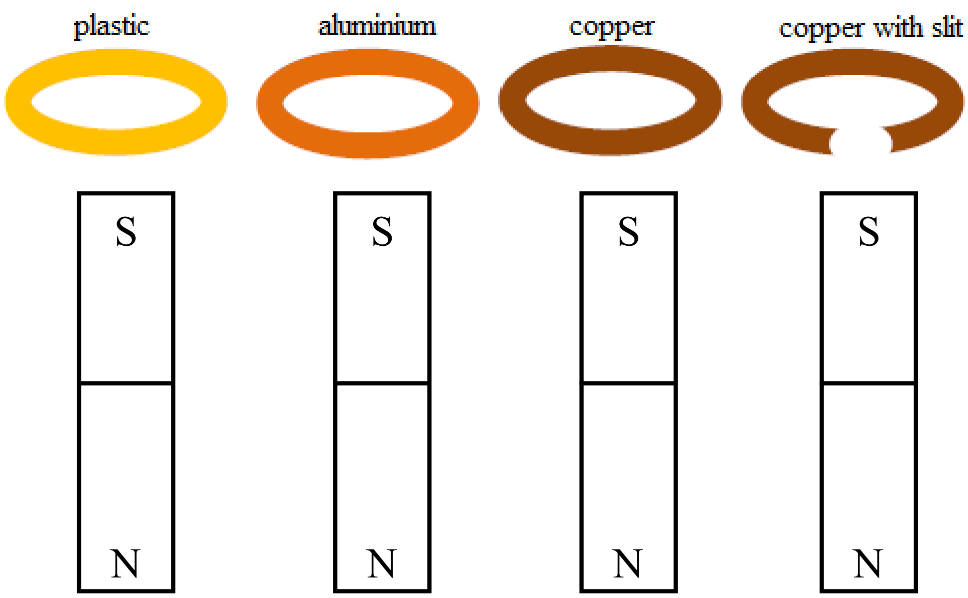
(D) there is no observable aether wind at the surface of Earth.

8. A simple AC generator has a rectangular coil of *N* turns and cross-sectional area *A*. It rotates with frequency *f* in a uniform magnetic field of strength *B*.

Which of the following changes will result in the greatest induced emf?

	Number of turns, N	*Cross-sectional area, A*	*Frequency, f*	*Magnetic field strength, B*
(A)	½ *N*	½ *A*	½ *f*	½ *B*
(B)	2 *N*	2 *A*	2 *f*	2 *B*
(C)	½ *N*	2 *A*	½ *f*	½ B
(D)	2 *N*	½ *A*	2 *f*	2 *B*

9. Four rings (plastic, aluminium, copper and copper with slit) are dropped at the same time over four identical magnets.



What is the order in which the rings reach the bottom of the magnets?

(A) plastic, copper with slit, aluminium, copper

(B) plastic, aluminium, copper, copper with slit

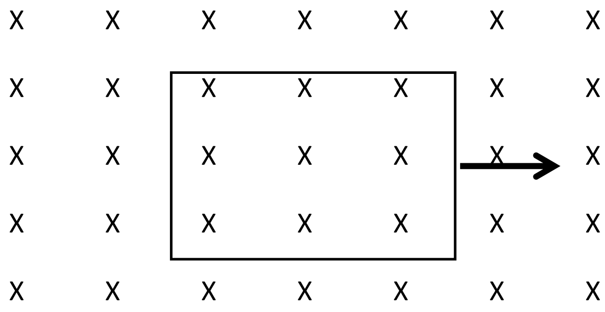
(C) copper, aluminium, copper with slit, plastic

(D) copper with slit, copper, aluminium, plastic

10. If a power line has a constant resistance of $6.2 \times 10^{-4}\ \Omega m^{-1}$, compare the power lost over 100 km of line if a current of 50 A flows in one line, while in another line, 0.05 A flows.

	50 A line	*0.05 A line*
(A)	1.55 MW	1.55 µW
(B)	155 kW	155 mW
(C)	1.55 MW	155 mW
(D)	155 kW	1.55 µW

11. A rectangular wire loop is being pulled through a uniform magnetic field, as shown.



Will an emf be induced and what is the direction of the induced current?

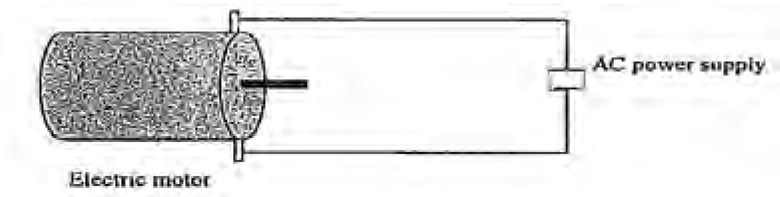
(A) no, and no induced current

(B) yes, clockwise

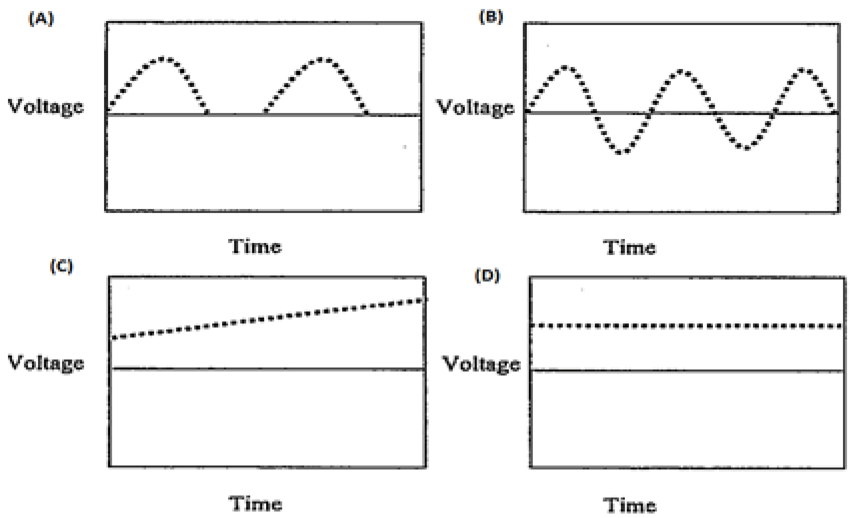
(C) yes, anticlockwise

(D) yes, and no induced current

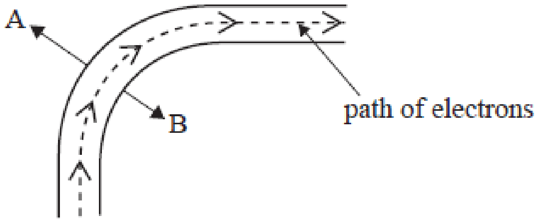
12. An electric motor is connected to an AC power supply as shown and a voltmeter is connected across the terminals of the motor.



Which graph represents the voltage over time after the motor has reached its maximum speed?



13. Electrons are travelling in the storage ring of a synchrotron at close to the speed of light. They are directed from a straight section into a curved section of the storage ring, as shown in the figure.



What must be the correct direction of the magnetic field to keep the electrons in this curved path?

(A) direction A on the diagram

(B) direction B on the diagram

(C) out of the page

(D) into the page

14. The output voltage from a transformer is greater than the input voltage. Why does this not contradict the law of conservation of energy?

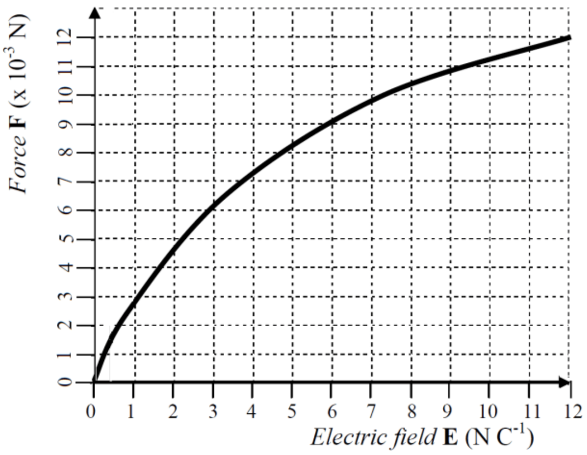
(A) Energy is taken from the mains supply.

(B) Energy is taken from the magnetic field.

(C) The output current is less than the input current.

(D) The efficiency of the transformer is greater than 1.

15. An investigation was performed to measure the force *F* on a charged object as the electric field *E* was varied. The results were plotted on a graph of *F* versus *E* which is shown below.



What conclusion can be drawn from the graph?

(A) The magnitude of the charge was 10^{-3} C.

(B) The force was proportional to the electric field.

(C) The particle was gaining charge as the electric field was strengthened.

(D) The particle was losing charge as the electric field was strengthened.

16. The wavelength of waves being broadcast from radio station 2MMM in Sydney is 2.86 m. Calculate the energy of a photon of this wave.

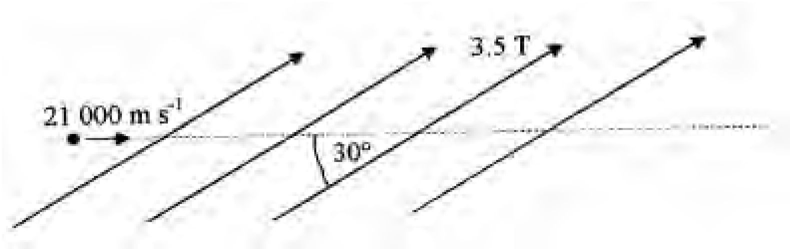
(A) 6.95×10^{-26} J

(B) 1.90×10^{-33} J

(C) 1.99×10^{-25} J

(D) 2.32×10^{-34} J

17. An electron moving at 21 000 m s^{-1} enters a magnetic field of 3.5 T at an angle of 30° as shown in the diagram.



What is the force on the electron just after it enters the magnetic field?

(A) 1.2×10^{-14} N into the page

(B) 1.2×10^{-14} N out of the page

(C) 5.9×10^{-15} N into the page

(D) 5.9×10^{-15} N out of the page

18. Which statement can be correctly described as Planck's hypothesis?

(A) Radio waves are created at right angles to the gap in an induction coil.

(B) The charge to mass ratio of an electron is quantised.

(C) Photons without enough energy can never release electrons from the surface of a metal.

(D) Radiation absorbed and emitted by the walls of a black body cavity is quantised.

19. The Braggs developed an X-ray spectrometer to study diffraction of X-rays from crystal surfaces.

Which of the following shows the correct arrangement of components for such a spectrometer?

(A) X-ray tube → Crystal → Photographic screen → Collimator

(B) X-ray tube → Collimator → Crystal → Photographic screen

(C) Crystal → X-ray tube → Collimator → Photographic screen

(D) X-ray tube → Crystal → Collimator → Photographic screen

20. Conductors have a large number of free electrons in the conduction band compared to semi-conductors and insulators. The number of free electrons in semiconductors can be increased. How is this achieved?

(A) by raising the temperature which gives the electrons enough energy to jump into the conduction band

(B) by shining light onto the material giving the electrons a higher frequency and ability to move

(C) by shining *uv* light onto the surface of the material giving the electrons the ability to jump the forbidden gap into the valence band

(D) by applying a potential difference to the material in order to move the electrons to the valence band

Student Number	
Mark / 100	

Section I

Part A

Multiple Choice Answer Sheet **Mark ----- /20**

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

Section I (continued)

Part B – 55 marks

Attempt Questions 21–32

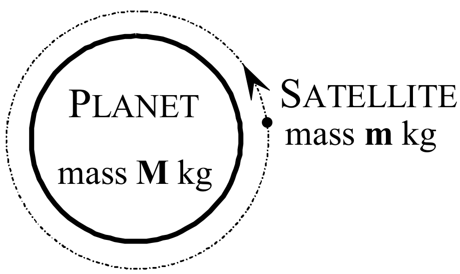
Allow about 1 hour and 40 minutes for this part

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.

Marks

Question 21 (3 marks)



A satellite having a mass of *m* kg is revolving in uniform circular motion around a certain planet that has a mass *M* kg. The radius of orbit of the satellite is *R* metres.

(a) Identify the force that provides the centripetal force keeping the satellite in orbit. **1**

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(b) Equate these forces to show that the orbital velocity of the satellite is: **2**

$$v_{orb} = \sqrt{\frac{G\,M}{R}}$$

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Marks

Question 22 (3 marks)

(a) Quantitatively compare the mass of an electron at rest with an electron moving with a velocity of 0.98 *c*. **2**

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(b) What significance does this result have for particle accelerators, which can accelerate particles to speeds approaching 0.9999 c? **1**

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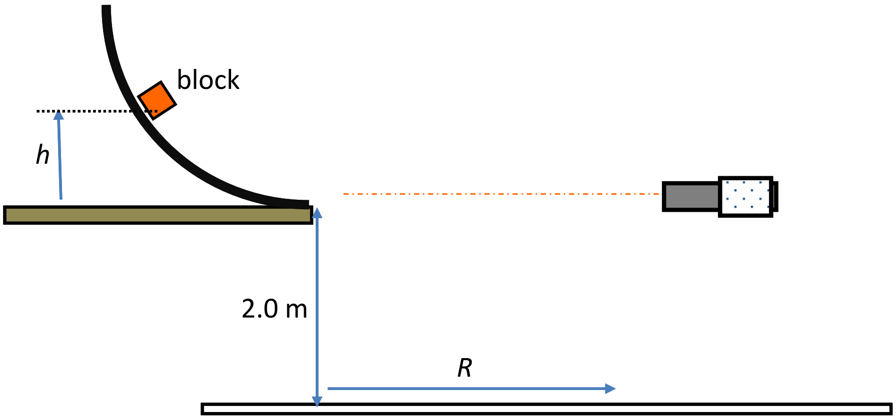
Question 23 (8 marks)

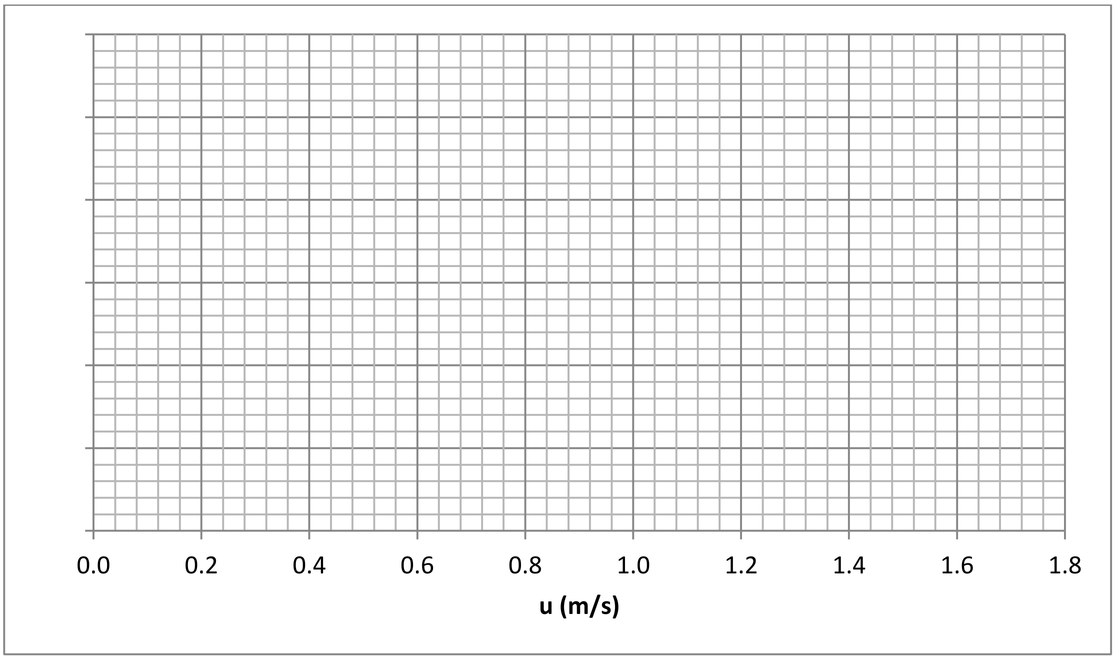
A small block is released from rest at a certain height *h* m above the platform and slides down a curved track. It shoots off horizontally from the track, which is 2.0 m above the floor level, with an initial speed *u* m s^{-1}. The block then hits the ground after achieving range *R* m. The height *h* was changed and the effect on *u* and *R* was measured.



The data table shows how *R* changes as the speed *u* is altered.

Speed u (m s^{-1})	0.80	1.00	1.20	1.40	1.60
Range R (m)	0.49	0.60	0.75	0.92	1.04

(a) On the graph paper below plot a graph of *R* versus *u,* and draw in the line of best fit. **3**



Question 23 continues on next page

Question 23 (continued)

(b) Given that $R = \frac{2u}{\sqrt{g}}$ is the equation for the line on the graph, write an algebraic expression for the slope of the line? **1**

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(c) Calculate the value of *g*, the acceleration due to gravity, using the slope of the line on the graph. **2**

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(d) Explain the relationship between *u* and *R*. **2**

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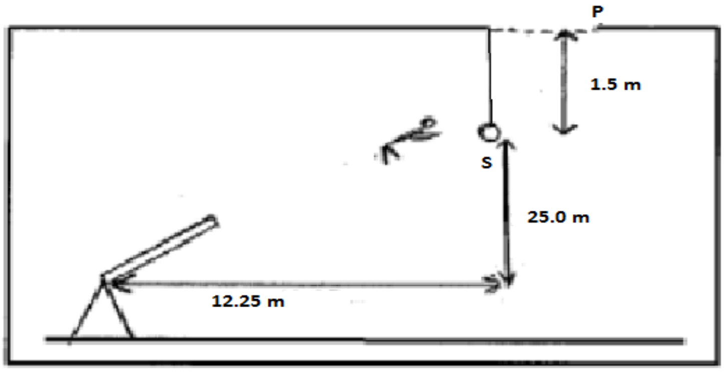
Question 24 (4 marks) **Marks**

In a circus act an acrobat of mass 70.0 kg is shot from cannon and at the top of their flight they grab a trapeze swing at S. They then use the swing to reach the platform at P. This is shown in the diagram below which is not drawn to scale.



(a) Neglecting air resistance, determine the initial velocity components, u_x and u_y, of the acrobat after the cannon is fired. **3**

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(b) The acrobat grabs the trapeze at S and swings up to P. If the radius of the swing is 1.50 m calculate the magnitude of the centripetal force on the acrobat after they grab the swing. **1**

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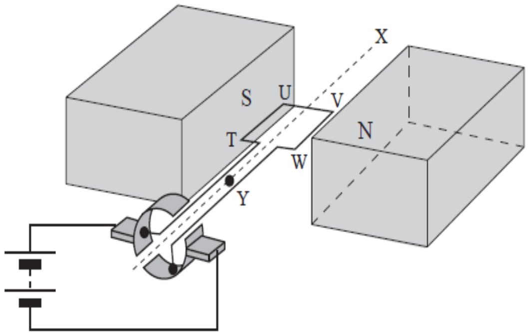
Question 25 (5 marks) **Marks**

The figure below is a simple DC motor. The single square loop coil TUVW, of side 0.0090 m, is free to rotate about the axis XY. Current is supplied from a battery via the split-ring commutator.

The two permanent magnets provide a uniform magnetic field *B* of magnitude 0.25 T in the region of the coil. The current flowing in the coil is 2.0 A



(a) Indicate with an arrow on the diagram, the direction of the force on side TU of the coil. **1**

(b) Determine the magnitude of the force on the side TU of the coil. Show all working. **1**

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(c) Determine the magnitude of the force on the side TU of the coil. Justify your answer. **1**

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(d) Calculate the magnitude of the torque experienced by the loop in the position shown. **2**

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Question 26 (4 marks) **Marks**

A motor operating from a 240 V power supply draws a current of 12 A and has a back emf of 180 V.

(a) Explain what is meant by 'back emf'. **2**

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(b) Calculate the resistance of the motor whilst operating. **1**

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(c) What current does the motor draw when it is first started? **1**

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Question 27 (6 marks) **Marks**

"In the late 19th century there was competition between Westinghouse and Edison to supply electricity to cities. In developing their respective technologies, it could be said that Westinghouse was more concerned with the production of eddy currents than Edison" **6**

Analyse the above statement from the perspective of the present day usage of electricity in which eddy currents have practical uses but also have undesirable effects.

In your analysis include an explanation of the production of eddy currents and an outline of the uses and problems of eddy currents.

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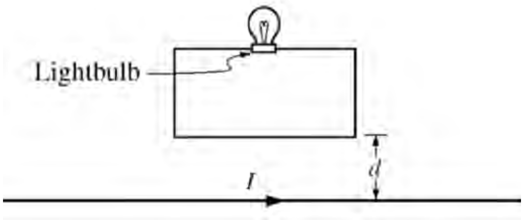
Question 28 (5 marks) **Marks**

The long straight wire carries a current *I* to the right.



The bottom of a rectangular loop of wire is located a distance *d* directly above the long wire. A light bulb is connected in the loop.

The current *I* in the long straight wire is now made to decrease with time at a constant rate but not reach zero.

(a) Account for the direction of any induced current in the loop. **3**

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(b) Does the light bulb get brighter, dimmer or stay the same brightness whilst the current in the wire *I* is decreasing. Justify your answer. **2**

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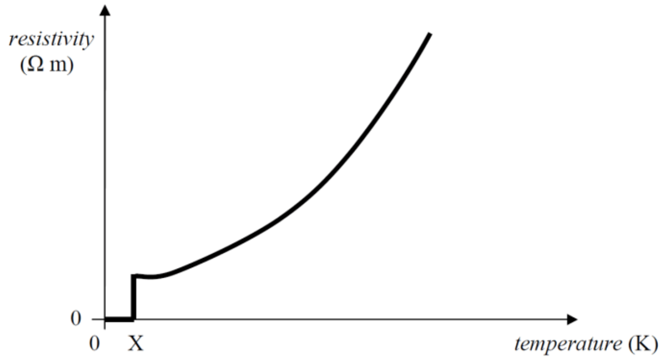
Question 29 (4 marks) **Marks**

The graph below shows the resistivity versus temperature for a Type I (metal) superconductor. **4**



With reference to the superconductor's structure and the behaviour of the conducting electrons moving through the material, explain the shape of the graph, particularly at the temperature labelled "X".

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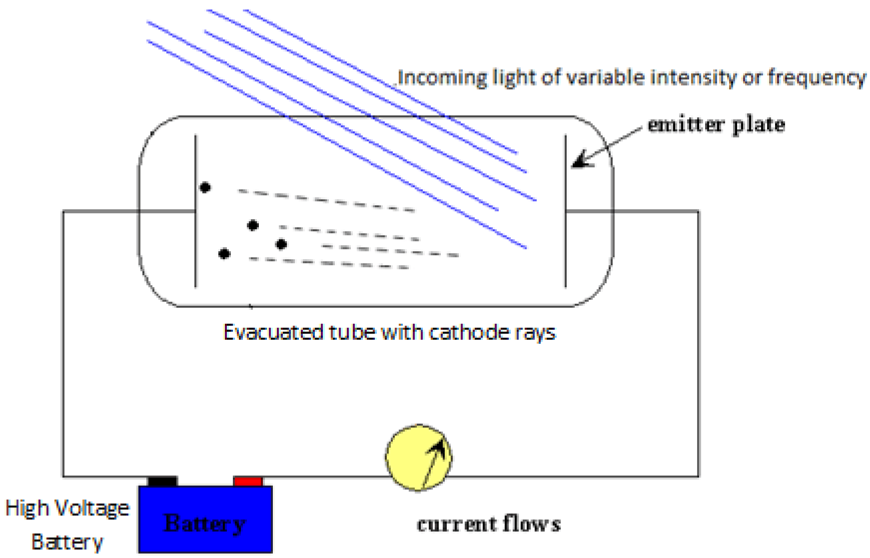
Question 30 (5 marks) **Marks**

In 1902, Lenard conducted an experiment to study photoelectrons. The results he obtained did not match those predicted by theory.

Lenard's Experiment



The results for the experiment are summarised in the table:

Characteristic	*Classical Predictions*	*Experimental results*
Intensity	As the intensity of the light increases the photocurrent will increase.	Above a threshold frequency as intensity increased so did photocurrent.
Emission time	For low intensities, should be very long.	If emission occurred, it was instantaneous.
Frequency	Emission is independent of frequency.	Emission is frequency dependant. Below threshold frequency no electrons emitted.
Energy	As light intensity increases, the kinetic energy of the photoelectrons will increase.	E_k remains constant with increased intensity but varies with the type of surface and the frequency.

Question 30 continues on next page

Question 30 (continued) **Marks**

Albert Einstein, however, was able to explain these results with a new theory of light. Einstein was later to receive a Nobel prize for this work. Outline Einstein's explanation of these results. **5**

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Question 31 (4 marks) **Marks**

During your Physics course you performed several investigations safely to gather information about the nature of cathode rays. **4**

Briefly describe ONE such safely conducted experiment, including observations made and how you determined if the experiment was valid.

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Question 32 (4 marks)

Concerns about the greenhouse effect and diminishing fossil fuel resources have renewed interest in solar energy. **4**

Draw a labelled diagram of a solar cell to show how the semiconductor materials in the solar cell can be used to can convert light energy to electricity.

Section II 25 marks

Attempt Question 33

Allow about 45 minutes for this section

Show all relevant working in questions involving calculations.

Question 33: From Quanta To Quarks (25 marks) **Marks**

(a) Two of the limitations of the Bohr model of the hydrogen atom include its inability to fully explain the relative intensity of spectral lines and the Zeeman effect. **3**

Discuss these TWO limitations.

(b) Outline Heisenberg's contribution to the development of atomic theory. **2**

(c) (i) Calculate the magnitude of both the gravitational and electrostatic forces between two protons separated by a distance of 1.3×10^{-15} m in the nucleus of an atom. **2**

The electrostatic force between any two protons is given by:

$$F = k\,\frac{q^2}{r^2}$$

where $k = 9\times10^9\ Nm^2C^{-2}$
q = charge on a proton
r = distance between the protons

(ii) Account for the need for the strong nuclear force. **2**

(iii) Outline the properties of the strong nuclear force. **2**

(d) A ${}^{235}_{92}U$ nucleus can undergo fission by this reaction: **3**

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{148}_{57}La + {}^{85}_{35}Br + 3\,{}^{1}_{0}n$$

The rest masses of some quantities are given:

$${}^{235}_{92}U = 235.124\,u \quad {}^{148}_{57}La = 147.961\,u \quad {}^{85}_{35}Br = 84.938\,u \quad {}^{1}_{0}n = 1.0087\,u$$

Calculate the energy released, in MeV, from the fission of an atom of ${}^{235}_{92}U$ undergoing the reaction above.

Question 33 continues on the next page

Question 33 (continued) **Marks**

(e) Describe how TWO properties of neutrons make them useful for probing the structure of matter. **2**

(f) Outline the role of bosons in the Standard Model of matter. **3**

(g) Assess the role of conservation laws to the development of atomic physics, with particular reference to the contributions made by Einstein, Chadwick and Pauli. **6**

End of paper

Student Number	
Mark / 100	

2014

TRIAL HSC EXAMINATION # ANSWERS

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Write your Student Number at the top of this page and on the response sheets on page 13 and 14
- Board-approved calculators may be used
- A data sheet, formulae sheets and Periodic Table are provided

Total Marks – 100

Section I Pages 2 - 22

75 marks

This section has two parts, Part A and Part B

Part A – 20 marks

- Attempt Questions 1- 20
- Allow about 30 minutes for this part

Part B – 55 marks

- Attempt Questions 21 - 32
- Allow about 1 hour and 45 minutes for this part

Section I 75 marks

Part A – 20 marks

Attempt Questions 1–20

Allow about 35 minutes for this part

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

Multiple Choice Answers

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

Section I (continued)

Part B – 55 marks

Attempt Questions 21–32

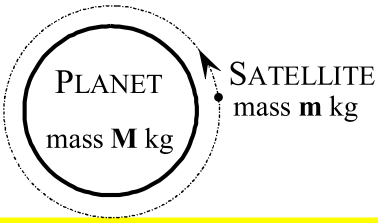
Allow about 1 hour and 40 minutes for this part

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.

Question 21 (4 marks) **Marks**

A satellite having a mass of m kg is revolving in uniform circular motion around a certain planet that has a mass M kg. The radius of orbit of the satellite is R metres.



(a) Identify the force that provides the centripetal force keeping the satellite in orbit **1**

Criteria	Mark
• Correct answer	1

Sample answer

Gravity is the force.

(b) Equate these forces to show that the orbital velocity of the satellite, **2**

$$v_{orb} = \sqrt{\frac{G\,M}{R}}$$

Criteria	Marks
• Complete solution using both F(centripetal) and F(gravity)	2
• Partial solution using either F(centripetal) and F(gravity)	1

Sample answer

F(centripetal) and F(gravity) becomes $m\,v^2/r = G\,M\,m/r^2$

simplifies to $v^2 = G\,M/r$

giving $v = [G\,M/r]^{1/2}$

Question 22 (4 marks)

(a) Quantitatively compare the mass of an electron at rest with an electron moving with a velocity of 0.98 *c*. **2**

Outcomes Assessed: H2, H9

Targeted Performance Bands: 2–4

Criteria	Mark
• Correct formula and calculation	2
• Correct formula and incorrect calculation	1

Sample answer

Mass of e^- at rest: 9.109×10^{-31} kg

Mass of e moving at 0.98 c

$m_v = 4.58 \times 10^{-30}$ kg ($5m_o$)

(b) What significance does this result have for particle accelerators, which can accelerate particles to speeds approaching 0.9999 c? **2**

Outcomes Assessed: H2, H9

Targeted Performance Bands: 2–4

Criteria	Mark
• 1correct significance discussed	1

Sample answer

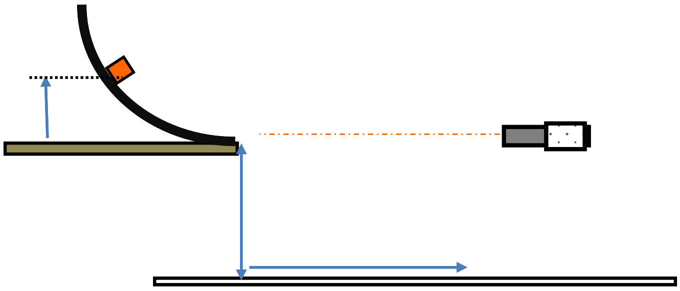
Varying magnetic fields will be required.

If charged particles can be accelerated to these speeds, then they can smash into a target and subsequently cause transmutation.

Low speed particle accelerators are used in TVs and CROs.

Question 23 (8 marks)

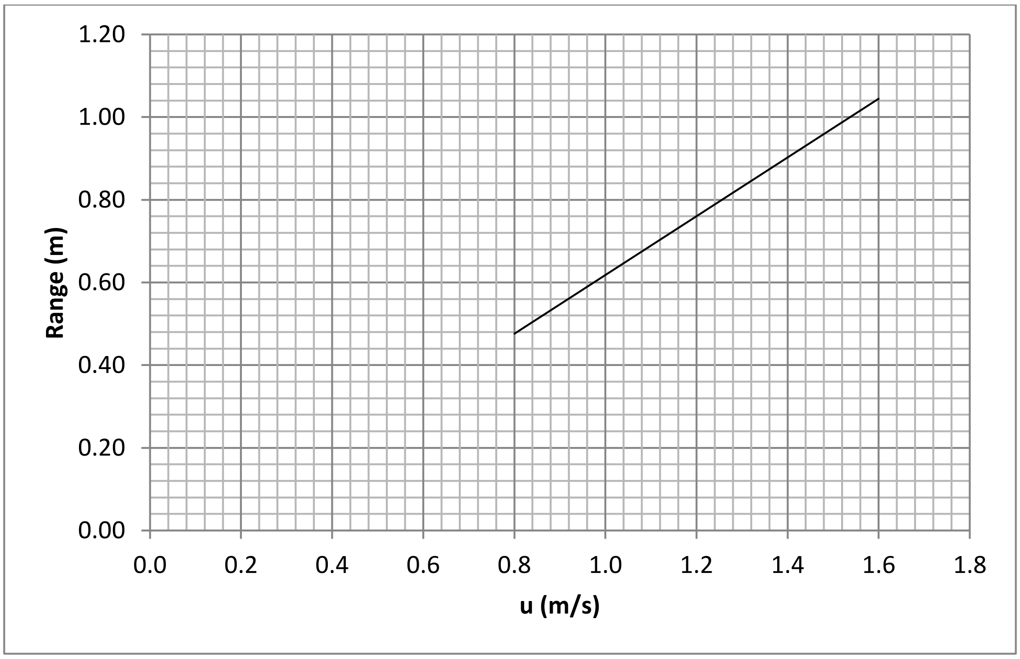
A small block is released from rest at a certain height h m above the platform and slides down a curved track. It shoots off horizontally from the track, which is 2.0 m above the floor level, with an initial speed u m s^{-1}. The block then hits the ground after achieving range R m. The height h was changed and the effect on u and R was measured.



The data table shows how R changes as the speed u is altered.

Speed u (m s^{-1})	0.80	1.00	1.20	1.40	1.60
Range R (m)	0.49	0.60	0.75	0.92	1.04

(a) On the graph paper below plot a graph of R versus u, and draw in the line of best fit. **3**



Criteria	Marks
• Correctly naming vertical axis of graph and appropriate scale • Placing all five points accurately • Drawing a reasonable *straight* line of best fit	3
• Two of the above	2
• One of the above	1

(b) Given that $R = \frac{2u}{\sqrt{g}}$ is the equation for the line on the graph, what does its slope represent? **1**

Outcomes Assessed: H2

Targeted Performance Bands: 3-4

Criteria	Mark
• Correctly identifies what the slope represents	1

Sample answer

The slope of the line of best fit is $\frac{R}{u}$, which is equal to $\frac{2}{\sqrt{g}}$

(c) Calculate the value of *g*, the acceleration due to gravity, using the slope of the line on the graph **2**

Outcomes Assessed: H2, H14

Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly assessing slope of their line of best fit • Correctly equating this slope with the formula given in part (b)	2
• One of the above	1

Sample answer

From the graph the slope of the line of best fit is approximately 1/1.55 = 0.645

Since $$\frac{1}{1.55} = \frac{2}{\sqrt{g}} \therefore g = 3.1^2 = 9.61\,ms^{-2}$$

(d) Explain the relationship between *u* and *R*. **2**

Outcomes Assessed: H6, H9

Targeted Performance Bands: 2-5

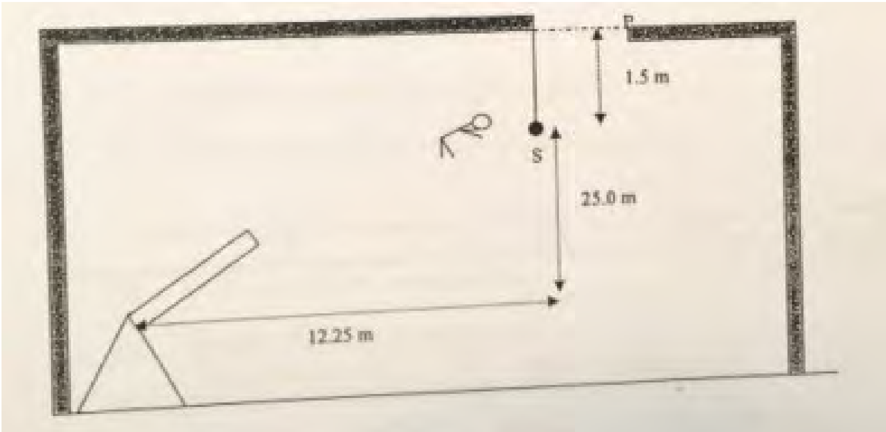
Criteria	Marks
• Identifies that there is zero horizontal acceleration • Explains that t depends only on vertical height which will remain constant • Relates *u* to *R*	2
• Identifies that there is zero horizontal acceleration **OR** • Describes a relationship between *u* to *R* by a different method	1

Sample answer

Because the block is initially travelling *horizontally* at *u* m s^{-1}, and its horizontal acceleration is *zero*, the range *R* it covers depends simply upon *u* and the time it takes to fall 2.0 metres. As time of flight depends on vertical height, which is constant, then time to fall remains unchanged, hence then *R* depends on u_x.

Question 24 (4 marks) **Marks**

In a circus act an acrobat of mass 70 kg is shot from a cannon and at the top of their flight they grab a trapeze swing at S. They then use the swing to reach the platform at P. This is shown in the diagram below which is not drawn to scale.



(a) Neglecting air resistance, determine the initial velocity components, ux and uy, of the acrobat after the canon is fired. **3**

Criteria	Marks
• Correct calculation of v_y • Correct calculation of u_x	3
• Correct calculation of v_y and t	2
• Correct calculation of t OR • Correct calculation u_x from range	1

Sample answer

(a) $v_y^2 = u_y^2 + 2a_y \Delta y$

$0^2 = u_y^2 - 2 \times 9.8 \times 25.0$

$\mathbf{u_y = 22.1\ ms^{-1}}$

$v_y = u_y + a_y t$

$0 = 22.1 - 9.8t$

$t = 2.26$ s

$u_x = \Delta x \div t$

$u_x = 12.25 \div 2.26 = 5.42\ ms^{-1}$

$\mathbf{u_x = 5.42\ ms^{-1}}$

(b) The acrobat grabs the trapeze at S and swings up to P. If the radius of the swing is 1.5 m calculate the magnitude of the centripetal force acting on the acrobat after they grab the swing. **1**

Criteria	Marks
• Correct calculation of F_c	1

Sample answer

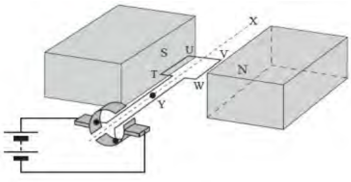
(b) $Fc = mv^2 \div r$

$F_c = 70 \times 5.42^2 \div 1.5 =$ **1373 N**

Question 25 (4 marks) **Marks**

The figure below is a simple DC motor. The single square loop coil TUVW, of side 0.009 m, is free to rotate about the axis XY. Current is supplied from a battery via the split-ring commutator.

The two permanent magnets provide a uniform magnetic field B of magnitude 0.25 T in the region of the coil. The current flowing in the coil is 2.0 A



(a) Indicate with an arrow on the diagram, the direction of the force on side TU of the coil. **1**

Up

(b) Calculate the magnitude of the force on the side **TU** of the coil. Show all working. **1**

Criteria	Marks
• Correct substitution into correct formula, correct answer with correct units	2
• Correct substitution into correct formulae, with incorrect answer or incorrect units	1

Sample answer

$$F = BiL = 0.25 \times 2 \times 0.009$$
$$= 4.5\ mN$$

(c)What is the magnitude of the force acting on side **UV** of the coil. Justify your answer.

Criteria	Marks
• Correctly deduces that the force is zero, and provides correct explanation	2
• Correctly deduces that the force is zero, but provides a vague or incorrect explanation	1

Sample answer

The force is zero since this side of the coil is parallel to the external magnetic field.

(d) Calculate the magnitude of the torque experienced by the loop in the position shown. **2**

Criteria	Marks
• Correct substitution into correct formula, correct answer with correct units	2
• Correct substitution into correct formulae, with incorrect answer or incorrect units	1

Sample answer

$$\tau = nBiA = 1 \times 0.25 \times 2 \times (0.009)^2 = 4.05 \times 10^{-5}\ Nm$$

Question 26 (6 marks)

A motor operating on 240 V has a 180 V back emf at operating speed and draws a 12.0 A current.

(a) Explain what is meant by 'back emf'. **2**

Criteria	Marks
• Correctly states when back emf occurs and why	**2**
• Correctly states when back emf occurs, but fails to provide a reason	**1**

Sample answer

Back emf is the induced voltage that opposes the supply emf, thereby ensuring that the conservation of energy is not violated.

(b) Calculate the resistance experienced by the motor. **1**

Criteria	Marks
• Correctly finds the difference between the supply voltage and the back emf, and correctly calculates the resistance	**2**
• Obtains some value for the resistance, with some degree of working	**1**

Sample answer

$$V = 240 - 180 = 60\ V$$
$$\therefore R = \frac{V}{I} = \frac{60}{12} = 5\ \Omega$$

(c) What current does it draw when it is first started? **1**

Criteria	Marks
• Correctly obtains the current, with working	**2**
• Obtains some value of the current, with some degree of working	**1**

Sample answer

$$I = \frac{240}{5} = 48\ A$$

(d) If the back emf increases to 240 V, describe the motion of the motor. **1**

Criteria	Marks
• Correctly describes the motion of the motor	**1**

Sample answer

The motor spins at constant speed.

Question 27 (6 marks)

"In the late 19th century there was competition between Westinghouse and Edison to supply electricity to cities. In developing their respective technologies, it could be said that Westinghouse was more concerned with the production of eddy currents than Edison"

Analyse the above statement from the perspective of the present day usage of electricity in which eddy currents have practical uses but also have undesirable effects.

In your analysis include an explanation of the production of eddy currents and an outline of the uses and problems of eddy currents.

Criteria	Marks
• Explains the production of eddy currents in terms of Lenz's Law • Outlines at least TWO uses of eddy currents • Describes the problem of resistive heating caused by eddy currents • Identifies Westinghouse as proponent of AC and Edison of DC • Links the use of transformers with AC and eddy current heating • Provides an analysis of the statement in the question with a response logically constructed and well thought out	**6**
• Any 5 of the above	**5**
• Any 4 of the above	**4**
• Any 3 of the above	**3**
• Any 2 of the above	**2**
• Any 1 of the above	**1**

Sample answer

When masses of metal move in magnetic fields or are located in changing magnetic fields, induced currents can circulate throughout the volume of the metal. These are called eddy currents. For example, consider a metal disk rotating in a magnetic field which is confined to a portion of the disk. Lenz's Law says that the induced currents in the region of the field will flow in a direction to produce a magnetic field that opposes the change that caused it. The circulating return currents are outside the field so don't feel magnetic forces.

The formation of eddy currents in this way is used in electromagnetic braking, where, as described above, a rotating disk will experience a force opposing the rotation. This is used to brake roller coasters and circular saw blades

Like all currents, eddy currents cause resistive heating and are therefore used in cook-tops in electric ranges, where a rapidly changing magnetic field in the cook-top induces eddy currents in a metal saucepan causing it to heat up and cook food.

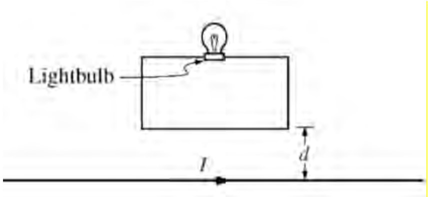
Eddy current heating is usually a problem however, as induced currents in motor armatures and especially transformers cause a lot of energy to be wasted as electrical energy is transformed into waste heat. This heating caused by eddy currents is minimised by using laminated iron cores which reduce the size of eddy currents.

Westinghouse was a proponent of AC electricity, while Edison supported DC. A key advantage in the competition between Westinghouse and Edison, and of AC electricity over DC, was AC's ability to be transformed. Transformers are used in the distribution of AC electricity to step up voltages for long distance transmission and then to step down again for domestic and industrial uses, to minimise energy wastage in line loss.

Therefore, even though Westinghouse and Edison may not have foreseen modern applications of eddy currents, because of the extensive use of transformers in AC and the fact that AC always has a varying magnetic field associated with it, and the significant problem of eddy current heating, it seems that the statement is accurate in presuming that Westinghouse would have been more concerned with eddy currents than Edison.

Question 28 (5 marks)

The long straight wire carries a current I to the right.



The bottom of a rectangular loop of wire is located a distance *d* directly above the long wire. A light bulb is connected in the loop.

The current *I* in the long straight wire is now made to decrease with time at a constant rate but not reach zero.

(a) Account for the direction of any induced current in the loop. **3**

Marking Criteria	***Marks***
• 3 correct statements	3
• any 2 of the above	2
• any 1 of the above	1

Sample answer

1. The magnetic field threading the loop of wire (circuit) is directed out of the page and is decreasing in magnitude.
2. Therefore, the induced magnetic field threading the loop will be in the same direction (out of the page) as the external magnetic field of the wire, in order to oppose this decreasing magnetic flux.
3. This implies that the induced current in the loop of wire flows anticlockwise (using the R H grip rule).

(b) Does the light bulb get brighter, dimmer or stay the same brightness whilst the current in the wire *I* is decreasing. Justify your answer. **2**

Marking Criteria	***Marks***
• 2 correct statements	2
• any 1 of the above	1

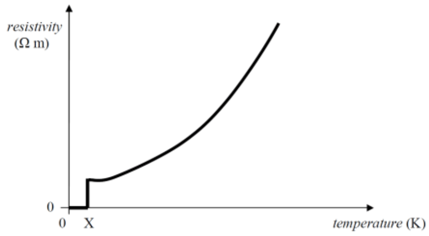
Sample answer

The brightness of the globe remains constant because:

1. The time rate of change of I_{wire} is constant, hence the time rate of change of B_{wire} and hence the time rate of change $\Delta\Phi_B$ is also constant.
2. This implies that $\mathcal{E}mf_{induced}$ is constant (Faraday's law) and hence the current flowing in the loop (and hence the brightness of the globe) is constant.

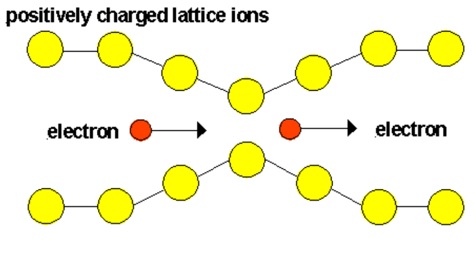
Question 29 (4 marks)

The graph below shows the resistivity versus temperature for a Type I (metal) superconductor.



With reference to the superconductor's structure and the behaviour of the conducting electrons moving through the material, explain the nature of the graph, particularly at the temperature labelled "X".

Marking Criteria	Marks
• lattice structure – sea of delocalised electrons • ↑↓collisions between (electrons and lattice ions) leads to ↑↓ in resistance (R) as ↑↓ temperature • At Tc (X), R↓ suddenly to zero due to no collisions with the lattice • Cooper pairs explanation of superconductivity (easiest with a diagram)	**4**
• 3 of the above	**3**
• 2 of the above	**2**
• 1 of the above	**1**



Cooper pair moving through lattice

Sample answer

A metal consists of a lattice structure of (+) ions surrounded by a sea of delocalised electrons.

Above Tc (X), as T↓, there ,is less vibration of (+) lattice leading to fewer collisions with electrons, implying a decrerase in electrical resistance of the conductor.

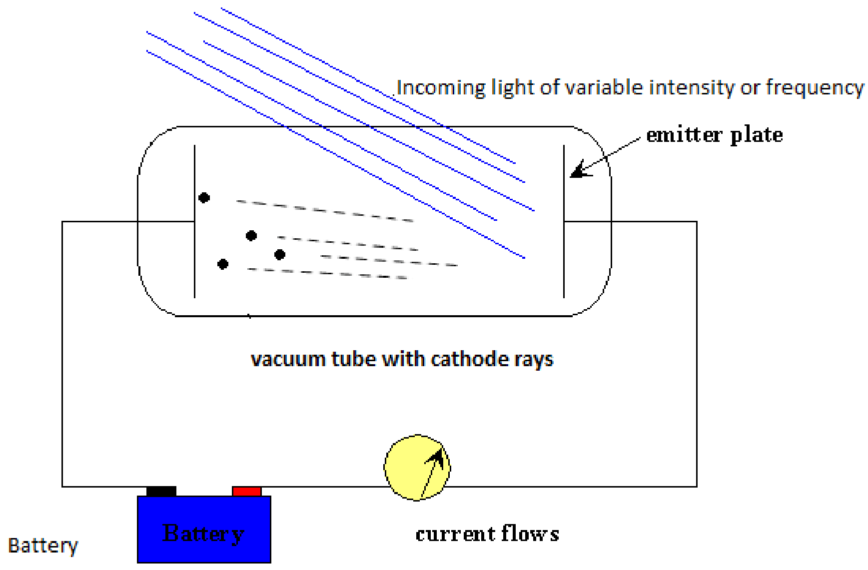
At (and/or below) Tc (X), the resistance suddenly drops to zero, due to lattice vibrations being so small that electrons travel unimpeded (conductivity actually enhanced by lattice) through the (+) lattice (i.e. no collisions) in "Cooper Pairs" of two electrons.

Cooper Pairs form because the first electron distorts the (+) lattice (phonon) enough to create a local (+) region. This region then attracts a second electron towards the first before the lattice relaxes again (phonon mediated conduction).

Question 30 (5 marks)

In an experiment conducted by Lenard the results did not match those predicted by theory.

Lenard's Experiment



The results for the experiment are summarised in the table:

Characteristic	*Classical Predictions*	*Experimental results*
Intensity	As the intensity of the light increases the photocurrent will increase	Above a threshold frequency as intensity increased so did photocurrent
Emission time	For low intensities should be very long.	If emission occurred, it was instantaneous
Frequency	Emission is independent of frequency	Emission is frequency dependant. Below threshold frequency no electrons emitted.
Energy	As light intensity increases, the kinetic energy of the photoelectrons will increase.	E_k remains constant with increased intensity but varies with the type of surface and the frequency.

Question 30 (continued)

Albert Einstein however was able to explain these experimental results with a new theory of light. Einstein was later to receive a Nobel prize for this work.

Outline Einstein's explanation of these results.

Criteria	Marks
• Proposal of particle model of photons, • an explanation for each of the four experimental results.	5
• Proposal of particle model of photons, • an explanation for each of three experimental results.	4
• Proposal of particle model of photons, • an explanation for each of two experimental results.	3
• Proposal of particle model of photons, • an explanation for one experimental result.	2
• Proposal of particle model of photons	1

Sample answer:

Light behaves like particles called photons, with each photon carrying a discrete package of energy, related to its frequency by E= hf.
Intensity: Light with higher intensity had more photons, each with the same energy. As light intensity of an appropriate frequency increased, photoemission increased to a max value, as more photoelectrons could be emitted. One photon can emit one electron.
Emission time: Energy is transferred from the photon to the electron if it is equal to or above the threshold energy and all energy (or none) is transferred instantaneously during the collision. Energy is not accumulated until the electron gets emitted.
Frequency: Each photon carried a specific amount of energy directly proportional to its frequency and given by E = hf.
Energy: Once photoelectrons are emitted, what determines their KE is the frequency of the incident emr and the value of the work function of the surface. Intensity is not part of the equation. Ek = hf - *W*

Question 31 (4 marks)

During your Physics course you performed several investigations safely to gather information about the nature/properties of cathode rays. Briefly describe ONE experiment, including how you determined if the experiment was valid.

Criteria	Marks
• Identifying appropriate exp • Description of appropriate exp either with diagram or text • Results of exp showing validity • Any one risk assessment	4
• Any 3 of the above	3
• Any 2 of the above	2
• Any 1 of the above	1

Sample answer:

Investigation: To study the particle or wave nature of cathode rays, the Maltese Cross exp was conducted. Connected the cathode ray tube containing the Maltese cross (Crooke's tube) to the terminals of the induction coil. Observed the end of the tube containing the cross when the cross was down and when the cross was up.
Safety: Care with handling equipment was taken by turning off electricity when handling equipment and stood back 3 m to avoid exposure to XRays.

Results/Observations: a dark sharp edged shadow of the cross formed on the tube at the back of the cross when the cross was up and when the cross was down, the glass fluoresced.

Validity: by comparing the tubes with the cross up and down, it showed that the cathode rays travel in straight lines (or were blocked by metal).

Common errors:

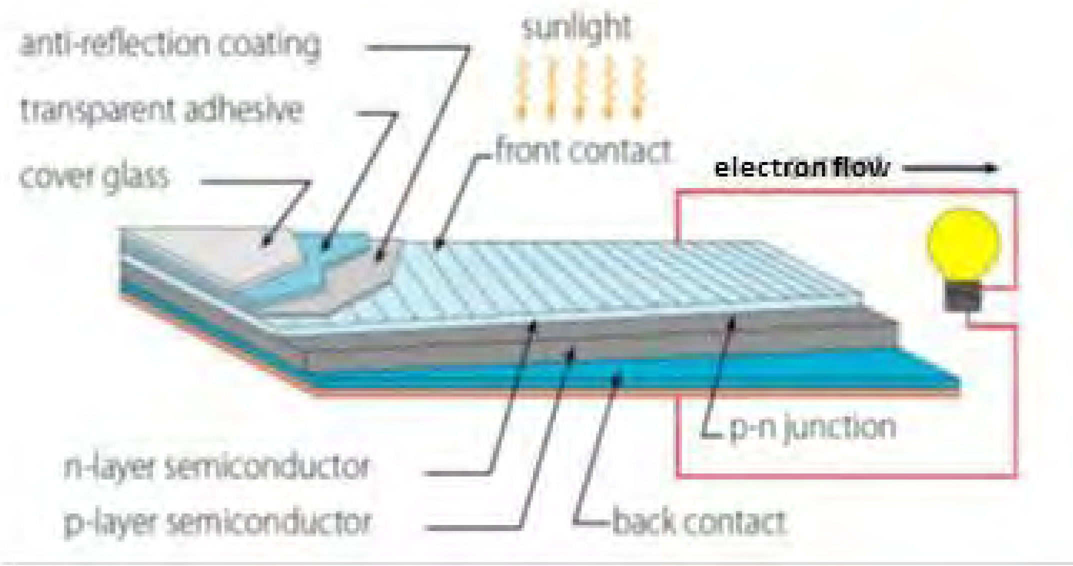
- Not indicating the reason for the investigation
- Confusing validity with reliability
- Not addressing safety aspects
- Discussing more than 1 experiment

Question 32 (4 marks)

Concerns about the greenhouse effect and diminishing fossil fuel resources have renewed interest in solar energy.

Draw a labelled diagram of a solar cell to show how the semiconductor materials can be used to can convert light energy to electricity.

Criteria	Marks
• Neat labelled diagram in pencil showing n-layer, p-layer, p-n junction, direction of current (or electron) in external circuit, sunlight (front contact, anti-reflective coating, cover glass) and metal contacts.	4
• Any 5 of the above	3
• Any 4 of the above	2
• Any 3 of the above	1



Section II 25 marks

Attempt Question 33

Allow about 45 minutes for this section

Show all relevant working in questions involving calculations.

From Quanta To Quarks (25 marks) **ANSWERS** **Marks**

(a) Two of the limitations of the Bohr model of the hydrogen atom include the inability to fully explain the relative intensity of spectral lines and the Zeeman effect. **3**

Discuss these two limitations.

Marking Criteria	***Marks***
• 2 correct statements displaying a thorough understanding of each limitation	2
• any 1 of the above	1

- **relative intensity of spectral lines**

1. Some spectral lines were brighter than others in the discrete visible spectrum of hydrogen.
2. This implied that some transitions between stationary states were more likely than others – no explanation.

- **Zeeman effect**

1. A spectral line splits into several (3 or more) lines in the presence of an external magnetic field.
2. This implied that other electron transitions between new "allowed" states of similar energies were possible – no explanation.

Other accepted arguments/answers:

- Bohr's model explanation
- Pauli/Heisenberg explanation
- Deeper explanation of either

(b) Outline Heisenberg's contribution to the development of atomic theory. **2**

Marking Criteria	***Marks***
• 2 correct descriptions displaying a thorough understanding of each contribution	2
• any 1 of the above	1

1. He developed the first completely **mathematical quantum mechanical model** that successfully explained atomic spectra (amongst others) – "matrix mechanics"

2. The Uncertainty Principle – there is a fundamental limit to the accuracy with which anyone can determine simultaneously both the position and momentum of a particle, defined by:

$$\Delta x \, \Delta p \geq h/2\pi$$

(c) (i) Calculate the magnitude of both the gravitational and electrostatic forces between two protons separated by a distance of 1.3×10^{-15} m in the nucleus of an atom. **2**

The electrostatic force between any two protons is given by:

$$F = k\,\frac{q^2}{r^2}$$

where $k = 9\times10^9$ Nm^2C^{-2}
q = charge on a proton
r = distance between the protons

Marking Criteria	***Marks***
• 2 correct calculations of F_{grav} and F_{elect}	2
• any 1 of the above	1

$$F_{grav} \approx 1.1 \times 10^{-34}\ N \qquad F_{elec} \approx 136\ N$$

- ridiculous number of sig. figs still from some students – aaaaaahhh!!!

(ii) Account for the need for the strong nuclear force. **2**

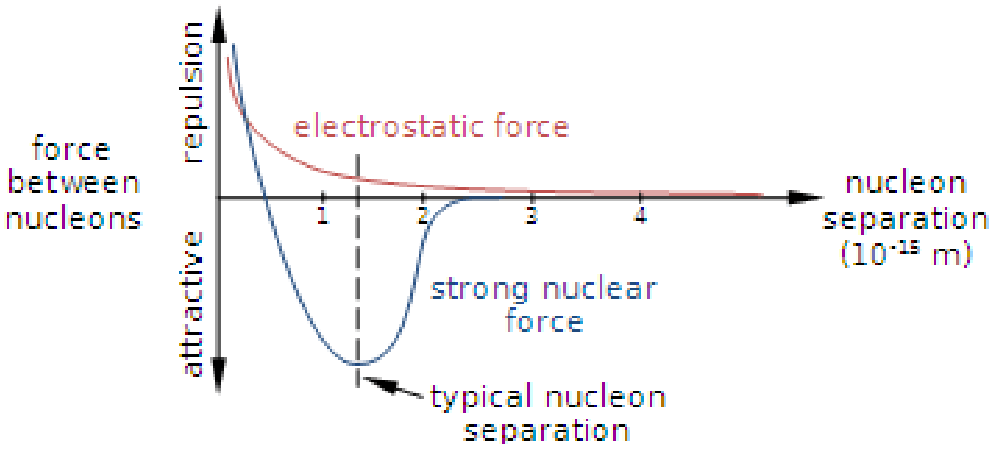
Marking Criteria	***Marks***
• 2 correct statements	2
• any 1 of the above	1

1. F_{grav} (attraction) « F_{elect} (repulsion).

2. A third ATTRACTIVE FORCE must exist to account for the stability of the nucleus of the atom (overcome the electrostatic repulsion of the two protons in the nucleus).

(iii) Outline the properties of the strong nuclear force. **2**

Marking Criteria	*Marks*
• 3 or more correct properties	2
• any 1or 2 of the above	1



1. Acts over a short range (approx. 2fm)/adjacent nucleons
2. attractive force between any two nucleons – independent of charge (1-2 fm)

Other accepted arguments/answers:

- mediated by gluons
- repulsive at less than approx. 1fm
- peak attraction at approx 1.3 fm

(d) A $^{235}_{92}U$ nucleus can undergo fission by this reaction: **3**

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{148}_{57}La + ^{85}_{35}Br + 3^{1}_{0}n$$

The rest masses of some quantities are listed:

$$^{235}_{92}U = 235.124\,u \quad ^{148}_{57}La = 147.961\,u \quad ^{85}_{35}Br = 84.938\,u \quad ^{1}_{0}n = 1.0087\,u$$

Calculate the energy released, in MeV, from the fission of an atom of $^{235}_{92}U$ undergoing the reaction above.

m_{react} = 235.124 + 1.0087
= 236.1327 u

m_{prod} = 147.961 + 84.938 + 3(1.0087)
= 235.9251 u

∴ Δm = 0.2076 u

E = (0.2076) (931.5)

∴ E ≈ 193.4 MeV

Marking Criteria	***Marks***
• correct expressions for the m_{react} and m_{prod} • correct calculation of mass defect, Δm • correct conversion to energy, in Mev.	3
• any 2 of the above	2
• any 1 of the above	1

(e) Describe how TWO properties of neutrons make them useful for probing the structure of matter. **2**

1. Neutral – penetrate deeper into matter (to interact with nuclei) than either protons or electrons as they don't experience electrostatic repulsion.

2. $\lambda_{DeBroglie}$ ≈ atomic spacing allowing investigations to determine interatomic spacing.

Marking Criteria	***Marks***
• 2 correct properties	2
• any 1 of the above	1

- the phrase "structure of matter" is too broad and vague to use in your answer without specific explanation.

Other accepted arguments/answers:

- thermal neutrons approx. lattice vibration energy
- scatter from protons – useful in determining h-bond structures (organic molecules)
- large enough mass to smash nuclei to explore constituents

(f) Outline the role of bosons in the Standard Model of matter. **3**

1. There are four bosons – force carrier particles – responsible for mediating the four fundamental forces of nature.

2. gluon – strong nuclear force intermediate vector bosons – weak force.

3. photon – electromagnetic force graviton (yet to be found) – gravitational force.

Marking Criteria	***Marks***
• 3 correct statements	3
• any 2 of the above	2
• any 1 of the above	1

(g) Assess the role of conservation laws in the contributions of Einstein, Chadwick and Pauli to the development of atomic physics. **6**

Marking Criteria	***Marks***
• Correctly identifies the appropriate conservation law(s) with the matching advancement in atomic physics for Pauli.	2
• Correctly identifies the appropriate conservation law(s) with the matching advancement in atomic physics for Einstein.	2
• Correctly identifies the appropriate conservation law(s) with the matching advancement in atomic physics for Chadwick. (Assessment of contribution must be included for full marks).	2

Conservation laws have played a key role in the development of many ideas in atomic physics:

1. Conservation **of momentum and energy (kinetic**) were crucial to Chadwick's "discovery" of the neutron +any deeper explanation/description of experimental analysis

2. Conservation of **energy (kinetic)** and momentum were crucial to Pauli's suggestion of the existence of the "neutrino" to solve the problem of the continous spectrum of kinetic energy of electrons emitted in beta decay (cf discrete spectrum for alpha decay).

3. The conservation of **mass/energy ($E=mc^2$)** as predicted by Einstein allowed for an explanation of natural and artificial transmutations (nuclear fission) as well as nuclear stability.

Other accepted arguments/answers:

- Correct link between Einstein, conservation of energy and the photoelectric effect
  - Only write ONE judgement/assessment.
  - Know which scientists were experimentalists
  - Momentum ≠ kinetic energy.