Teacher: _____

Newington College

Year 12 TRIAL HSC EXAMINATION

August, 2023

PHYSICS

General Instructions

- Reading Time – 5 minutes
- Working Time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- A data sheet, formulae sheet and Periodic Table is provided with this paper
- NESA-approved calculators may be used
- Write your Student Number, at the top of the multiple-choice answer sheet and on the top of each page in this booklet.

Total marks – 100

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

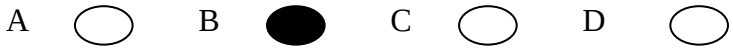
Part B
80 marks
- Attempt **all** Questions 21–35
- Allow about 2 hours and 15 minutes for this part

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

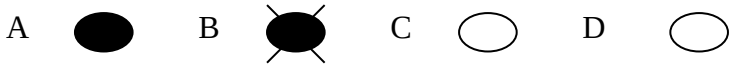
Use the multiple-choice answer sheet to record your answers.

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

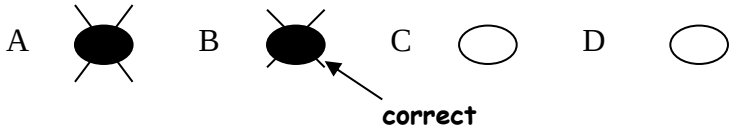
Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9



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.



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

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1. Projectile **A** is launched on Earth with an initial speed of 40 m s^{-1} at an angle of 30° to the horizontal.

Projectile **B** is launched with the same initial conditions on a planet where the acceleration due to gravity is exactly half that on Earth.

Projectile **B**'s path compared to projectile **A** will have:

	maximum height reached	**final speed**
(A)	equal	double
(B)	equal	equal
(C)	double	double
(D)	double	equal

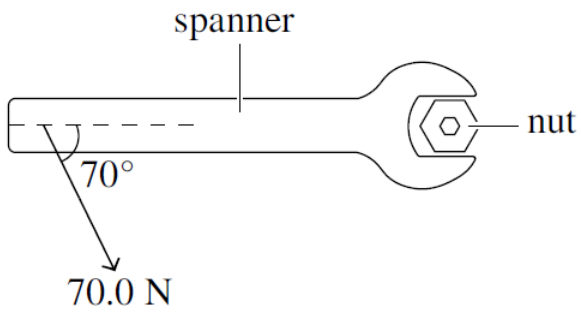
2. Two objects are launched into space from the ground so that they will just escape Earth's gravitational field forever, by being given an initial velocity.

Object **A** had a mass of 10 kg, while object **B** had a mass of 100 kg.

Which alternative is correct?

	Objects' initial speed	Objects' initial kinetic energy
(A)	equal	equal
(B)	equal	**B** is 10 times greater than **A**
(C)	equal	**B** is 100 times greater than **A**
(D)	**B** is 10 times greater than **A**	**B** is 100 times greater than **A**

3. In cycling, it is important for the nuts on bike seats to be tightened appropriately so they do not come loose during a race. Before a race, a cyclist tightens the nuts with a 50.0 cm spanner and applied a force of 70.0 N at an angle of 70^0 to the spanner, as shown in the diagram.



What magnitude of torque has the cyclist applied to the nut?

(A) 11.97 N m

(B) 32.89 N m

(C) 1197.07 N m

(D) 3289.92 N m

4. Most stars have at least one planet orbiting them. Two planets, Centaur and Tri, have been observed to orbit a star. Centaur has an orbital path with a radius that is four times smaller than the radius of Tri's orbital path.

Which of the following statements about Centaur and Tri is correct?

(A) Tri would take 8 times longer than Centaur to make a full orbit of the star

(B) Centaur would take 8 times longer than Tri to make a full orbit of the star

(C) Tri would take 64 times longer than Centaur to make a full orbit of the star

(D) Centaur would take 64 times longer than Tri to make a full orbit of the star

5. Jupiter's moon Ganymede is its largest satellite.

Ganymede has a mass of 1.5×10^{23} kg and a radius of 2.6×10^{6} m.

Which one of the following is closest to the magnitude of Ganymede's surface gravity?

(A) 0.8 m s^{-2}

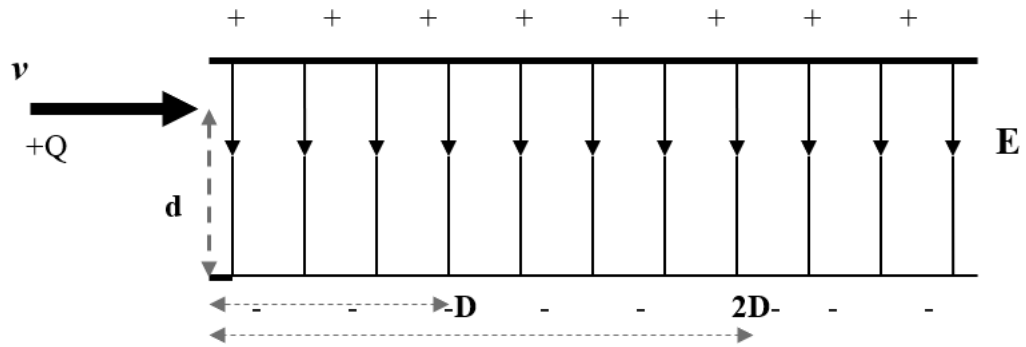
(B) 1.5 m s^{-2}

(C) 3.8 m s^{-2}

(D) 9.8 m s^{-2}

6. A charged particle +Q enters a region of uniform electric field E between two parallel plates, as shown. The particle's speed before entering is ***v***.

The apparatus is in a vacuum and the experiment is being performed in weightless conditions. The charged particle travels a horizontal distance **D** before striking the charged plate.



What change would result in the charged particle travelling twice the horizontal distance, i.e. **2D** ?

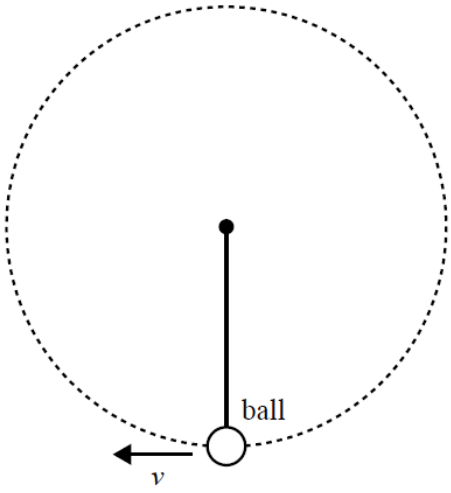
(A) doubling the initial velocity to **2*v***

(B) halving the vertical distance, **d**, the particle must move

(C) halving the electric field strength

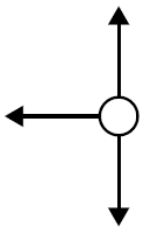
(D) halving the mass of the particle

7. A ball is attached to the end of a string a rotated in a circle at constant speed in a vertical plane, as shown in the diagram below.

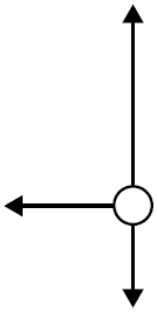


The arrows in options A. to D. below indicate the direction and the size of the forces acting on the ball.
Ignoring air resistance, which one of the following best represents the forces acting on the ball when it is at the bottom of the circular path and moving to the left?

A.



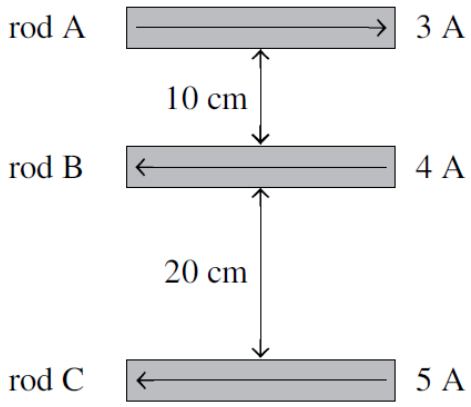
B.



C.

D.

8. The diagram below shows an arrangement that uses three metal rods (A, B and C), each carrying a current in the direction indicated by the arrows.



What is the magnitude and direction of the force per unit length on rod C?

(A) 1×10^{-5} N m^{-1} down

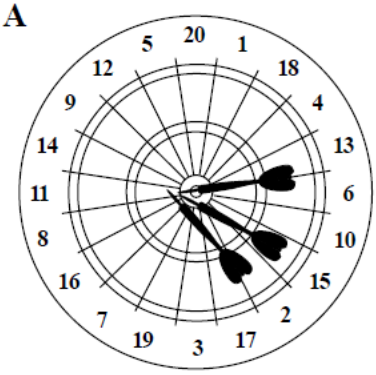
(B) 1×10^{-5} N m^{-1} up

(C) 3×10^{-5} N m^{-1} up

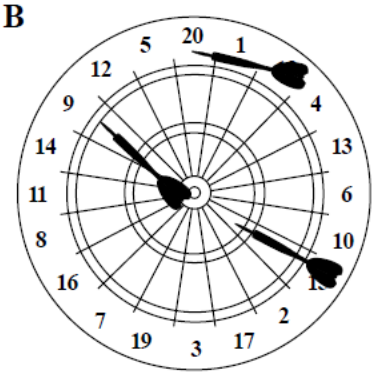
(D) 3×10^{-5} N m^{-1} down

9. The aim of the game of darts is to hit the bullseye at the centre of the dartboard. Four darts players (A, B, C and D) each threw three darts. The results of their throws are shown below.

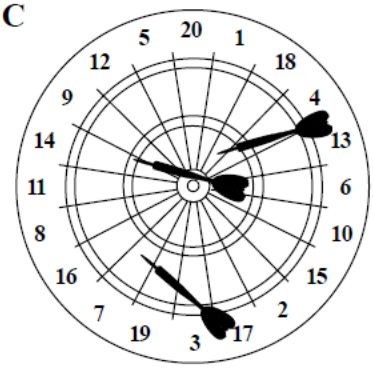
Player A



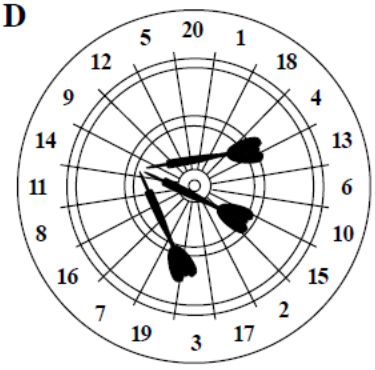
Player B



Player C



Player D



Which one of the players produced a set of attempts that could be described as being precise but inaccurate?

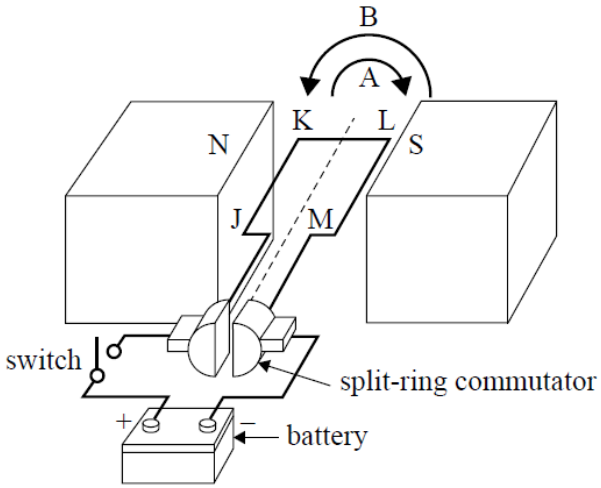
(A) Player A

(B) Player B

(C) Player C

(D) Player D

10. The diagram below shows a small DC electric motor, powered by a battery that is connected via a split-ring commutator. The rectangular coil has sides KJ and LM. The magnetic field between the poles of the magnet is uniform and constant.



The switch is now closed allowing current to flow, and the coil is stationary and in the position shown in the diagram.

Which one of the following statements best describes the motion of the coil when the switch is closed?

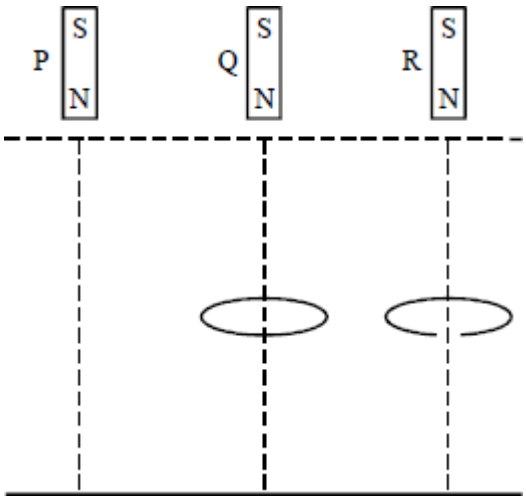
(A) The coil will remain stationary

(B) The coil will rotate in direction A, as shown in the diagram

(C) The coil will rotate in direction B, as shown in the diagram.

(D) The coil will oscillate regularly between directions A and B, as shown in the diagram.

11. Three identical magnets P, Q and R are released simultaneously from rest and fall to the ground from the same height. P falls directly to the ground, Q falls through the centre of a thick conducting ring and R falls through a ring which is identical except for a gap cut into it. Which one of the statements below best describes the sequence in which the magnets reach the ground?



(A) P and R arrive together followed by Q.

(B) P and Q arrive together followed by R.

(C) P arrives first, followed by Q which is followed by R.

(D) All three magnets arrive simultaneously.

12. Which line, **A** to **D**, correctly describes the trajectory of charged particles which enter, at right angles, (a) a uniform electric field, and (b) a uniform magnetic field?

	(a) uniform electric field	**(b) uniform magnetic field**
A	circular	circular
B	circular	parabolic
C	parabolic	circular
D	parabolic	parabolic

13. In the second half of the 19th century James Maxwell wrote a series of equations that unified electricity and magnetism.

Consider the following statements about these equations.

I The equations predict the wave-particle duality of light

II The equations predict that electromagnetic waves travel at 3×10^8 ms^{-1} in a vacuum

III Radiation from black bodies is emitted in discrete packets called quanta

IV Oscillating charges produce electromagnetic radiation

Which of the above statements are correct?

(A) I, II, III and IV

(B) I and II only

(C) II and IV only

(D) II only

14. It is estimated that the Sun is producing 5.4 x 10^{25} J of energy each second by the conversion of mass to energy.

How many positron-electron annihilations would need to occur each second for an equivalent amount of energy to be produced (all mass is converted to energy in this instance).

(A) 1.6 x 10^{19}

(B) 6.0 x 10^{8}

(C) 6.6 x 10^{38}

(D) 3.3 x 10^{38}

15. As a star rotates, the observed atomic absorption bands change. Consider the statement about this relationship.

When a star is rotating away from an observer, light is *X*. When the star is rotating towards the observer, light is *Y*. The *Z* it rotates, the wider the absorption band will appear in its spectrum.

Which row of the table completes the statement?

	X	*Y*	*Z*
A	blue-shifted	red-shifted	faster
B	red-shifted	blue-shifted	faster
C	blue-shifted	red-shifted	slower
D	red-shifted	blue-shifted	slower

16. In a Young's double-slit experiment, monochromatic light is incident on two narrow slits and the resulting interference pattern is observed on a screen.

Which change **decreases** the fringe separation?

(A) decreasing the separation between the two slits

(B) increasing the distance between the slits and the screen

(C) using monochromatic light of higher frequency

(D) using monochromatic light of longer wavelength

17. The nuclear fuel, which provides the power output in a nuclear reactor, decreases in mass at a rate of 6.0×10^{-6} kg per hour. What is the maximum possible power output of the reactor?

(A) 42 kW

(B) 75 MW

(C) 150 MW

(D) 300 MW

18. A deuterium nucleus and a tritium nucleus fuse together to form a helium nucleus and a particle **X**. The equation for this process is:

$$^{2}_{1}\mathrm{H} + ^{3}_{1}\mathrm{H} \rightarrow ^{4}_{2}\mathrm{He} + \mathrm{X}$$

What is **X**?

(A) electron

(B) neutron

(C) positron

(D) proton

19. On the horizontal axis of a Hertzsprung-Russell diagram, what can be plotted instead of temperature on the horizontal axis?

(A) colour

(B) size

(C) brightness

(D) age

20. When light of a certain frequency greater than the threshold frequency of a metal is directed at the metal, photoelectrons are emitted from the surface.
The power of the light incident on the metal surface is doubled.

Which row shows the effect on the maximum kinetic energy and the number of photoelectrons emitted per second?

	Maximum kinetic energy	**Number of photoelectrons emitted per second**
A	remains unchanged	remains unchanged
B	doubles	remains unchanged
C	remains unchanged	doubles
D	doubles	doubles

END OF PART A

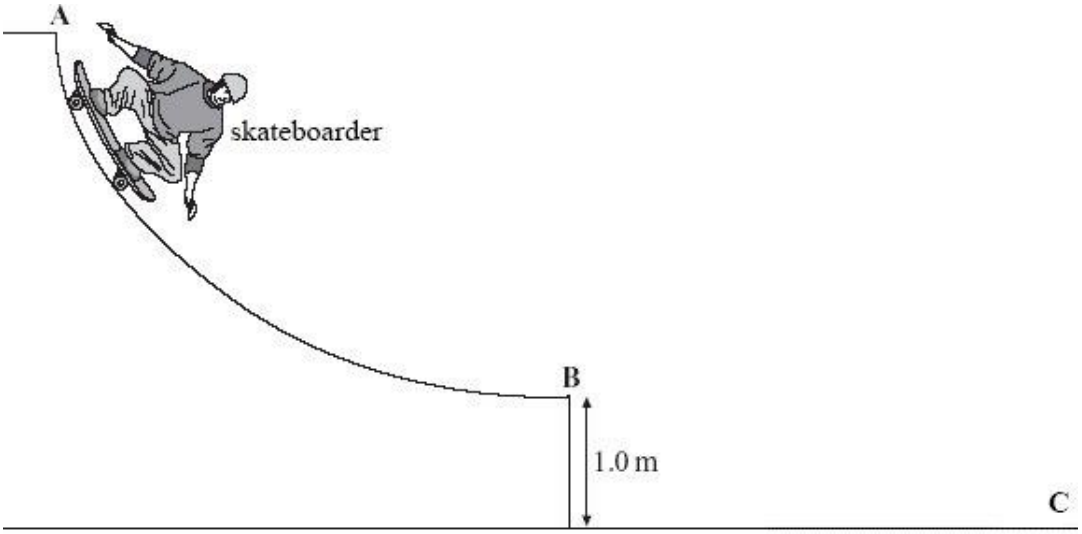
Part B – 80 marks
Attempt Questions 21-35
Allow about 2 hours and 15 minutes for this part.

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations, paying attention to significant figures and units.

Marks

Question 21 (7 marks)

The figure below shows a skateboarder descending a ramp.



The skateboarder starts from rest at the top of the ramp at **A** and leaves the ramp at **B** horizontally with a velocity *v*.

(a) In going from **A** to **B** the skateboarder's centre of gravity descends a vertical height of 1.5 m. Show that the horizontal velocity, *v*, is 5.4 m s^{-1}, stating an assumption that you make. **2**

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(b) Identify with an **X** the location *on the ramp* where the skateboarder has the highest value of acceleration. **1**

Question 21 continues on the next page ---------->

Question 21 continued:

(c) After leaving the ramp at **B** the skateboarder lands on the ground at **C** 0.42 s later.

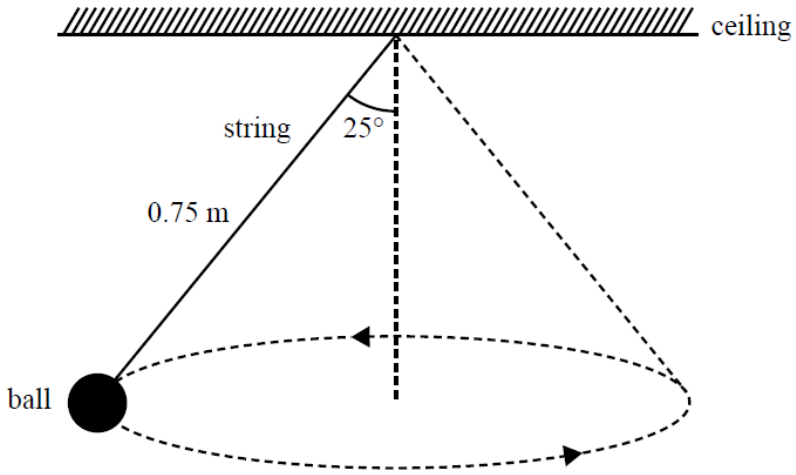
Find the horizontal distance travelled between **B** and **C**. **1**

(d) Calculate the vertical component of the velocity immediately before impact at **C**. **1**

(e) Determine the magnitude of the resultant velocity immediately before impact at **C**. **2**

Question 22 (4 marks)

The diagram below shows a small ball of mass 1.8 kg travelling in a horizontal circular path at a constant speed while suspended from the ceiling by a 0.75 m long string.



(a) Use labelled arrows the indicate the two physical forces acting on the ball **2**

(b) Calculate the speed of the ball. **2**

Question 23 (8 marks)

(a) Supertankers are large cargo ships that often transport oil. The supertankers *Europe* and *Oceania* are two of the largest man-made objects. They float with their centres 100.00 m apart and each has mass of 5.00×10^8 kg. Calculate the gravitational force between the two supertankers. **2**

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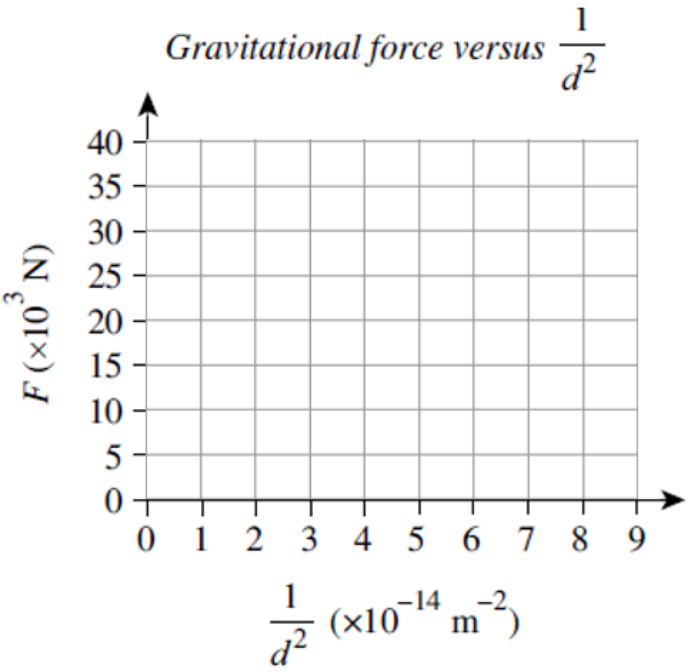
(b) The centre of a planet of mass 1.00×10^{24} kg is a distance, d, from the centre of one of its moons. The table shows the gravitational force of attraction between the planet and this moon.

$F\ (\times 10^3\ N)$	37	32	23	17	11	6
$d\ (\times 10^6\ m)$	3.43	3.70	4.34	5.06	6.32	8.45
$\frac{1}{d^2}\ (\times 10^{-14}\ m^{-2})$	8.5	7.3	5.3	3.9	2.5	1.4

Plot the graph of F and $1/d^2$ Draw the line of best fit **2**



Question 23 continues on the next page ---------->

Question 23 continued:

(c) Determine the gradient of the graph, including units.

Show all working. **2**

(d) Use the gradient of the graph to help determine the mass of the moon. **2**

Question 24 (5 marks)

A communications satellite has a mass of 250 kg. The satellite is in orbit around Earth of radius 33 500 km.

(a) Determine the gravitational potential energy of the satellite. **2**

(b) If the satellite was to move to an orbit of a higher radius, state what would happen to its:

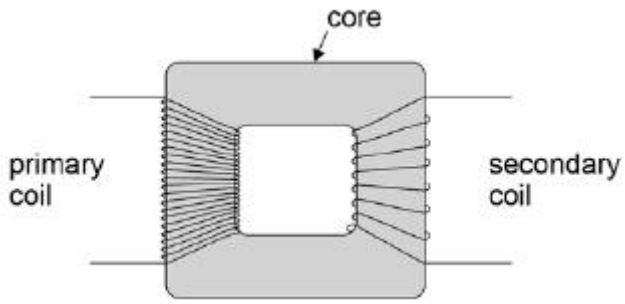
(i) kinetic energy **1**

(ii) gravitational potential energy **1**

(iii) total mechanical energy **1**

Question 25 (6 marks)

The diagram below shows a transformer with an iron core.



(a) Identify whether this is a step-up or step-down transformer. **1**

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(b) Explain a feature of the iron core that would significantly improve the efficiency of the transformer. **2**

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(c) Explain why transformers only work continuously when supplied with an alternating current. **1**

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(d) The primary coil of the transformer is connected to a 230 V AC supply. The secondary coil has 300 turns and provides an output of 20 V and a power of 65 W.

Calculate the number of turns on the primary coil. **1**

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(e) If the primary current is 0.30 A, determine the primary power. **1**

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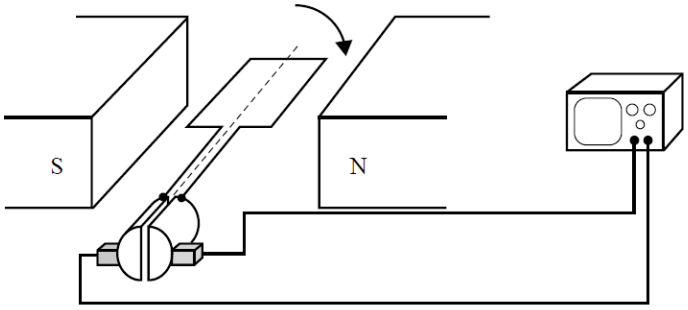
Question 26 (8 marks)

A rectangular wire loop with dimensions 0.050 m x 0.035 m is placed between two magnets that create a uniform magnetic field of strength 0.20 mT. The loop is rotated with a frequency of 50 Hz in the direction shown. The ends of the loop are connected to a split ring commutator.



(a) On the diagram, show induced current travel direction through the loop for the first quarter turn of the loop. **1**

(b) Calculate the emf induced in the loop for the first quarter turn of the loop. **3**

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(c) What is the effect of using a split ring commutator instead of slip rings in this generator? **1**

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(d) Identify the main energy change that is happening in this generator. **1**

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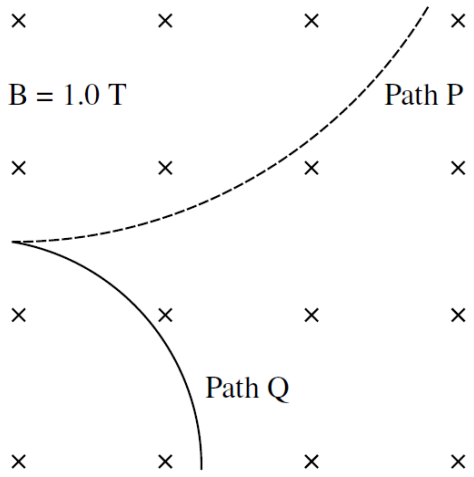
(e) On the axes below, draw the graph of the emf produced for one complete cycle of the loop. **2**

Assume that the loop starts moving from its current position. Values of emf or time not required.

Question 27 (5 marks)

This question refers to the diagram below, showing the paths of two charged particles, in a magnetic field of strength 1.0 T.



(a) Identify the sign of the charge following path P. Assume it enters the field from the left. **1**

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(b) Explain what happens to the kinetic energy of a charge that follows either path P or path Q as it moves through the field. **2**

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(c) Calculate the size of the magnetic force on a proton entering the field at 2.4×10^6 ms^{-1} **2**

(Assume the proton enters the field perpendicular to the field direction).

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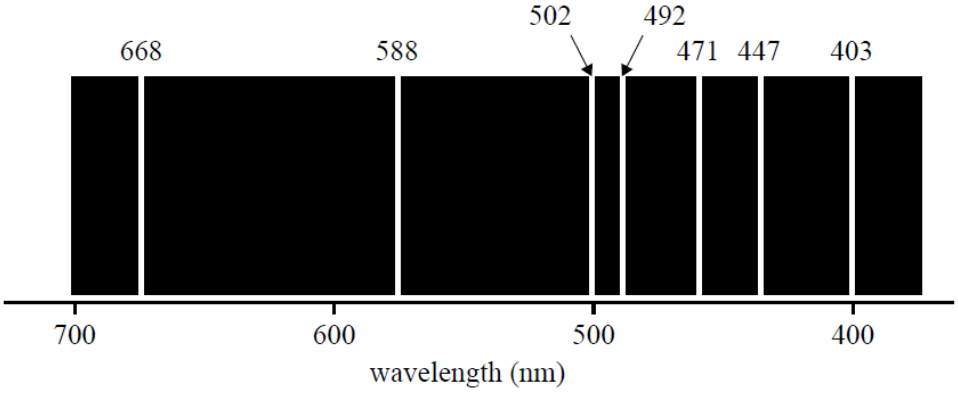
Question 28 (3 marks)

The diagram below shows the emission spectrum for helium gas.



(a) Which spectral line (in nm) indicates the photon emitted with the lowest energy? **1**

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(b) Calculate the frequency of the photon emitted at the 588 nm line. **1**

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(c) Determine the energy of the photon emitted at the 588 nm line. **1**

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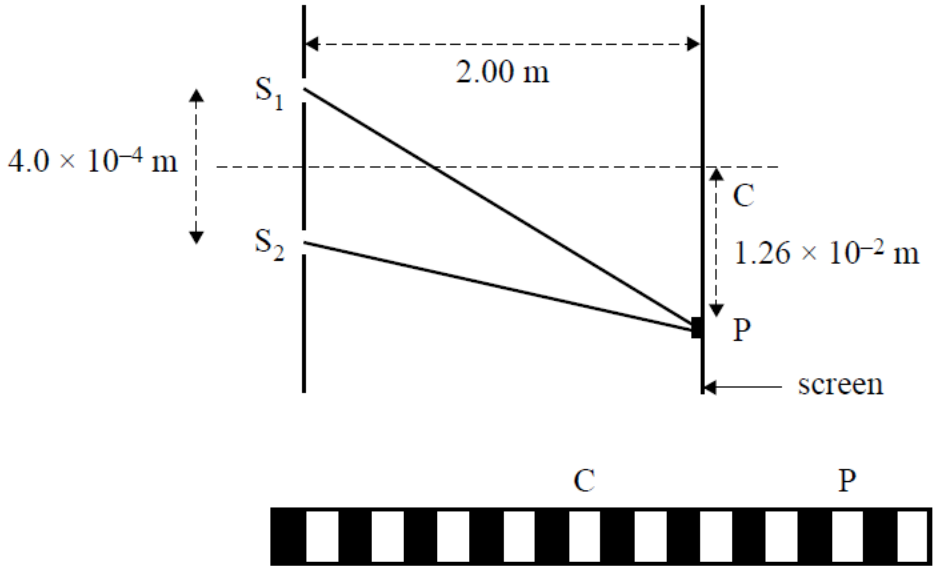
Question 29 (5 marks)

In a Young's double-slit experiment, monochromatic laser light is incident on two slits, S_1 and S_2, that are 4.0×10^{-4} m apart.

Rays from the slits meet on a screen 2.00 m from the slits to produce a pattern of bright and dark bands.

Point C is a bright spot at the centre of the pattern.



(a) State the path difference, in terms of integer multiples of wavelength, at P. **1**

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(b) Calculate the wavelength of the laser. **2**

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(c) Describe the significance of Young's experiment in the wider debate about the nature of light. **2**

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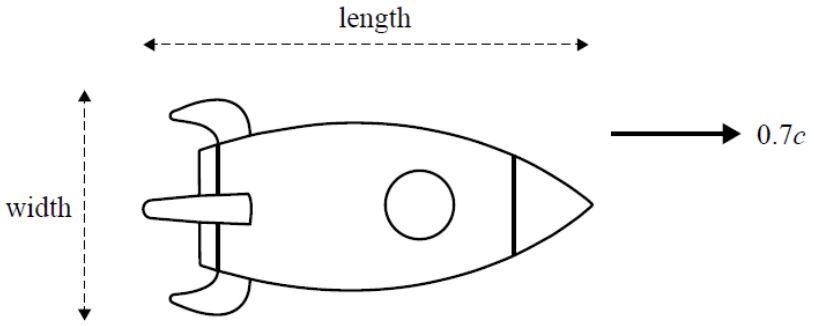
Question 30 (5 marks)

A new spaceship that can travel at 0.7 *c* has been constructed on Earth. A technician on Earth is observing the spaceship travelling past in space at 0.7 *c*, as shown below. The technician notices that the length of the spaceship does not match the measurement taken when the spaceship was stationary in a laboratory.



(a) The technician on Earth notes that the spaceship fires a laser light beam *forwards* while the spaceship is moving past. What is the speed of the laser light as seen by the technician? **1**

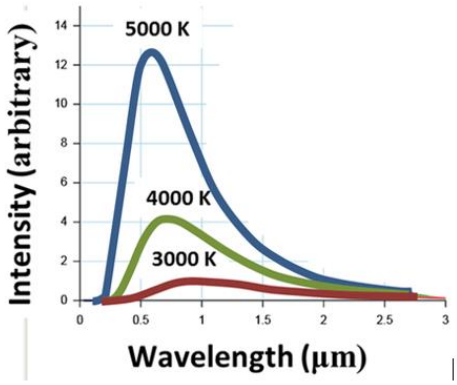
(b) If the technician measures the spaceship to be 135 m in length and 35 m in width while travelling at 0.7 *c*, what is the length and width of the spaceship when measured at rest on Earth? **3**

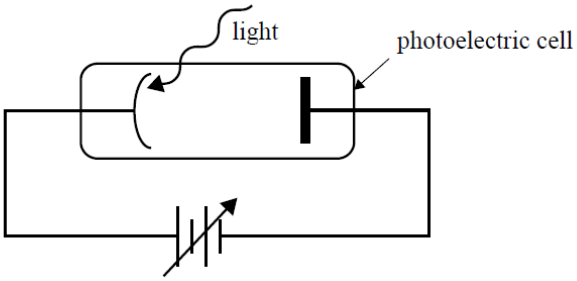
(c) Is the moving spaceship an inertial or non-inertial frame of reference? Justify your answer. **1**

Question 31 (8 marks)

At the turn of the 20th century scientific thinking about the nature of light underwent significant changes.

These changes were heavily influenced by issues scientists were having with successfully explaining black body radiation and the photoelectric effect.



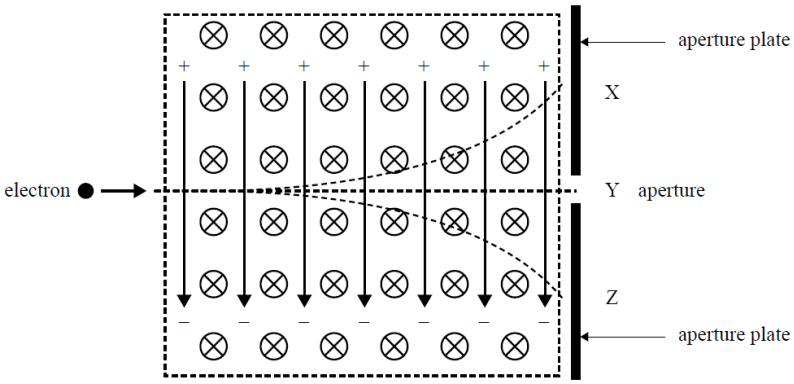


Describe the nature of black body radiation and the photoelectric effect and then analyse the problems that the prevailing model of light had with both black body radiation and the photoelectric effect, and how these problems were solved. Make reference to appropriate equations in your response.

Question 32 (4 marks)

Electron microscopes use a high-precision electron velocity selector consisting of an electric field, *E*, perpendicular to a magnetic field, *B*.

Electrons travelling at the required velocity, v_0, hit the aperture at point Y, while electrons travelling slower or faster than the required velocity, v_0 , hit the aperture plate as shown below.



(a) Show that the velocity of an electron that travels straight through the aperture to point Y is given by:

$$v_0 = \frac{E}{B}$$

1

.....

.....

.....

(b) Calculate the magnitude of the velocity, v_0 , of an electron that travels straight through the aperture to point Y if E = 500 kVm^{-1} and B = 0.25 T. **2**

.....

.....

.....

.....

(c) At which of the points, X, Y or Z would an electron travelling faster than v_0 arrive? **1**

.....

Question 33 (6 marks)

(a) In stars, helium-3 and helium-4 are formed by the fusion of hydrogen nuclei. As the temperature rises, a helium-3 nucleus and a helium-4 nucleus can fuse to produce beryllium-7 with the release of energy in the form of gamma radiation.

The table below shows the masses of these nuclei.

Nucleus	**Mass / u**
Helium-3	3.01493
Helium-4	4.00151
Beryllium-7	7.01473

Calculate the energy released, in J, when a helium-3 nucleus fuses with a helium-4 nucleus. **2**

(b) Assume that in this interaction the energy is released as a single gamma-ray photon.

Calculate the wavelength of the gamma radiation. **2**

(c) The above reaction where beryllium is formed occurs in some red giant stars before they become white dwarves. Compare the surface temperatures and luminosities of red giant stars with white dwarf stars. **2**

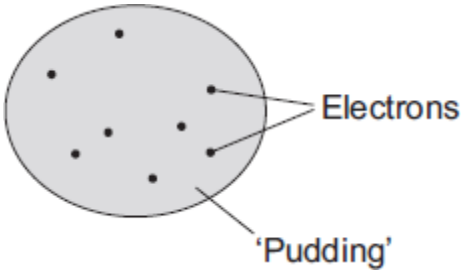
Question 34 (3 marks)

(a) The activity of a radioactive source is initially 600 counts per minute but drops to 100 after 6 hours. Determine the decay constant for this source. **2**

(b) Use your answer to (a) to help determine the half-life for this radioactive source. **1**

Question 35 (3 marks)

(a) The 'plum pudding' model of the atom was used by scientists in the early part of the 20th century to explain atomic structure.



Those scientists knew that atoms contained electrons and that the electrons had a negative charge. They also knew that an atom was electrically neutral overall. What did this allow the scientists to deduce about the 'pudding' part of the atom? **1**

.....

(b) In 1909 Rutherford (assisted by Geiger and Marsden) fired alpha particles at a very thin sheet of gold. Over a period of several months, the scientists made over 100 000 measurements. These measurements showed that while most alpha particles went through the gold foil undeflected, very few alpha particles were deflected backwards from the gold foil.

Explain how Rutherford accounted for this result. **2**

.....

.....

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.....

.....

END OF EXAMINATION

Teacher: _____

Newington College

Year 12 TRIAL HSC EXAMINATION

August, 2023 **PHYSICS**

MARKING CRITERIA

General Instructions

- Reading Time – 5 minutes
- Working Time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- A data sheet, formulae sheet and Periodic Table is provided with this paper
- NESA-approved calculators may be used
- Write your Student Number, at the top of the multiple-choice answer sheet and on the top of each page in this booklet.

Total marks – 100

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

Part B
80 marks
- Attempt **all** Questions 21–33
- Allow about 2 hours and 15 minutes for this part

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

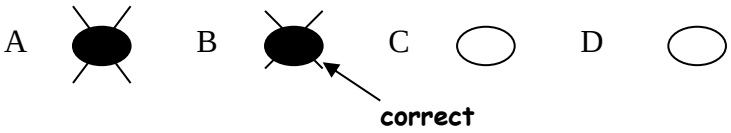
Use the multiple-choice answer sheet to record your answers.

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.



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

---

1. Projectile **A** is launched on Earth with an initial speed of 40 m s^{-1} at an angle of 30° to the horizontal.

Projectile **B** is launched with the same initial conditions on a planet where the acceleration due to gravity is exactly half that on Earth.

Projectile **B**'s path compared to projectile **A** will have:

	maximum height reached	**final speed**
(A)	equal	double
(B)	equal	equal
(C)	double	double
(D)	double	equal

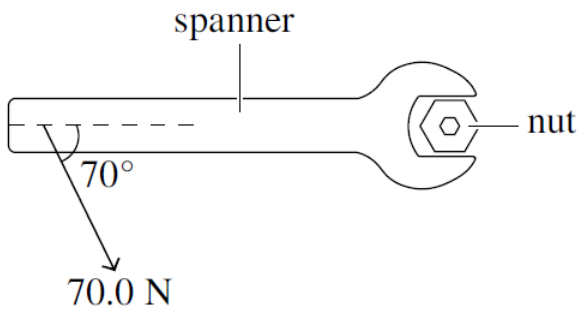
2. Two objects are launched into space from the ground so that they will just escape Earth's gravitational field forever, by being given an initial velocity.

Object **A** had a mass of 10 kg, while object **B** had a mass of 100 kg.

Which alternative is correct?

	Objects' initial speed	Objects' initial kinetic energy
(A)	equal	equal
(B)	equal	**B** is 10 times greater than **A**
(C)	equal	**B** is 100 times greater than **A**
(D)	**B** is 10 times greater than **A**	**B** is 100 times greater than **A**

3. In cycling, it is important for the nuts on bike seats to be tightened appropriately so they do not come loose during a race. Before a race, a cyclist tightens the nuts with a 50.0 cm spanner and applied a force of 70.0 N at an angle of 70^0 to the spanner, as shown in the diagram.



What magnitude of torque has the cyclist applied to the nut?

(A) 11.97 N m

(B) 32.89 N m

(C) 1197.07 N m

(D) 3289.92 N m

4. Most stars have at least one planet orbiting them. Two planets, Centaur and Tri, have been observed to orbit a star. Centaur has an orbital path with a radius that is four times smaller than the radius of Tri's orbital path.

Which of the following statements about Centaur and Tri is correct?

(A) Tri would take 8 times longer than Centaur to make a full orbit of the star

(B) Centaur would take 8 times longer than Tri to make a full orbit of the star

(C) Tri would take 64 times longer than Centaur to make a full orbit of the star

(D) Centaur would take 64 times longer than Tri to make a full orbit of the star

5. Jupiter's moon Ganymede is its largest satellite.

Ganymede has a mass of 1.5×10^{23} kg and a radius of 2.6×10^{6} m.

Which one of the following is closest to the magnitude of Ganymede's surface gravity?

(A) $0.8\ m\ s^{-2}$

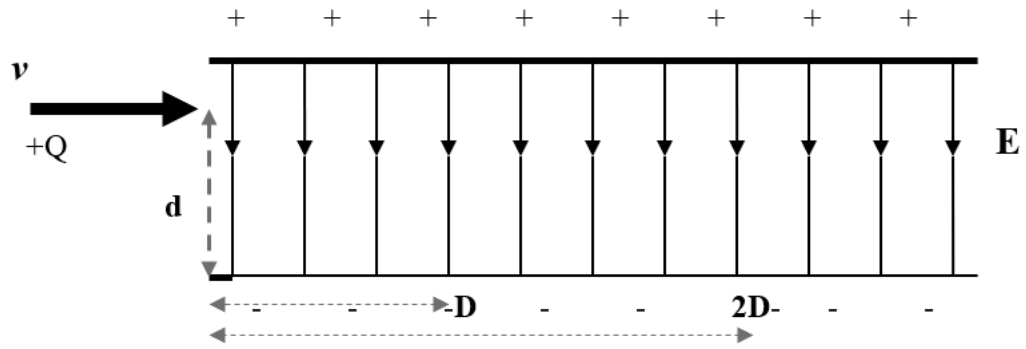
(B) $1.5\ m\ s^{-2}$

(C) $3.8\ m\ s^{-2}$

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

6. A charged particle +Q enters a region of uniform electric field E between two parallel plates, as shown. The particle's speed before entering is ***v***.

The apparatus is in a vacuum and the experiment is being performed in weightless conditions. The charged particle travels a horizontal distance **D** before striking the charged plate.



What change would result in the charged particle travelling twice the horizontal distance, i.e. **2D** ?

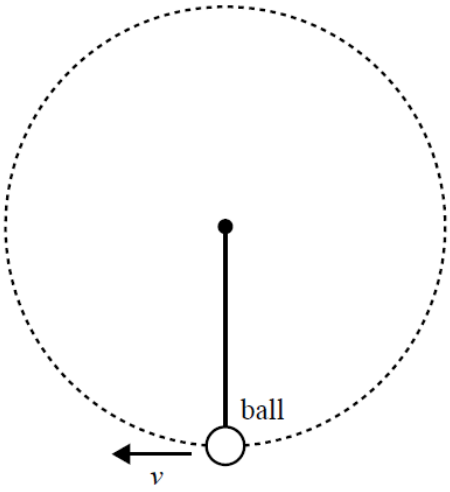
(A) doubling the initial velocity to **2*v***

(B) halving the vertical distance, **d**, the particle must move

(C) halving the electric field strength

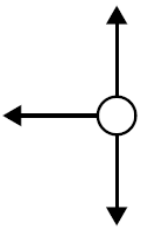
(D) halving the mass of the particle

7. A ball is attached to the end of a string a rotated in a circle at constant speed in a vertical plane, as shown in the diagram below.

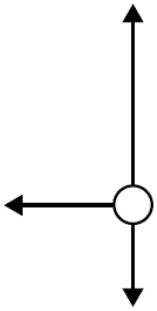


The arrows in options A. to D. below indicate the direction and the size of the forces acting on the ball.
Ignoring air resistance, which one of the following best represents the forces acting on the ball when it is at the bottom of the circular path and moving to the left?

A.



B.

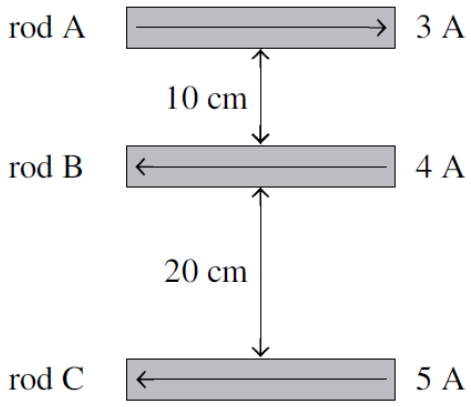


C.

D.

THE ANSWER TO QUESTION 7 IS D

8. The diagram below shows an arrangement that uses three metal rods (A, B and C), each carrying a current in the direction indicated by the arrows.



What is the magnitude and direction of the force per unit length on rod C?

(A) 1×10^{-5} N m^{-1} down

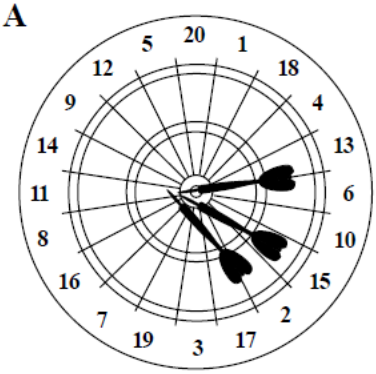
(B) 1×10^{-5} N m^{-1} up

(C) 3×10^{-5} N m^{-1} up

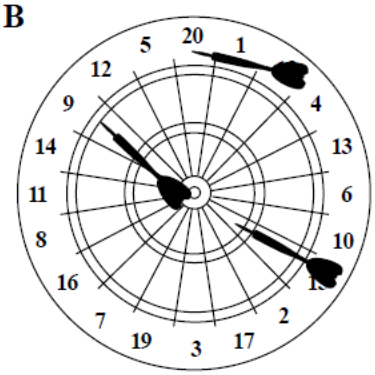
(D) 3×10^{-5} N m^{-1} down

9. The aim of the game of darts is to hit the bullseye at the centre of the dartboard. Four darts players (A, B, C and D) each threw three darts. The results of their throws are shown below.

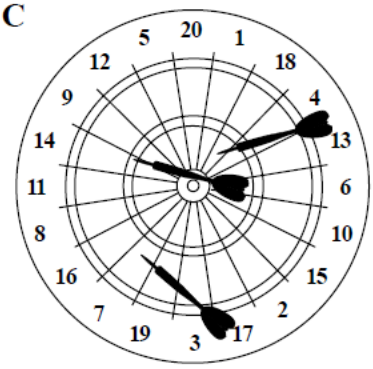
Player A



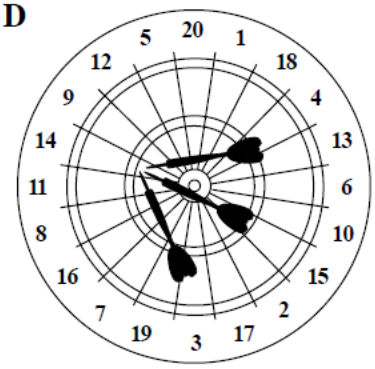
Player B



Player C



Player D



Which one of the players produced a set of attempts that could be described as being precise but inaccurate?

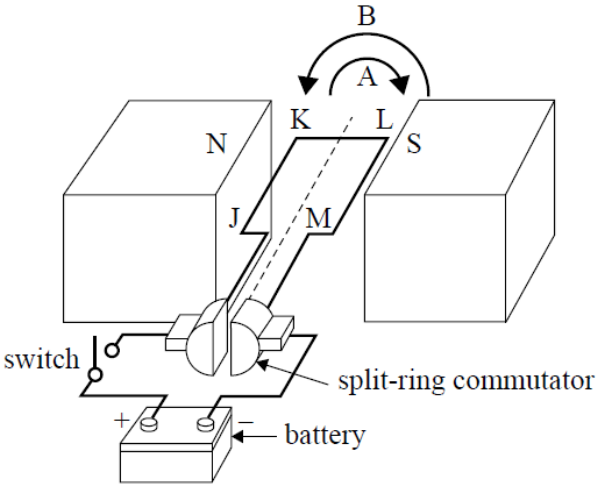
(A) Player A

(B) Player B

(C) Player C

(D) Player D

10. The diagram below shows a small DC electric motor, powered by a battery that is connected via a split-ring commutator. The rectangular coil has sides KJ and LM. The magnetic field between the poles of the magnet is uniform and constant.



The switch is now closed allowing current to flow, and the coil is stationary and in the position shown in the diagram.

Which one of the following statements best describes the motion of the coil when the switch is closed?

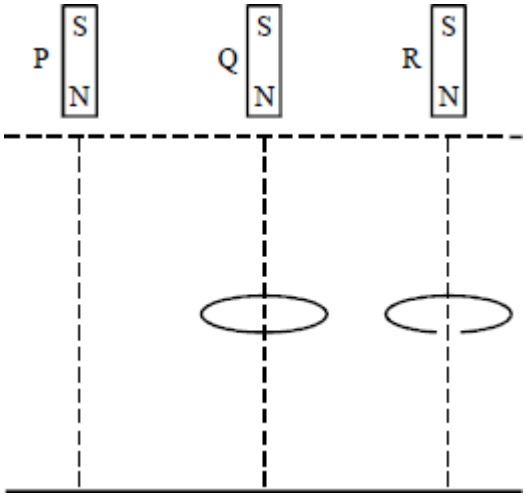
(A) The coil will remain stationary

(B) The coil will rotate in direction A, as shown in the diagram

(C) The coil will rotate in direction B, as shown in the diagram.

(D) The coil will oscillate regularly between directions A and B, as shown in the diagram.

11. Three identical magnets P, Q and R are released simultaneously from rest and fall to the ground from the same height. P falls directly to the ground, Q falls through the centre of a thick conducting ring and R falls through a ring which is identical except for a gap cut into it. Which one of the statements below best describes the sequence in which the magnets reach the ground?



(A) P and R arrive together followed by Q.

(B) P and Q arrive together followed by R.

(C) P arrives first, followed by Q which is followed by R.

(D) All three magnets arrive simultaneously.

12. Which line, **A** to **D**, correctly describes the trajectory of charged particles which enter, at right angles, (a) a uniform electric field, and (b) a uniform magnetic field?

	(a) uniform electric field	**(b) uniform magnetic field**
A	circular	circular
B	circular	parabolic
C	parabolic	circular
D	parabolic	parabolic

13. In the second half of the 19th century James Maxwell wrote a series of equations that unified electricity and magnetism.

Consider the following statements about these equations.

I The equations predict the wave-particle duality of light

II The equations predict that electromagnetic waves travel at 3×10^8 ms^{-1} in a vacuum

III Radiation from black bodies is emitted in discrete packets called quanta

IV Oscillating charges produce electromagnetic radiation

Which of the above statements are correct?

(A) I, II, III and IV

(B) I and II only

(C) II and IV only

(D) II only

14. It is estimated that the Sun is producing 5.4 x 10^{25} J of energy each second by the conversion of mass to energy.

How many positron-electron annihilations would need to occur each second for an equivalent amount of energy to be produced? (all mass is converted to energy in this instance).

(A) 1.6 x 10^{19}

(B) 6.0 x 10^{8}

(C) 6.6 x 10^{38}

(D) 3.3 x 10^{38}

15. As a star rotates, the observed atomic absorption bands change. Consider the statement about this relationship.

When a star is rotating away from an observer, light is <u>*X*</u> . When the star is rotating towards the observer, light is <u>*Y*</u> . The <u>*Z*</u> it rotates, the wider the absorption band will appear in its spectrum.

Which row of the table completes the statement?

	X	*Y*	*Z*
A	blue-shifted	red-shifted	faster
B	red-shifted	blue-shifted	faster
C	blue-shifted	red-shifted	slower
D	red-shifted	blue-shifted	slower

16. In a Young's double-slit experiment, monochromatic light is incident on two narrow slits and the resulting interference pattern is observed on a screen.

Which change **decreases** the fringe separation?

(A) decreasing the separation between the two slits

(B) increasing the distance between the slits and the screen

(C) using monochromatic light of higher frequency

(D) using monochromatic light of longer wavelength

17. The nuclear fuel, which provides the power output in a nuclear reactor, decreases in mass at a rate of 6.0×10^{-6} kg per hour. What is the maximum possible power output of the reactor?

(A) 42 kW

(B) 75 MW

(C) 150 MW

(D) 300 MW

18. A deuterium nucleus and a tritium nucleus fuse together to form a helium nucleus and a particle **X**. The equation for this process is:

$$^{2}_{1}\mathrm{H} + ^{3}_{1}\mathrm{H} \rightarrow ^{4}_{2}\mathrm{He} + \mathrm{X}$$

What is **X**?

(A) electron

(B) neutron

(C) positron

(D) proton

19. On the horizontal axis of a Hertzsprung-Russell diagram, what can be plotted instead of temperature on the horizontal axis?

(A) colour

(B) size

(C) brightness

(D) age

20. When light of a certain frequency greater than the threshold frequency of a metal is directed at the metal, photoelectrons are emitted from the surface.
The power of the light incident on the metal surface is doubled.

Which row shows the effect on the maximum kinetic energy and the number of photoelectrons emitted per second?

	Maximum kinetic energy	**Number of photoelectrons emitted per second**
A	remains unchanged	remains unchanged
B	doubles	remains unchanged
C	remains unchanged	doubles
D	doubles	doubles

END OF PART A

Part B – 80 marks
Attempt Questions 21-33
Allow about 2 hours and 15 minutes for this part.

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations, paying attention to significant figures and units.

Marks

Question 21 (6 marks)

(a) (use of ½ $mv^2 = mgh$ gives) ½ $v_h^2 = 9.81 \times 1.5$
$v_h = 5.42 = 5.4$ ms^{-1} **(1)**

(In questions like this, candidates should show an unrounded answer before rounding to the value given I the question).

The key assumption: energy converted to thermal energy (due to working against friction is negligible / no energy losses in converting GPE to KE

OR

Also allowed: assumption that g = 9.81 if SUVAT equations used **(1)**

(b) **X** is drawn at the top of the ramp. (1)

(c) distance = v_x t = 0.42 × 5.4) = 2.3m **(1)**

(d) $v_v = 9.8 \times 0.42$ **(1)**
= 4.1(l) m s^{-1} **(1)**

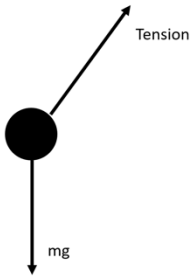
Note: students should use the data provided t = 0.42s. However if they used other information available in the question (using $v^2 = u^2 + 2as$) the answer v=4.4ms^{-1} was allowed

(e) Use Pythagoras theorem.

$v^2 = 4.1^2 + 5.4^2$ **(1)**
$v = 6.78 = 6.8$ m s^{-1} **(1)** (7.0ms^{-1} allowed if (d) was 4.4ms^{-1})

22.

(a)

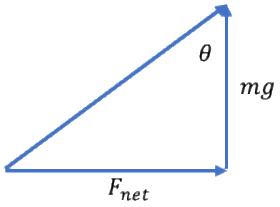


1 mark for two correct arrows
1 mark for labels correct

There are only two physical forces acting on the ball.

Some students wrongly identified the centripetal force as one of the physical forces, in addition to tension and weight, rather than being the result of the applying the tension force at an angle.

(b)



$$F_{net} = mg\ tan\theta = \frac{mv^2}{r}$$

$$\therefore 9.8 \times tan25 = \frac{v^2}{0.75\ \times sin25}$$

$$4.6 = \frac{v^2}{0.32}$$

$$v = \sqrt{4.6 \times 0.32}$$

$$v = 1.2\ m\ s^{-1}$$

1 mark for correct substitution into final correct formula

1 mark for correct answer for speed.

There were other approaches that were also acceptable.

(Students are encouraged to draw the triangle involved to help them identify the components they require)

(One global mark awarded for candidates who recognize the *mv^2 / r relationship*)

23.

(a) $m_1 = m_2 = 5.0 \times 10^8$ kg

$R = 100$ m

$G = 6.67 \times 10^{-11}$ Nm^2 kg^{-2}

$$F = \frac{Gm_1m_2}{r^2}$$

$$= \frac{6.67 \times 10^{-11} \times 5 \times 10^8 \times 5 \times 10^8}{100^2}$$

$$= 1668 \text{ N}$$

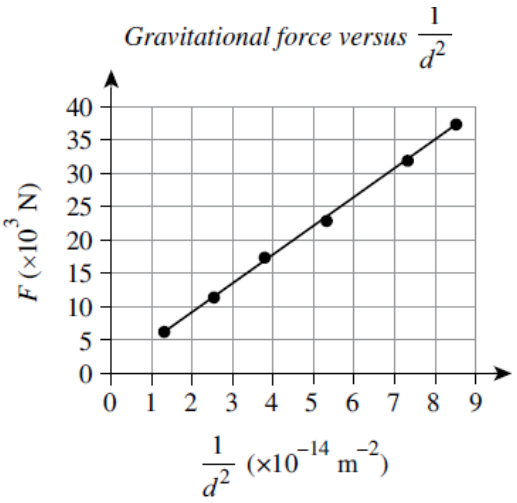
- Identifies the appropriate data and formulae to use.

AND

- Calculates the force of attraction 2

- Any ONE of the above points 1

(b)



Points correctly plotted (1 mark)

Line of best fit correctly drawn (1 mark)

Continues next page ----------→

(c) Let gradient be *k*.

$$k = \frac{(37-6)\times 10^{3}}{(8.5-1.4)\times 10^{-14}}$$

$$= \frac{31\times 10^{3}}{7.1\times 10^{-17}}$$

$= 4.366 \text{ x } 10^{17} \text{ N m}^{2}$

Note: one-point gradient formula was accepted only if the l.b.f. was <u>clearly</u> through 0,0 exactly.

Points chosen from LOBF over a wide range = 1 mark

Correct gradient value ***<u>with units</u>*** found = 1 mark

(d) Gradient, $K = G\,M\,m$ (1 mark)

$$4.366\times 10^{17}\ \text{Nm}^2 = 6.67\times 10^{-11}\ \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2}\times 1.00\times 10^{24}\ \text{kg}\times \text{mass of moon}$$

$$\text{mass of moon} = \frac{4.366\times 10^{17}}{6.67\times 10^{-11}\times 1.00\times 10^{24}}$$

$$= 6546\ \text{kg}$$

(correct final answer = 1 mark)

24.

(a)

$$U = -\frac{GMm}{r}$$
$$= \frac{-6.67\times10^{-11}\times6.0\times10^{24}\times250}{3.35\times10^{7}}$$
$$= -2.99\times10^{9}\ \text{J}$$

1 mark = correct substitution

1 mark = correct final answer

(award maximum of one mark if km not converted to metres)

(b) (i) KE decreases

(ii) GPE increases

(iii) Total mechanical energy increases

25.

(a) step-down transformer (1)

(b) laminate the core (1)

This reduces energy (thermal energy losses) due to eddy currents (1)

(c) We need to have a *changing* magnetic flux (changing magnetic field) (1)

(d) $N_P = N_S V_P / V_S = 300 \times 230 / 20 = 3450 = 3500$ (2 sf) turns (1)

(e) P = I V = 0.30 x 230 = 69 *W* (1)

26.

(a) as seen from above, the direction is ANTICLOCKWISE (see diagram…current appears like it is coming out of the page).

(b)

$$\varepsilon = -N\frac{\Delta\phi}{\Delta t}$$

$$\varepsilon = -1 \times \frac{0.2 \times 10^{-3} \times 0.050 \times 0.035}{0.005}$$

$$\varepsilon = 7 \times 10^{-5}\ V$$

Correct value for time found (50 Hz = period of 0.02 s. One quarter turn = 0.02/4 = 0.005 s) =1 mark
Correct substitution into equation (including converting mT to T) = 1 mark
Correct value for emf = 1 mark
(ignore wrong units)
The most common errors were forgetting to convert the mT to T or incorrectly calculating the period.

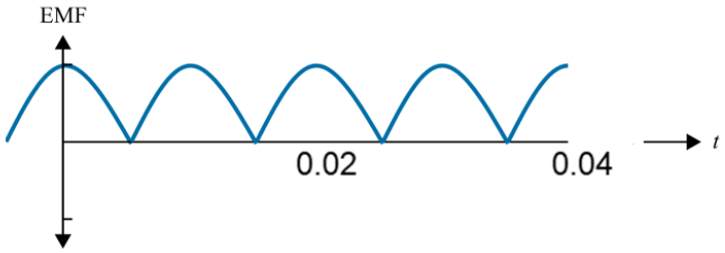
(c) The split ring commutator ensures that direct current is produced, instead of AC. (1)

(d) Kinetic energy ----------> electrical energy (need both of these statements) (1)

(e)

1 mark = correct general shape (ie: no negative values of emf)

1 mark = emf starts at a maximum value



27.

(a) Path P is positive (1 mark)s

(b) Kinetic energy is reduced (1 mark)

The particle is accelerating from the centripetal force (even if magnitude of velocity is unchanged), therefore emits EMR which reduces KE (1 mark)

Note: accelerating particles emitting EMR, hence losing energy, is a difficult concept and relates to the Bohr model (Ch 15). In these 'particle in a field' questions this loss of energy is usually negligible, but not always (see 2017 exam, Q30). So:

(1) global mark is awarded if students state that KE is 'unchanged'

and

(1) global mark is awarded if they support that response with a clear understanding of UCM.

(c) $F = q\ v\ B$

$F = 1.6 \times 10^{-19} \times 2.4 \times 10^{6} \times 1.0$ (1 mark for correct substitution)

$F = 3.84 \times 10^{-13}$ N (1 mark correct answer)

28.

(a) The lowest energy has the longest wavelength; 668 nm (1)

(b)

$$f = \frac{c}{\lambda} = \frac{3.0 \times 10^{8}}{588 \times 10^{-9}}$$

$$f = 5.1 \times 10^{14}\ Hz$$ (1 mark)

(c) E = h f

E = 6.63 x 10^{-34} x 5.1 x 10^{14}

E = 3.38 x 10^{-19} J (1 mark)

29.

(a) four wavelengths (4λ) (1 mark)

(b)

$$\Delta x = \frac{\lambda L}{d}$$

Where $\Delta x = \frac{1.26 \times 10^{-2}}{4} = 3.15 \times 10^{-3}$

$$3.15 \times 10^{-3} = \frac{\lambda \times 2.00}{4.0 \times 10^{-4}}$$

$\lambda = 630\ nm$ (2 marks. Award one mark if a single error made).

The most common error was to use 1.26 x 10^{-2} m as the actual delta *x* value rather than divide it by four first.

(c) This was considered that light was a wave (not a particle) (1)

Only waves can perform interference (or diffraction through the slits) (1)

30.

(a) The laser light will be observed to be travelling at *c* (the speed of light, 3 x 10^8 ms^{-1}). (1)

(b) The length will be contracted.

The first step was to calculate gamma from the relative velocity provided.

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\gamma = \frac{1}{\sqrt{1 - 0.7^2}}$$

$$\gamma = 1.4$$

If the spaceship is moving in the technician's frame of reference, then they will observe contracted length. The proper length, L_0, is found:

$$L = \frac{L_0}{\gamma}$$

$$135 = \frac{L_0}{1.4}$$

$$L_0 = 189 \text{ m}$$

Correct substitution of data = 1 mark

Correct final answer = 1 mark

The <u>width is unchanged, and remains at 35 m</u>. (1 mark)

(c) It is an inertial frame of reference, as it is <u>moving at constant velocity (it is not accelerating).</u> (1)

31.

Points to cover in a successful response:

The **prevailing** model of light initially thought as being a (electromagnetic) wave and *then* being viewed as *also* a particle (ie: quantized) to needs to be **explicitly mentioned** as being the result of both photoelectric effect and black body radiation curves being correctly explained **(2 marks)**

Blackbody radiation:

Fully define and describe black body radiation **(1)**

Issue/Problem: **(1)**ie: ultraviolet catastrophe (not enough to simply state this); where at UV peak emission the prevailing wave theory predicted runaway (infinite) emission of radiation, violating energy conservation laws.

Solution:

Planck's model of energy emitted in discrete amounts (not continuous) with E = h f referenced AND explained in full (**1**)

(Total of three marks available for describing black body radiation and its solution. There were some *global* marks awarded where individual aspects of the explanation may have fallen short of what was expected)

Photoelectric effect:

Define photoelectric effect (**1** mark)

Issues/problems:

(Need one or more issues/problems described); (**1** mark)

Intensity of incident unrelated to stopping voltage and/or kinetic energy of the electrons

Or

The effect was instantaneous or not at all (ie: energy did not slowly accumulate before electrons released as the wave model predicted).

Or

Below a threshold frequency there was no emission, regardless of intensity (the wave model assumed that merely making a given frequency brighter would result in higher kinetic energy of the electrons)

Continued next page:…….

Question 31 continued:

Photoelectric solution:

Solution explained with reference to the identified issue (**1** mark)

Eg:

Einstein's equation cited *an*d explained with reference to the given problem previously identified.

OR

Link explicitly made to need for energy of incident light to be higher than work function, with appropriate algebra being referenced and explained.

(Total of three marks available for describing photoelectric effect and its solution. There were some *global* marks awarded where individual aspects of the explanation may have fallen short of what was expected)

Students are advised to spend a few minutes planning their responses for questions of this nature. This can ensure that your answer flows correctly and links the correct issues.

Also, be careful not to contradict yourself at any point in your answer, or offer wrong explanations or irrelevant equations; as this cannot be overlooked.

32.

(a) The correct approach is to equate the force due to the electric field to the force due to the magnetic field, thus:

$Eq = Bqv_0$

$v_0 = \frac{E_q}{B_q}$

$v_0 = \frac{E}{B}$

(1 mark)

(b)

$v_0 = \frac{E}{B}$

$v_0 = \frac{500 \times 10^3}{0.25}$

$v_0 = 2.0 \times 10^6\ m\ s^{-1}$

The most common error was to not convert the voltage from kV to V. Students at this level are expected to be able to convert between SI prefixes.

(First mark awarded for correct substitution, award 2 marks for correct answer; but award only one mark if incorrect metric conversion or some other minor error).

(c) **Z** (1 mark)

Explanation: The force due to the electric field will remain unchanged as it is independent of velocity. The force due to the magnetic field will increase as it is dependent on velocity. This will result in an unbalanced force down the page towards Z.

(explanation not required to be awarded the mark).

33.

(a) Mass change in amu= 1.71×10^{-3} (1)

$1.71 \times 10^{-3} \times 931.5 = 1.59$ MeV

Multiply x $1.6 \times 10^{-13} = 2.5 \times 10^{-13}$ J (1)

or Converts their mass defect to kg = 2.84×10^{-30} (kg)

Substitution in $E = mc^2$

2.55×10^{-13} (J) to 2.6×10^{-13} (J)

NOTE: $E = m c^2$ uses SI units. Be careful about substituting the correct mass value into this equation.

(b) Use of $E=hc / \lambda$ (1 mark)

7.7×10^{-13} (m) to 7.8×10^{-13} (m) (1 mark)

(c) Red giant stars have lower surface temperatures than white dwarf stars (1)

Red giant stars have higher luminosities than white dwarf stars (1)

Examiner comment: This question was generally well-answered.

34.

(a)

$$N_t = N_0 e^{-\lambda t}$$

$$100 = 600 e^{-6\lambda}$$

$$\frac{100}{600} = e^{-6\lambda}$$

$$\ln\left(\frac{100}{600}\right) = -6\lambda$$

$$\Rightarrow \lambda = \frac{\ln\left(\frac{100}{600}\right)}{-6}$$

$= 0.299\ h^{-1}$

Correct substitution = 1 mark

Correct final answer = 1 mark

Note: the count rate (activity) is a measure of the amount of atoms in the sample; as when there are fewer atoms the count rate will decrease (this is a feature of exponential decay).

It was not necessary to convert to SI units for this question.

(b)

And hence the half-life can be found using $t_{\frac{1}{2}} = \frac{0.6931}{\lambda}$

$$= \frac{0.6931}{0.299}$$

$$= 2.32 \text{ hours}$$

1 mark for correct answer

35.

(a) The ‘pudding’ is positively charged (1)

(b) The atom is mainly empty space (1)

The nucleus contains **most of the mass** (ie: has a very high density, due to the mass mainly being located in that small volume) ***and*** **is positively charged** (1)

(hence the repulsion by the positively charged alpha particles).

Examiner note: Most students obtained at least one mark, but many students did not offer the full explanation necessary to be awarded full marks.