Student Number _____

Caringbah High School
Year 12 Physics
Trial Exam 2024

Write all your answers in this answer booklet.

Use pen for written responses and pencil for diagrams and graphs.

Total Marks: 100

Task Length: 3 hours + 5 minutes reading time

PART A: Multiple Choice Questions (20 marks)

PART B: Longer Response Questions (80 marks)

OUTCOME	*MARK*
Knowledge and Understanding	*/ 78*
Working Scientifically *Q3, Q6, Q7, Q9, Q12, Q15, Q19,* *Q27, Q29a, Q34 & Q34*	*/ 22*
Total	*/ 100*

PART A: Answer the multiple choice questions HERE. Circle the letter of the BEST answer.

Do NOT detach this page from the rest of the task.

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

PART A: Circle the letter of the BEST answer on the grid (20 marks)

1. Which of the following scientists is credited with the mathematical unification of electricity and magnetism?

A. Newton
B. Planck
C. Wien
D. Maxwell

2. Which of the following is a standard assumption when analysing the motion of projectiles?

A. Zero air resistance
B. A non-uniform vertical acceleration
C. Mass is infinite
D. The path of the projectile is an ellipse

3. The force of gravity between two objects is *F*. What happens to the force of gravity between both objects if the distance between the objects is doubled?

A. $F/2$
B. $2F$
C. $F/4$
D. $F/8$

4. Which of the following variables need to be aligned for a satellite to be in geostationary orbit around a planet?

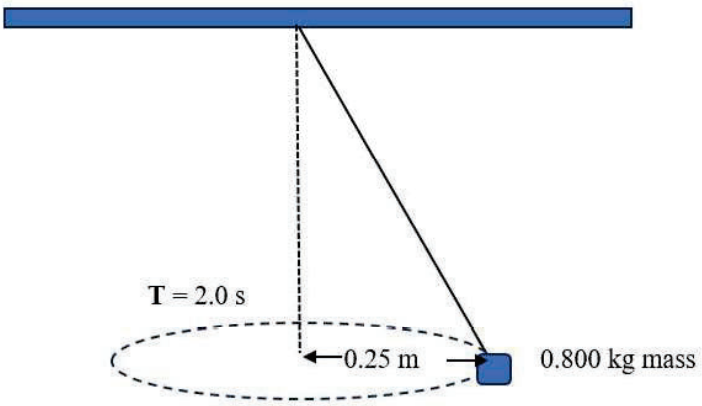
A. The orbital velocity of both the satellite and the planet are equal.
B. The period of one revolution of the satellite is equal to the time taken for one spin of the planet on its axis.
C. The period of the planet and the satellite are equal.
D. The mass of the planet and the satellite must be equal.

5. A person with a viral infection has their body temperature rise from 37 ^{o}C (310 K) to 40 ^{o}C. What is the change in the peak wavelength of electromagnetic radiation emitted?

A. Increase by 8.96×10^{-8} m
B. Decrease by 8.96×10^{-8} m
C. Increase by 9.66×10^{-4} m
D. Decrease by 9.66×10^{-4} m

6. A 0.800 kg mass is swinging in a horizontal circle on the end of a conical pendulum as shown.

The radius of the circle *r* is 0.25 m and the period *T* is 2.0 s.



What is the kinetic energy of the mass?

A. 0.79 J

B. 0.25 J

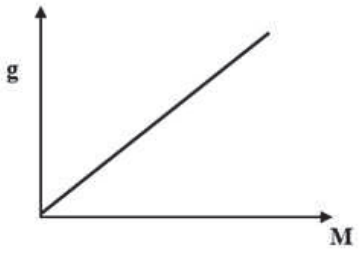
C. 0.50 J

D. 0.25 J

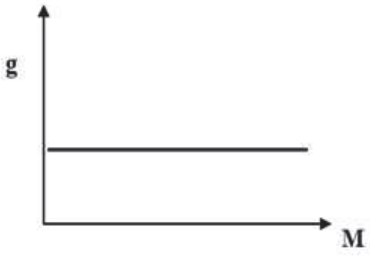
7. Several planets with identical size but different masses had their surface gravitational acceleration *g* plotted against their masses *M*.

Which alternative best represents this graph?

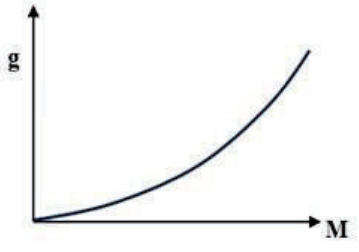
A.



B.



C.



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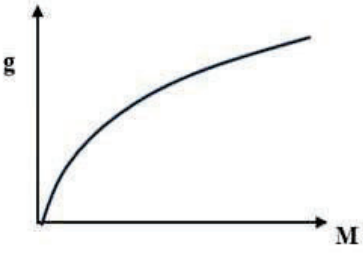


8. How does back EMF affect the operation of an electric motor?

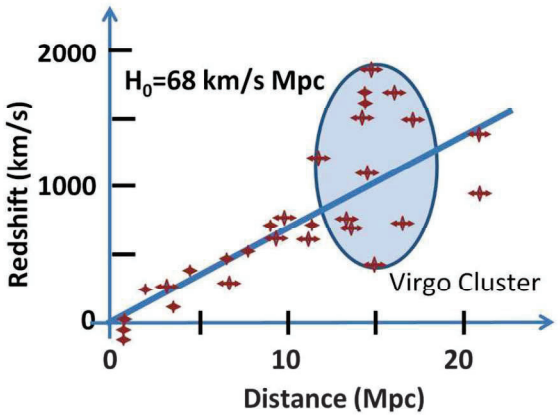
A. It prevents the motor from starting.

B. It increases the power output of the motor.

C. It increases the current drawn from the power source.

D. It reduces the current drawn from the power source when the motor speeds up.

9. The following graph plots data for a number of galaxies.



Which of the following is true about the trend shown in this graph?

A. It is linear because all galaxies are receding at the same rate.

B. It provides evidence for the 'Big Bang'.

C. It shows that the expansion of the universe is slowing.

D. It proves that every galaxy is redshifted.

10. The role of a commutator in a DC motor is to:

A. provide the axis of rotation.

B. close the circuit.

C. change the direction of current relative to the coil.

D. keep the current flowing in the same direction relative to the coil.

11. Calculate the wavelength of a tennis ball of mass 59.4g travelling at 170 $km.h^{-1}$.

A. 6.56×10^{-38}m

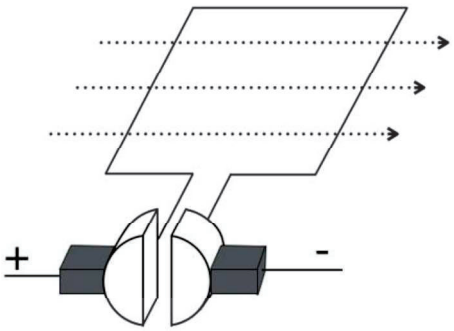
B. 2.36×10^{-37}m

C. 6.56×10^{-35}m

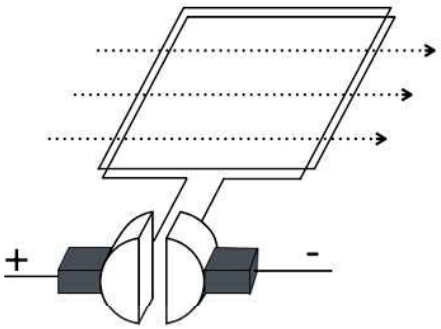
D. 2.36×10^{-34}m

12. Which of the following scenarios shown will produce the greatest torque on the coil?

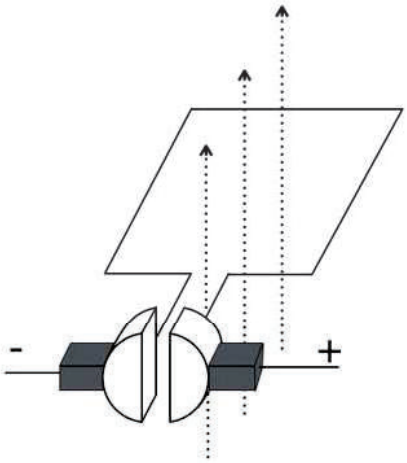
A.



B.



C.



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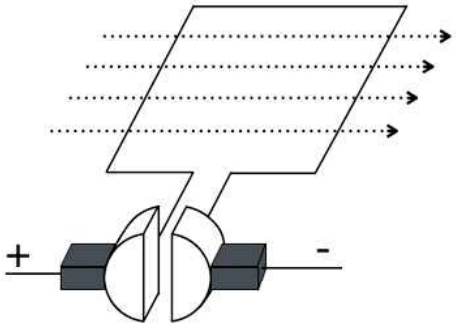


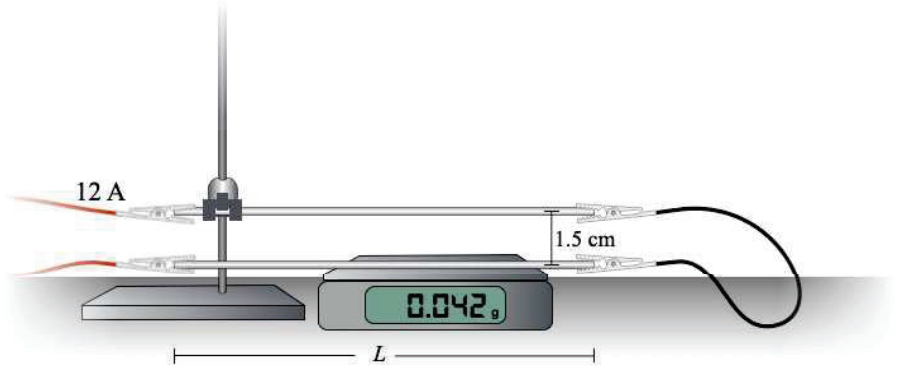
13. Which of the following is an observation from the Hafele-Keating experiment that supports Einstein's theory of special relativity?

A. Clocks flown westward (in the opposite direction to Earth's rotation) were slowed the most.
B. Clocks flown eastward (in the same direction as Earth's rotation) were slowed the most.
C. Clocks flown eastward and westward were equally slowed.
D. Clocks flown eastward and westward were not slowed.

14. A Ferris wheel car covers an arc distance of 62.8 meters in 2 minutes. If the radius of the Ferris wheel is 10 meters, what is the angular velocity in degrees per second?

A. $0.90^\circ\ s^{-1}$
B. $1.80^\circ\ s^{-1}$
C. $3.00^\circ\ s^{-1}$
D. $6.00^\circ\ s^{-1}$

15. The apparatus shown below was setup to measure the force between two current carrying conductors. Before the current was turned on, the scale was zeroed.



Determine the length of the two current carrying conductors shown in the image above.

A. 2.1×10^{2} m

B. 2.1 m

C. 2.1×10^{-1} m

D. 2.1×10^{-2} m

16. A car of mass 1200 kg is driving in a horizontal circular track of radius 50 m with a constant speed of 20 m s^{-1}. If the coefficient of friction between the car's tyres and the track is 0.1, what is the work done by friction over one complete revolution?

A. 0 J

B. 75 360 J

C. 150 720 J

D. 226 080 J

17. If the value of Planck's constant *h* was higher than it is, the effect on a photoelectric effect experiment would be:

A. the threshold frequency would be lower for all metals.

B. the energy of incident photons would be less.

C. the threshold frequency would be greater for all metals.

D. the photoelectric current would be greater.

18. How long does it take to emit one million photons from a 10 mW laser with frequency 4.5×10^{14} Hz?

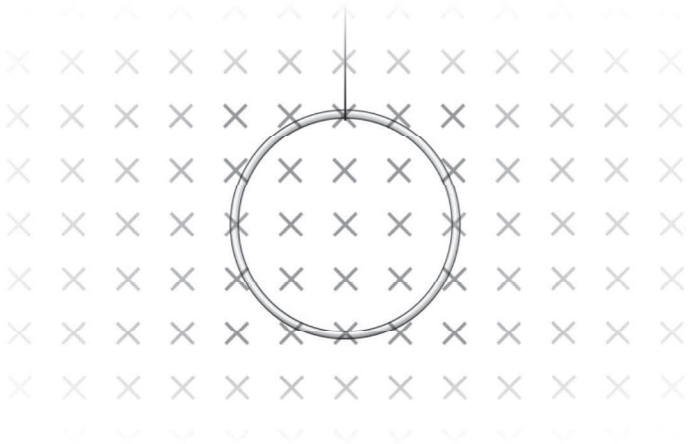
A. 3.0×10^{-11} s

B. 3.0×10^{-23} s

C. 3.4×10^{22} s

D. 3.4×10^{10} s

19. A ring is hung by a fishing line so that is sits within a magnetic field as shown below.



Determine the change in flux when the ring spins from its position by 120˚.

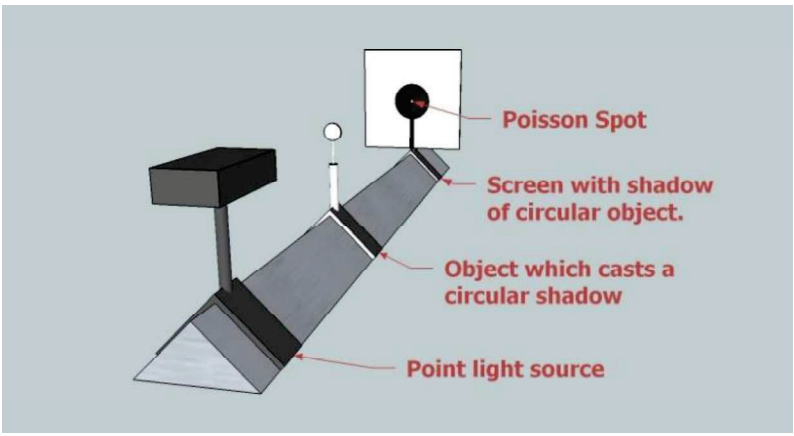
A. -3/2 *BA*

B. -1/2 *BA*

C. 1/2 *BA*

D. 2/3 *BA*

20. The following experimental set-up can be used to produce a 'Poisson Spot'; a bright spot that can be seen in the centre of a circular object's shadow.



Which of the following would increase the size of the Poisson Spot?

A. Moving the light source closer to the circular object

B. Moving the circular object closer to the screen

C. Increasing the wavelength of the light source

D. Increasing the diameter of the circular object

PART B: Longer Answers (80 marks)

21. A current carrying conductor of length 1.5 m is placed in a uniform magnetic field of strength 0.5 T. **2**

Determine the magnitude of magnetic force experienced by the current carrying conductor if the current through the conductor is 0.6 A and the current flows perpendicular to the magnetic field.

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22. Describe how spectra provides information about TWO features of stars. **3**

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23. Following a lesson on Special Relativity, a student made the following statement: **3**

"The surface of the Earth is not an inertial frame of reference"

Assess the validity of this statement.

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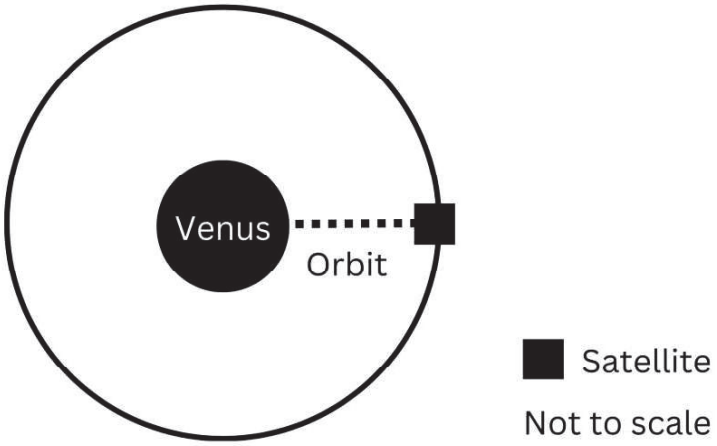
24. On May 4, 1989, the objective of the Magellan mission to Venus was to place a satellite in orbit to image the entire surface of the planet.



Mass of Venus = 4.867×10^{24} kg

Mass of satellite = 3445 kg

Orbital radius = 6.346×10^{6} m

a. Determine the orbital period of the satellite around Venus. Assume a circular orbit. **2**

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b. How much additional work would need to be done for the satellite to escape the planet Venus? Use relevant equations and calculations to support your answer. **3**

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25. A space organisation is planning to send an astronaut to a distant planet *P*. The spacecraft will travel at a speed of 0.8*c* and the journey is expected to take 15 years, as measured by observers on Earth. The spacecraft and astronaut have a combined mass of 1500 kg.

a. Calculate the distance to *P*, as measured by observers on Earth. **2**

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b. Determine how many years will have passed on the spaceship's clock when observed by Earth. **2**

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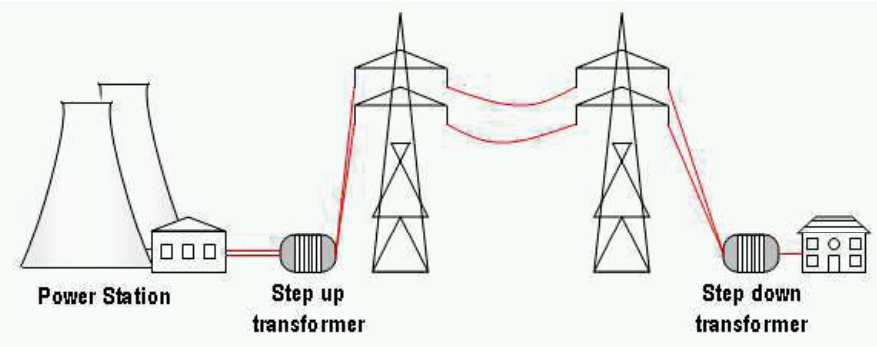
26. The diagram below shows a simplified power distribution network. **3**



Explain why transformers are used in the distribution of energy.

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27. Before an experiment to find the half-life of a radioactive isotope, a nuclear scientist switched on her radiation counter in the lab for five 60 second intervals and recorded the following results:

Radiation Recorded (counts/min)
1123
1126
1128
1127
1121

The scientist then placed a sample of radioactive isotope *X* near the counter and measured the counts per minute each second Monday for 14 weeks. Counting the first week as week 0, her results are shown in the table below.

Time (weeks)	Total Radiation Recorded (counts/min)
0	11125
2	7725
4	5525
6	4125
8	3125
10	2425
12	2075
14	1625

a. Create a graph to show the relationship between time and the radiation of *X*. **4**

b. Use your graph to show that the half-life of *X* is approximately 3.4 weeks. **1**

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c. Calculate the decay constant. **2**

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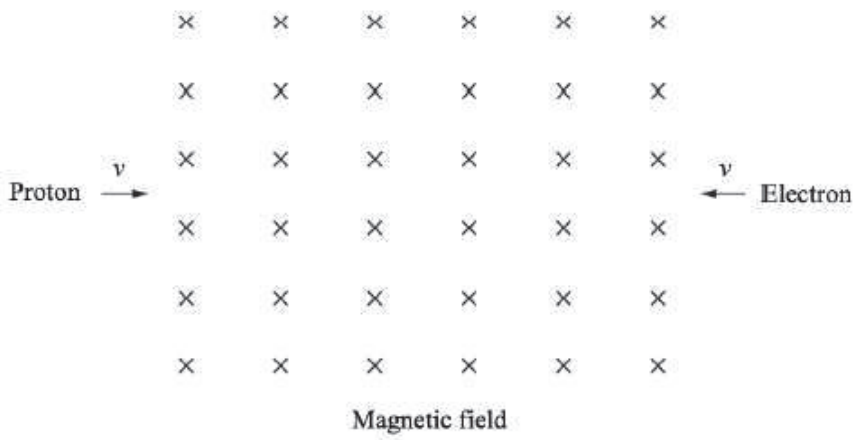
28. A uniform magnetic field of strength 0.5 T is directed into the page. An electron and proton are both fired simultaneously into the magnetic field at 1×10^4 m s^{-1}. **4**

Assume the particles do not interact with each other.



Describe the paths that the particles will follow through the magnetic field.

Support your answer with relevant calculations.

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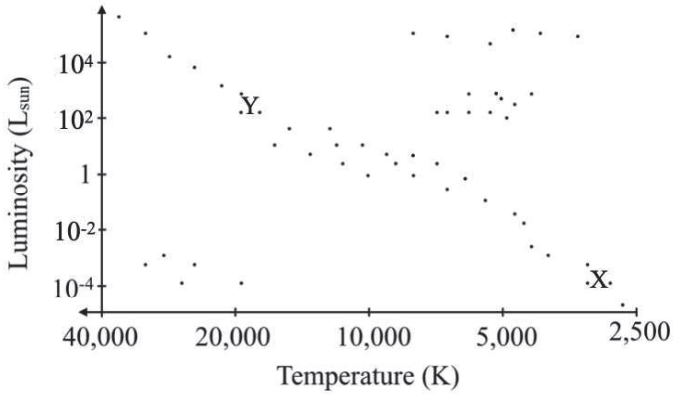
29. Below shows a Hertzsprung-Russell diagram with two labelled stars, *X* and *Y*.



The reaction that produces energy in Star *X* can be summarised as:

$$4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{-1}e$$

Nucleus	Mass (amu)
${}^{4}_{2}He$	4.002603
${}^{1}_{1}H$	1.007825
${}^{0}_{-1}e$	0.000549

a. Calculate the energy released from this reaction. **2**

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b. Using the HR diagram above, draw the pathway that Star *X* will take on its life cycle. **1**

c. Compare the energy production in Star *Y* to Star *X*. **2**

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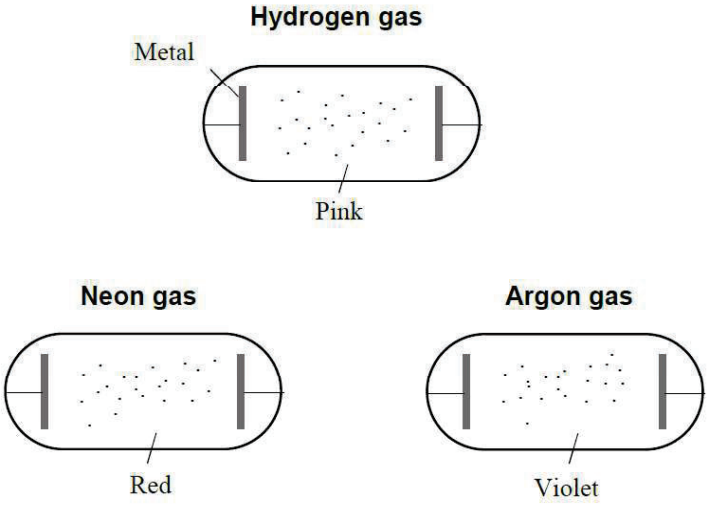
30. A student performed an experiment to investigate the light emitted from discharge tubes containing various gases.

The student's observations are shown.



a. Explain why the gases emit different colours inside the discharge tubes. **3**

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The spectra of light from the discharge tubes are examined through a spectroscope.

b. How will the spectra differ from those produced by an incandescent filament? **2**

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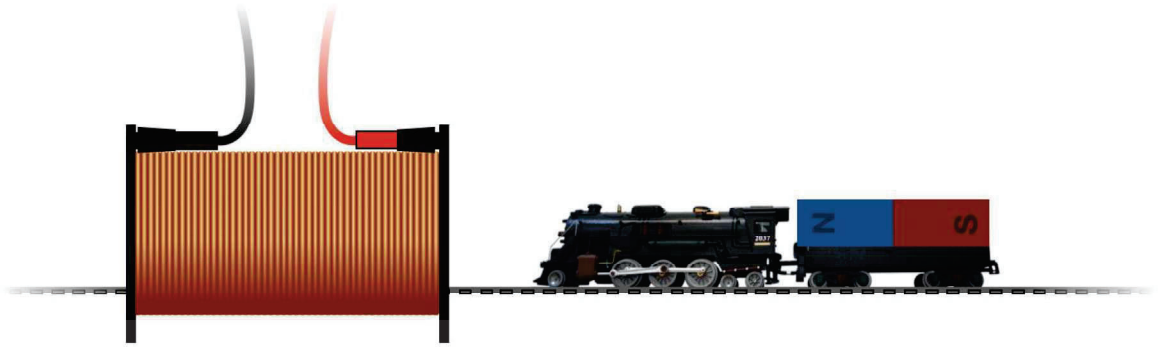
31. A physics student, who is also a model train enthusiast, is combining their two interests to undertake a study in electromagnetic induction. They rig up one of their trains with a strong bar magnet on its load carriage and have its track pass through a solenoid. The solenoid is attached to a galvanometer to measure the induced current. **4**



They notice that the train exits the solenoid tunnel with a lower speed than when it entered and does not begin to accelerate to a normal operating speed for a small distance after exiting.

Explain their observations.

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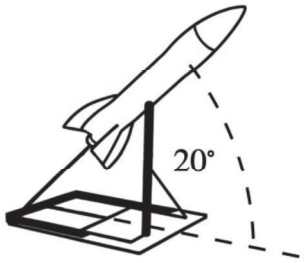
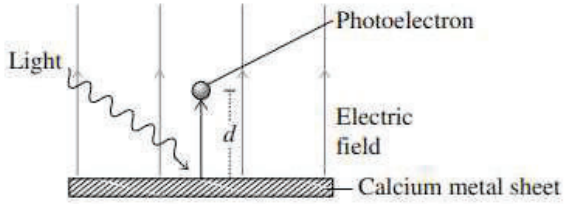
32. A model rocket, initially on the ground, was launched at an angle of 20.0˚ from the horizontal. After a 2.50 s motor burn, the model had a velocity of 82.0 m s^{-1} and then followed projectile motion for the remainder of its flight. **5**



Determine the horizontal range of the rocket after landing. Assume its initial trajectory did not change during its motor burn.

33. Light of a particular frequency is incident on a calcium metal sheet and photoelectrons are emitted. The metal is in a uniform electric field, perpendicular to the surface of the metal, as shown. **3**



Explain the behaviour of this photoelectron with reference to the law of conservation of energy.

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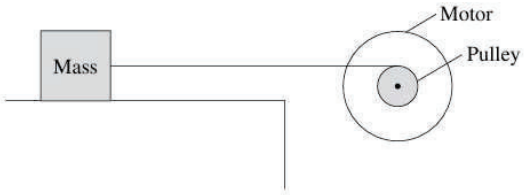
34. A rope connects a mass on a horizontal surface to a pulley attached to an electric motor as shown. **3**



Assuming the mass is moving at a constant velocity, show that the velocity of the mass as it moves along the horizontal surface is given by $v = \frac{VI}{\mu_k F_N}$.

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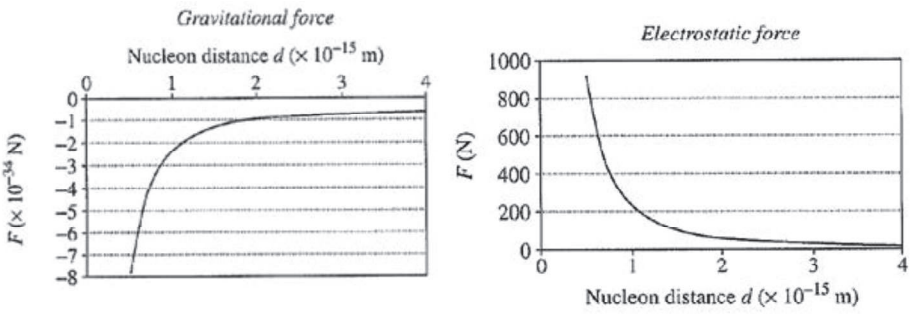
35. The two graphs below show the gravitational and electrostatic forces acting between two protons in the nucleus of an atom. **3**



Analyse the graphs and account for the stability of the nucleus.

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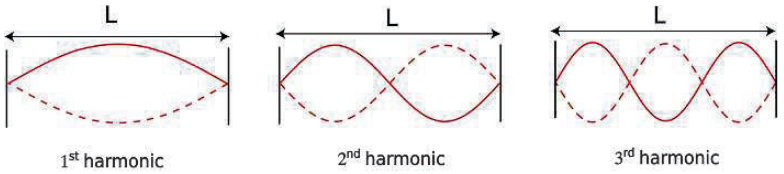
36. Below is a diagram showing the harmonics of standing waves for a string with 2 fixed ends. **3**



Explain how the concept of standing wave harmonics can be used to improve Bohr's model of the atom.

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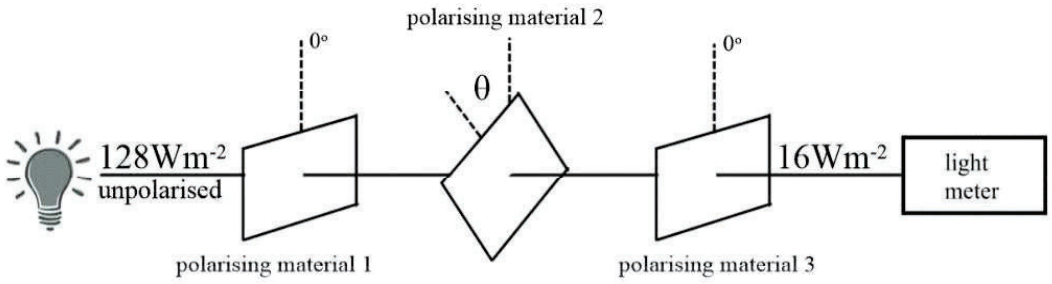
37. Unpolarised light of intensity 128 W m^{-2} passes through three polarising filters. The polarising axes of first and third filters are at 0°. **4**



If the intensity of the light passing out of the third filter is 16 W m^{-2}, calculate the angle with which the polarising material 2 is rotated.

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38. Explain why the total energy of a satellite orbiting the Earth is always negative. **3**

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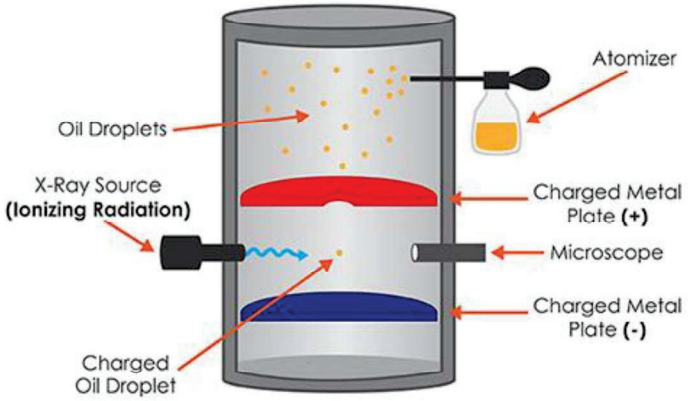
39. In a version of Millikan's oil-drop experiment, a charged oil droplet with mass 3.6×10^{-14} kg falls with an acceleration of 1.256 m s^{-2} while the electric field is turned on. The potential difference across the electric field is 6.0×10^{4} V and the distance of plate separation is 25 cm. **5**

Assume drag force is negligible.



Calculate the number of electrons within the charged oil droplet.

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40. Consider the following statement: **6**

"Einstein's equation $E = mc^2$ has revolutionized science leading to significant advancements in both theoretical physics and practical applications in society."

Justify this statement.

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End of paper.

90Student Number _____

MARKING CRITERIA

Caringbah High School
Year 12 Physics
Trial Exam 2024

Write all your answers in this answer booklet.

Use pen for written responses and pencil for diagrams and graphs.

Total Marks: 100

Task Length: 3 hours + 5 minutes reading time

PART A: Multiple Choice Questions (20 marks)

PART B: Longer Response Questions (80 marks)

OUTCOME	*MARK*
Knowledge and Understanding	*/ 78*
Working Scientifically *Q3, Q6, Q7, Q9, Q12, Q15, Q19,* *Q27, Q29a, Q34 & Q35*	*/ 22*
Total	*/ 100*

PART A: Answer the multiple choice questions HERE. Circle the letter of the BEST answer.

Do NOT detach this page from the rest of the task.

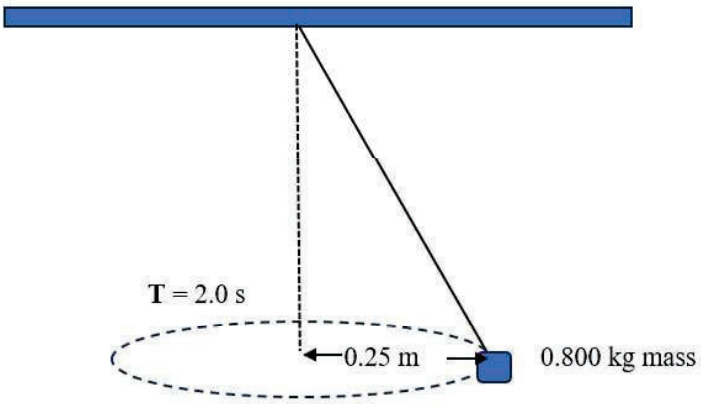
1	A B C **D**	11	A B C **D**
2	**A** B C D	12	A **B** C D
3	A B **C** D	13	A **B** C D
4	A **B** C D	14	A B **C** D
5	A **B** C D	15	A B **C** D
6	A **B** C **D**	16	**A** B C D
7	**A** B C D	17	A B C **D**
8	A B C **D**	18	**A** B C D
9	A **B** C D	19	**A** B C D
10	A B **C** D	20	A B **C** D

PART A: Circle the letter of the BEST answer on the grid (20 marks)

1.	*Which of the following scientists is credited with the mathematical unification of electricity and magnetism?* *A. Newton* *B. Planck* *C. Wien* *D. Maxwell*	
2.	*Which of the following is a standard assumption when analysing the motion of projectiles?* *A. Zero air resistance* *B. A non-uniform vertical acceleration* *C. Mass is infinite* *D. The path of the projectile is an ellipse*	
3.	*The force of gravity between two objects is F. What happens to the force of gravity between both objects if the distance between the objects is doubled?* *A. F/2* *B. 2F* *C. F/4* *D. F/8*	
4.	*Which of the following variables need to be aligned for a satellite to be in geostationary orbit around a planet?* *A. The orbital velocity of both the satellite and the planet are equal.* *B. The period of one revolution of the satellite is equal to the time taken for one spin of the planet on its axis.* *C. The period of the planet and the satellite is equal.* *D. The mass of the planet and the satellite must be equal.*	
5.	*A person with a viral infection has their body temperature rise from 37 ^{o}C (310 K) to 40 ^{o}C. What is the change in the peak wavelength of electromagnetic radiation emitted?* *A. Increase by 8.96 ×10 $^{-8}$ m* *B. Decrease by 8.96 ×10 $^{-8}$ m* *C. Increase by 9.66 ×10 $^{-4}$ m* *D. Decrease by 9.66 ×10 $^{-4}$ m*	

6. An 0.800 kg mass is swinging in a horizontal circle on the end of a conical pendulum as shown.

The radius of the circle **r** is 0.25 m and the period **T** is 2.0 s.



What is the kinetic energy of the mass?

A. *0.79 J*

B. *0.25 J*

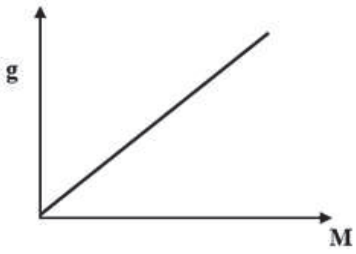
C. *0.50 J*

D. *0.25 J*

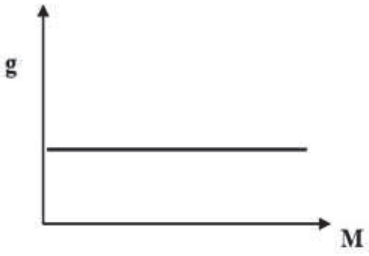
7. *Several planets with identical size but different masses had their surface gravitational acceleration, g, plotted against their masses, M.*

Which alternative best represents this graph?

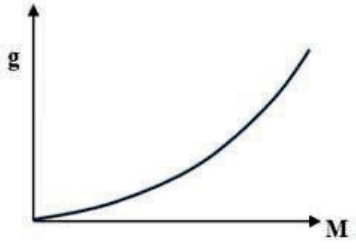
A.



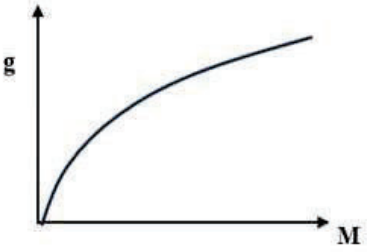
B.



C.



D.



8. *How does back EMF affect the operation of an electric motor?*

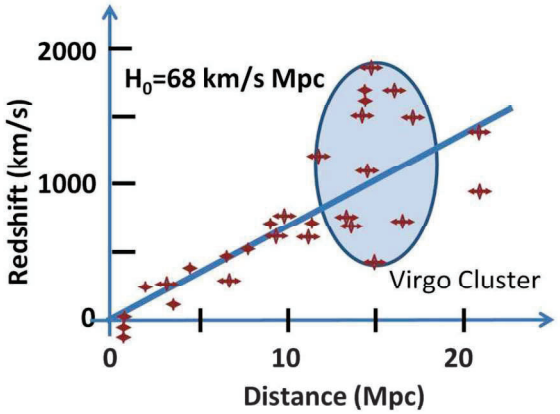
A. It prevents the motor from starting.

B. It increases the power output of the motor.

C. It increases the current drawn from the power source.

D. It reduces the current drawn from the power source when the motor speeds up.

9. *The following graph plots data for a number of galaxies.*



Which of the following is true about the trend shown in this graph?

A. It is linear because all galaxies are receding at the same rate.

B. It provides evidence for the 'Big Bang'.

C. It shows that the expansion of the universe is slowing.

D. It proves that every galaxy is redshifted.

10. *The role of a commutator in a DC motor is to:*

A. provide the axis of rotation.

B. close the circuit.

C. change the direction of current relative to the coil.

D. keep the current flowing in the same direction relative to the coil.

11. *Calculate the wavelength of a tennis ball of mass 59.4g travelling at 170 km.h^{-1}.*

A. 6.56×10^{-38}m

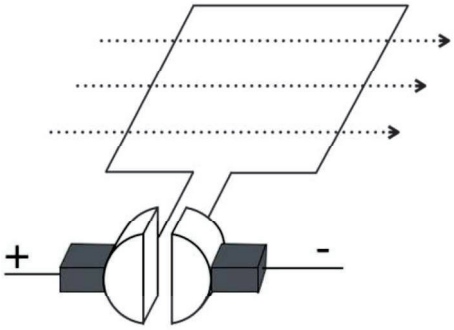
B. 2.36×10^{-37}m

C. 6.56×10^{-35}m

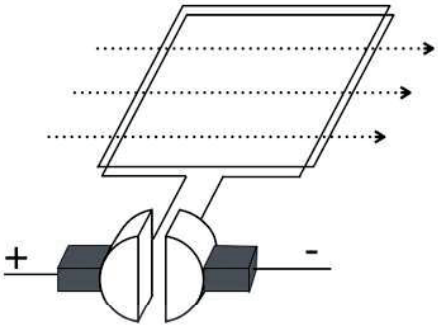
D. 2.36×10^{-34}m

12. *Which of the following scenarios shown will produce the greatest torque on the coil?*

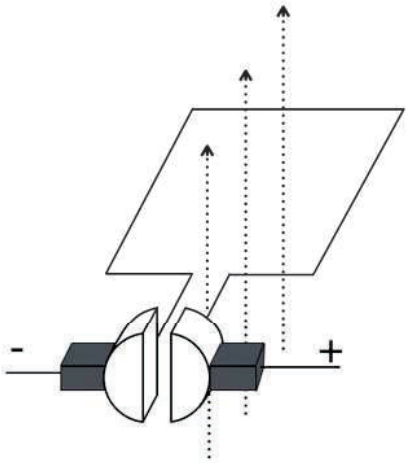
A.



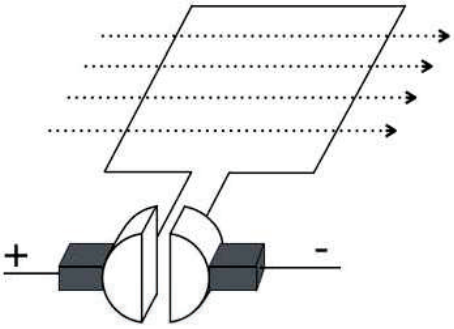
B.



C.



D.



13. *Which of the following is an observation from the Hafele-Keating experiment that supports Einstein's theory of special relativity?*

A. Clocks flown westward (in the opposite direction to Earth's rotation) were slowed the most.

B. Clocks flown eastward (in the same direction as Earth's rotation) were slowed the most.

C. Clocks flown eastward and westward were equally slowed.

D. Clocks flown eastward and westward were not slowed.

14. *A Ferris wheel car covers an arc distance of 62.8 meters in 2 minutes. If the radius of the Ferris wheel is 10 meters, what is the angular velocity in degrees per second?*

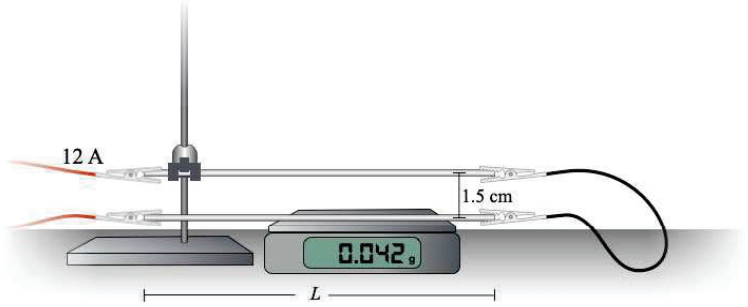
A. $0.90^\circ s^{-1}$

B. $1.80^\circ s^{-1}$

C. $3.00^\circ s^{-1}$

D. $6.00^\circ s^{-1}$

15. *The apparatus shown below was setup to measure the force between two current carrying conductors. Before the current was turned on, the scale was zeroed.*



Determine the length of the two current carrying conductors shown in the image above.

A. 2.1×10^{2} m 2

B. 2.1 m 2

C. 2.1×10^{-1} m 2

D. 2.1×10^{-2} m 2

16. *A car of mass 1200 kg is driving in a horizontal circular track of radius 50 meters with a constant speed of 20 m s^{-1}. If the coefficient of friction between the car's tires and the track is 0.1, what is the work done by friction over one complete revolution?*

A. *0 J*

B. *75 360 J*

C. *150 720 J*

D. *226 080 J*

17. *If the value of Planck's constant, h, was higher than it is, the effect on a photoelectric effect experiment would be:*

A. *the photoelectric current would be greater.*

B. *the energy of incident photons would be less.*

C. *the threshold frequency would be greater for all metals.*

D. *the threshold frequency would be lower for all metals.*

18. *How long does it take to emit one million photons from a 10 mW laser with frequency 4.5 $\times 10^{14}$ Hz?*

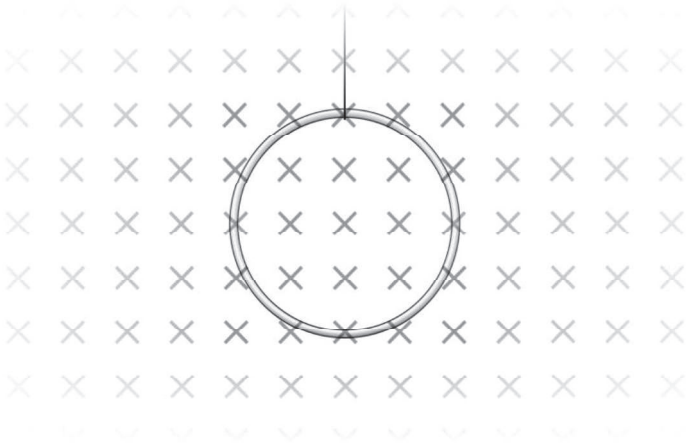
A. *3.0×10^{-11} s*

B. *3.0×10^{-23} s*

C. *3.4×10^{22} s*

D. *3.4×10^{10} s*

19. *A ring is hung by a fishing line so that is sits within a magnetic field as shown below.*



Determine the change in flux when the ring spins from its position by 120˚.

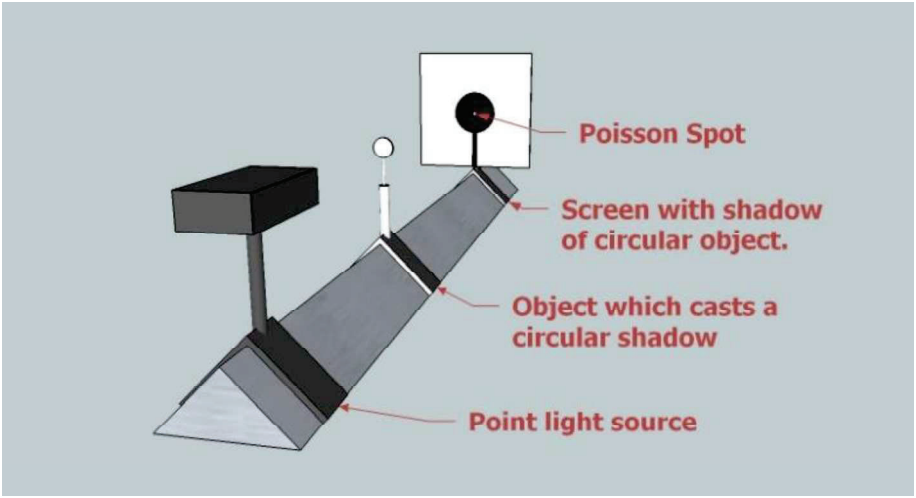
A. *-3/2 B×A*

B. *-1/2 B×A*

C. *1/2 B×A*

D. *2/3 B×A*

20. *The following experimental set-up can be used to produce a 'Poisson Spot'; a bright spot that can be seen in the centre of a circular object's shadow.*



Which of the following would increase the size of the Poisson Spot?

A. *Moving the light source closer to the circular object*

B. *Moving the circular object closer to the screen*

C. *Increasing the wavelength of the light source*

D. *Increasing the diameter of the circular object*

PART B: Longer Answers (80 marks)

21. A current carrying conductor of length 1.5 m is placed a uniform magnetic field of strength 0.5 T. **2**

Determine the magnitude of magnetic force experienced by the current carrying conductor if the current through the conductor is 0.6 A and the current flows perpendicular to the magnetic field.

2 marks: correct answer 0.45N

1 mark: relevant formula F = BIL

22. Describe how spectra provides information about TWO features of stars. **3**

Criteria	Marks
• Relates observations to features of stars	3
• Relates an observation to a feature of a star	2
• Identifies an observation or other feature of a star	1

Absorption spectra can reveal information about the density of a star. Darker, broader spectral lines indicate significant levels of absorption associated with denser stars, whereas fainter, narrower spectral lines are associated with less dense stars. The frequency of lines in absorption spectra can reveal information about the motion of a star. A shift towards lower frequencies indicates that the star is moving away from the observer.

Answers may include: Red and blue shifts from the edges of a star's light disc which can provide information about its rotational velocity. Binary/multiple star systems. Chemical composition and surface temperature…

Students need to revise the terms absorption and emission spectra. We must analyse absorption spectra (and the dark bands within it) from stars as emission spectra would only show a continuous spectrum. Many students incorrectly said we analyse the emission spectra of stars and did not discuss absorption spectra.

23. Following a lesson on Special Relativity, a student made the following statement: **3**

"The surface of the Earth is not an inertial frame of reference"

Assess the validity of this statement.

Assess the validity of this statement.

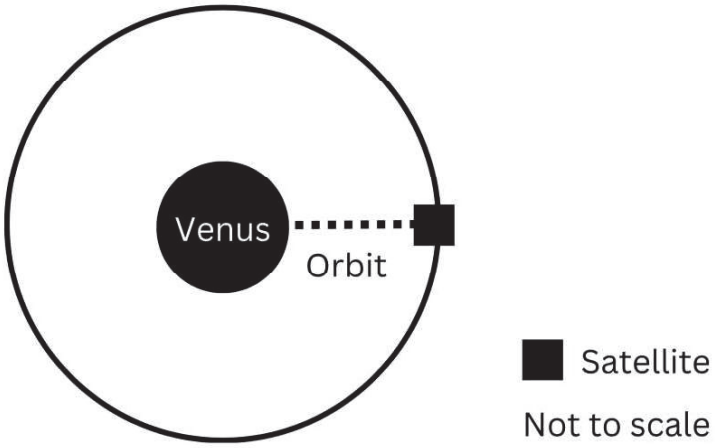
For 3 Marks:

- Identifies an inertial frame as one that is not accelerating.
- Recognises that the Earth's rotational or orbital motion includes acceleration.
- Therefore correctly assesses that the statement is valid.

An inertial frame of reference is one that is not accelerating. As the surface of the earth has rotational motion, it is it accelerating. Therefore, this statement is valid.

Students could discuss the perspective where the Earth IS an inertial frame and still receive full marks if their justification was correct. This question is an example of applying knowledge to a new scenario and was answered poorly, and students need to revise the definition of an inertial frame of reference.

24. *On May 4, 1989, the objective of the Magellan mission to Venus was to place a satellite in orbit to image the entire surface of the planet.*



Mass of Venus is 4.867 x 10^{24} kg
Mass of satellite is 3445 kg
Orbital radius = 6.346 x 10^{6} m

c. Determine the orbital period of the satellite around Venus. Assume circular orbit. **2**

Criteria	Marks
• Correctly calculates the force of gravity between the satellite and Venus	2
• Provides some relevant information	1

Sample response/solution:

$$T^2 = \frac{4\pi^2 r^3}{GM} = \frac{4\pi^2(6.346 \times 10^6)^3}{6.67 \times 10^{-11} \times 4.867 \times 10^{24}}$$
$$T = 5574.89\ s$$

Therefore, the orbital period around Venus s 92.9 minutes.

Relevant info must be the correct formula

b. How much additional work would need to be done for the satellite to escape the planet, Venus? Use relevant equations and calculations to support your answer. **3**

Criteria	Marks
• Explains the energy changes as the satellite manoeuvres with relevant calculations	3
• Describes the energy changes as the satellite manoeuvres AND/OR includes relevant calculations	2
• Provides some relevant information	1

Sample response/solution:
For a satellite to escape to infinity, the total mechanical energy of the satellite must be zero.

$$U + K = -\frac{GMm}{2r} = -\frac{6.67 \times 10^{-11} \times 4.867 \times 10^{24} \times 3445}{2 \times 6.346 \times 10^{6}} = -8.81 \times 10^{10}\text{J}$$

Therefore, the amount of required work done by the rocket boosters attached the satellite would equal to 8.81 x 10^{13} J to increase the total energy to zero.

This was answered poorly. Common error was subtracting the current velocity from the required velocity instead of subtracting the current kinetic energy from the required kinetic energy. V – U is not the same as $V^2 – U^2$

25. *A space organisation is planning to send an astronaut to a distant planet, P. The spacecraft will travel at a speed of 0.8c and the journey is expected to take 15 years, as measured by observers on Earth. The spacecraft and astronaut have a combined mass of 1500kg.*

a. Calculate the distance to P, as measured by observers on Earth. **2**

Criteria	Marks
• Correctly calculates distance to P	2
• Provides some relevant information	1

Sample response/solution:
d = v x t = 0.8 x 15 = 12 light years
$12 \times 3 \times 10^8 \times 365 \times 24 \times 60 \times 60 = 1.14 \times 10^{17}$ m

Relevant info = correct formula

b. Determine how many years will have passed on the spaceship's clock when observed by Earth. **2**

Criteria	Marks
• Correctly calculates t_0	2
• Provides some relevant information	1

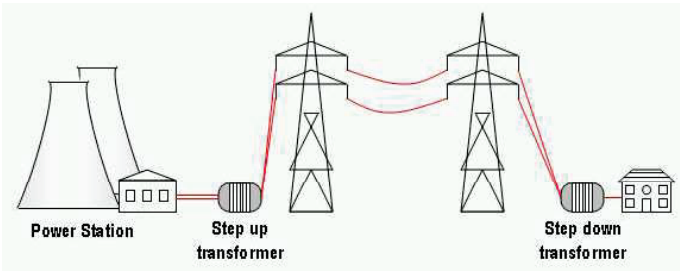
Sample response/solution:

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$t_0 = 15 \times 0.6 = 9$ *years*

This was answered poorly. Students need to revise how to use the time dilation formula. Relevant info = correct formula

26. The diagram below shows a simplified power distribution network. **3**



Explain why transformers are used in the distribution of energy.

1 mark *Identifies that transformers are used to change the voltage of electricity during distribution.*

2 marks *Explains that transformers reduce energy loss during transmission by stepping up the voltage and reducing current.* $P_{loss} = I^2R$

3 marks *Provides a detailed explanation, including both stepping up voltage for transmission and stepping down voltage for safe consumer use.*

Transformers are used in the distribution of energy to efficiently transmit electrical power over long distances. By stepping up the voltage, and hence reducing current, energy loss due to resistance in the transmission lines is reduced. At the distribution end, transformers step down the voltage to a safer level for consumer use.

Some student incorrectly discussed the velocity of the current and also incorrectly stated the power is increased/decrease. This needs to be revised as power remains constant and current decreases with an increased voltage.

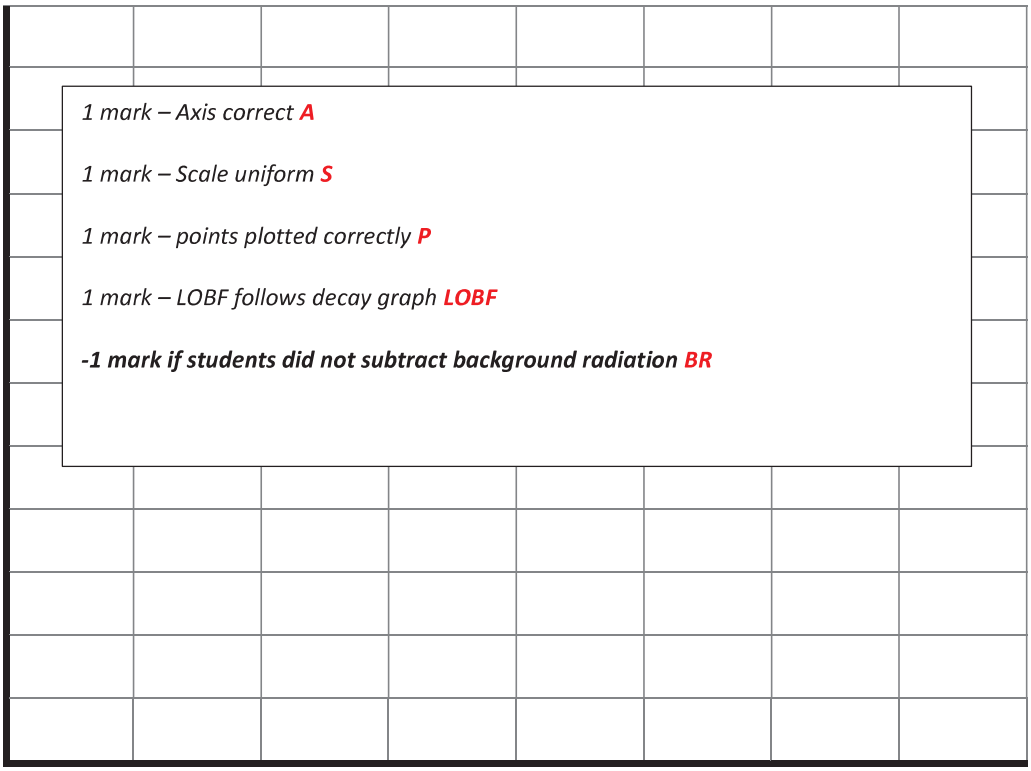
27. Before an experiment to find the half-life of a radioactive isotope, a nuclear scientist switched on her radiation counter in the lab for five 60 second intervals and recorded the following results:

Radiation Recorded *(counts/min)*
1123
1126
1128
1127
1121

The scientist then placed a sample of radioactive isotope X near the counter and measured the counts per minute each second Monday for 14 weeks. Counting the first week as week 0, her results are shown in the table below.

Time (weeks)	***Total Radiation Recorded (counts/min)***
0	*11125*
2	*7725*
4	*5525*
6	*4125*
8	*3125*
10	*2425*
12	*2075*
14	*1625*

a. Create a graph to show the relationship between time and the radiation of X. **4**



1 mark – Axis correct ***A***

1 mark – Scale uniform ***S***

1 mark – points plotted correctly ***P***

1 mark – LOBF follows decay graph ***LOBF***

-1 mark if students did not subtract background radiation BR

b. Use your graph to show that the half-life of X is approximately 3.4 weeks. **1**

Some variation is allowed including those who did not subtract background radiation.

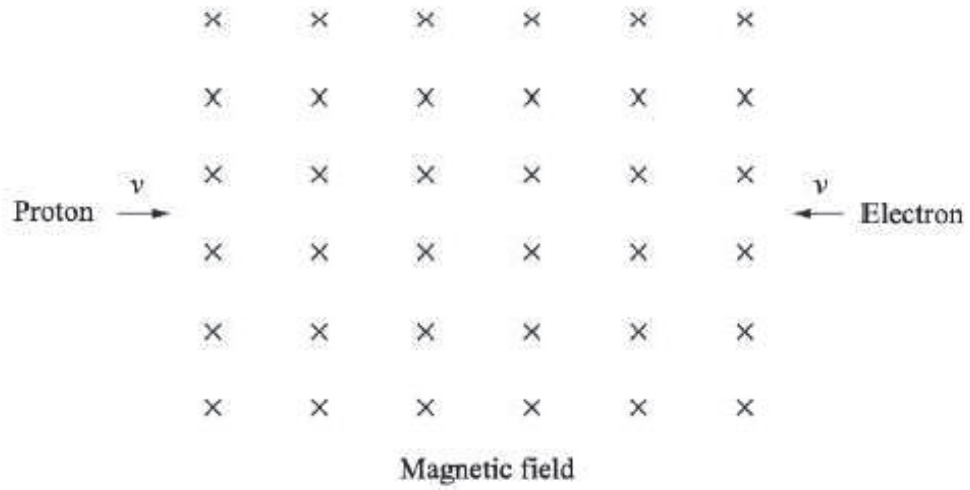
Graph should show interpolation around 3 weeks.

Accounted for carry on if students did not subtract background radiation

c. Calculate the decay constant. **2**

- *2 marks for correct value*
- *1 mark for correct formula*
- *Constant = ln 2/3 = 0.23 weeks^{-1}* ***(variation allowed depending on part b)***

28.	A uniform magnetic field of strength 0.5T is directed into the page. An electron and proton are both fired simultaneously into the magnetic field at 1 x 10^4 $m.s^{-1}$. Assume the particles do not interact with each other.	**4**



Describe the paths that the particles will follow through the magnetic field.

Support your answer with relevant calculations.

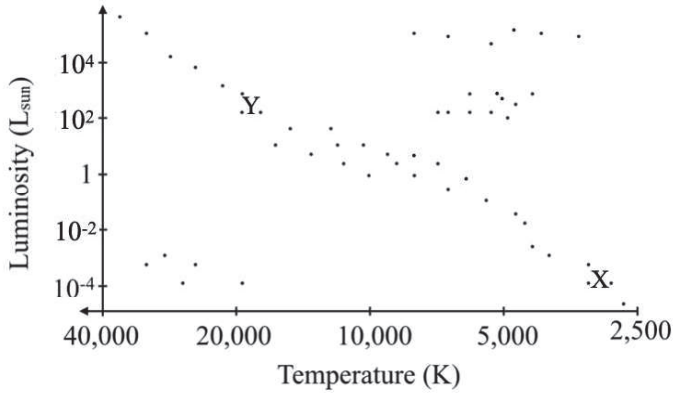
Marks	*Criteria*
4 marks	*Describes paths of both particles direction and radius including calculations*
3 marks	*Describes paths of both particles with only 1 calculation*
2 marks	*Identifies direction of particles*
1 mark	*Provides some relevant info*

When an electron and a proton are fired into a uniform magnetic field, they follow circular paths due to a magnetic force. The radius of these paths is given by r = mv/qB. For the electron, with a much smaller mass, the radius is 1.1 x 10^{-7} m leading to a smaller circular path compared to the proton. The proton, having a larger mass, has a radius of 2.1 x 10^{-4} m, resulting in a wider circular path.

Additionally, the electron's path will be clockwise and the proton's path counterclockwise when viewed from above due to their opposite charges.

This question was generally well done, Students needed to include radius as part of their discussion

29. Below shows a Hertzsprung-Russell diagram with two labelled stars, X and Y.



The reaction that produces energy in Star X can be summarised below:

$$4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{-1}e$$

Nucleus	Mass (amu)
${}^{4}_{2}He$	4.002603
${}^{1}_{1}H$	1.007825
${}^{0}_{-1}e$	0.000549

a. Calculate the energy released from this reaction. **2**

1 mark: working is correct with 1 mistake or have correctly calculated mass defect

2 marks: correctly calculates energy released

$E = mc^2 = (4 \times 1.00782 - 4.002603 - 2 \times 0.000549)(1.661 \times 10^{-27})(3 \times 10^8)^2$

$= 4.13 \times 10^{-12}$ J or 25.7 MeV

b. Using the HR diagram above, draw the pathway that Star X will take on its life cycle. **1**

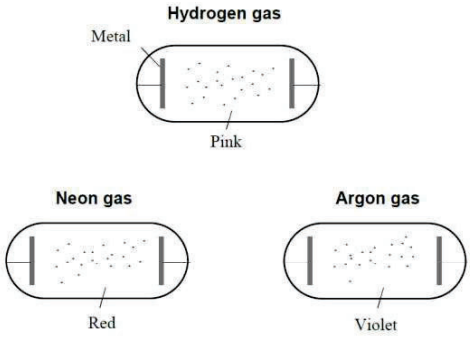
c. Compare the energy production in Star Y to Star X. **2**

2 marks: 2 similarities or two differences or one of each

High-mass main sequence stars (Star Y) produce energy at a much higher rate than low-mass stars (Star X) due to their greater core temperatures and pressures, leading to faster nuclear fusion processes. Both Star X and Y fuse hydrogen to helium for energy production.

30. A student performed an experiment to investigate the light emitted from discharge tubes containing various gases.

The student's observations are shown.



a. Explain why the gases emit different colours inside the discharge tubes.

Marks	Criteria
1 mark	Provides some relevant info
2 marks	Explains that electrons emit photons of specific wavelengths when transitioning between energy levels.
3 marks	Provides a detailed explanation that each gas has unique energy levels, resulting in specific wavelengths (colours) of light being emitted during electron transitions.

A high potential difference between the metal electrode causes electric current to pass through the gases. The energy of the current can be absorbed by ground-state electrons found in the atoms of these gases. When this occurs, electrons will be excited to a higher energy state. When excited electrons return to the ground state, energy is emitted in the form of electromagnetic radiation.

Since the energy states differ among atoms of different gases, the frequency of visible light emitted during electrons' return to ground state will be different, resulting in different colours.

Many students confused this with the photoelectric effect

3

The spectra of light from the discharge tubes are examined through a spectroscope.

b. How will the spectra differ from those produced by an incandescent filament?

2

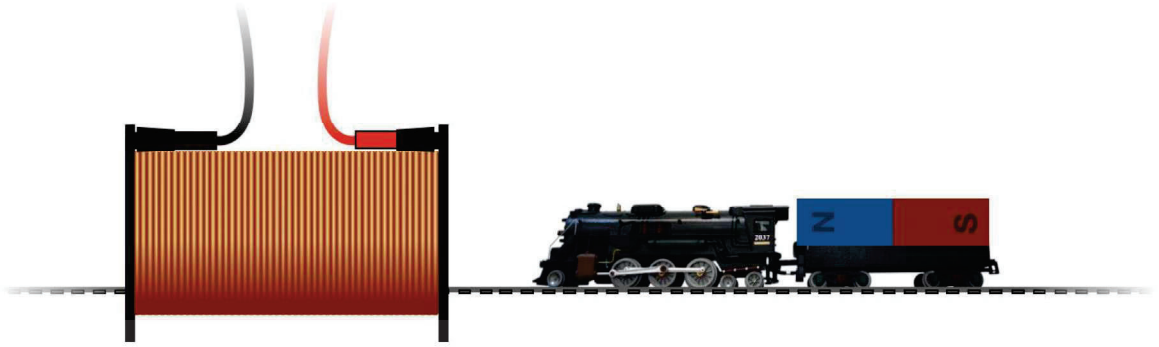
2 marks: Identifies that discharge tubes produce a discontinuous spectrum and incandescent filaments produce a continuous spectrum.

1 mark: Identifies one of the spectra

Gases in discharge tubes produce emission spectra where streaks of light of various wavelengths (discrete) are observed. In contrast, an incandescent filament produces a continuous spectrum of visible light of all wavelengths.

Generally, well answered

31. A physics student, who is also a model train enthusiast, is combining their two interests to undertake a study in electromagnetic induction. They rig up one of their trains with a strong bar magnet on its load carriage and has its track pass through a solenoid. The solenoid is attached to a galvanometer to measure the induced current. **4**



They notice that the train exits the solenoid tunnel with a lower speed than when it entered and does not begin to accelerate to a normal operating speed for a small distance after exiting.

Explain their observations.

Criteria	Marks
Uses Lenz's law and Faraday's to explain the difference in speed entering and exiting the solenoid and the delay in acceleration.	4
Uses Lenz's law and Faraday's to explain the difference in speed entering and exiting the solenoid.	3
Identifies Lenz's law or Faraday's to explain a change in train motion.	2
Provides some relevant information.	1

As the train enters the solenoid, the magnetic field of the magnet in the second carriage is not yet strong enough to have a visible effect so it enters at full speed. When the bar magnet enters the solenoid, the changing magnetic field inside the solenoid induces an electromotive force (EMF) in the solenoid according to Faraday's Law. This induced EMF generates a current in the solenoid, which in turn produces its own magnetic field.

According to Lenz's Law, the direction of the induced EMF will be such that it opposes the change in magnetic flux that produced it. Consequently, the magnetic field created by the induced current in the solenoid opposes the magnet's motion. This opposing magnetic field acts against the direction of the train's motion, resulting in a decrease in the train's speed as it passes through the solenoid.

This interaction effectively extends beyond the physical confines of the solenoid, causing the train to experience a force that opposes its motion for a short distance even after it has left the solenoid whilst the magnetic field is within a short range. It is this continued magnetic interaction that delays the train's return to normal operating speed.

Students should revise when back emf occurs, it is not needed to answer this question. Students should ensure they know Faraday and Lenz's Law. The most common error was that student thought a current was being passed through the solenoid.

32. A model rocket, initially on the ground, was launched at an angle of 20.0° from the horizontal. After a 2.50 s motor burn, the model had a velocity of 82.0 m s^{-1} and then followed projectile motion for the remainder of its flight. **5**

Determine the horizontal range of the rocket after landing. Assume its initial trajectory did not change during its motor burn.

Criteria	*Marks*
Correctly determines the horizontal range.	*5*
Correctly determines the total time of flight or has found the horizontal range based on incorrect initial height during the motor burn phase	*4*
Correctly determines some components of the total time of flight.	*3*
*Correctly determines the range and height of the motor burn **OR** attempts to solve for projectile motion from end of motor burn.*	*2*
Provides some relevant info	*1*

Sample answer:

$v = 82 \qquad \theta = 20 \qquad t_1 = 2.5$

$a = \frac{v-u}{t_1}$

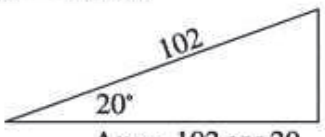
$a = \frac{82-0}{2.5}$

$a = 32.8 \text{ m s}^{-2}$

$\Delta s = ut_1 + \frac{1}{2}at_1^2$

$\Delta s = \frac{32.8 \times 2.5^2}{2}$

$\Delta s = 102 \text{ m}$



$\Delta y_1 = 102 \sin 20$

$\Delta y_1 = 34.8 \text{ m}$

$\Delta x_1 = 102 \cos 20$

$\Delta x_1 = 95.8 \text{ m}$

$v_y = u_y + at_2$

$t_2 = \frac{0-82 \sin 20}{-9.8}$

$v^2 = u^2 + 2a\Delta y_2$

$\Delta y_2 = \frac{0-(82 \sin 20)^2}{2 \times -9.8}$

$-(\Delta y_1 + \Delta y_2) = ut_3 + \frac{1}{2}at_3^2$

$t_3 = \sqrt{\frac{-2(\Delta y_1 + \Delta y_2)}{a}}$

$t_3 = \sqrt{\frac{-2(34.7+40.1)}{-9.8}}$

$t_3 = 3.91 \text{ s}$

$\Delta t = t_1 + t_2 + t_3$

$\Delta t = 9.27 \text{ s}$

Correct values:

Initial range = 96.3m

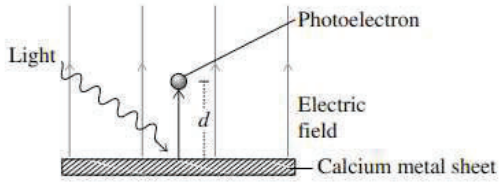
Total time = 6.77s

Final range = 618.5m

Some variation of these numbers was accepted based on rounding.

Students need to set their working out. Was extremely hard to follow and as a result very hard to find working that could have resulted in marks

33. Light of a particular frequency is incident on a calcium metal sheet and photoelectrons are emitted. The metal is in a uniform electric field, perpendicular to the surface of the metal, as shown. **3**



Explain the behaviour of this photoelectron with reference to the law of conservation of energy.

1 mark *States that the photoelectron is emitted when the photon energy exceeds the work function.*

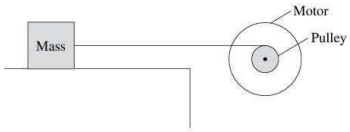
2 marks *Explains that the initial kinetic energy of the photoelectron is determined by the photon energy minus the work function, according to the law of conservation of energy.*

3 marks *Provides a detailed explanation including how the electric field reduces the photoelectron's kinetic energy by doing work against it, and/or how the final position of the photoelectron in the field is determined by the balance between its initial kinetic energy and the work done by the field.*

When light strikes the calcium metal sheet, a photoelectron is emitted if the photon energy exceeds the work function of the metal. According to the law of conservation of energy, the initial kinetic energy of the photoelectron equals the photon energy minus the work function. As the photoelectron moves through the electric field, the field does work against it, reducing its kinetic energy. The photoelectron will continue to move until the work done by the electric field equals its initial kinetic energy, at which point it will come to rest. The position of the photoelectron in the field will therefore depend on the initial kinetic energy minus the work done by the field.

Many students did not address the electric plate

34. A rope connects a mass on a horizontal surface to a pulley attached to an electric motor as shown. **3**



Assuming the mass is moving at a constant velocity, show that the velocity of the mass as it moves along the horizontal surface is given by $v = \frac{VI}{\mu_k F_N}$.

3 marks: correct derivation

2 marks: a correct substitution into P = Fv

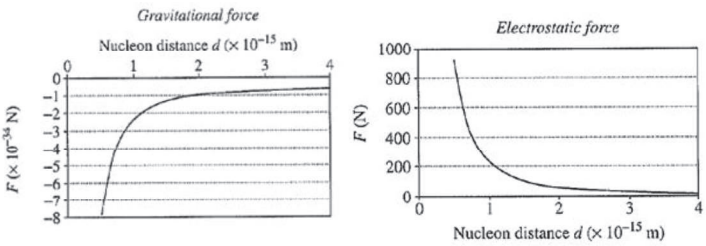
1 mark: a relevant formula

$P = Fv$ and $P = VI$ and $F_{friction} = \mu_k F_N$

$v = P/F$

$v = VI/\mu_k F_N$

35. The two graphs below show the gravitational and electrostatic forces acting between two protons in the nucleus of an atom. **3**



Analyse the graphs and account for the stability of the nucleus.

3 marks: accounts for the stability of the nucleus with reference to data from both graphs

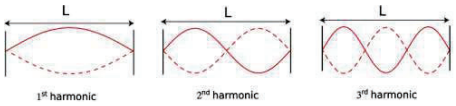
2 marks: Analyses the graphs without data AND accounts for the stability with reference to the strong force

1 mark: Analyses the graphs OR accounts for the stability with reference to the strong force

The graphs show that the gravitational force between two protons is attractive but extremely weak ($F = 2.5 \times 10^{-34}$ N at $d = 1 \times 10^{-15}$m), while the electrostatic force is repulsive and significantly stronger ($F = 250$ N at $d = 1 \times 10^{-15}$m). Despite this, the stability of the nucleus is maintained by the strong nuclear force, which much stronger than both gravitational and electrostatic forces at short distances.

Students generally answered poorly – many students stating that gravity cancelled out the electrostatics or was a repulsive force (people fall upwards?) Many did not refer to the data directly or did not mention strong nuclear force at all missing marks.

36. Below is a diagram showing the harmonics of standing waves for a string with 2 fixed ends. **3**



Explain how the concept of standing wave harmonics can be used to improve Bohr's model of the atom.

1 mark *Identifies that the concept of standing waves can be related to electron orbits in the atom.*

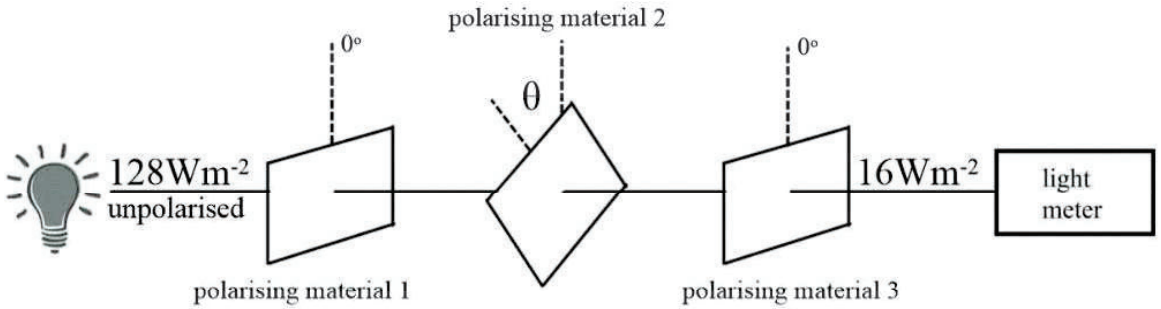
2 marks *Explains that electrons form stable orbits when their de Broglie wavelength forms a standing wave*

3 marks *Provides a detailed explanation including how the condition of standing waves leads to discrete energy levels and quantized orbits in the atom, improving Bohr's model by preventing continuous radiation of energy.*

The concept of standing wave harmonics can be used to improve Bohr's model by explaining that electrons in an atom exist in stable orbits where their de Broglie wavelength forms a standing wave. This condition requires that the circumference of the electron's orbit be an integer multiple of the electron's wavelength. This improvement accounts for why only certain discrete energy levels are allowed in the atom, corresponding to specific quantized orbits, and why electrons do not radiate energy as they move within these stable orbits.

Most students linked standing waves to stability but failed to mention how that linked to no energy lost to the environment. Very few students made a link to the wavelength of electron for the 3rd mark.

37. Unpolarised light of intensity 128 Wm^{-2} passes through three polarising filters. The polarising axes of first and third filters are at 0°. **4**



If th
the

1 mark – Student demonstrated the understanding to use the equation

$$I = I_{max}cos^2\theta$$

1 mark – Student showed the first filter drops the intensity by 50%

$$I_1 = 0.5 \times 128 = 64.0$$

1 mark – Student shows that the second filter changes the intensity the same as the third

$$I_2 = 64.0cos^2\theta \quad (1) \qquad 16 = I_2cos^2\theta \quad (2)$$

1 mark – Student correct substitutes the values into the correct equation

$$16 = (64.0cos^2\theta)cos^2\theta \quad \therefore \quad \theta = cos^{-4}\left(\frac{16}{64}\right) = 45°$$

Step 4 could also be:

$Cos^2\theta = 16/I_2$ substitute into equation (1) -> $I_2 = 64 \times 16 / I_2$

$I_2^2 = 1024$ -> $I_2 = 32$

$32 = 64\ Cos^2\theta$

$\theta = 45°$

Generally answered well. Several students made the assumption that every filter just halved the value. They ended with the correct answer but did not demonstrate why this worked so given only 3 marks

38. Explain why the total energy of a satellite orbiting the Earth is always negative. **3**

1 mark: Identifies that the total energy of a satellite consists of kinetic and gravitational potential energy.

2 marks: Explains that gravitational potential energy is negative due to the attractive force of gravity between the Earth and the satellite.

3 marks: Further elaborates that the negative total energy signifies a bound system, indicating the satellite cannot escape Earth's gravitational pull.

Sample answer:

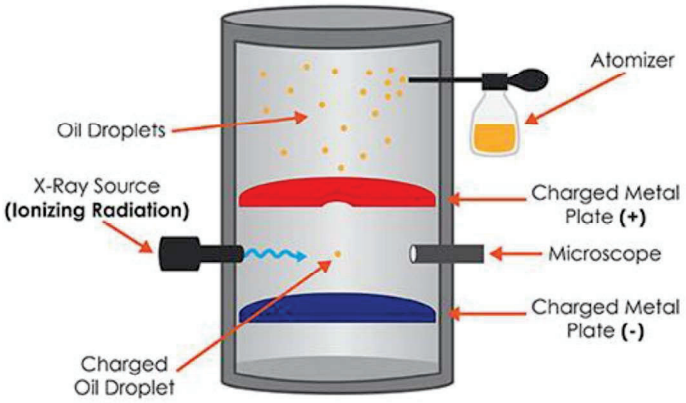
The total energy of a satellite orbiting the Earth is the sum of its kinetic energy and gravitational potential energy. Gravitational potential energy is negative because the force of gravity is attractive, is 0 at an infinite distance from Earth and it decreases (becomes more negative) as the satellite moves closer to Earth. The negative total energy signifies that the satellite is bound to the Earth, meaning it does not have enough energy to escape the gravitational pull and must remain in orbit.

Many students did not link to gravity being attractive or approaching infinity. Many also did not link how the negative denotes the satellite is in a bound system – paid this mark if escape velocity was correctly discussed.

39. In a version of Millikan's oil-drop experiment, a charged oil droplet with mass 3.6×10^{-14} kg falls with an acceleration of $1.256\ m.s^{-2}$ while the electric field is turned on. The potential difference across the electric field is 6.0×10^{4} V and the distance of plate separation is 25 cm.

5

Assume drag force is negligible.



Calculate the number of electrons within the charged oil droplet.

Mark	*Criteria*
1	*Makes a relevant calculation*
2	*Makes 2 relevant calculations*
3	*Calculates the force due to the electric field*
4	*Calculates the total charge of the oil drop*
5	*Correctly calculates number of electrons*

$F_{net} = ma = 3.6 \times 10^{-14} \times 1.256 = 4.5216 \times 10^{-14}$

$F_W = mg = 3.6 \times 10^{-14} \times 9.8 = 3.528 \times 10^{-13}$

$F_E = F_W - F_{net} = 3.07584 \times 10^{-13}$

$E = V/d = 6 \times 10^{4} / 0.25 = 2.4 \times 10^{5}$

$q = F_E / E = 1.2816 \times 10^{-18}$

No. of electron = $1.2816 \times 10^{-18} / 1.602 \times 10^{-19}$ = 8 electrons

Mostly done well – most common error was assuming that FE and Fw were equal and working from there.

Many students also have values without showing how values were obtained and due to prior mistakes, it was very difficult to pay carry on error marks.

40. Consider the following statement: **6**

"Einstein's equation $E = mc^2$ has revolutionized science leading to significant advancements in both theoretical physics and practical applications in society."

Justify this statement.

Mark	*Criteria*
1	*Provides some relevant info*
2	*Clearly explains the concept of mass-energy equivalence and briefly discusses its impact on either a theoretical or practical aspect of science.*
3	*Discusses the application of the formula in a theoretical context, such as energy released in fission and fusion, or its role in stellar processes.*
4	*Explains two theoretical advancements (e.g., fusion in stars, Big Bang theory, special relativity) and begins to connect these to practical applications.*
5	*Provides a balanced justification of both theoretical advancements and practical applications, mentioning specific examples like nuclear power, weapons, or particle accelerators.*
6	*Offers an extensive justification, seamlessly integrating multiple theoretical and practical applications of the formula, demonstrating a deep understanding of its impact on both science and society. All key areas are discussed: mass-energy equivalence, nuclear reactions, stellar processes, Big Bang theory, and technological advancements.*

Einstein's equation $E = mc^2$ established the principle of mass-energy equivalence, showing that mass can be converted into energy and vice versa. This concept is fundamental to understanding the immense energy released in nuclear reactions, such as fission and fusion, where a small amount of mass is transformed into a significant amount of energy. In theoretical physics, this equation has enhanced our understanding of stellar processes, particularly nuclear fusion in stars, which powers their lifecycle and explains their energy output. Additionally, $E = mc^2$ supports the Big Bang theory by explaining how the universe's energy originated from a dense, hot state, and it is a cornerstone of special relativity, which redefined our understanding of space, time, and energy.

In practical terms, the equation has been pivotal in the development of both controlled and uncontrolled fission reactions. Controlled fission is used in nuclear power plants to generate electricity, while uncontrolled fission underlies the explosive power of nuclear weapons. The mass-energy equivalence principle also guides the design of particle accelerators, where particles are accelerated to high speeds, allowing scientists to explore fundamental aspects of matter and energy. Thus $E = mc^2$ has revolutionized both our understanding of the universe and led to significant technological advancements.

Mostly answered well. Main problem was not enough applications for theoretical/practical. Needed 4 applications. Accepted Fission (weapons and reactors), particle accelerators, relativity, star processes, big bang evidence. Most students did justify their response well but some did miss this. Some applications lacked detail and were just mentioned with no linking to the formula

19/9/