Student Number: ……

Teacher's Name: ……

2021

Task 4: Trial Examination

Weighting: 30%

HSC Physics

General Instructions

- Reading time - 5 minutes
- Working time - 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A data sheet, formulae sheets and Periodic Table are provided with this paper

Subject Teachers:

Ms Disney, Mr Sloan, Mr Solomonides, Mr Fiander, Mr Truong, Mr Smith

Total marks - 100

Attempt all questions.

Section I – Multiple Choice Questions

20 marks (pages 2-14)

- Attempt Questions 1-20
- Allow about 35 minutes for this section
- Write the answer to each multiple choice question in the box provided. Multiple choice answers that are not clear may not receive a mark.

Section II – Short Answer Questions

80 marks (pages 15-37)

- Attempt Questions 21-34
- Allow about 2 hours 25 minutes for this part
- Show all relevant working in questions involving calculations

Extra writing booklets can be used.

If you use an extra booklet, clearly indicate which question you are answering and indicate in this paper that a booklet has been used.

At the end of the examination, place extra booklets at the END of the paper and upload with the rest of the examination.

Total pages scanned:	

Section I

20 marks

Attempt Questions 1-20
Allow about 35 minutes for this section

Write the answer to each multiple choice question in the Answer box provided. Ensure final answer is clear. If you make a mistake, cross the incorrect answer out and make final answer clear.

1. Which of the following factors about a rocket would affect the rocket's escape velocity?

   A. Mass only.

   B. Initial velocity only.

   C. Mass and initial velocity.

   D. Neither mass nor initial velocity.

   Answer: ____

2. Millikan measured the magnitude of the electron charge by balancing an upwards force with a gravitational force on a small oil drop.

   A student performed this experiment so that an oil drop of charge 9.6×10^{-19} C was held stationary in an electric field of 1.0×10^{4} Vm^{-1}.

   What is the electrical force acting on the oil drop?

   A. 9.6×10^{-14} N

   B. 9.6×10^{-15} N

   C. 9.6×10^{-22} N

   D. 9.6×10^{-23} N

   Answer: ____

3. Which of the following is considered a piece of evidence for the Big Bang Theory?

A. Cepheid stars.

B. Cosmic microwave background radiation.

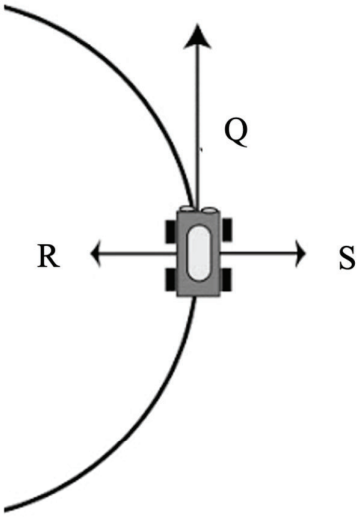
C. The presence of antimatter in the universe.

D. The existence of the four fundamental forces.

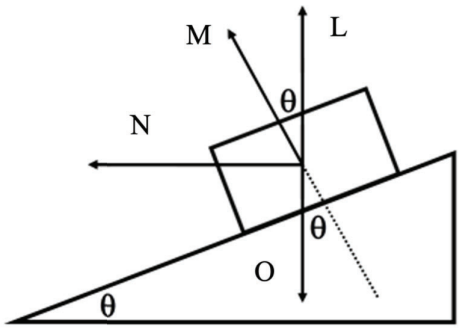
Answer: ____

4. The diagrams below show possible force vectors that could act on objects moving in uniform circular motion on a flat corner and on a banked curve.

Flat curve (top view)



Banked curve (side view)



Identify the letter(s) that matches the vector(s) that provide centripetal force in both situations.

	Flat corner	Banked curve
A.	R	N
B.	R + S	N
C.	R	N + M
D.	R + Q	N + L

Answer: ____

5. Which of the following most correctly describes Newton's and Huygen's models of light?

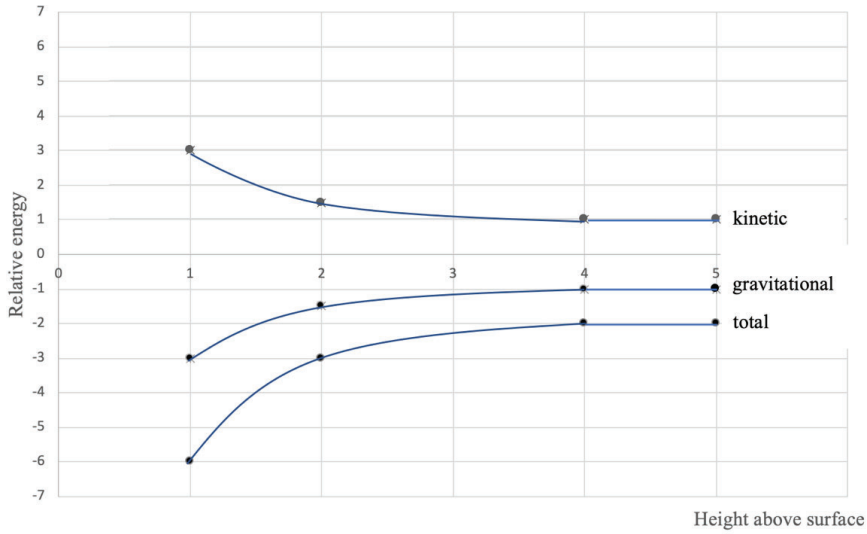
	Newton	Huygen
A.	Light consists of small particles that have mass but do not obey the laws of physics.	Light consists of waves that do not have mass but obey all laws of physics.
B.	Each point on a wave behaves as a point source for new waves to form.	Light consists of particles that do not have mass, but obey all laws of physics.
C.	Light consists of small particles that have mass and obey the laws of physics.	Each point on a wave behaves as a point source for waves in the direction of propagation.
D.	Light consists of waves that do not have mass but obey all laws of physics.	Light consists of particles that have mass and obey the laws of physics.

Answer: ____

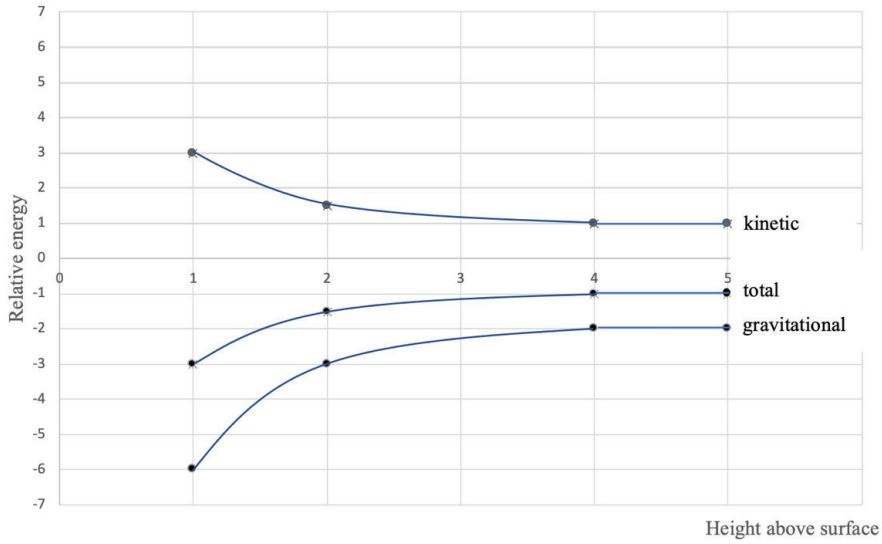
6. A graph can be used to represent the energies of satellites at different heights above the surface.

Which graph below (options continue over page) correctly shows the kinetic, gravitational potential and total energies of a satellite as the orbital radius of the satellite changes?

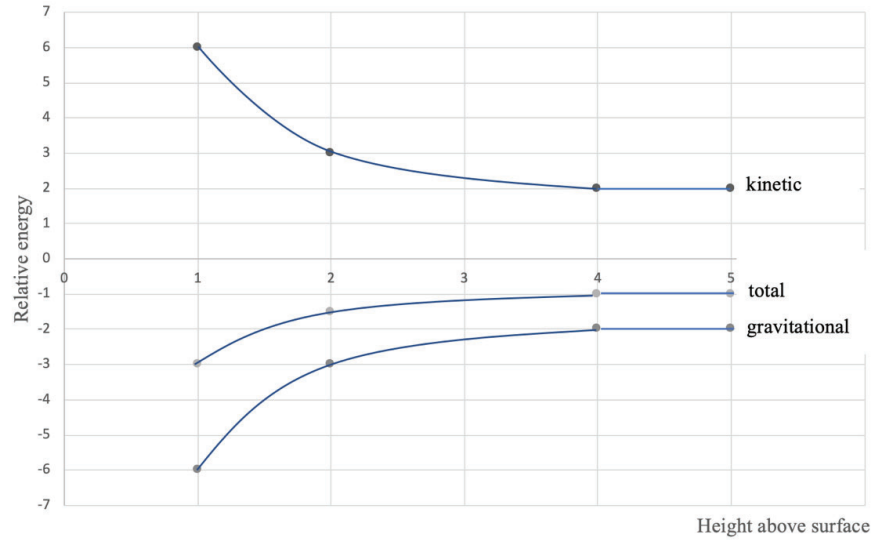
A.



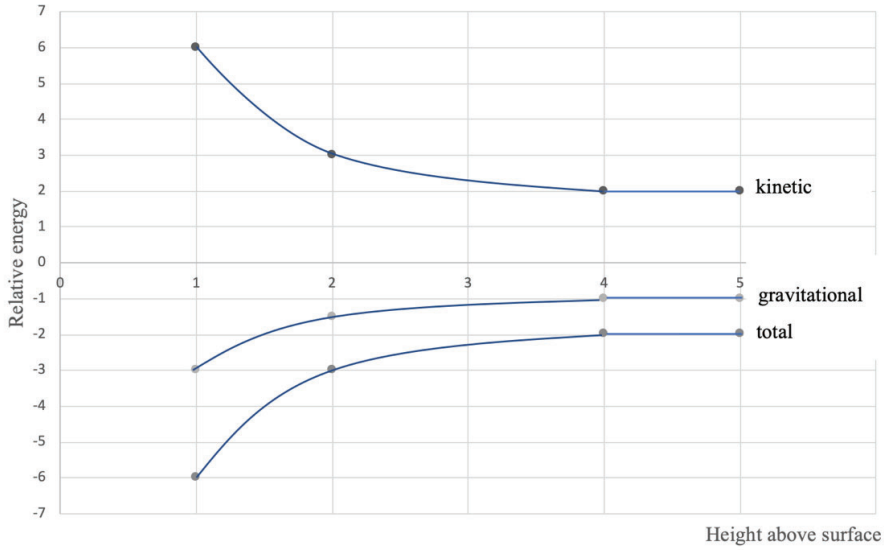
B.


Relative energy
Height above surface
kinetic
total
gravitational

C.

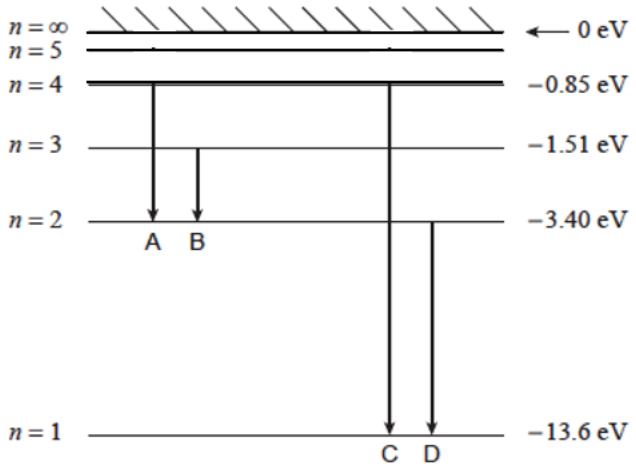

Relative energy
Height above surface
kinetic
total
gravitational

D.


Relative energy
Height above surface
kinetic
gravitational
total

Answer:

7. The diagram below shows the energy levels of hydrogen with four different electron transitions highlighted (A, B, C, D).



[*This diagram is not drawn to scale.*]

Which of the transitions shown corresponds to an emitted photon of wavelength 486 nm?

Answer: _____

8. Lightning storms can create highly accelerated electrons that in turn create gamma photons as a result of the high acceleration.

N-13 is then produced when a gamma photon strikes an N-14 nucleus and removes a nuetron.

$$ {}^{0}_{0}\gamma + {}^{14}_{7}N \rightarrow {}^{13}_{7}N + {}^{1}_{0}n $$

${}^{14}_{7}N$ 14.00307 u, ${}^{13}_{7}N$ 13.00574 u, ${}^{1}_{0}n$ 1.00867 u

Calculate the energy, in MJ, that is absorbed in this reaction.

A. 1.69522×10^{-6}

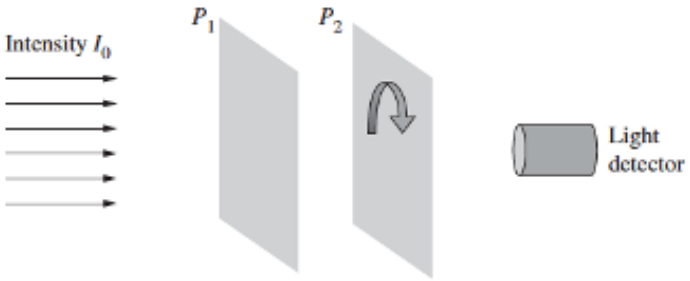
B. 1.69522×10^{-12}

C. 1.69522×10^{-18}

D. 1.69522×10^{-27}

Answer: _____

9. Polarised light of intensity I_0 passes through a polarising filter, P_1, with the same plane of polarisation as the incoming light. The light then passes through a filter, P_2, that is able to be rotated and set to have varying angles between P_1 and P_2.



Which of the following correctly shows the light intensity at the light detector when the angle between the planes of polarisation of P_1 and P_2 is set at 30°?

A. $0.375\ I_0$

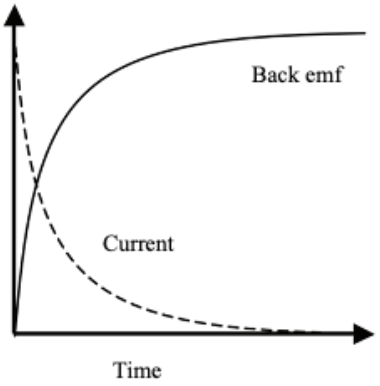
B. $0.435\ I_0$

C. $0.75\ I_0$

D. $0.87\ I_0$

Answer:

10. The graph below shows current and back emf against time in a DC motor that is starting up from stationary.



Why does the current decrease as the back emf increases?

A. Net voltage across the motor decreases as the motor speeds up.

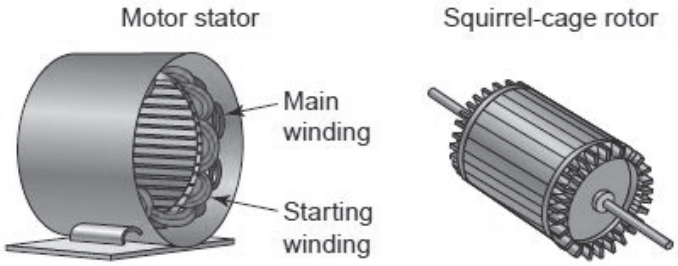
B. Resistance in the circuit becomes greater as more current flows.

C. Overall voltage across the motor increases as the motor speeds up.

D. Back emf causes a decrease in the supply emf as the motor speeds up.

Answer:

11. The diagram below shows components of an AC induction motor.



A student was trying to explain the operation of an AC motor and wrote out the correct steps, but did not get the order right.

Order the steps below so they correctly explain the operation of an AC induction motor.

1	Causes a change in flux to be experienced by the squirrel cage bars.
2	Alternating current is supplied to the electromagnets in the stator.
3	A rotating magnetic field forms.
4	The squirrel cage generates a magnetic field that interacts with the rotating magnetic field to create a force, and thus a torque.
5	An emf is induced and thus a current in the bars

A. 2, 3, 1, 4, 5

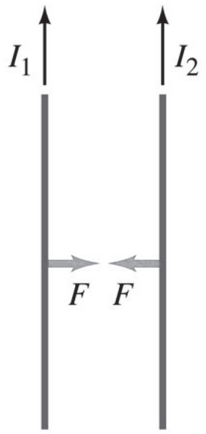
B. 3, 2, 5, 4, 1

C. 2, 3, 1, 5, 4

D. 2, 3, 5, 1, 4

Answer: ____

12. The diagram below shows the current, measured in amperes, running through two parallel wires. The definition of the SI unit of the ampere is based upon the forces acting between two parallel wires with current running through them.



Newton's third law of motion is related to the definition of the ampere for which reason?

A. Forces acting on each wire are of the same magnitude.

B. The force between the two wires is only related to the current in the wires.

C. The direction of the force between the two wires changes depending on the direction of the current flow.

D. The equal force between the two wires depends on the length of the wire and the distance between the wires.

Answer: ☐

13. At one point on the Earth's surface at a distance of R from the centre of the Earth, the gravitational field strength is measured as 9.76 N kg^{-1}.

Which of the following is closest to Earth's gravitational field strength as a distance of 2R above the surface of the Earth at that point?

A. 1.08 N kg^{-1}

B. 2.44 N kg^{-1}

C. 3.25 N kg^{-1}

D. 4.88 N kg^{-1}

Answer: ☐

14. The following table shows some of the laws that were used by Maxwell to explain the features of EM waves.

Faraday's Law	Oscillating magnetic fields produce an electric field.
Ampere's Law	Oscillating electric fields produce a magnetic field.
Gauss' Law	Electric charges produce a field that radiates outward, the electric flux (strength of field) is related to the size of the charge.

Identify which option below correctly matches the law to the feature of electromagnetic waves that is explained by that law.

	Law	**Feature of electromagnetic waves resulting from law**
A.	Gauss' Law	Electromagnetic waves are self-propagating.
B.	Ampere's Law	The strength of an electromagnetic wave is related to the size of the oscillating charge.
C.	Faraday's Law and Ampere's Law	Electromagnetic waves are self-propagating.
D.	Faraday's Law	Electric and magnetic fields are produced at 90° to each other and 90° to the direction of propagation.

Answer: ____

15. Quasars are some of the brightest objects in the universe. Quasar 3C446 has a brightness that changes rapidly over time. The quasar is moving away from Earth at a speed of 0.704 c. Scientists observe the changes to the quasars brightness over a 20 hour time interval in a laboratory on Earth.

What is the time interval of the scientists observation period from the quasar's frame of reference?

A. 10.08 hours

B. 10.88 hours

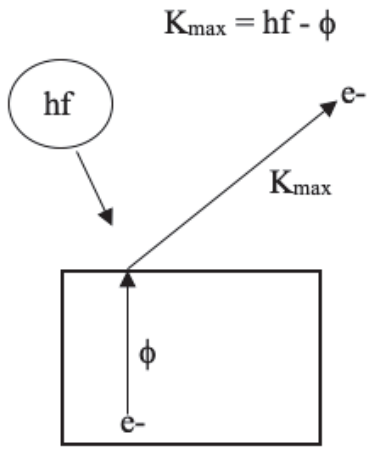
C. 14.204 hours

D. 28.16 hours

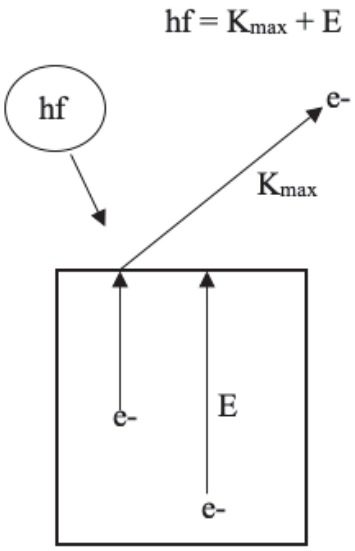
Answer: ____

16. Which of the following diagrams most correctly shows the conservation of energy that occurs during the release of a photoelectron during the photoelectric effect?

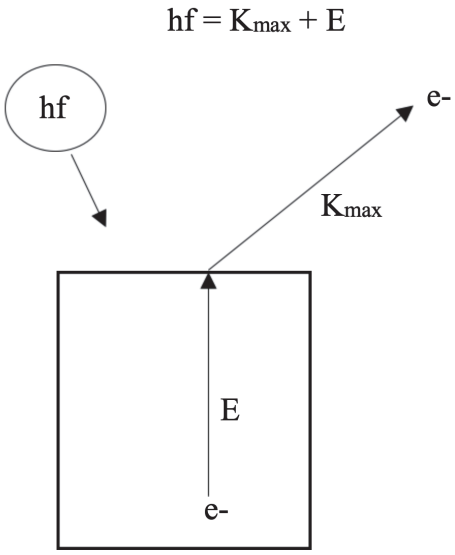
A.



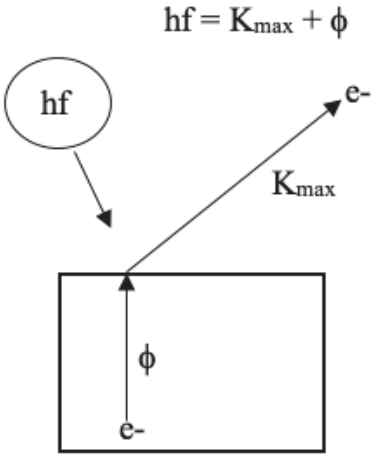
B.



C.

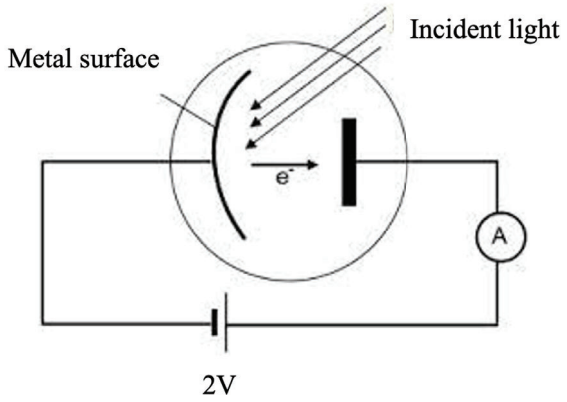


D.

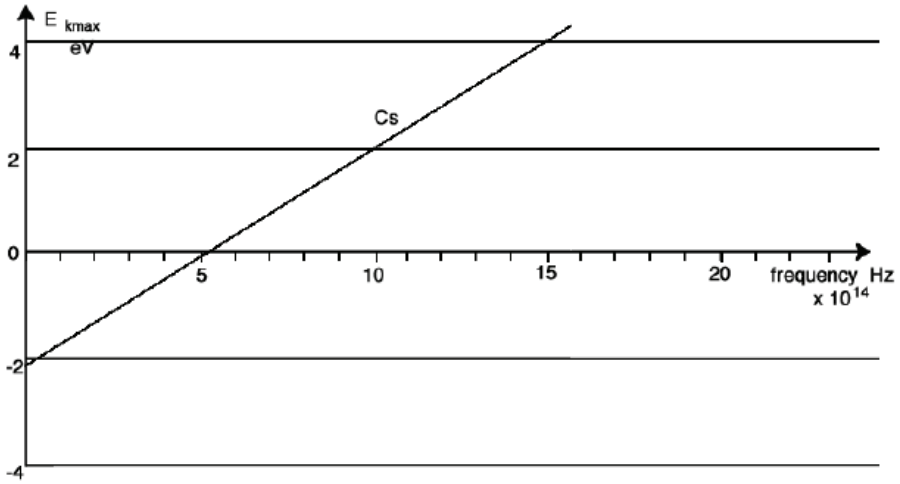


Answer:

17. A photoelectric circuit is set up using caesium (Cs) metal as shown below.



A student then conducted an experiment and plotted the maximum kinetic energy of emitted photoelectrons against incoming light frequency for the caesium (Cs) metal.



What is the approximate value for the cutoff frequency and work function of the caesium metal?

	Cutoff frequency (x 10^{14} Hz)	Work function (eV)
A.	5	-2
B.	5	2
C.	10	-4
D.	10	4

Answer: ____

18. All rocks on Earth contain uranium-235. Over a long period of time the uranium-235 decays into other nuclides.

If a sample of rock contains 5% of the original amount of uranium-235 after a period of 4.5×10^6 years, calculate the decay constant for uranium-235.

A. $6.657 \times 10^{-7}\ s^{-1}$

B. $1.1341 \times 10^{-14}\ s^{-1}$

C. $2.111 \times 10^{-14}\ s^{-1}$

D. $4.884 \times 10^{-15}\ s^{-1}$

Answer: [ ]

19. Mars has a radius of 3.40×10^6 m and a period of rotation on its axis of 8.86×10^4 s. Two satellites are in orbit around Mars. Satellite A has an altitude of 1.15×10^6 m and a period of 9314 s. Satellite B is used to continually monitor the activity of a particular volcano.

What is the altitude of satellite B?

A. 1.76×10^6 m

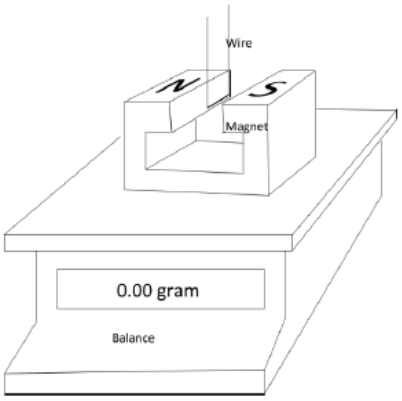
B. 5.16×10^6 m

C. 1.70×10^7 m

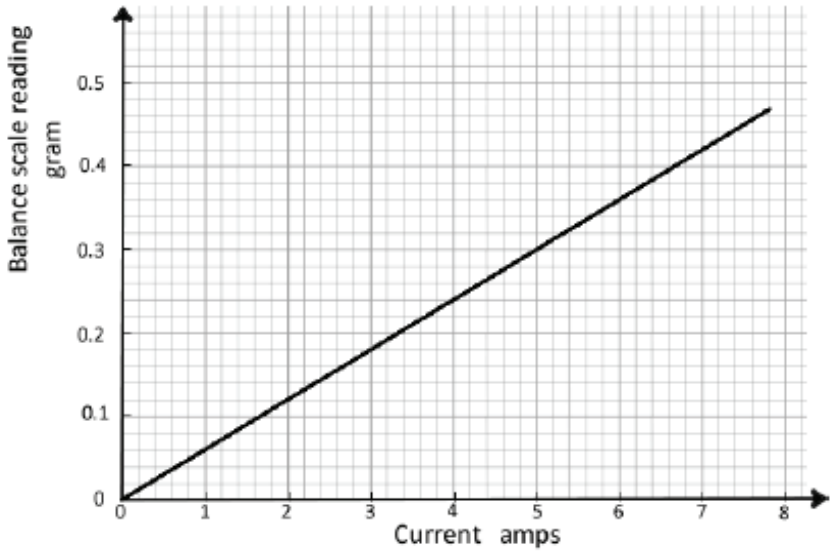
D. 2.04×10^7 m

Answer: [ ]

20. A wire 2.0 cm long is placed perpendicular to the magnetic field of a magnet that is placed on an electric balance as seen in the diagram below. The electronic balance is zeroed with the magnet on the balance as shown, and no current flowing through the wire.



The graph below shows how the mass readings on the electronic balance changed as the current in the wire was increased.



What is the magnetic field of the magnet?

A. 2.94×10^{-4} T

B. 0.0294 T

C. 0.294 T

D. 29.4 T

Answer:

Section II (80 marks)

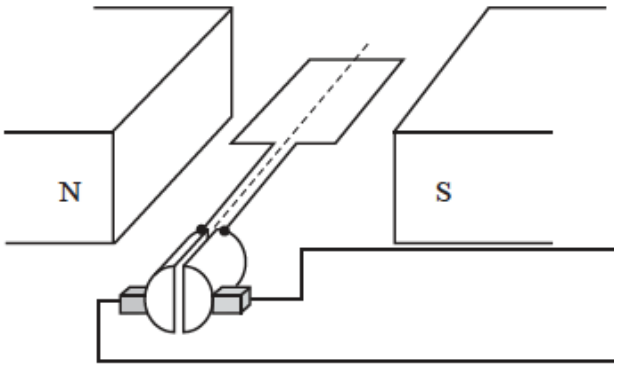
Questions: 21 – 34
Marks: 80
Time: Allow approximately 2 hours and 25 minutes for this Part.

Instructions:
Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

Question 21 (5 marks)

The diagram below shows a simple DC motor connected to an input power source. The coil is square with all sides 6.0 cm in length, and there are 60 loops in the coil.



(a) The coil is supplied with a current of 1.5 A and is placed in a magnetic field of strength 0.50 T. Calculate the maximum torque in the coil. **2**

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(b) Justify TWO adjustments that could be made to the motor to increase the torque in the coil. **3**

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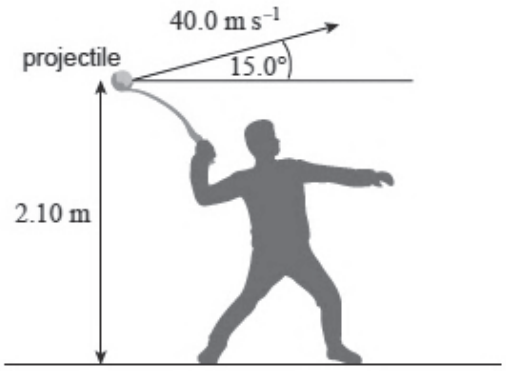
Question 22 (5 marks)

A person throws a ball which is projected at a speed of 40 ms^{-1} at 15° above the horizontal. The ball leaves the thrower at 2.10 m above the ground as seen in the diagram below.



(a) Calculate the time of flight if the ball is caught at the same height as thrown. **3**

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(b) The person catching the ball is standing 90 m from the thrower at the same level. Determine how much closer or further away the catcher must move in order to catch the ball. **2**

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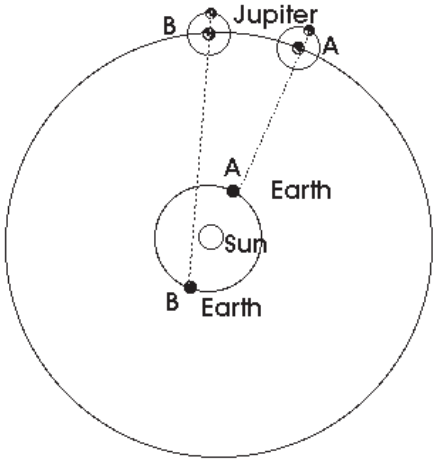
Question 23 (6 marks)

Scientist's understanding of light has changed and developed over time.

(a) Io is a moon of Jupiter which can be observed from Earth going into and coming out of eclipses as it moves in and out of Jupiters shadow. Scientist Ole Romer is credited with an early attempt to calculate the speed of light. He obtained a value of 200 000 km s^{-1}.

His method involved using the time difference between the predicted time period of an eclipse of Io and the actual time period of the eclipse, measured when the Earth is closest to Jupiter, and measured again when the Earth is furthest from Jupiter. He assumed that the time difference was related to the extra distance that light had to travel.



2

Justify why Romer's measurements of the speed of light were inaccurate.

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(b) Muons are particles created in the upper atmosphere, around 10 km above the Earth. In a lab on Earth, muons have a mean lifetime of 2.20×10^{-6} s. The speed of muons as they move towards Earth is 2.997×10^{8} ms^{-1}. **4**

Explain, using both qualitative and quantitative ideas, how muons show evidence of length contraction.

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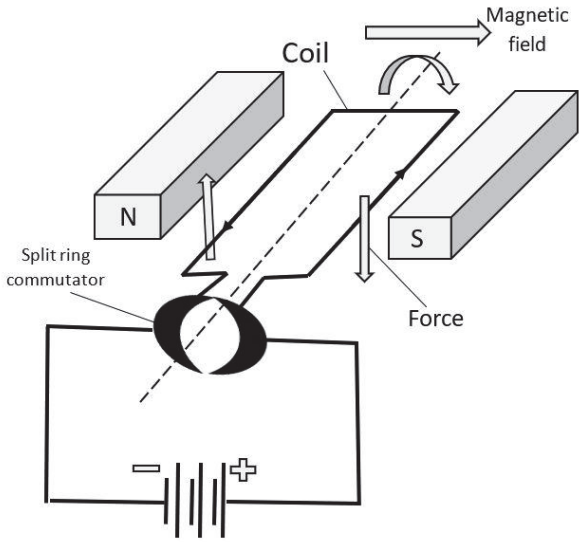
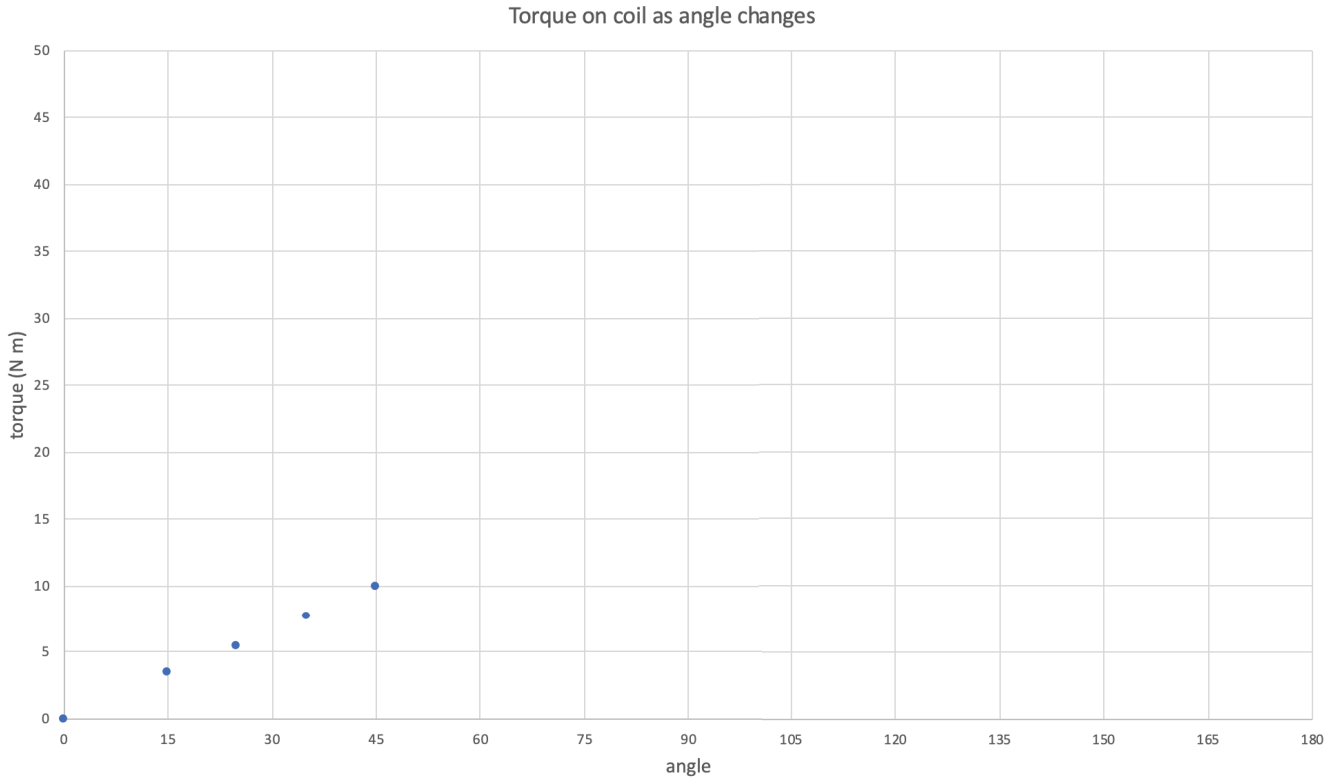
Question 24 (5 marks)

A simple DC single coil motor is shown below. A constant current runs through the coil, and it is rotating with constant speed.



A student measures the torque provided by the coil at a range of different angular positions. Note that the coil starting position is NOT necessarily shown in the diagram.

The results of his measurements are shown on the graph below.



Complete the graph to show the torque of the motor between 0-180 degrees and justify the trend of the graph you have drawn. **5**

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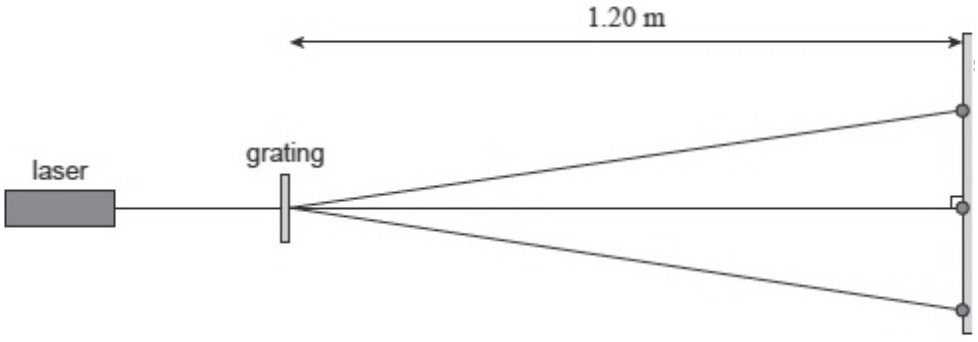
Question 25 (6 marks)

The wavelength of light can be analysed by use of either a double slit or a diffraction grating. Different patterns are produced and different analysis is used for the two methods.

(a) The diagram below shows laser light passing through a diffraction grating that has 600 slits per mm. The central maxima and the two first-order maxima are shown on a screen that is 1.20 m from the diffraction grating.



[*This diagram is not drawn to scale.*]

If the two first order maxima are 30° apart, calculate the wavelength of the light used. **2**

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(b) The patterns produced by a double slit and a diffraction grating can be projected onto a flat screen for qualitative analysis.

A student used two identical lasers, and projected a double slit pattern and a diffraction grating pattern onto a screen so they were side by side and could be observed together.

An image of the double slit pattern is shown below.

Contrast the main features of the double slit and diffraction patterns the student observed. **4**

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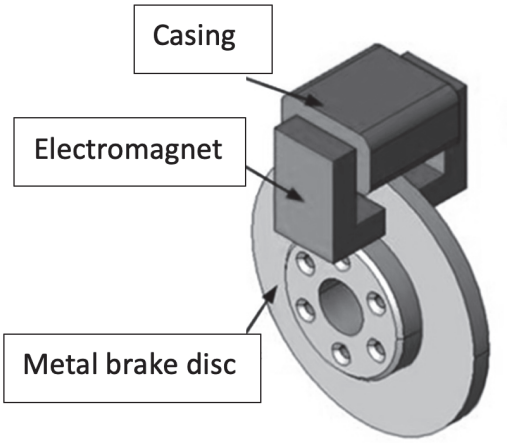
Question 26 (7 marks)

The following shows a simplified diagram of magnetic braking used in cars. The metal brake disc is surrounded by an electromagnet that can be switched on and off.



(a) Electromagnetic induction can be used to explain why magnetic braking slows the car. Use this theory to explain how magnetic braking works. **4**

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(b) Under magnetic braking the car decreases in velocity and the metal brake disc increases in temperature. **3**

Use the law of conservation of energy to explain these observations.

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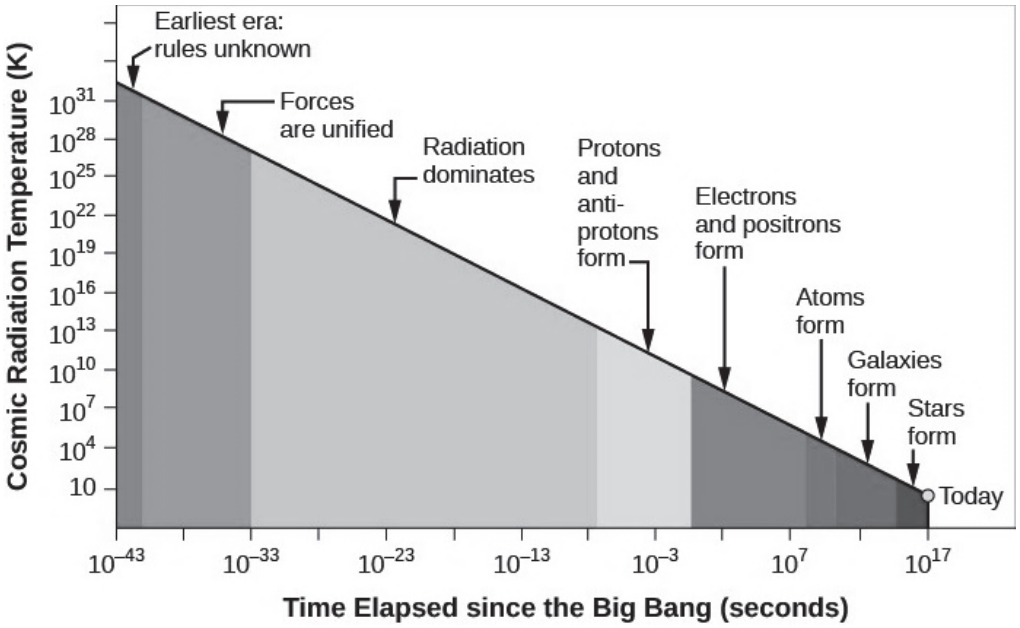
Question 27 (4 marks)

The image below shows significant events in the formation of the Universe.



By considering the importance and role of the fundamental forces, outline the process by which atoms formed in the early Universe.

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Question 28 (3 marks)

Two satellites, A and B, are in orbit above the Earth.

Satellite A is used to take images of the weather over different continents, while Satellite B is a communications satellite.

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Justify each satellite as either a LEO (low Earth orbit) or GEO (geostationary) based on their uses and features of their orbit.

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Question 29 (5 marks)

Use the Standard Model to describe the structure of the helium-4 atom. **5**

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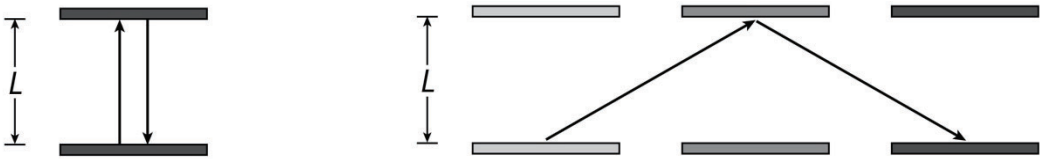
Question 30 (7 marks)

Understanding relative motion and frames of reference led to the development of new theories including Einstein's proposal of special relativity. When observing motion, the frame of reference is important, as is the speed of the frames relative to each other. **7**

Scenario 1: shows observations made by two people when a ball is thrown vertically upright by a person in a train carriage. The train is moving at constant velocity at non-relativistic speeds.

Scenario 2: shows observations that could be made by two people when a pulse of light is shone vertically upwards towards a mirror on the roof of a train that is moving at a constant relativistic speed.



Observer on train Observer at station

Explain the observations that the two observers would make in EACH situation.

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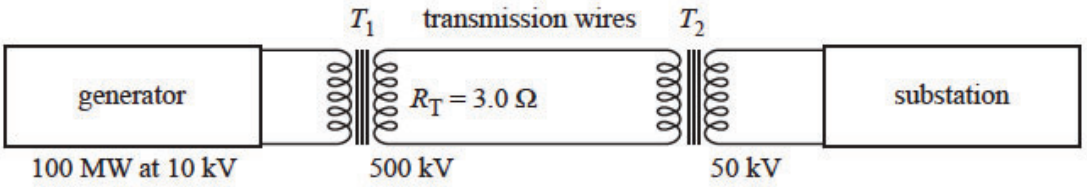
Question 31 (5 marks)

The diagram below shows a simplified diagram of the transmission of electricity from a power station to a substation. The current in the transmission lines is 200 A. **5**



Analyse the diagram quantitatively and qualitatively to describe the method of transmission of electricity from a generator (power station) to a substation (surburban area a substantial distance away) with minimal energy loss.

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Question 32 (9 marks)

The development of the current atomic model has involved the work of multiple scientists and included several specific experiments that led to new discoveries.

(a) Atomic models develop as scientists suggest solutions to the limitations of a previous model. However, all atomic models have their own limitations. **5**

Analyse this idea in terms of Rutherford's and Bohr's atomic models.

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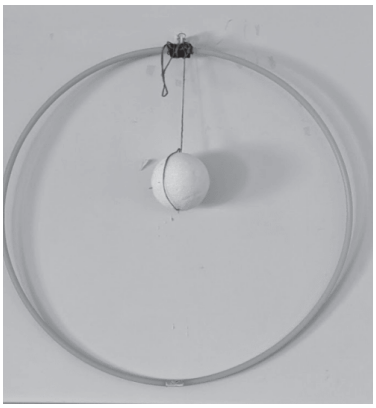
(b) A student was asked to construct a model to demonstrate the experiment used to develop Rutherford's model of the atom.

He used the setup in the photograph below – a suspended solid hoop with a heavy ball hanging on a string near the centre of the "atom".



He then threw 100 rice grains through the hoop and recorded how many passed through and how many were deflected by the ball.

Assess the use of the student's modelling experiment to demonstrate the development of Rutherford's model. **4**

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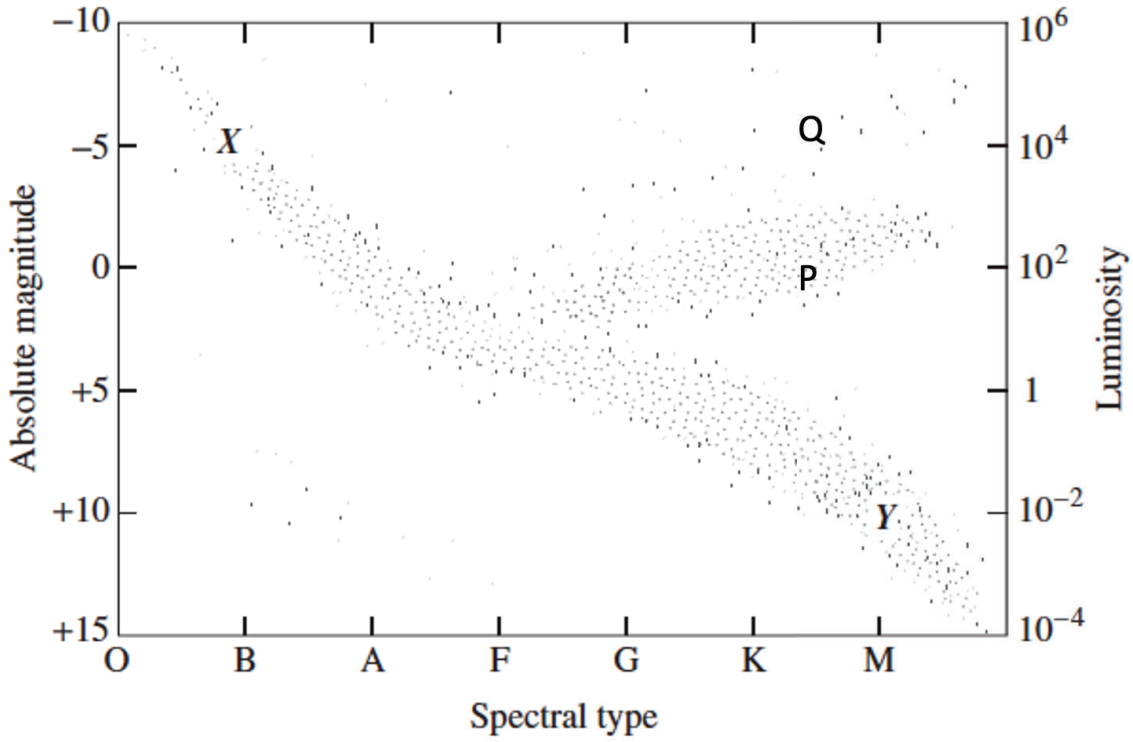
Question 33 (7 marks)

The diagram below shows the position of four stars, P, Q, X and Y on the Hertzsprung-Russell diagram. **7**



Compare the production of energy and predicted future life evolutionary path of these four stars.

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Question 34 (6 marks)

The photoelectric effect was one of the first experiments to confirm that light could act as a particle in certain situations.

(a) The wave model predicts that during the photoelectric effect, light of any frequency should release electrons, as energy would eventually build up enough to release an electron from the metal surface.

The table below shows the light wave prediction and the observations that were made through experiments.

Frequency (x 10^{14} Hz)	Light as a wave prediction	Observations
1.2	Electrons emitted	No electrons emitted
2.7	Electrons emitted	No electrons emitted
3.6	Electrons emitted	Electrons emitted
4.9	Electrons emitted	Electrons emitted

Explain why there is a difference in the prediction and observation. **3**

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(b) Describe another example of where wave theory and the observations do not match for the photoelectric effect. **3**

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Year 12 Physics Trial Exam
Marking Guidelines and Answers

MCQ Answers

1	2	3	4	5	6	7	8	9	10
D	B	B	A	C	B	A	C	C	A

11	12	13	14	15	16	17	18	19	20
C	D	A	C	C	D	D	C	C	B

Working for MCQ calc questions:

(2) $F = Eq$

$F = 9.6 \times 10^{-19} \times 1.0 \times 10^{4}$

$F = 9.6 \times 10^{-15}\ N$

(7) $486 \times 10^{-9}\ m$ $\quad E = hf = \frac{hc}{\lambda}$

$E = \frac{6.626 \times 10^{-34} \times 3.0 \times 10^{8}}{486 \times 10^{-9}}$

$E = \frac{4.0901 \times 10^{-19}}{1.602 \times 10^{-19}} = 2.55\ eV$

$4 \rightarrow 2 = -0.85 - (-3.40) = 2.55\ eV.$

(8) $\Delta m = (14.00307) - (13.00574 + 1.00867)$

$\Delta m = -0.01134\ u$

$\Delta m = 0.01134 \times 1.66 \times 10^{-27}$

$= 1.883574 \times 10^{-29}\ kg$

$E = \Delta mc^2 = (1.883574 \times 10^{-29}) \times (3.00 \times 10^{8})^2$

$= 1.69522 \times 10^{-12}\ J$

$E = 1.69522 \times 10^{-18}\ MJ$

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

$I = I_{max} \cos^2 30$

$\frac{I}{I_{max}} = 0.75 \quad \therefore \quad 0.75\ I_0$

(13) $R_1 = R$ $R_2 = 3R_1$ (2R+R = 2R above surface)

$g = \frac{GM}{r^2}$ $g_1 = \frac{GM}{R^2}$ $g_2 = \frac{GM}{(3R_1)^2} = \frac{1}{9} \times \frac{GM}{R_1^2}$

$\frac{1}{9} \times 9.76 = 1.084$

Qu 15

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

$v = 0.704c$

$c = 1.00$

$\sqrt{1-\frac{v^2}{c^2}} = \sqrt{1-\left(\frac{0.704}{1.00}\right)^2}$

$= \sqrt{0.50458}$

$= 0.7102$

correct

$20 = \frac{t_0}{0.7102}$

$t_0 = 14.204$ hours

incorrect

(1) $t = \frac{20}{0.7102}$ $t = 28.16$ hours. (obvious)

(2) $t = \frac{t_0}{0.504}$ $20 = \frac{t_0}{0.504}$ $t_0 = 10.08$ hours

(wrong (not $\sqrt{}$))

(3) $\sqrt{1-0.704} = 0.544$ ($\frac{v^2}{c^2}$ not squared)

$20 = \frac{t_0}{0.544}$ $t_0 = 10.88$ hours.

Qu 18

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

$\lambda = \frac{\ln 2}{t_{1/2}}$.

N_0 = initial
N_t = particles after time t

Correct

$\frac{N_t}{N_0} = e^{-\lambda t}$ $\qquad \frac{N_t}{N_0} = 0.05$

$0.05 = e^{-\lambda t}$.
$\ln(0.05) = -\lambda t$.
$\ln(0.05) = -\lambda \times 1.41912 \times 10^{14}$
$\lambda = -\frac{\ln(0.05)}{1.41912 \times 10^{14}}$
$= 2.11098 \times 10^{-14}\ s^{-1}$

4.5×10^6 years $\times$ $365 \times 24 \times 60 \times 60$
$= 1.41912 \times 10^{14}$ s.

Wrong

① net conv years → s. $= 6.657 \times 10^{-7}\ s^{-1}$

② $N_t/N_0 = 0.5$ $= 4.8843 \times 10^{-15}\ s^{-1}$

③ $N_t/N_0 = 5$ (use $\ln 5$) $= 1.1341 \times 10^{-14}\ s^{-1}$

Qu 19

$\frac{r_A^3}{T_A^2} = \frac{r_B^3}{T_B^2}$

$r_A = (1.15\times10^6 + 3.40\times10^6)$
$= 4.55\times10^6$ m

Theoretical radius B

$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$ $\quad r^3 = \frac{GMT^2}{4\pi^2}$

$r^3 = \frac{6.67\times10^{-11}\times6.42\times10^{23}\times(8.86\times10^4)^2}{4\pi^2}$

$r^3 = 8.5233\times10^{21}$ m.

$r = 2.0427\times10^7$ m

Theoretical period A

$\frac{r_A^3}{T_A^2} = \frac{r_B^3}{T_B^2}$

$\frac{(4.55\times10^6)^3}{(T_A)^2} = \frac{(2.0427\times10^7)^3}{(8.86\times10^4)^2}$

$(T_A)^2 = \frac{9.4196\times10^{19}}{\left(\frac{8.52342\times10^{21}}{7.84996\times10^9}\right)}$

$T_A = 9314$ s $\quad (2.58$ hours$)$.

correct

$\frac{r_A^3}{T_A^2} = \frac{r_B^3}{T_A^2}$

$r_A = 4.55\times10^6$ m $\quad (1.15 + 3.40\times10^6)$
$r_B = ?$
$T_A = 9314$ s
$T_B = 8.86\times10^4$ s

$\frac{(4.55\times10^6)^3}{9314^2} = \frac{r_B^3}{(8.86\times10^4)^2}$

$r_B^3 = 8.5237\times10^{21}$

$r_B = 2.043\times10^7$ m

$h_B = (2.043\times10^7) - (3.40\times10^6)$

$h_B = 1.703\times10^7$ m

incorrect

1. same as correct → don't subt radius
2. use altitudes only NOT radius
3. ??

Qu 20

$$\text{slope} = \frac{0.42 - 0}{7} = \frac{0.42 \times 10^{-3}}{7} \text{ (kg)}$$

$$\text{slope} = 6 \times 10^{-5} \text{ kg A}^{-1}$$

$$\text{slope} = \frac{M}{I} \quad \therefore \text{slope} \times 9.8 = \frac{F}{I}$$

$$\frac{F}{I} = B \times l \quad \therefore \quad 6 \times 10^{-5} \times 9.8 = B \times 2.0 \times 10^{-2}$$

$$B = 0.0294 \text{ T}$$

Incorrect:

(1) not conv to kg = 29.4 T

(2) not conv to kg or m = 0.294 T

(3) not conv to m = 2.94×10^{-4} T

QUESTION 21 - (3 marks)
Marker - Paul

(a) Band 2-5

Criteria	Marks
Correct substitution and calculation shown with correct unit identified	2
Some correct information	1

Generally well done
Marks usually lost by substitution error
Need to watch units in eq

21 a) $I = 1.5A$
$B = 0.5\ T$ $\theta = 90°$
$A = (0.06)^2 = 3.6 \times 10^{-3}\ m^2$
$n = 60$
$\tau = n B I A \sin\theta$
$\tau = 60 \times 0.5 \times 1.5 \times 3.6 \times 10^{-3}$
$\tau = 0.162\ Nm$
$\tau = 0.16\ Nm$ (2sf)

Max torque = $NIBA \sin\theta$
$= 60 \times 1.5 \times 0.5 \times (6 \times 10^{-2})^2 \sin 90$ (Max torque at $\angle = 90°$)
$= 0.162\ Nm^{-1}$

The coil is supplied with a current of 1.5 A and is placed in a magnetic field of strength 0.50 T. Calculate the maximum torque in the coil. **2**

$n = 60$ $I = 1.5$ $A = 0.06^2 = 3.6 \times 10^{-3}\ m^2$ $B = 0.5$

$\tau = nIA_\perp B = 60 \times 1.5 \times 3.6 \times 10^{-3} \times 0.5$

$0.162\ Nm$

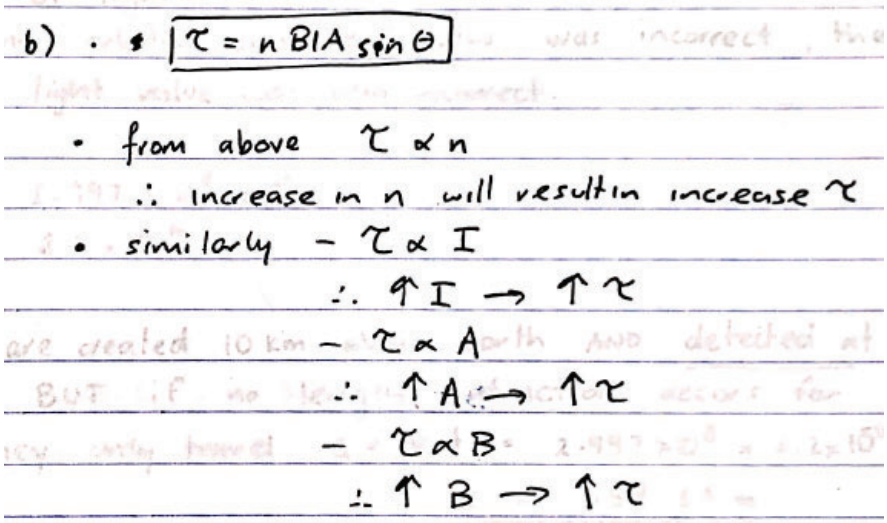
$\tau_{max} = 0.16\ Nm$ (2sf)

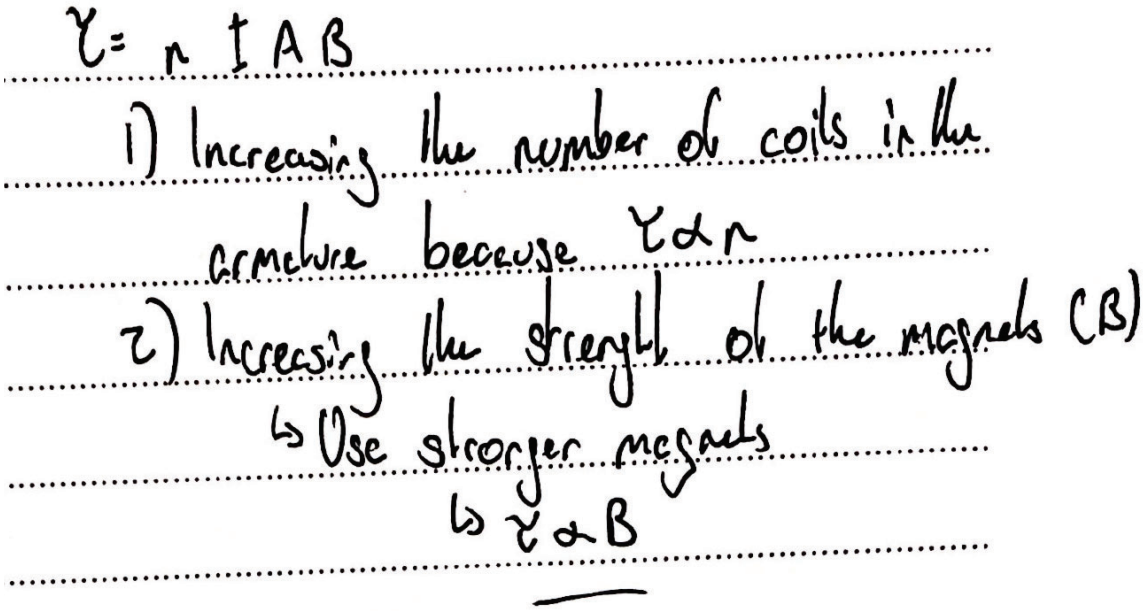
(b) Band 2-4

Criteria	Marks
Two valid adjustments identified with justification	3
One valid adjustment identified with justification OR Two valid adjustments identified	2
One adjustment identified	1

Generally well done
Straight forward if using equation for force
Needed to link arguments to equation

Answer:





1. Increase the current in the wire

→ By increasing the current the wire will experience a greater force in the field by $F = BIl\sin\theta$ and thus a greater torque resulting

2. Increase the strength of the magnetic field

→ By increasing the strength of the magnetic field - the coil will experience a greater force by $F = BIl\sin\theta$. a greater force in the field and thus a greater torque resulting.

⇒ By Right hand push rule, the force will be perpendicular to the coil (directed upwards). thus there will be more torque for both cases.

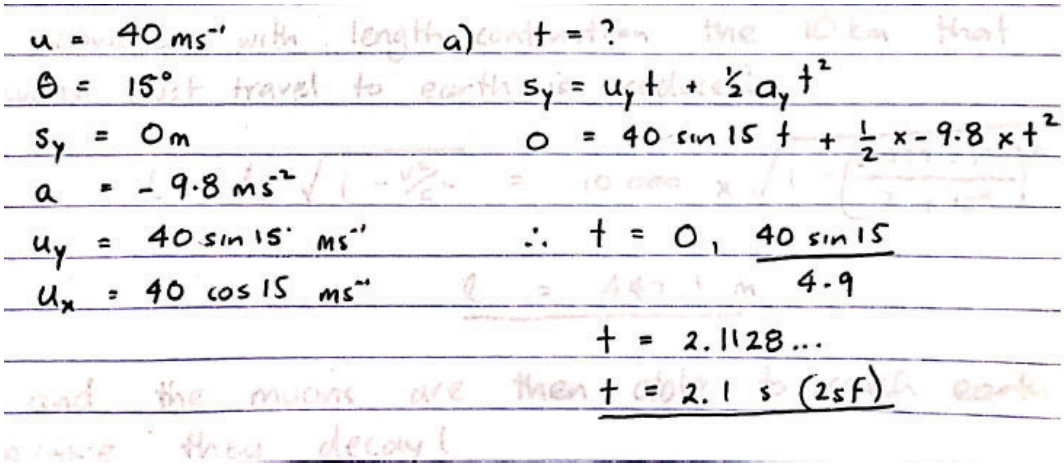
QUESTION 22 – (5 marks)
Marker - Paul

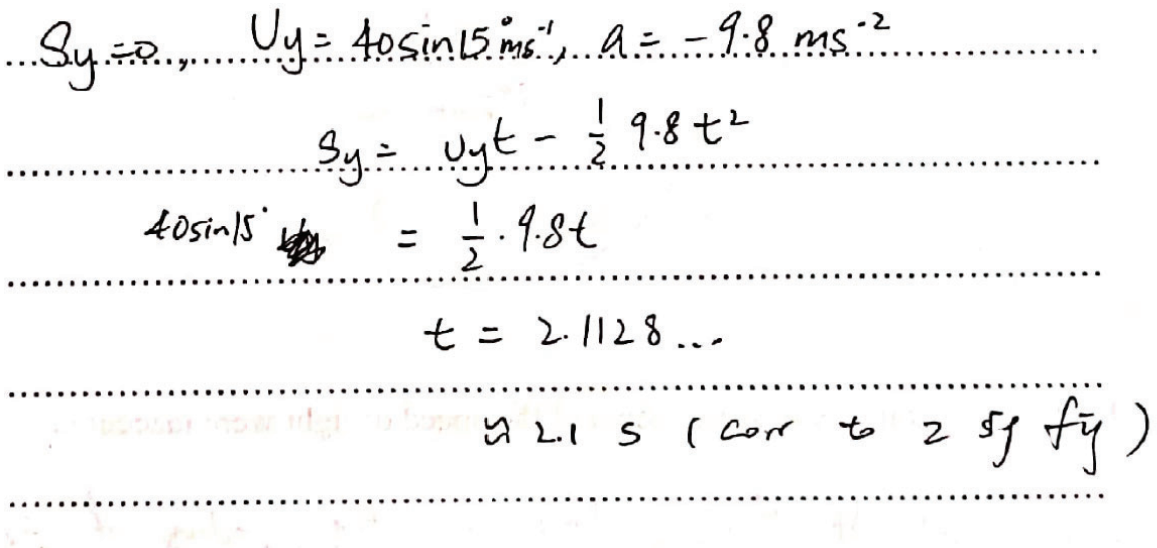
(a) Band 2-4

Criteria	Marks
Correct substitution and answer, including vertical component	3
Mostly correct substitution with minor errors	2
One valid step in calculation attempted	1

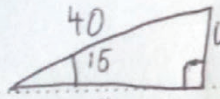
Needed working to show component vector and equation substitution
Errors mainly in x and y component velocity calculations

Answer:





Calculate the time of flight if the ball is caught at the same height as thrown. 3



when $v_y = 0$ $t = \frac{1}{2} t_{total}$

u_y: $\sin 15 = \frac{u_y}{40}$

$\therefore u_y = 10.35$

u_x: $\cos 15 = \frac{u_x}{40}$

$\therefore u_x = 36.64$

$v = u + at$

let $v_y = 0$ $0 = (10.35) + (-9.8)t$

$0 = 10.35 - 9.8t$

$9.8t = 10.35$

$t = 1.056$

$\therefore t_{total} = 2.11_5$ (3sf)

(b) Band 2-5

Criteria	Marks
Correct calculation of range and movement of catcher	2
One correct step in finding range	1

Mostly well done
If error from previous question students could still achieve full marks

Answer:

b) $S_x = u_x \cdot t$

$= 40\cos 15 \times \frac{40\sin 15}{4.9}$

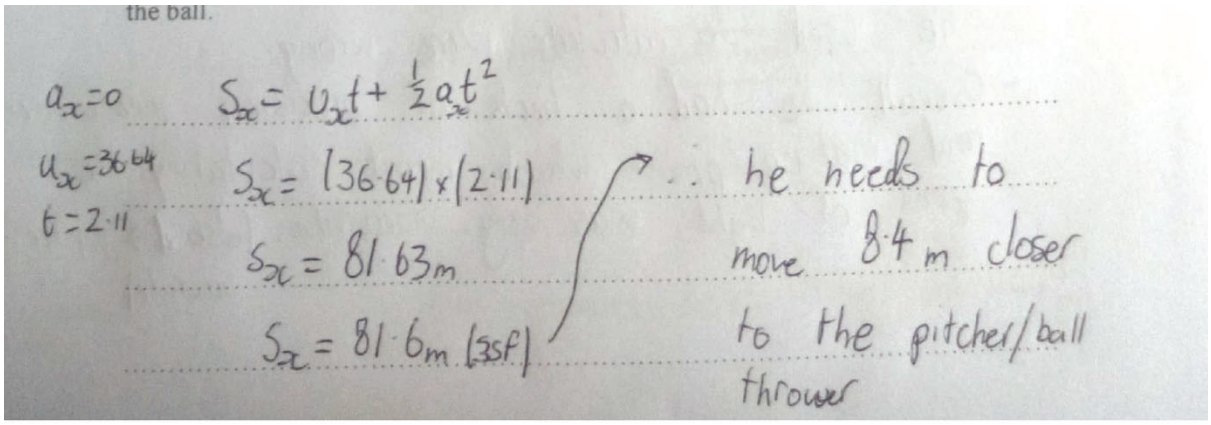
$S_x = 81.632653\ldots$

person is 90 m away

∴ person must move forward $90 - 81.632653\ldots$

∴ person moves forward $s = 8.367346$ m

$s = 8.4$ m (2sf)



Time of flight = 2.1s ∴ $U_x = 40\cos 15$

Range = $40\cos 15 \times 2.1$ s = 81.13 m ≈ 81m (2 sig fig)

∴ The ball falls ≈ 9m short of the catcher

∴ The catcher must move 9m towards the person in order to catch the ball.

QUESTION 23 – (6 marks)
Marker - Paul

(a) Band 2-5

Criteria	Marks
Identification of correct reason with link to speed of light measurement	2
Some relevant information	1

Poorly done – Orbital distances not known with accuracy
Students often quoted that the "radius of the earth was not known"

Answer:

a) Romer relied on incorrect data about the diameter of Earth's [redacted] orbit around the Sun to determine the speed of light.
Since the orbital diameter/radius was incorrect, the speed of light value was also incorrect.

Justify why Romer's measurements of the speed of light were inaccurate.

→ At Romer's time, the radius of Earth's motion was unknown ⇒ Accurate distance between Earth and Jupiter was not known
⇒ Inaccurate speed of light ∴ calculated.

Justify why Romer's measurements of the speed of light were inaccurate.

↳ Romers measurements were inaccurate due to the accuracy of the diameter of the earths orbit being poor *

↳ This resulted in a lower speed being calculated.

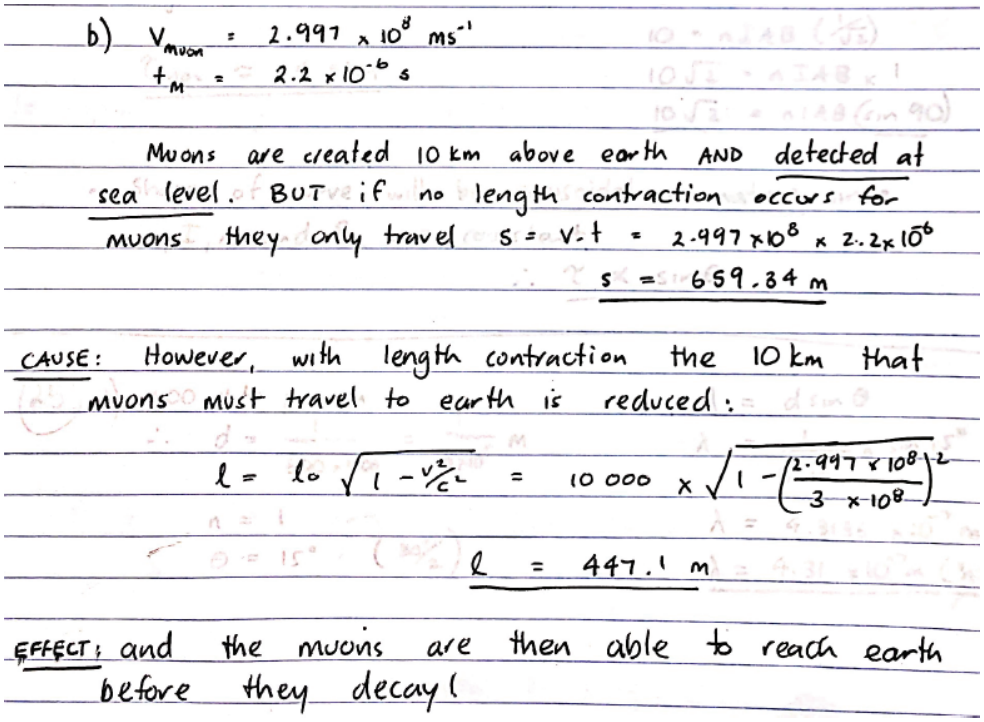
B1* ↳ As the calculations used the earths diameter of the orbits to find the speed of light. The calculated speed was using incorrect data giving an inaccurate result

(b) Band 2-6

Criteria	Marks
Extensive explanation of the application of length contraction to muons. Quantitative calculations included using stimulus data.	4
Thorough explanation of length contraction involving muons, with some quantitative aspect included	3
Sound explanation of length contraction OR through quantitative analysis completed	2
Some relevant information included	1

Generally done well
Some students unsure of how to qualify their answers without calculations
Still some errors in using the length contraction equation

Answer:



• In expectation life time × speed = distance travelled

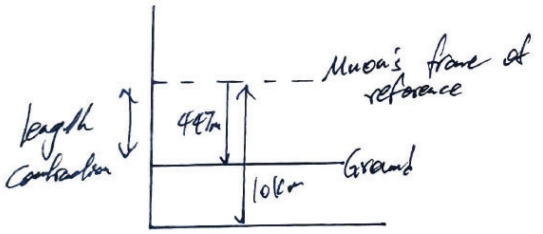
⇒ expected distance travelled by Muon = $(2.997\times10^{8}\,m/s)\times(2.20\times10^{-6}\,s)$

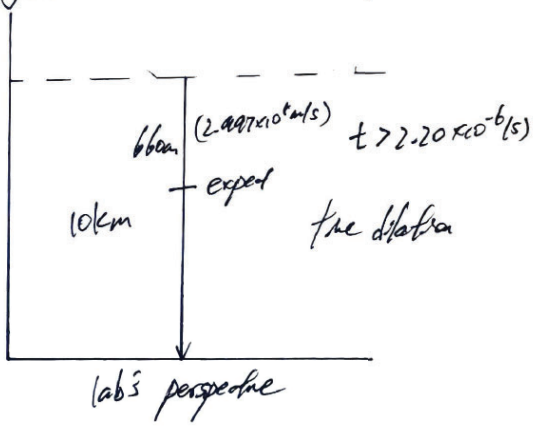
660m is no where close to 10km $\doteq 660\,m$

In scientist on earth observed Muon landing on the ground. Using length contraction ⇒

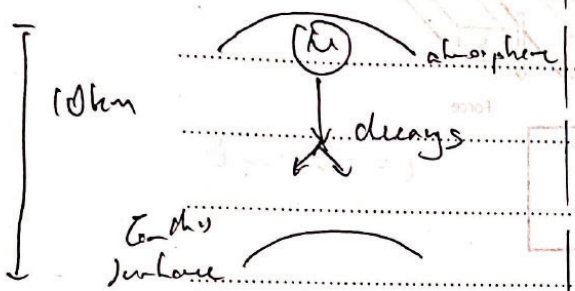
$L = L_0\sqrt{1-\frac{v^2}{c^2}}$, Actual length travelled by Muon in Muon's frame of reference $= 10\times10^{3}\times\sqrt{1-\left(\frac{2.997\times10^{8}\,m/s}{3.0\times10^{8}\,m/s}\right)^2} = 447\,m < 660\,m$

⇒ This provided evidence for length contraction which explained how Muon could land on earth.





Non-Relativistic



- Considering non-relativistic physics, the muons should not reach the surface of the Earth, as they will decay before they do so.
- Quantitatively:

$$s = ut + \frac{1}{2}at^2$$
$$= at \quad (a=0)$$
$$= (2.997\times10^8\,ms^{-1})(2.20\times10^{-6}s)$$
$$= 659.34m$$

$659.34m < 10000m$

$\therefore$ Muons should not reach Earth surface.

Relativistic

- However, although muons are actually detected (in abundance) on the Earth surface, and since it can be explained by length contraction, it provides evidence for it.
- Since the muons are travelling at relativistic speeds, the distance that they travel contracts in their direction of motion, allowing them to reach the surface before decay:

$$l = l_0\sqrt{1-\frac{v^2}{c^2}}$$
$$= (10000m)\sqrt{1-\frac{(2.997\times10^8\,ms^{-1})^2}{(3.00\times10^8\,ms^{-1})^2}}$$
$$\doteq 447m \ (3s.f.)$$

Since $659.34m > 447m$, this explains why muons are found at the Earth surface

$\therefore$ Muons show evidence of length contraction.

QUESTION 24 – Band 2-6 (5 marks)
Marker: Mr Solomonides

Criteria	Marks
Graph drawn correctly (sinusoidal shape) with max torque shown. Extensive justification of shape based on and linking torque formula and angle. Maximum, minimum angle and sin shape justified.	5
Graph shape correct (sinusoidal shape). Thorough justification of shape based on and linking torque formula and angle, with minor errors or omissions. Minimum angles and sin shape justified.	4
Graph has correct basic shape, with sound justification of shape using torque formula or relationship between torque/angle.	3
Some attempt at a justified graph shape is presented	2
Some attempt to draw a curve or identify the correct torque formula	1

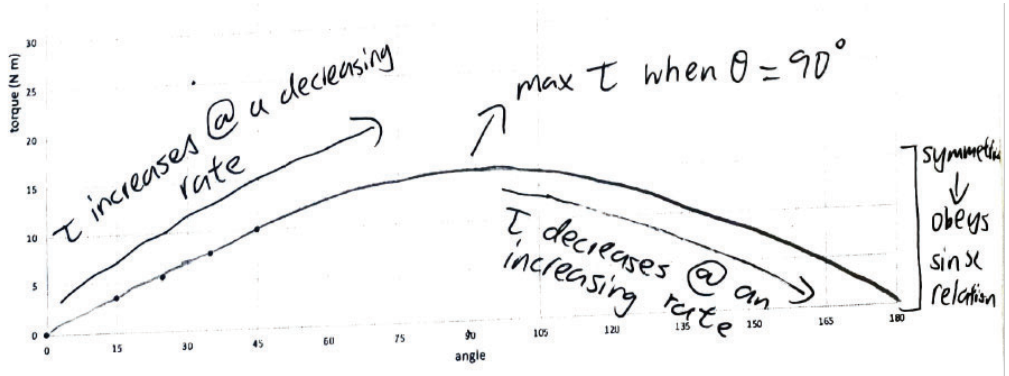
What Worked Well (WWW):

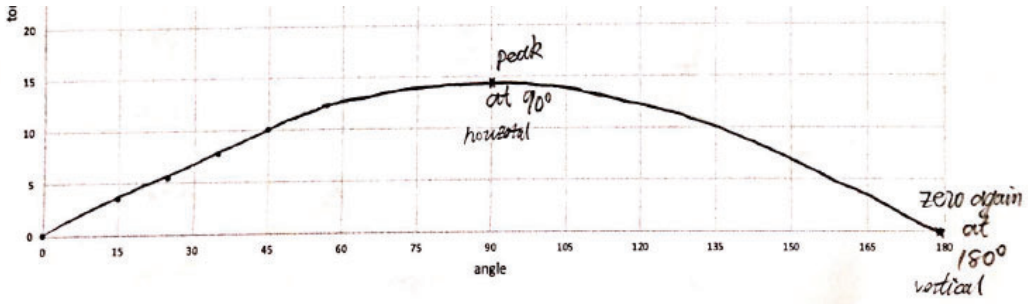
- A well attempted question with completing the graph and justifying the trend. Many boys scoring in the 3-5mark range.
- Main ideas of the shape of the trend written.

Even Better If (EBI):

- Must utilise/link/relate relevant equation(s) to your response. Your ideas or understanding can be purposefully and moreover, strongly developed when linking and relating to an equation.
- Use the mathematics to support your justification of the trend! It makes it easier to read, follow and more importantly, access more marks.
- Structure your response – be methodical in how you present your ideas.

Sample Answer:





Complete the graph to show the torque of the motor between 0-180 degrees and justify the trend of the graph you have drawn. 5

$\tau = nIAB\sin\theta$

→ n is constant (cannot change number of loops in a coil while motor is running)

→ I is constant as stated

→ B is constant (permanent magnet)

→ A is constant (can't change area of the coil).

∴ $\tau \propto \sin\theta$ only affected by θ.

SHAPE

→ ∴ T graph will be a sinusoidal curve with a maximum at $\theta = 90°$ as $\sin(0) = 1$

$\sin(0) = 0$

$\sin(180) = 0$.

→ the graph will be symmetrical about 90° due to $\sin(\theta) = \sin(90 + \theta)$ $0 \leq \theta \leq 90$.

→ PEAK

→ when $\theta = 45$ $\tau = 10$ so $nIAB = \frac{10}{\sin(45)}$

∴ max $\theta = 90°$ ∴ $\tau = \frac{10}{\sin(45)} \times \sin(90)$

$= 14.142$.

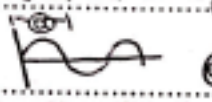
$\tau_{max} \approx 14$

Complete the graph to show the torque of the motor between 0-180 degrees and justify the trend of the graph you have drawn. 5

$\tau = nIAB\sin\theta$

↳ the shape of the graph is a sine curve

- this is as τ is $\propto \sin\theta$ which increases at a decreasing rate until 90° and decreases at an increasing rate afterwards

↳ follows sine curve  as shown on graph

↳ The graph is at a maximum when $\theta = 90$

- this is as $\sin 90 = 1$, which is the highest value that $\sin\theta$ can give

↳ After 90°, the all points are equal to it opposite pairing on the graph (parabolic shape)

↳ this is as $\sin\theta$ is equal to $\sin(180-\theta)$

↳ Max point when $\sin\theta = 90$

↳ eqns $\tau_1 = nIAB\sin 90$, $\tau_2 = nIAB\sin 45$

$$\frac{\tau_1}{\tau_2} = \frac{\sin 90}{\sin 45} \quad (nIAB \text{ constant})$$

$$\tau_1 = \frac{\tau_2}{\sin 45}$$

$$= \frac{10}{\sin 45}$$

$$= 14.14\,m$$

Main ideas summarised below:

- If $\tau = 0$ at $\theta = 0°$, then $\tau = 0$ at $\theta = 180°$ from equation

- Also at $\theta = 90°$ τ will be maximum.

  using $\theta = 45°$ and $\tau = 10$

  $\tau_{max} \simeq 14$ Nm

$$\tau = nIAB \sin\theta$$
$$10 = nIAB\left(\frac{1}{\sqrt{2}}\right)$$
$$10\sqrt{2} = nIAB \times 1$$
$$10\sqrt{2} = nIAB(\sin 90)$$

- Shape of curve will be sinusoidal in nature since n, I, A and B are constant

$$\therefore \tau \propto \sin\theta$$

QUESTION 25 – (6 marks)
Marker: Mr Solomonides

(a) Band 2-6

Criteria	Marks
Correct substitution into appropriate equation and correct answer with working.	2
One correct step in the calculation presented	1

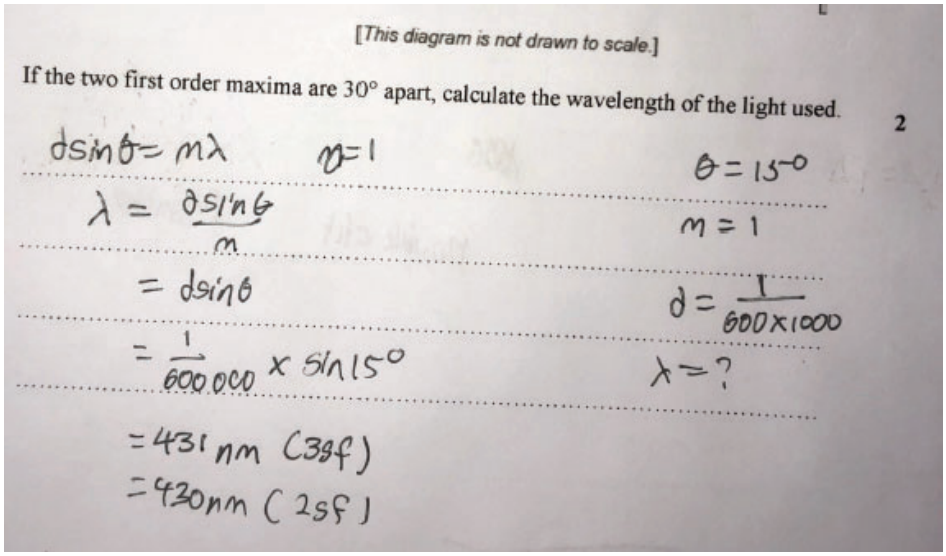
What Worked Well (WWW):

- All students engaged with the question identifying the correct formula to use and apply. Responses showed good mathematical structure with units.

Even Better If (EBI):

- Read The Question AND annotate the stimulus. Far too many responses showed incorrect substituted value for the sin theta. Some responses also incorrectly substituted incorrect value for *m* and *d.*
- Stop and check the value of your answer when finished a calculation. If you get an answer ranging from 0.2m to 1.4m for the wavelength; just ask yourself, 'does this answer seem correct for the wavelength of light?'

Sample Answer


[This diagram is not drawn to scale.]

If the two first order maxima are 30° apart, calculate the wavelength of the light used. 2

$d\sin\theta = m\lambda$ $\quad m=1$ $\quad \theta = 15^{-0}$

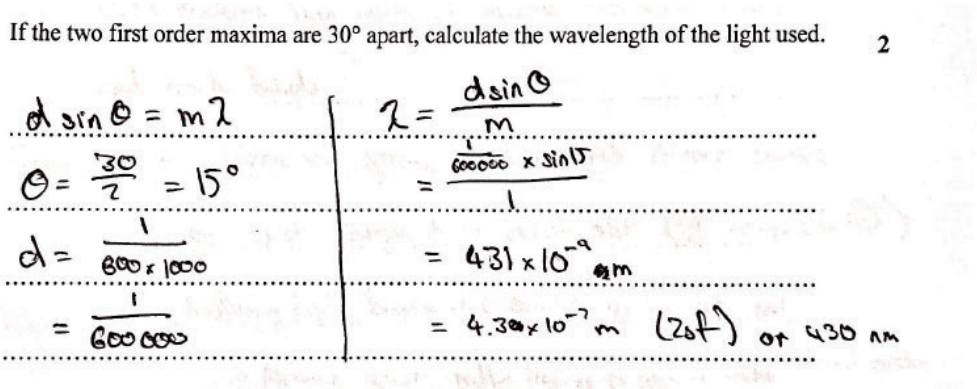
$\lambda = \frac{d\sin\theta}{m}$ $\quad m = 1$

$= d\sin\theta$ $\quad d = \frac{1}{600\times1000}$

$= \frac{1}{600000} \times \sin 15^{0}$ $\quad \lambda = ?$

$= 431\,nm$ (3sf)

$= 430\,nm$ (2sf)


If the two first order maxima are 30° apart, calculate the wavelength of the light used. 2

$d\sin\theta = m\lambda$ $\quad \lambda = \frac{d\sin\theta}{m}$

$\theta = \frac{30}{2} = 15^{\circ}$ $\quad = \frac{\frac{1}{600000} \times \sin 15}{1}$

$d = \frac{1}{600\times1000}$ $\quad = 431\times10^{-9}\,m$

$= \frac{1}{600000}$ $\quad = 4.30\times10^{-7}\,m$ (2sf) or 430 nm

(b) Band 2-6

Criteria	Marks
Three valid differences clearly and thoroughly described	4
Two valid differences clearly and thoroughly described OR Three valid differences described	3
One valid difference described OR Two valid differences identified	2
Some relevant information	1

What Worked Well (WWW):

- Many students engaged reasonable well with this question showing an understanding of the features of a double slit and diffraction grating.
- A diagram or sketch was drawn of a double slit and diffraction pattern.

Even Better If (EBI):

- Read The Question – it asked for Contrast (which means differences). Many responses showed similarities between the double slit and the diffraction grating. Similarities was not required and ignored when marking.
- Most responses lacked structure. Your response could be in the form of a table, dot points, sub-headings or numbered differences.
- Be clear and specific in your writing and when showing your ideas and understanding. Don't assume the marker 'knows what you mean.'
- Annotate/label a diagram or sketch when used in a response and relate to it.

Sample Answer:

dif — wide — Blurry

Contrast the main features of the double slit and diffraction patterns the student observed. 4

(Bright Bands)

D_1 — The maxima observed on a double slit pattern are wide, as seen on the diagram above. On a diffraction grating interference pattern, however they are more thin

D_2 — Additionally, on a double slit interference pattern, bright bands observed are blurry (as seen above) whereas on a diffraction grating interference pattern less more strong (less blurred) bright bands

D_3 — on a double slit interference pattern, maxima appear the same distance apart (as seen above) whereas on a diffraction grating pattern, the distance between maxima increases as the maxima number increases

D_4 — on a double slit pattern, the relative intensity of the maxima decreases as the maxima number increases. On a diffraction grating, this does not occur, with 23 all bright bands having similar intensities.

Contrast the main features of the double slit and diffraction patterns the student observed. 4

• In diffraction grating pattern, the maxima appear as bright dots that are sharp, whereas in double slit pattern, the maxima appear as bright bands that are blurry.

• In diffraction grating pattern, intensities of maxima are the same, whereas in double slit pattern (in real life), the intensities decrease as the pattern spreads out from centre (due to Fraunhofer diffraction)

• Diffraction grating: V.S. Double slit:

Dark and bright spots are not of equal width (distance between maxima increases as order increases) (∴ Δy doesn't exist)

Dark & bright bands are of equal width ∴ Δy exists

QUESTION 26 – (7 marks)
Marker - Mr Solomonides

(a) Band 2-6

Criteria	Marks
Extensive explanation of magnetic braking explicitly using both Faraday and Lenz's laws.	4
Thorough explanation of magnetic braking including reference to both Faraday and Lenz's laws	3
Sound explanation of magnetic braking using some electromagnetic induction theory	2
Some relevant information	1

What Worked Well (WWW):

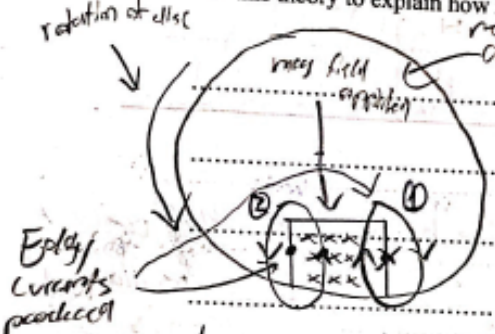
- A very well attempted question here where many boys accessed the 3-4 mark range, obviously practice questions through completing 'weeklies' and past paper questions and revision around this concept has helped and rewarded.
- Many showed some annotating of the stimulus and referred to this in their response.

Even Better If (EBI):

- Structure your response – be methodical in how you present your ideas.
- Must refer to BOTH Faraday and Lenz's laws (and write the names too).
- Many students need to develop the concept and application of Lenz's Law and 'eddy current.' Eddy currents produce their own magnetic fields which have polarities such that they exert a force to oppose the motion that caused the emf to be induced.
- Some of the concepts explored appeared 'robotic/automated' or rehearsed. Must refer and specifically link to the stimulus of magnetic braking.

Sample Answer

(a) Electromagnetic induction can be used to explain why magnetic braking slows the car. Use this theory to explain how magnetic braking works. 4



Faraday's Law

↳ As the Electromagnet is placed on, a magnetic field is diected into the disc, this causes a change in flux Φ which in turn generates an EMF of magnitude $-N\frac{\Delta\Phi}{\Delta t}$ in disc by Faradays Law.

Lenz's law ↳ Lenz's law states this emf will have ~~how~~ have currents with their own magnetic fields that oppose the motion which initially caused the change to flux. with ~~the~~ disc holes ~~flux~~ flow as eddy currents in the metal as demonstrated by ① and ② in diagram. thus the fields push against the direction of motion causing braking.

↳ Therefore Kinetic energy is lost in machine as eddy currents experience resistance in metal causing ~~a~~ a conversion to heat energy - causing braking.

(a) Electromagnetic induction can be used to explain why magnetic braking slows the car. Use this theory to explain how magnetic braking works. 4

- The metal disc passes through the electromagnets as there is a relative movement of the disc to the magnetic field (provided the E-magnet is switched on). There is a change in flux.
- According to Faradays law of induction, this induces an EMF (Electromotive force) causing the delocalised electrons in the metallic lattice to move and form eddy currents.
- According to Lenz's law, these eddy currents will act to oppose the change in flux which caused them & therefore their magnetic field (moving charged particles have a magnetic field), interacts with that of the Electromagnets electric field, producing a resistive force thereby reducing the rate of change of flux
- As such, the car slows due to the resistive force from the formed eddy currents ⇒ regular Braking.

Main ideas summarised below:

(26) a) CAUSE • Electromagnet switched on

EFFECT • spinning metal brake disc experiences $\Delta\phi$

(ELECTROMAGNETIC INDUCTION) → ∴ ε induced in metal disc (Faraday's L.)

∴ eddy currents flow in metal disc

∴ magnetic fields are created by Eddy cur.

These magnetic fields will have polarities such that they exert a force to oppose the motion that caused the ε to be induced. (Lenz Law)

∴ this force slows the wheel

This is electromagnetic braking.

(b) Band 2-6

Criteria	Marks
Law of conservation of energy explicitly used to explain BOTH observations	3
Law of conservation of energy explicitly used to explain ONE observation OR A sound explanation of BOTH features	2
Some relevant information	1

What Worked Well (WWW):

- The Law of Conservation of Energy is well understood.

Even Better If (EBI):

- avoid the paraphrasing and rephrasing the question here.
- Answer The Question and refer/link to the law of Conservation of Energy.
- Strengthen your understanding of Eddy currents forming heat, more like… 'this is the result of the eddy current flow in the metal disc resulting in resistive heating…'

Sample Answer

(b) Under magnetic braking the car decreases in velocity and the metal brake disc increases in temperature. **3**

Use the law of conservation of energy to explain these observations.

Due to the slowing in velocity, the car loses kinetic energy as $k=\frac{1}{2}mv^2$ & as $v \downarrow$ $k \downarrow$. Due to the law of conservation of energy, this loss of energy must be converted into another form. As such, the kinetic energy is converted to heat energy by the resistive heating of the magnetic breaking disc & magnet induced eddy current.

Main ideas summarised below:

(26). (b) Conservation of Energy states that energy total within a system is constant.

CAUSE: The vehicle has kinetic energy which will be reduced as the vehicle slows

Since the energy total is constant, this energy must be transformed.

EFFECT: Thermal energy of the metal disc INCREASES.

This is the result of the eddy current flow in the metal disc resulting in resistive heating.

(26). (b) Conservation of Energy states that energy total within a system is constant.

CAUSE: The vehicle has kinetic energy which will be reduced as the vehicle slows

Since the energy total is constant, this energy must be transformed.

EFFECT: Thermal energy of the metal disc INCREASES.

This is the result of the eddy current flow in the metal disc resulting in resistive heating.

QUESTION 27 – Band 2-5 (4 marks)
Marker - Anne

Criteria	Marks
- All parts of atoms (quarks, leptons, protons, neutrons, electrons) described - Two fundamental forces role described	4
- Nucleus of atom described or all particles mentioned/identified - Role of strong nuclear force in nucleus formation identified	3
- Identification of protons, neutrons and electron arrangement - AND - identification of fundamental forces OR decoupling of forces	2
- some relevant information regarding fundamental forces or atomic particles	1

Marker comments:

- Marking scheme had to be massively changed due to a general lack of knowledge in this area.
- Students did not break question down:
    - *By considering the role and importance of the fundamental forces* – you needed to identify the fundamental forces and describe what they do – most students could not correctly name all four forces, let alone provide a description of what they do.
    - *Outline the process by which atoms formed in the early universe* – discuss what an atom is (majority of students could not identify a nucleus with protons and neutrons, surrounded by electrons) – discuss how these particles formed (majority of students think p/n are fundamental particles and electrons are made by joining leptons) – discuss how particles formed, what the fundamental particles are, why the universe needed to cool for atoms to form….
- Role of forces very misunderstood
    - Strong nuclear force (note… the name has NUCLEAR in it, it's not the "strong force") – responsible for joining quarks to form p/n and joining p/n to form the nucleus
    - Weak nuclear force – NOT RELEVANT IN ATOM FORMATION OR STRUCTURE
    - Gravitational force – sure, it might attract particles together, but it does not act in formation of the nucleus
    - ELECTROMAGNETIC FORCE – NOT the electrostatic force that was most common – allows electrons to orbit the nucleus.
- Concepts need urgent review.

Sample answer:

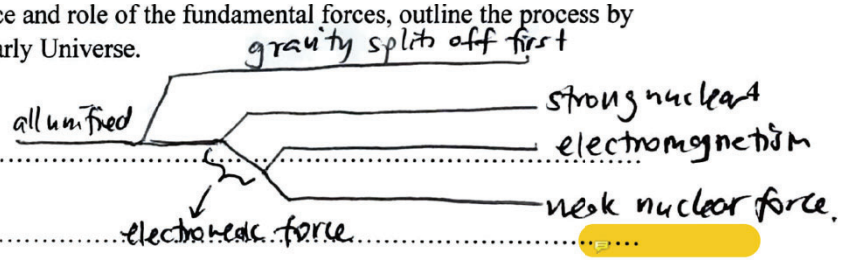
(27) As the universe expanded and cooled the most fundamental particles - leptons, quarks - were formed by conversion of energy to matter.

- 10^{-6} s → 1s — SNF bonds QUARKS to form HADRONS such as PROTONS and NEUTRONS
- 3 min – 20 min — SNF bonds PROTONS and NEUTRONS to form small nuclei such as H-2, He-3, He-4, Li
- 240 000 yrs – 300 000 yrs — EM force brings electrons into orbit around the above nuclei forming atoms

Sample student answer:

By considering the importance and role of the fundamental forces, outline the process by which atoms formed in the early Universe.

Timeline of forces:



(1) Just after the Big Bang the temperatures were about 10^{32} K and too hot for any form of matter to exist. Thus, only energy existed at the time.

(2) As temperatures cooled at the universe underwent rapid expansion leptons, quarks and bosons (force particles) began to form. As seen in the diagram above, at about 10^{-3} s after the explosion, proton and antiproton formed, while electron and positron formed at about 10^{2} seconds

- Overall, slightly more matter was created thus allowing the formation of matter than antimatter.

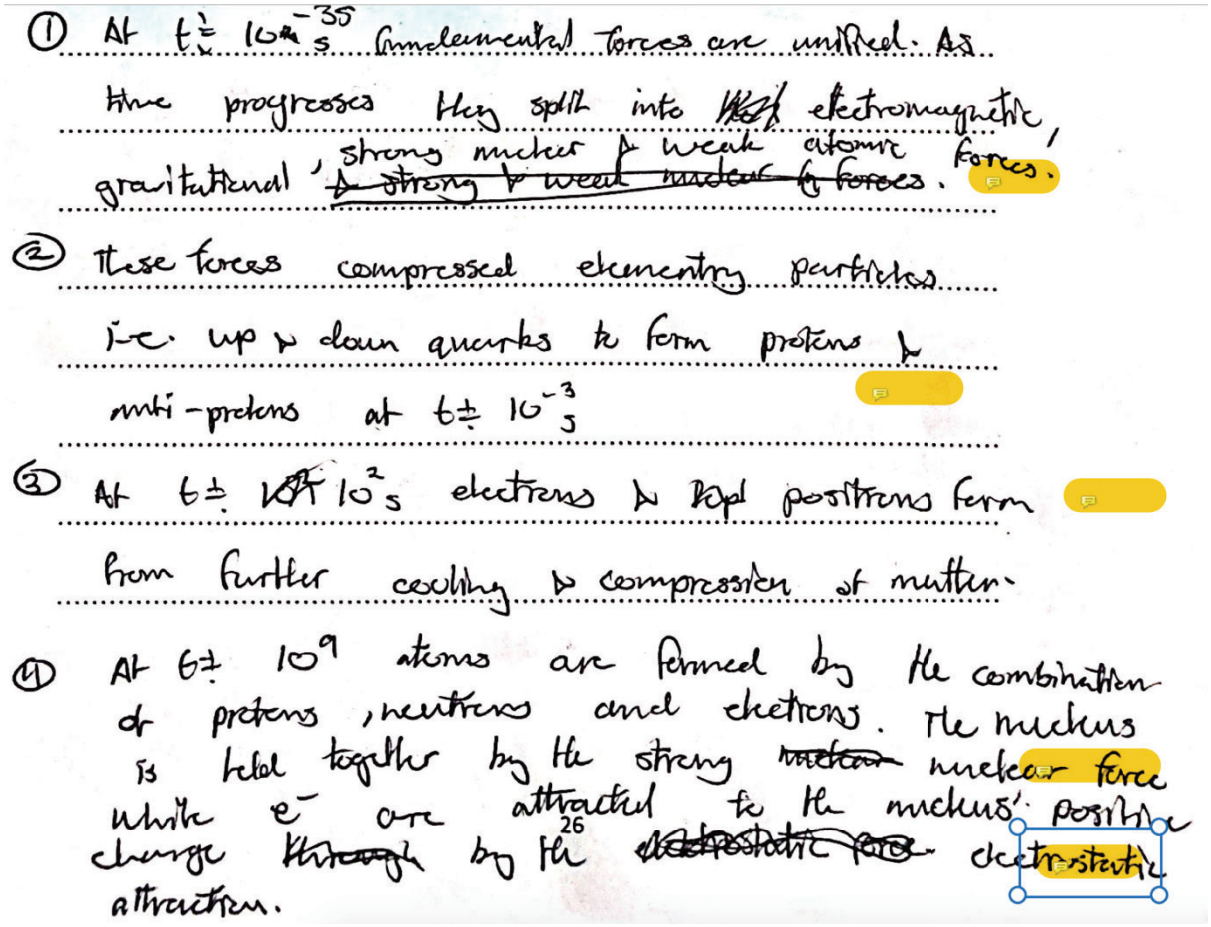
(3) the decoupling of the 4 forces allowed atoms to form.

- The strong nuclear force (mediated by the gluon) allowed for quarks to combine to form hadrons (baryons like protons and neutrons)
- The weak nuclear force allowed for hadrons to interconvert (e.g. protons into neutrons)
- The electromagnetic force also prevented positive protons from combining together via a repulsive force.

(4) These protons and neutrons combined via the strong nuclear force, and by 380 000 years, the universe cooled to 3000K and allowed nuclei to capture electrons via the electrostatic force.

(5) Hence, atoms were formed in the early Universe.

Sample student answer 2 (more concise):



① At $t \doteq 10^{-35}$ s fundamental forces are unified. As time progresses they split into electromagnetic, gravitational, strong nuclear & weak atomic forces.

② These forces compressed elementary particles i.e. up & down quarks to form protons & anti-protons at $t \doteq 10^{-3}$ s

③ At $t \doteq 10^{2}$ s electrons & their positrons form from further cooling & compression of matter.

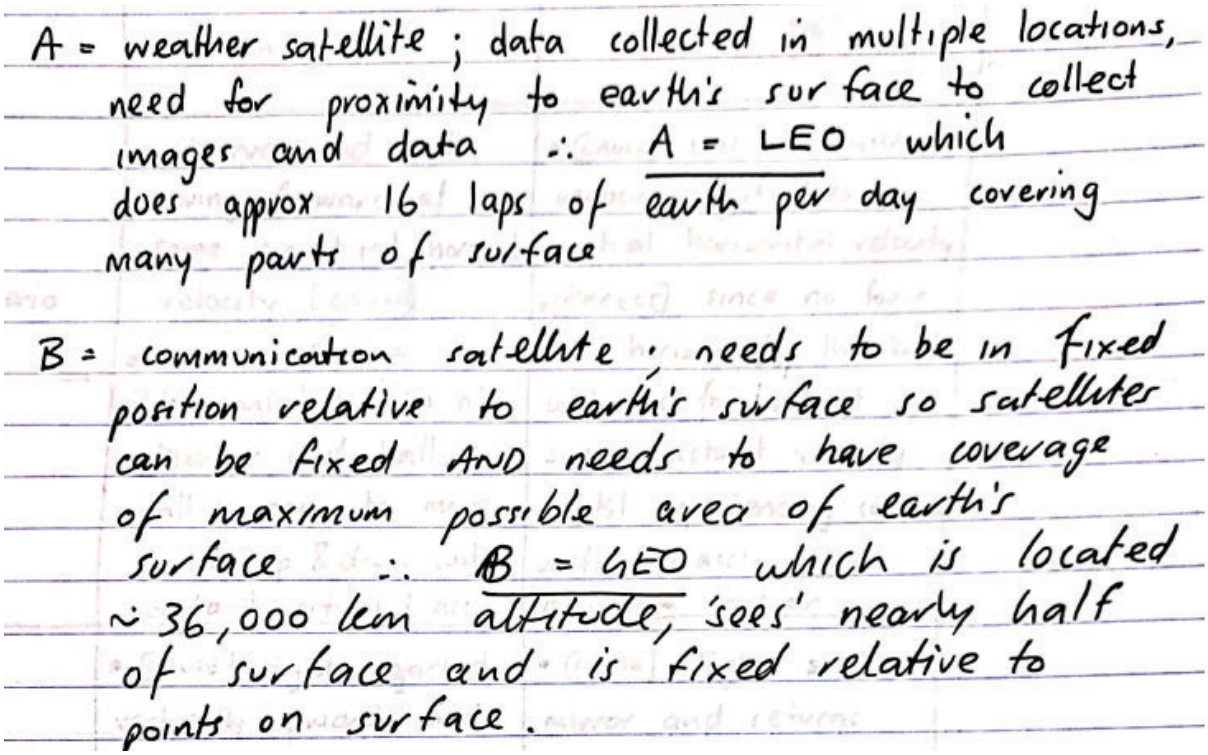
④ At $t \doteq 10^{9}$ atoms are formed by the combination of protons, neutrons and electrons. The nucleus is held together by the strong nuclear force while e^- are attracted to the nucleus' positive charge by the 10^{26} electrostatic attraction.

QUESTION 28 – Band 2-5 (3 marks)
Marker - Ethan

Criteria	Marks
Correct identification of each satellite, with thorough justification provided using stimulus data. Features of orbit correctly identified.	3
Correct identification of each satellite with some justification referring to either uses or orbital features.	2
Some relevant information	1

Students had difficulty in linking roles and orbital behaviour
Need a "thorough" description to gain full marks

Answer:



- Satellite A - Due to it's requirements to cover a large area quickly, be close to Earth to take high quality images, it requires a low radius, and short period, ∴ a low Earth orbit (LEO) is best suited

- Satellite B - Due to the requirements of the satellite to maintain connection over one location, it would be best suited to have a period (T) matching the period of Earth, ∴ a geostationary (LEO) orbit is better suited

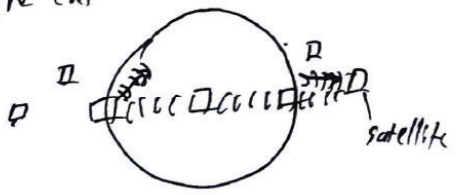
Satellite A: LEO satellite.

LEO Satellite generally have a low altitude. This allows clear & quality images to be taken of ~~weather~~ Earth's atmosphere & allow better analysis of weather. by $\frac{mv^2}{r} = \frac{GMm}{r^2}$, $v = \sqrt{\frac{GM}{r}}$, as altitude decrease, velocity of satellite is also high allowing satellite to orbit Earth quickly with a lower period. This allow weather of different continent to be recorded by satellite as it orbit Earth quickly

Satellite B: GEO satellite.

GEO satellite has an altitude of 36000 km, This altitude allows satellite to orbit Earth at the period same as earth rotational period. GEO stays above equator, allowing ~~GEO~~ satellite to be above the same position on earth

multiple GEO orbits the earth



This GEO satellite system allows information to be transferred, ~~for~~ for communication

QUESTION 29 – Band 2-6 (5 marks)
Marker - Ethan

Band 2-6

Criteria	**Marks**
Extensive description of the structure of the particles and overall nature of the helium-4 atom. Including the following: • Composition of protons and neutrons – including names for quarks • Electrons are leptons and fundamental particle • Reference made to the role bosons/gluons in mediating strong nuclear force in the nucleus	5
Thorough description of the structure of the helium-4 atom with one minor error/omission OR Extensive description of fundamental particles but bosons not incorporated	4
Thorough description of the structure of the helium-4 atom with multiple minor errors/omissions OR Sound description – one key omission	3
Some correct features described in a limited manner	2
Some relevant information OR Response has no relevance to the standard model of the atom	1

WWW (What worked well)

- Student responses were very clear, with good use of structure evident in a good number of student responses
- Students that incorporated a diagram really made their response stronger, in questions like these, a diagram speaks a thousand words – just remember to use your diagram! Annotate it, refer to it in your response! Don't just draw one and then ignore it.

EBI (Even better if)

- Students need to read the question! A very high proportion of students did not refer to the standard model of the atom in any way.
- Students need to refer to ALL parts of the standard model, including the force particles – were not able to achieve top marks without this.

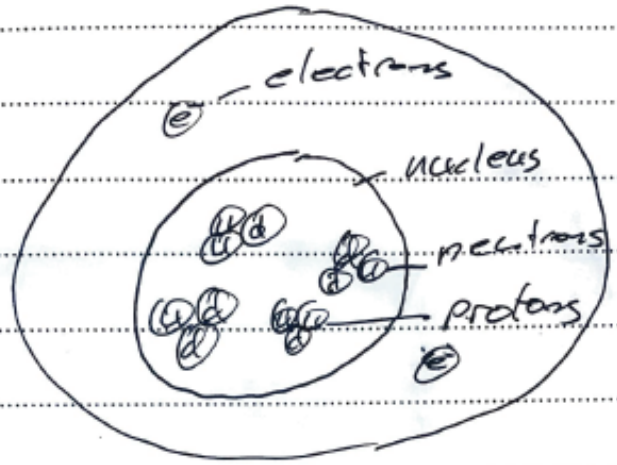
General Markers Comments

- This question is VERY similar to a question provided to students in their revision package (the only word changed was hydrogen to helium), therefore it rewarded students that completed good revision and got feedback from their teachers and peers.
- Handwriting is an issue, it needs to be legible to markers, if we cant read it, we cannot mark it.

Student samples

Question (9 marks)

Use the Standard Model to describe the structure of the helium-4 atom. -> ^4_2He 5



In Nucleus: nucleus contains 2 protons and 2 neutrons which are made up of 2 ups and 1 down or 2 down and 1 up quarks respectively
∴ the charges of the neutron equals 0 as a down has a charge of $-\frac{1}{3}$ and an up has a charge of $+\frac{2}{3}$
∴ the composition of the Nucleus is shown above as helium has 2 protons

outside nucleus - electrons are fundamental particle so can't be divided into smaller components like protons and neutrons
∴ have a charge of -1 each
∴ electrons combine to have -2 charge
This balances with the positive charge of the nucleus due to the protons
∴ atom has balanced charges

Question 29 (5 marks) ^4_2He

Use the Standard Model to describe the structure of the helium-4 atom. 5

→ A helium atom is written as ^4_2H, the atomic number of 4, means 2 protons and 2 neutrons, mass number of 2 means 2 protons/2 electrons

→ A proton is made of 2 up quarks and one down quark

↳ $u = +\frac{2}{3}$ charge & $d = -\frac{1}{3}$, creating the +1 charge

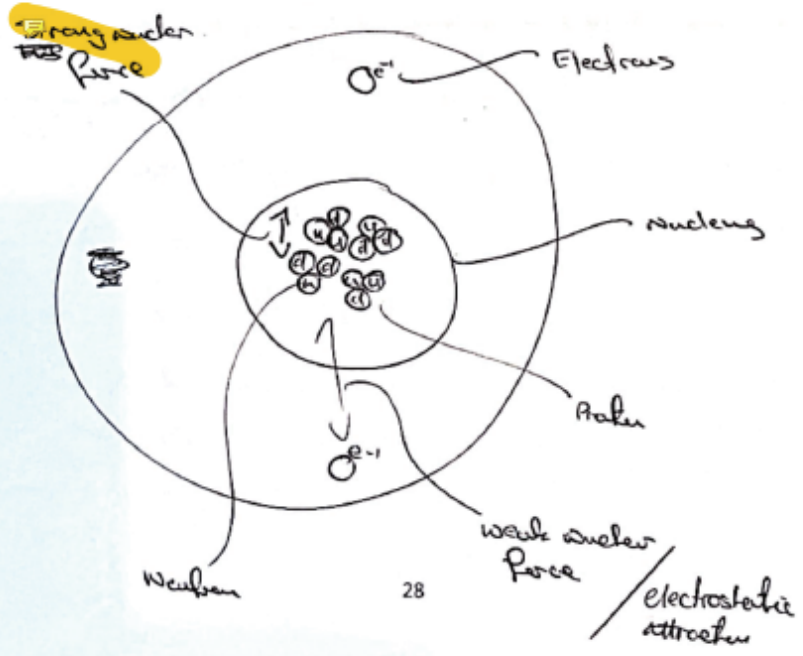
→ A neutron is made of 2 down quarks and one up quark

↳ $u = +\frac{2}{3}$ $d = -\frac{1}{3}$, resulting a neutral charge total

→ Electrons are fundamental particles in the region paired with a −1 charge.

→ As shown below the centre of atom nuclie will the nucleus with protons surrounded by the electrons and held by forces.

Atom Model



QUESTION 30 – Band 2-6 (7 marks)
Marker - Adam

Criteria	Marks
Extensive explanation of observations of relative motion in Scenario 1. AND Extensive explanation of the observations of special relativity and time dilation in Scenario 2	7
Thorough explanation of BOTH scenario observations with minor errors or omissions	6-5
Sound explanation of BOTH scenario observations with key errors or omissions. OR Thorough explanation of ONE scenario observations with minor errors/omissions	4-3
Multiple relevant points made	2
Some relevant information provided	1

If only one scenario – MAX = 4 marks

WWW (What worked well)

- Responses were very clearly written, with good use of structure evident and thorough knowledge obvious in a significant proportion of student work.
- Students incorporated an effective, labelled diagram or annotated the stimulus and were able to enhance their response, and write less, as a consequence.

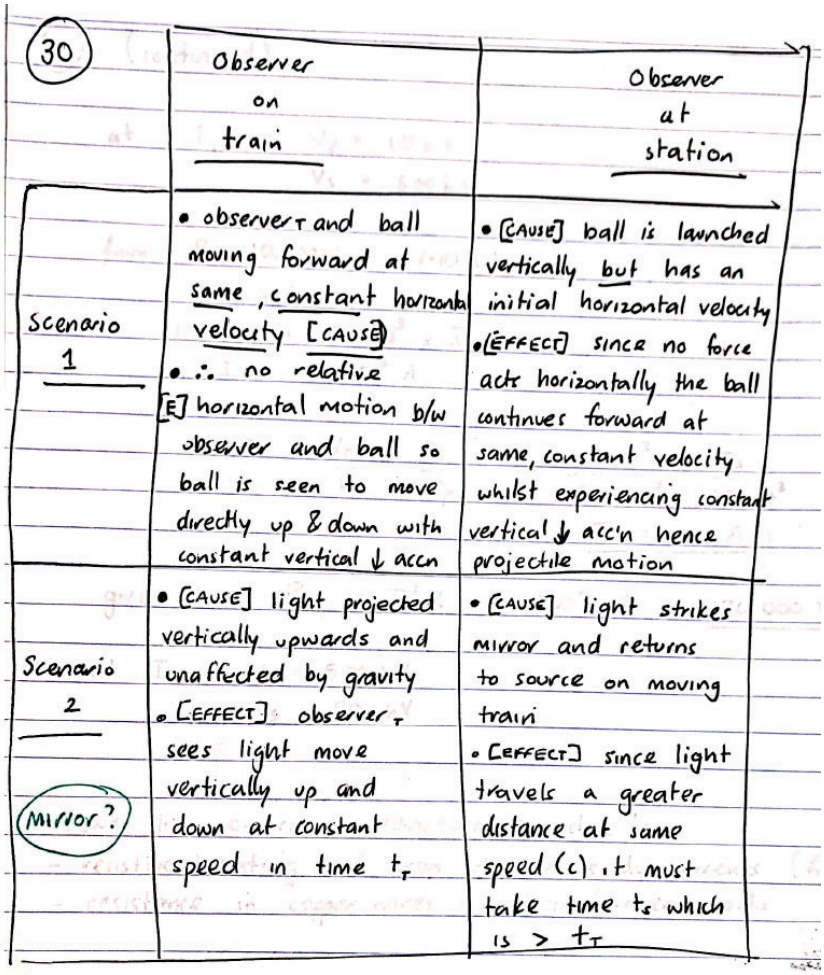
EBI (Even better if)

- Students need to read the question and use the stimulus to inspire their response! A very high proportion of students did not relate their response to the stimulus in any effective way. Quite a few students addressed ONLY ONE SCENARIO
- Students need to have a clear structure, with subheadings, so that it is obvious what they are writing about.
- Students need to practice phrases that are effective scientific writing to improve communication.
- Students need to communicate at a level of sophistication appropriate to the course, level and question. Some responses were overly simplistic and, thus, not appropriate for a YEAR 12 PHYSICS 7 MARK question. Many also did not ADDRESS THE VERB – EXPLAIN. Quite literally at least 10 % of students wrote ".. the man on the train sees the ball go up and down but the man on the station sees it go in a curved path". This was never going to be adequate at this level.

General Markers Comments

- This question is a great question across two areas of Module 5 & 7 respectively. This cross-modular style of question is very common in the HSC. Students needed to understand that the question was asking about their understanding of Projectile motion (M5T1) and Relativity (M7 T5) and access their knowledge from both.
- Handwriting is an issue, it needs to be legible to markers, if we can't read it, we cannot mark it.

Student samples



30

	Observer on train	Observer at station
Scenario 1	• observer$_T$ and ball moving forward at same, constant horizontal velocity [CAUSE] • ∴ no relative [E] horizontal motion b/w observer and ball so ball is seen to move directly up & down with constant vertical ↓ accn	• [CAUSE] ball is launched vertically but has an initial horizontal velocity • [EFFECT] since no force acts horizontally the ball continues forward at same, constant velocity whilst experiencing constant vertical ↓ acc'n hence projectile motion
Scenario 2 Mirror?	• [CAUSE] light projected vertically upwards and unaffected by gravity • [EFFECT] observer$_T$ sees light move vertically up and down at constant speed in time t_T	• [CAUSE] light strikes mirror and returns to source on moving train • [EFFECT] since light travels a greater distance at same speed (c), it must take time t_S which is $> t_T$

QUESTION 31 – Band 2-6 (5 marks)
Marker - Ethan

Criteria	
Extensive analysis of the distribution of power with minimum energy loss including: - Role of transformers - Role of current in power loss – including calc - How voltage changes at different sections Qualitative and quantitative methods used	5
Thorough analysis of the distribution of power including all points above but with minor errors, including some qualitative and some quantitative aspects OR All points above done well but missing energy loss in transformers.	4
Sound description of the distribution of power including some qualitative OR some quantitative aspects OR Sound description of the distribution of power including some qualitative and some quantitative aspects with multiple minor errors or omissions.	3
Some features of power distribution methods described	2
Some relevant information.	1

WWW (What worked well)

- Most students understood that current needed to be minimised to reduce energy loss
- Most students were able to recognise the safety aspects of high voltage during transmission and the need to reduce this voltage for the consumer.
- Majority of students did some calculation using the power loss equation

EBI (Even better if)

- The biggest mistake was students analysed the network for power loss but did not consider power loss in transformers and how this can be minimised.
- There were a large number of students that did not analyse all components of the distribution network – only analysing from the generator to the transmission wires.
- There were a large number of students that did not use the stimulus in their analysis, hence not completing any quantitative analysis
- Better responses were able to provide evidence to support their response, including use of proportionality.

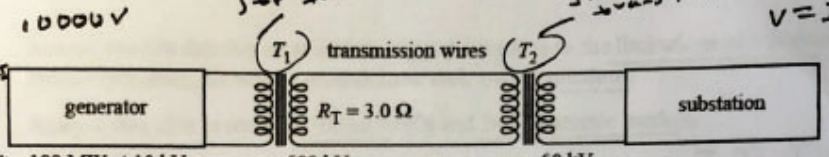
General Markers Comments

- It was evident that some students took time planning their response, annotating the stimulus, writing relevant equations, and structuring their response well, this correlated with generally a good mark.
- Handwriting…. you need to improve your handwriting

Student Samples

Question 31 (5 marks)

The diagram below shows a simplified diagram of the transmission of electricity from a power station to a substation. The current in the transmission lines is 200 A. 5



Analyse the diagram quantitatively and qualitatively to describe the method of transmission of electricity from a generator (power station) to a substation (surburban area a substantial distance away) with minimal energy loss.

In order to transmit electricity from a generator to a substation at a substantial distance away, the voltage must be stepped up before transmission by wires as the resistance increased and the length of the wire increases. ∴ The power loss formula, $P = I^2R$ shows that as current increases, the power loss is. Contains on cross sectional area.

$V = IR$

$P = VI$

$P = I^2(I)$

$= I^2R$

$V_p I_p = V_s I_s$

$10000 \times I_p = 500000 \times 200$

$I_p = 10000A$

∴ Transformer 1 steps up the voltage from 10 kV to 500 kV.

$V_p I_p = V_s I_s$

$10000 \times I_p = 500000 \times 200$

$I_p = 10000$ A.

∴ By increasing the voltage to 500 kV, the power loss is 120000 W rather than 1.0×10^9 W.

After travelling to the substation, the voltage is stepped down to 50 kV by another transformer.

For the transformers, in order to minimise the power loss in the transformer, the transformers must be laminated in the soft iron core to prevent large eddy currents from forming which converts the electric energy to heat

QUESTION 32 – (9 marks)
Marker - Anne

(a) Band 2-6

Criteria	**Marks**
Extensive analysis of statement made including: - Clear, accurate descriptions of both models - Limitations of both models - How Bohr dealt with Rutherford limitations	5
Thorough description of both models, with limitations/solutions identified	4
Correct description of both models, with some limitations/solutions identified	3
Some description of two of - Models - limitations and/or - solutions presented	2
Some relevant information	1

Marker comments:

- An area for targeted study post Trial review.
- A large number of boys could not recall the Rutherford and Bohr models accurately – confusing other models, experiments that were not relevant.
- A large number of boys spent most of their answer discussing Thomson's plum pudding model – which is strange since the question specifically asked for Rutherford and Bohr.
- Limitations are not well understood, even less well done was understanding that Bohr's model is largely about electrons (not the nucleus) so the most appropriate limitations to discuss from Rutherfords model would be those involving electrons.
- Most responses included statements NOT explanations or descriptions. It was unclear that people knew:
    - What stationary states were or how they worked
    - Which of Bohr's postulates were relevant to Rutherfords limitations
    - Why electrons in Rutherfords model should emit energy and spiral into the nucleus

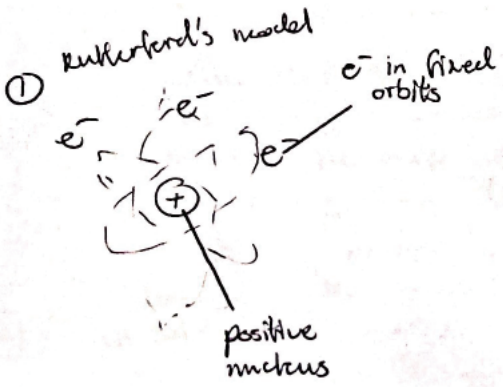
Student Sample:

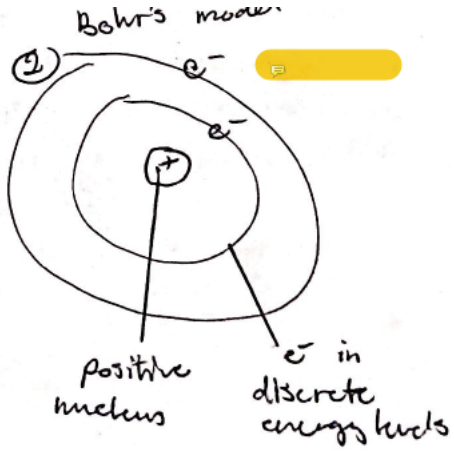
Rutherford's 'planitary model' (diagram ①):

- atoms consist of a positively charged dense mass called a nucleus with orbiting electrons orbiting the nucleus in fixed orbits

Limitations: - Could not explain the composition of the nucleus although Rutherford did propose that it contained most of the atom's mass & was positively charged.

- Could not explain the arrangement of e^- simply proposed that they were in circular orbits.
- Could not explain why e^- did not spiral into & collide with the nucleus. Due to the electrostatic attraction the e^- would undergo UCM ∴ an F_c would be applied.





- Could not explain why e^- did not emit EM radiation. Due to the F_c applied the e^- would've had an a_c ∴ would be accelerating charged particles hence should have emitted radiation however this did not occur.

Bohr's model: diagram ②

- electrons exist in discrete stable energy levels ∴ do not loose KE & do not emit radiations.
- electrons can absorb / emit energy through 'jumping' to higher / lower energy levels. Energy emitted / absorbed as photons, & energy emitted / absorbed was exactly equal to the energy required to traverse energy levels ∴ (conservation of energy) energy levels were quantised.

How it addressed limitations:

- explained the arrangement of e^- as being in discrete energy levels.
- explained that as energy levels were stable e^- did not emit radiations.

∴ as shown by the Rutherford & and Bohr atomic models the idea that atomic models develop as limitations are addressed is affirmed.

(b) Band 2-5

Criteria	Marks
Thorough explanation of pros and cons of the model presented, with specific reference to the stimulus. Justified judgement presented	4
Sound explanation of BOTH pros and cons of the model with a judgement made	3
Sound explanation of EITHER pros OR cons of the model	2
Some relevant information	1

Marker comments:

- Address the verb – assess = pros/cons/judgement
- If you have something listed under PRO – explain why it's a good thing?
- If you have something listed under CON – explain why it's a potential problem?

- Refer to stimulus – it's not there just for decorating the paper. The majority of answers in a question about whether a student model was good or not – DIDN'T ONCE REFER TO THE STUDENT MODEL…. Bizarre.

- What do the rice grains, the ball, the results show – LINK the features of the model to the features of the experiment.

Answer:

b) PROS – the modelling experiment features light, moving particles encountering a heavy stationary obstacle in an open space just like Rutherford's.
– the rice grains that encounter the ball will be deflected at a range of angles, as those that don't will pass through the space as with the experiment that led to Rutherford's model

CONS there are significant differences between the model and the experimat that led to Rutherford's model such as:
– the rice grains are at much lower speed
– there were >>> number of α particles
– the ratio of nuclear radius to atomic radius is much smaller in Gold atom.
– there were multiple gold atoms not one.

However, OVERALL this is an accessible and straightforward model that illustrates the key features of the experiment that helped develop Rutherford's model.

Student Sample:

Benefits

- Nice represent alpha particles, ball → big positive charge, ring → negatively-charged space. Well represented with physical features.
- Clear visual representation of alpha particles going through vs deflected by positive 'ball' and not going through. This helps understand the theory of alpha particles travelling through atom unless deflected by positive ball, effectively demonstrating Rutherford's model.

Limitations

- Nice only deflected if direct contact is made with the ball.
- This is inaccurate as alpha particles were deflected to a varying degree based on how close they were to hitting positive charge (e.g. a particle directly hitting the charge may deflect 180°, whereas a particle going close to the charge may only deflect 30°).
- Thus this does not demonstrate a key aspect of Rutherford's model.

Judgement

- This inaccuracy is the limitation is significant, and almost counters the visual representation benefit as the model does not accurately represent Rutherford's.
- Therefore the model is ineffective.

QUESTION 33 – Band 2-6 (7 marks)
Marker - Anne

Compare the production of energy and predicted future life cycle evolutionary path of these four stars.

Criteria	Marks
Extensive explanation of similarities and differences between the four stars related to energy production and life cycle stage	7
Thorough explanation of multiple similarities and differences for both energy prodution and life cycle stage with some minor errors/omissions	6-5
Sound explanation of at least one similarity and one difference with key errors/omissions	4
Sound outlining of the life cycle stages and/or energy production	3
Several relevant points made regarding energy and/or life cycle	2
Some relevant information	1

Only lifecycle discussed (max 3 if extensive)
Only energy discussed (max 4 if extensive)
No similarities/differences (max 3 if points extensive)

Marker Comments:
Structure:

- Very few students attempted any form of comparison. Clear similarities and differences hard to find. Note, putting facts into a table with "similarities" and "differences" headings that does not actually compare features at all does not count as a compare answer. Make it explicitly clear what is same, similar, different
- Use of headings and attempt to make answer easy to read was quite good, quite a few good uses of flowcharts and diagrams.

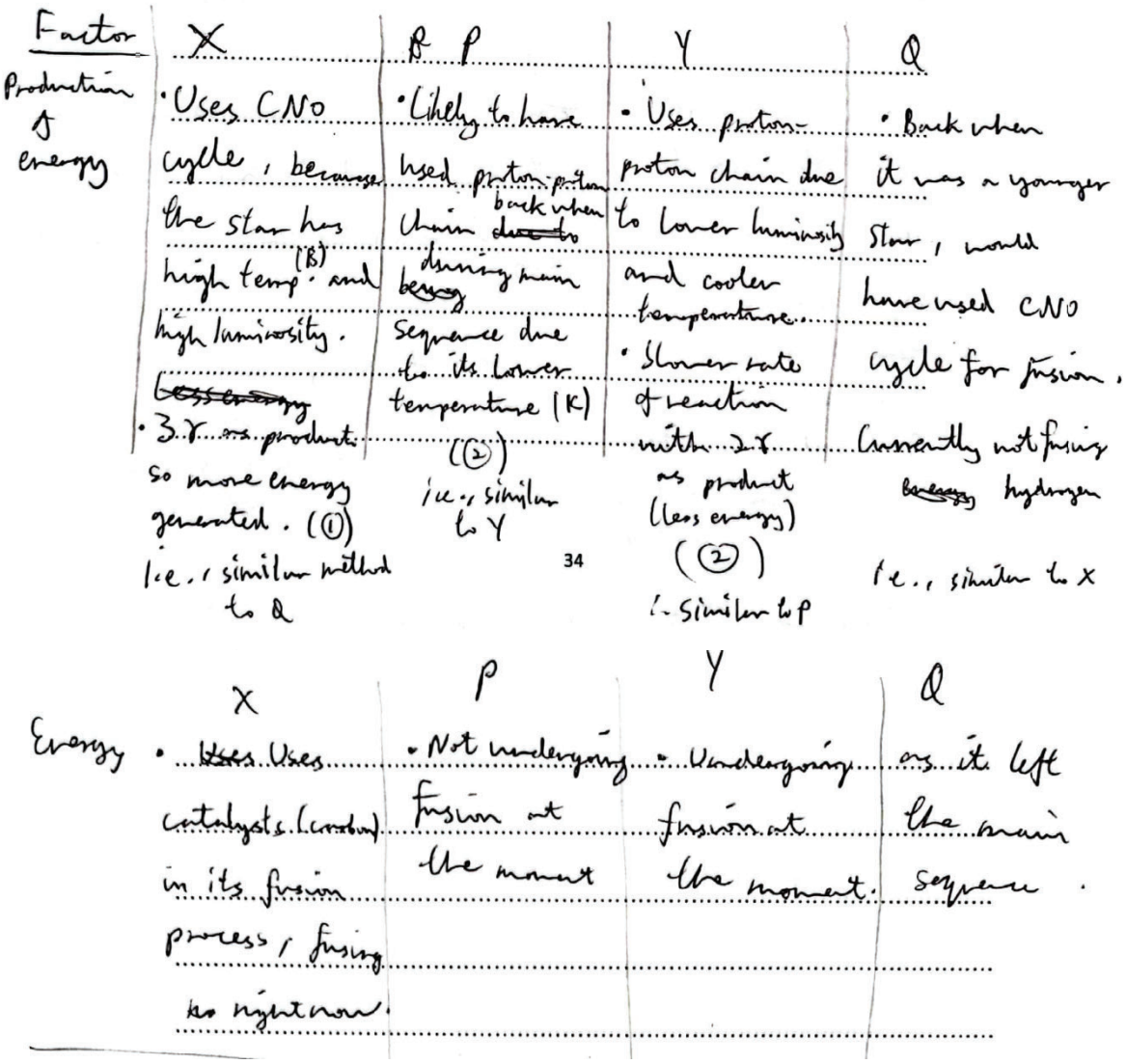
Content:

- Very very poor. Two parts to question:
    - Energy production – in stars this means nuclear fusion. Syllabus states "including but not limited to: proton-proton chain, CNO fusion". We also covered post main sequence fusion (fusion of elements starting with helium and potentially ending up at iron).
    - Life cycle – this means what it is doing (main sequence, red giant, red supergiant) and what comes next.
- Very few people addressed both parts of question well. Most people didn't understand energy production and tried to rank stars in terms of their energy.
- A majority of students seem to want to be the Discovery Channel and introduced lots of terms we did not discuss.
    - You need to stick to the intended syllabus intentions – main sequence, red giant, red supergiant, neutron star, black hole, supernova, planetary nebula, white dwarf
    - Instead I got the following list – blue giant, nova, brown dwarf, black dwarf, dwarf (no colours), giant (no colours), red dwarf (great TV show but not really relevant here). STICK TO THE MAIN NAMES…..
- Demonstration of understanding of fusion was poor.

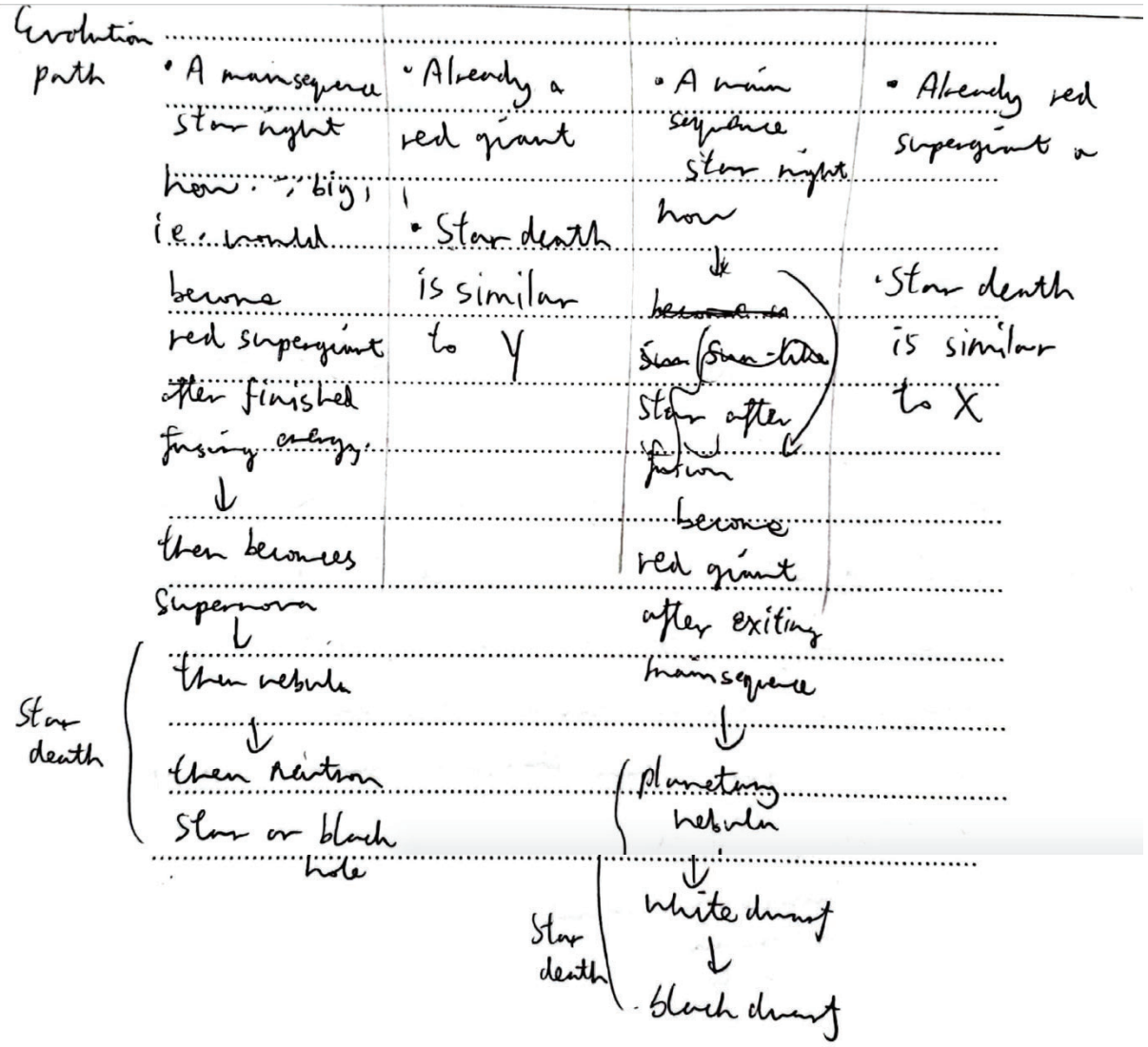
- Demonstration of knowledge of life cycle stages was poor.

We will be reviewing this in class.

Student Answer (Note: not for content but possible structure)



Factor	X	P	Y	Q
Production of energy	• Uses CNO cycle, because the star has high temp (B) and high luminosity. • ~~Less energy~~ 3 α as product so more energy generated. (1) i.e., similar method to Q	• Likely to have used proton-proton chain ~~due~~ back when during main ~~being~~ Sequence due to its lower temperature (K) (2) i.e., similar to Y	• Uses proton proton chain due to lower luminosity and cooler temperature. • Slower rate of reaction with 3 α as product (less energy) (2) i.e., similar to P	• Back when it was a younger star, would have used CNO cycle for fusion. • Currently not fusing ~~because~~ hydrogen i.e., similar to X
Energy	X • ~~Uses~~ Uses catalysts (carbon) in its fusion process, fusing as right now.	P • Not undergoing fusion at the moment	Y • Undergoing fusion at the moment.	Q as it left the main sequence.


Evolution path
• A mainsequence star might
how big
i.e. would
become
red supergiant
after finished
fusing energy
then becomes
Supernova
then nebula
then Neutron
Star or black hole
Star death
• Already a
red giant
• Star death
is similar
to Y
• A main
sequence
star might
how
become
Star after
fusion
becomes
red giant
after exiting
mainsequence
planetary
nebula
white dwarf
black dwarf
Star death
• Already red
supergiant a
• Star death
is similar
to X

QUESTION 34 – Band 2-6 (6 marks)
Marker - Ethan

(a)

Criteria	Marks
Clear explanation using light particle theory of why wave theory gave incorrect observation AND particle theory explained observations made	3
Several correct points made regarding BOTH wave and particle theory related to the predictions/observations OR Clear explanation using light particle theory OR wave theory but does not relate to prediction or observations made	2
Some relevant information or repetition of the stimulus	1

WWW (What worked well)

- Majority of students understand the photoelectric effect well

EBI (Even better if)

- Students need to be very careful and answer the question – in this case, relate it back to the prediction and observations made. Knowing theory is great, but answer the question!
- A lot of students just merely repeated information provided in the stimulus, this is not good enough…again, answer the question
- Use of structure in explain verbs
    - A lot of students wrote down cause and effect – good structure…but did not identify a correct cause or effect, effectively only splitting their response in two. Know when to use the structure and when not to use the structure.

General Markers Comments

- Exam fatigue was starting to be evident here, handwriting was getting messier, students were rambling, some responses didn't even make sense!
- Handwriting…. you need to improve your handwriting

Student samples

Explain why there is a difference in the prediction and observation. 3

• Classical wave theory states that the energy from light can build up to eventually release an electron, while quantum predictions state that a photon will release ALL it's energy (E=hf) to ONE electron, if the energy is not enough to release the least bound electron (E=hf-ϕ) no electrons will be emmitted

• Therefore, if the frequency (energy of photons) is too low, no electrons will be released which does not agree with classical physics)

Explain why there is a difference in the prediction and observation. 3

- Predictions based on wave theory of light which predicted that energy would accumulate to release the electrons from the metal
- However, the observation occured due to the particle nature of light as quanta
- each of these quanta could only transfer all of its energy to one electron
  - E=hf or low f means low E
  - if the frequency was below the work function of the metal then no photoelectrons would be emmitted
- explaining the differences between the predictions and observations of the photoelectric effect.

(b)

Criteria	Marks
Clear description of a VALID example using light particle theory of why wave theory gave incorrect observation AND particle theory explained observations made	3
Several correct points about a VALID example made regarding BOTH wave and particle theory related to the predictions/observations	2
Some relevant information	1

WWW (What worked well)

- Majority of correct responses focussed on light intensity and the difference in light intensity for wave and particle model – this was generally well done.

EBI (Even better if)

- Some students did not give another example but repeated the difference in part A.
- Some students did not read the question, writing about theory that did not match the question (UV catastrophe or Black body radiation), some good physics…but did not answer the question
- WRITE SOMETHING DOWN – quite a few non attempts in this question.

General Markers Comments

- Exam fatigue was VERY evident here, handwriting was getting messier, students were rambling, some responses didn't even make sense!

Student Samples

(b) Describe another example of where wave theory and the observations do not match for the photoelectric effect. **3**

The intensity of the light in the photoelectric effect simply increases the amount of photons being emitted, and thus the amount of electrons emitted, increasing current.

However the wave theory predicts that this will lead to greater amounts of energy, which does not match observations.

Explain why there is a difference in the prediction and observation. **3**

- Using the classical wave model, as energy emitted from light is continuous, the electrons will be emitted eventually, regardless of frequency, as long as they have enough energy
- However, the quantum model of light suggests that the energy carried by each photon is $E=hf$ and electrons can only absorb energy from ONE photon... Electrons only emitted when a certain frequency (or above) of light is used → contradiction