Insert School Logo

**Semester 2 Examination, 2021**

**Question/Answer booklet**

**PHYSICS**

**UNITS 3 & 4**

**Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Teacher \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Time allowed for this paper**

Reading time before commencing work: ten minutes

Working time: three hours

**Materials required/recommended for this paper**

***To be provides by the supervisor***

This Question/Answer booklet

Formulae and Data booklet

***To be provided by the candidate***

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener,

correction fluid, eraser, ruler, highlighters.

Special items: up to three non-programmable calculators approved for use in the WACE examinations, drawing templates, drawing compass and a protractor.

**Important note to candidates**

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

**Structure of this paper**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Section | Number of Questions | Questions to be answered | Suggested working time (minutes) | Marks available | Percentage of exam |
| Section One  Short Response | 11 | 11 | 50 | 54 | 30 |
| Section Two  Problem Solving | 6 | 6 | 90 | 90 | 50 |
| Section Three  Comprehension | 2 | 2 | 40 | 36 | 20 |
| **Total** | 180 | 100 |

**Instructions to candidates**



1. Write your answers in the spaces provided beneath each question. The value of each question (out of 180) is shown following each question.
2. Answers to questions involving calculations should be evaluated and given in decimal form. Final answers should be given up to a maximum of three significant figures and include appropriate units where applicable.
3. Questions containing the instruction “estimate” may give insufficient numerical data for their solution. Give final answers to a maximum of two significant figures and include appropriate units.
4. Despite an incorrect result, credit may be obtained for method and working providing these are clearly and legibly set out.
5. Questions containing specific instructions to “show working” should be answered with a complete, logical, clear sequence of reasoning showing how the final answer was arrived at; correct answers which do not show working will not be awarded full marks.
6. Supplementary pages for the use of planning/continuing your answer to a question have been provided at the end of this Question & Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.
7. Extra/spare graphs have also been provided at the end of this Question & Answer booklet.



**Section One: Short Response 30% (54 marks)**

This section has eleven (11) questions. Answer **all** questions. Write your answers in the spaces provided.

Suggested working time: 50 minutes.

**Question 1 (4 marks)**

In a Physics experiment, a group of students run a DC current through a horizontal wire aligned in a North-South direction. They measure the magnetic field strength 13.5 cm from the wire and its magnitude is 3.56 x 10-6 T. When a compass is placed directly **below** the wire when the current is flowing, it points to the west (see diagram below).

NORTH

Compass beneath wire pointing west

SOUTH

1. State the direction in which the current will be flowing – North or South.

(1 mark)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Calculate the size of the current flowing in the wire.

(3 marks)

\_\_\_\_\_\_\_\_\_ A

**Question 2 (4 marks)**

A worker is about to push a uniform wooden box across some concrete. The dimensions of the box are shown below.

**85.0 cm**

**PUSH**

**75.0 cm**

**95.0 cm**

**Mass = 56.5 kg**

The worker will push with a horizontal force at a height of 75.0 cm above the ground. Given that there is sufficient frictional force, calculate the minimum force of friction that would cause the box to rotate forwards.

\_\_\_\_\_\_\_\_\_ N

**Question 3 (5 marks)**

The planet Uranus has a mass of 8.68 x 1025 kg and is circled by 27 known moons. One of these is called Portia, which has the following characteristics:

|  |  |
| --- | --- |
| **Mass** | **1.70 x 1018 kg** |
| **Orbital period** | **0.513 days** |
| **Diameter of the Moon** | **135.2 km** |
| **Orbital Speed** | **9.37 km s-1** |

An object launched vertically upwards from the surface of the Earth would reach a much lower maximum height than if it was launched in the same way on Portia. By calculating and comparing the gravitational field strength on the surface of each body – and by using relevant equations of motion – explain why this is the case.

**Question 4 (4 marks)**

A student is investigating electromagnetism and performs the following experiment.

The student has two coils made of copper. One of the coils (Coil 1) is connected to an audio generator which is normally used to create sound by providing alternating currents to loudspeakers.

The other coil (Coil 2) is connected to a loudspeaker and is not supplied with any electric power whatsoever. It also has no physical connection to Coil 1.

Coil 2

Coil 1

Loudspeaker

Audio generator

The audio generator is set to a frequency of 400 Hz. A sound of the same frequency is produced by Coil 2. Explain how this sound in Coil 2 is produced.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question 5 (4 marks)**

The diagram below shows the first three energy levels for an unknown atom.

n = 1

n = 2

n = 3

E1

E2

E3

Two downward electron transitions are shown: n = 3 to n = 2; and n = 3 to n = 1.

The transition from n = 3 to n = 2 causes a visible light photon to be emitted – the other transition shown does not. Name a region in the electromagnetic spectrum that the photon emitted by the transition from n = 3 to n = 1 is likely to come from. Explain your choice.

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**Question 6 (7 marks)**

A generator is capable of producing 5.00 x 102 kW of power at a voltage of 550 V AC (RMS). A transformer at the generator has a turns ratio (Ns : Np) of 150:1.The power is then transmitted via power lines to a town a short distance away.

1. Calculate the maximum EMF (εmax) produced by the generator.

(2 marks)

\_\_\_\_\_\_\_\_\_ V

1. Calculate the transmission RMS voltage in the power lines.

(2 marks)

\_\_\_\_\_\_\_\_\_ V

1. The transmission lines to the nearby town are about 20 km long. Explain how the power and voltage delivered to the town compare with the output power and voltage at the generator.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question 7 (5 marks)**

The diagram below shows Minh in a futuristic train carriage which is travelling with a constant relativistic speed, in an easterly direction, in a straight line.

Minh is halfway between two people - Delta and Liam - who are at opposite ends of the carriage.

Nancy is standing on a platform as the train travels past. At the instant that Minh and Nancy are directly opposite each other, Nancy sees both Delta and Liam strike matches simultaneously.

LIAM

DELTA

MINH

NANCY

East

1. Circle the option (A-D) that best describes how Nancy would expect Minh to see these two events.

A Minh sees the light from Delta first.

B Minh sees the light from Liam first.

C Minh sees the light from both simultaneously, because both are at equal distances from her when they light the matches.

D Minh sees the light from both simultaneously, because special relativity requires that light travels at the same speed in all frames of reference.

(1 marks)

1. Minh measures the carriage she is travelling in to be 20.0 m long. Nancy measures the platform she is standing on to be 10.0 m long. The train rushes past at such a high speed that Nancy sees the carriage and the platform to be the same length. Calculate the speed (in m s-1) at which the train is moving.

(4 marks)

\_\_\_\_\_\_\_\_\_\_ m s-1

**Question 8 (5 marks)**

Rock climbers often need assistance to descend at a safe speed from great heights. A braking system can be applied to create this safe speed. One zip line system is illustrated below.

Pulley/disc rotating in an anticlockwise direction

Direction of climber’s descent

Weight of climber supported by zip line

The rotating pulley is an aluminium disc. When the climber is descending, they are able to switch on electromagnets situated alongside the rotating disc which creates the ‘brakes’. The electromagnets’ current and strength can be varied by the climber to control their speed.

Explain how this braking system works and how the speed of the climber can be varied.

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**Question 9 (6 marks)**

One of the thrilling parts of a rollercoaster ride is when the passengers travel **over the top** and **through the bottom** of a vertical circular path. Apart from the high speeds that can be reached, the other interesting feature is the change in ‘apparent weight’ experienced by the occupants of the ride at these points. [NOTE: at the top of the loop, the carriage carrying the occupants is on top of the track]

TOP

BOTTOM

1. Compare and explain the ‘apparent weight’ experienced by the occupants at the top and bottom of the vertical circular path as they travel through these points. Use appropriate mathematical expressions in your answer.

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. In a ‘loop-the-loop’ design, the rollercoaster can travel upside down at the top of the vertical circle. Obviously, the occupants are strapped in very securely. However, it is possible for them to travel upside down without falling out of the rollercoaster. Explain, with reference to the forces involved, the minimum conditions that would allow this to occur.

(2 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question 10 (6 marks)**

Two charged particles of the same mass and with the same speed enter vacuum chamber at point ‘P’ and follow the paths (‘1’ and ‘2’) shown. The magnetic field in the vacuum chamber is uniform, perpendicular to and into the page.

2

1

P

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

X

1. State the type of charge on each particle.

(1 mark)

1. Which path represents the particle with the largest charge? Explain.

(2 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. If the chamber was filled with air instead of a vacuum, draw the shape of the particles’ paths and explain your answer.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question 11 (4 marks)**

A group of Physics students constructed an AC generator out of a single rectangular coil, a reasonably strong horseshoe magnet and other materials lying round the house.

Once they started to rotate the coil at 3.00 Hz, they measured an RMS voltage output of 0.0249 mV.

The coil has dimensions of 1.50 cm x 2.50 cm. Calculate the strength of the horseshoe magnet’s field (B).

\_\_\_\_\_\_\_\_\_\_\_\_\_ T

**END OF SECTION ONE**

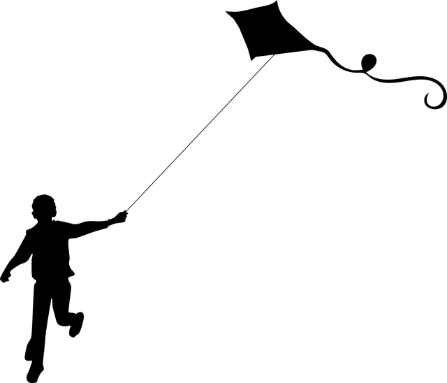
**Section Two: Problem Solving 50% (90 marks)**

This section contains six (6) questions. Answer **all** questions. Answer the questions in the space provided.

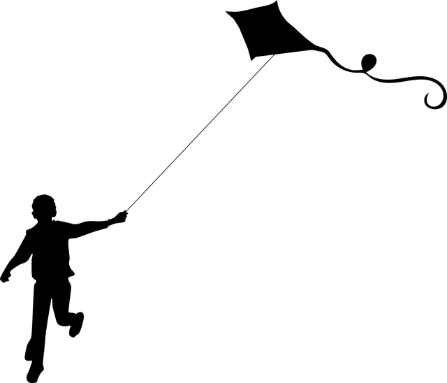
Suggested working time is 90 minutes.

**Question 12 (9 marks)**

A boy is flying a kite and makes it trace out a horizontal circular path. He steers the kite by applying a force to it via tension in a connecting cable. The situation is illustrated in the diagrams below (diagrams not to scale).



LIFT = 68.2 N



51°

TENSION = 25.0 N

At a particular instant, as the kite traces out its circular path, the tension in the cable is 25.0 N. The kite experiences a lift force equal to 68.2 N which acts normal to the tension force, as shown.

1. Calculate the mass of the kite.

(5 marks)

\_\_\_\_\_\_\_\_\_\_\_ kg

1. If the kite is travelling in a horizontal circular path with a radius of 15.6 m, calculate the average circular speed achieved.

[If you were unable to calculate an answer for part (a), use a value of 2.50 kg]

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_ m s-1

**Question 13 (15 marks)**

Some Physics students decide to calculate an experimental value for Planck’s constant (h) using a light emitting diode (LED).

LED’s are semi-conductors that emit electromagnetic radiation in optical and near-optical wavelengths when a voltage is applied to them. LED’s only emit this light when the voltage is above a minimum threshold value. As the voltage applied to the electrons in the LED (V0) is increased above this minimum value (this is called the threshold voltage), photons of increasing energy are produced. The light produced is monochromatic (ie – has a very specific wavelength range). Each photon emitted has an energy equal to the energy lost by the electrons in the LED.

The students create a circuit that allows them to measure the threshold voltage (V0) applied to an LED and the maximum wavelength (λ) of the emitted photons with a spectroscope. The students use LED’s of different colours (ie – different maximum wavelengths) and measure their corresponding values for V0.

1. Using formulae from the Formulae and Data Booklet, show that the relationship between the threshold voltage (V0) and the maximum wavelength (λ) for an LED is given by:

(2 marks)

The students perform the experiment using four (4) different LED’s and gather the following results.

|  |  |  |  |
| --- | --- | --- | --- |
| **LED colour** | **Vo (V)** | **λ (nm)** | **1/λ (x 106 m-1)** |
| **Infrared** | **1.24** | **1000** | **1.00** |
| **Red** | **1.79** | **695** |  |
| **Yellow** | **1.88** | **660** | **1.52** |
| **Green** | **1.97** | **630** | **1.59** |

1. Complete the table by filling in the missing value in the ‘1/λ’ column.

(1 mark)

1. On the graph paper provided on the next page, plot a graph of ‘Vo’ against ‘1/λ’. Place ‘1/λ’ on the horizontal axis. Draw a line of best fit for the data.

(4 marks)

1. Calculate the slope of your line of best fit. Include units in your answer.

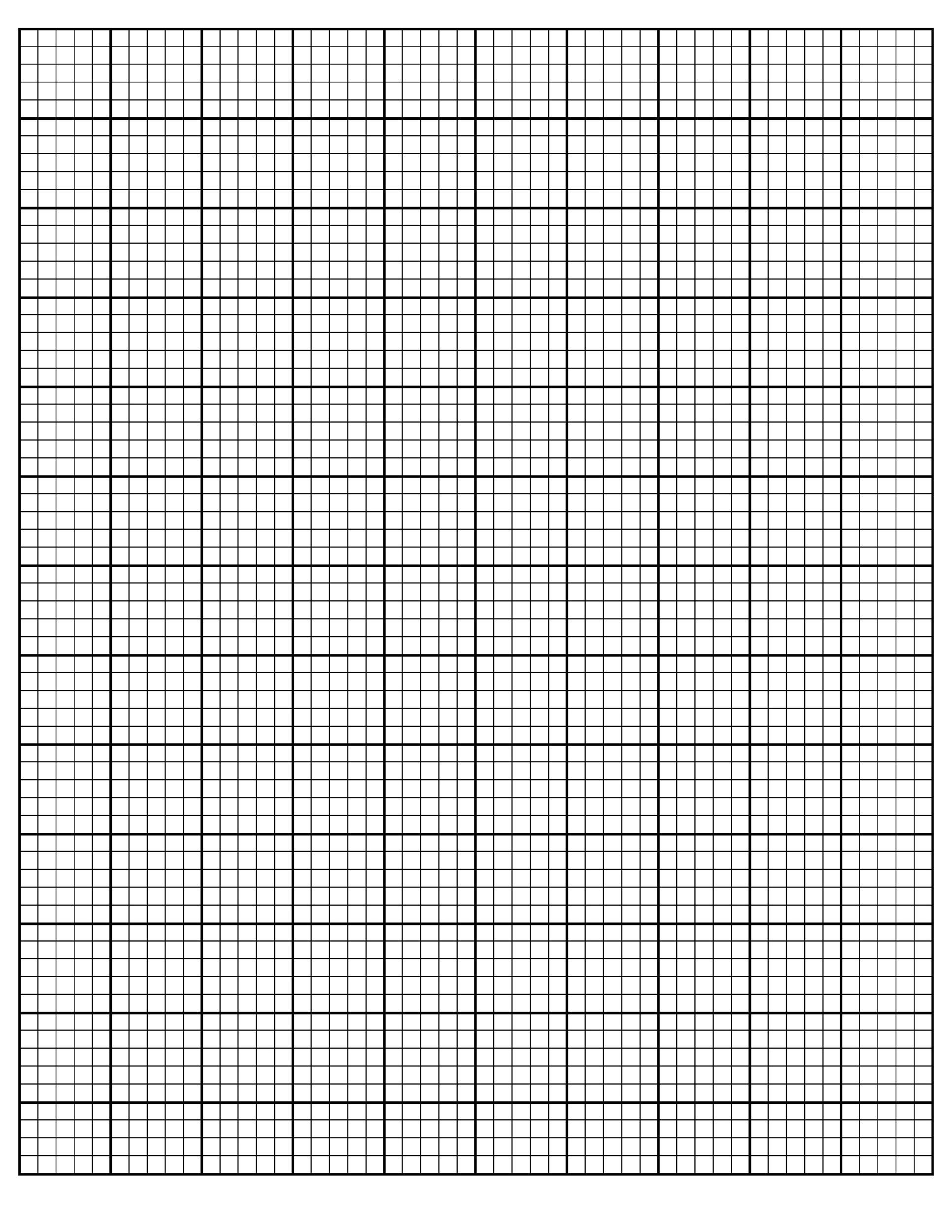
(4 marks)

Slope: \_\_\_\_\_\_\_\_\_\_\_\_ Units: \_\_\_\_\_\_\_\_\_\_\_\_\_

1. Use the slope from part (d) to calculate an experimental value for Planck’s constant (h).

(4 marks)

Planck’s Constant (h): \_\_\_\_\_\_\_\_\_\_\_



**Question 14 (15 marks)**

Some students perform the ‘double slit’ experiment using high speed electrons. The electrons pass through a barrier with two openings and are detected when they collide with an optical screen. The optical screen exposes a pattern of dark and light fringes. This experiment is shown in the diagram below.

Dark fringe

Dark fringe

Dark fringe

Dark fringe

Dark fringe

Optical screen

Double slit screen

High speed electrons

The electrons are acted on by an accelerating electric potential and arrive at the screen with a maximum speed of 2.50 x 105 m s-1.

1. Calculate the magnitude (in Volts) of the accelerating electric potential. Show working. Ignore relativistic effects.

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_ V

1. State what the experiment demonstrated about the behaviour of the electrons.

(1 mark)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Explain how the dark and light fringes are formed.

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Calculate the minimum de Broglie wavelength for these electrons.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m

1. Explain what would happen to the dark and light fringe patterns on the optical screen if the speed of the electrons was decreased.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question 15 (17 marks)**

The diagram below shows a horizontal drawbridge which is supported by a cable and pulley system. This system is used to raise and lower the drawbridge when required.

PULLEY

6.50 m

11.5 m

16.0 m

WALL

CABLE

OBJECT

42.0°

DRAWBRIDGE

HINGE

The drawbridge has a mass of 250.0 kg is and 16.0 m long. Its centre of mass is located 6.50 m from the hinge as shown. At the instant that it is held in the horizontal position shown, a 70.0 kg object is placed right at the end of the drawbridge. The cable is attached to the drawbridge 11.5 m from the hinge at an angle of 42.0° to the horizontal.

1. Draw a free-body diagram to represent the drawbridge when it is in the horizontal position shown. Include all important dimensions and angles.

(4 marks)

1. Calculate the tension (T) in the cable when the drawbridge is in this horizontal position.

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ N

1. Hence, calculate the force (magnitude and direction) the wall exerts on the drawbridge at point ‘P’.

(5 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ N Direction: \_\_\_\_\_\_\_\_\_\_\_\_\_

1. The drawbridge is elevated into a position where the object just begins to slide towards the hinge. If the maximum frictional force experienced between the object and the drawbridge is 320 N, calculate the angle to the horizontal to which the drawbridge has been elevated.

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_ °

**Question 16 (19 marks)**

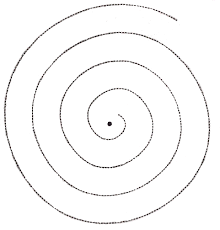
The Milky Way Galaxy is our home in the Universe. It has the structure of a typical spiral galaxy and consists of six separate parts:

1. A nucleus (which contains a massive black hole); (ii) a central bulge; (iii) a disk (both thick and thin); (iv) spiral arms; (v) a spherical component; and (vi) a massive halo.

The diagrams below show simplified diagrams of what we think the Milky Way Galaxy looks like.

Spiral arms

Nucleus and bulge



Disk, arms and halo

Galaxy viewed front-on

Galaxy viewed edge-on

100 000 light years

Astronomers have made observations that confirm the Milky Way’s structure. They have also confirmed:

* the spiral arms of the galaxy are rotating around the central bulge and nucleus;
* the mass of the entire galaxy.

Our own Sun orbits the centre of the Milky Way on one of the spiral arms with an orbital radius of 2.60 x 104 light years and period of 225 million years. The mass of the Milky Way can be calculated by observing the motion of satellites (stars) like our Sun as they orbit the central bulge.

1. Using the orbital data for our Sun, show that the mass of the Milky Way is about 100 billion (1011) solar masses (1 solar mass = mass of Sun).

(5 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ solar masses

Outside of the Sun’s orbit, there doesn’t appear to be much more luminous matter that can be seen – so 1011 solar masses is continually calculated as a good estimate for the Milky Way’s mass. Also, the orbital speeds of stars inside the Sun’s orbit appear to match the predicted effects of the gravity as they orbit around the Milky Way’s galactic centre.

1. (i) Using formulae from the Formulae and Data Booklet, derive an expression that shows a stars orbital speed (v) with an orbital radius (r) as it orbits the Milky Way’s centre of mass (M).

(3 marks)

(ii) Use this expression to calculate the orbital speed of the Sun.

(2 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m s-1

(iii) On the axes below, sketch a graph that shows how the orbital speed (v) of stars in the Milky Way should vary with their orbital radius (r).There is no need to provide any values on the axes.

(2 marks)

v

r

1. Astronomers are able to confirm that stars in an orbital radius smaller than that of our Sun are orbiting around the centre of the galaxy by observing the red- and blue-shifted light emitted by these stars. Explain this observation.

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

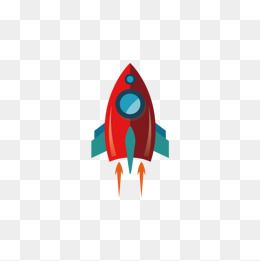
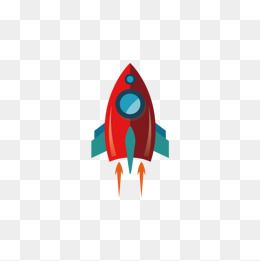
1. Explain why the observed orbital speeds, being higher than expected, suggest the presence of dark matter in the Milky Way.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question 17 (15 marks)**

Two spaceships (A and B) are travelling at high speeds towards each other as shown in the diagram. An observer on Earth measures their velocities and these are also shown on the diagram provided.

Spaceship B

0.850c

Observer on Earth

Spaceship A

0.600c

1. Calculate the velocity of Spaceship B as measured by Spaceship A.

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_ c

1. A light is turned on in Spaceship A for 1.20 s. Calculate how long the light appeared to be turned as measured in Spaceship B.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_ s

1. Spaceship B fires a rocket with a velocity of 0.550c with respect to itself in the direction of Spaceship A. Calculate the velocity of the rocket as measured by the observer on Earth.

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_ c

1. Calculate the velocity of the rocket as measured by Spaceship A.

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_ c

**END OF SECTION TWO**

**Section Three: Comprehension 20% (36 marks)**

This section has two (2) questions. Answer **both** questions. Answer the questions in the spaces provided.

Suggested working time: 40 minutes.

**Question 18 (18 marks)**

**How Should You Kick a Football to Achieve the Greatest Distance?**

**Physics has the answer – as always - at least in an ‘ideal setting’**

In any AFL football game, two teams are pitted against each other in the pursuit of glory. It turns out that they both have a common foe they need to defeat which is always trying to pull them (and the football) down – the force of gravity. The Earth's gravitational pull is constantly acting downwards on players and the football itself – preventing it from sailing through the goal posts from extra-long distances, or from hanging in the air for eternity.

Gravity is constant, so football players learn how to instinctively account for its effects when kicking the football around the field. They learn very quickly that a football, once kicked or handpassed, follows a parabolic path - a path that is essentially a symmetrical arc which eventually results in the ball landing back on the ground.

(In reality, the football’s path is NOT a perfectly parabolic path; this is because its path is not only affected by gravity, but also by air resistance - which is created by drag in the air and even wind.)

The properties of parabolas are well understood by Physicists and Mathematicians (and even footballers!). For example, it can be shown mathematically that the maximum horizontal distance (sh) achieved by a football after it has been kicked into the air will be equal to:

**where ‘v’ is the projectile's initial speed; ‘g’ is the acceleration toward Earth due to gravity (9.80 m s-2); and ‘θ’ is the angle to the horizontal at which the projectile is launched.** In this case, it is assumed that the football is returning to the same height from which it is launched.

In this equation, a couple of the variables are pretty much fixed. The acceleration due to gravity ‘*g*’ is obviously constant no matter how the ball is kicked.

In addition to this, if a footballer is trying to kick a football as far as they possibly can, they will launch it with a maximum launch speed ‘v’ – which, in turn, simply depends on how hard they can kick the football.

The only decision, therefore, a footballer has to make when kicking a football to maximise horizontal distance is the launch angle ‘*θ*’ at which the football is kicked. The equation above shows us that the horizontal distance travelled by the ball will be a maximum when *sin 2θ* is at its greatest value. So, a football will achieve its greatest horizontal distance when it is launched at an angle of 45° to the horizontal. Again, it is assumed that the football is returning to the same height from which it is launched.

Part of the kicking strategy in football is not only to kick the football as far as possible, but to control the flight time (or ‘hang time’) for the ball. A player may need to kick over another (tall) player; vary the time it takes for the football to reach another point on the ground; or kick it a shorter distance with a particular height.

**The maximum height (sv) achieved by a kicked football is given by:**

**Like before, *‘*v’*and ‘*g’ are fixed values for a given type of kick*.***

From this equation, it can be seen that to achieve maximum height (sv) a player needs to produce a launch angle of *θ = 90°*. In other words, the ball needs to be kicked vertically upwards – a rare kick in football without much strategic value.

1. The article states: “… a football, once kicked or handpassed, follows a parabolic path”.

Assume the football is launched and lands at the same vertical height. By examining important aspects of a projectile’s path, explain why a parabolic path is followed by the football.

[Note – a projectile’s path is an inverted parabola which is symmetrical around the maximum height achieved by the projectile]

(4 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. “In reality, the football’s path is NOT a perfectly parabolic path; this is because its path is not only affected by gravity, but also by air resistance - which is created by drag in the air and even wind.”
2. In the table below, state how the following aspects of a projectile’s path would change from an ‘ideal situation’ when air resistance is taken into account.

(2 marks)

|  |  |
| --- | --- |
| RANGE |  |
| MAXIMUM HEIGHT |  |

1. Let the time taken for the football to travel from the ground **to maximum height be ‘tUP’**.

Let the time taken for the football to travel from maximum height **to the ground be ‘tDOWN’**.

**When air resistance is ignored,** these two values are the same (ie – tUP = tDOWN).

Compare these two values when **air resistance is taken into account**. Explain any differences between these values. As part of your answer, consider how gravity’s effects would be affected by air resistance.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. If air resistance is ignored, for a projectile launched at an angle of ‘θ’ to the horizontal and with a speed of ‘v’, the horizontal and vertical components of the launch velocity are given by:

Use these expressions - and appropriate formulae from the Formulae and Data Booklet – to show that for a projectile that is launched and lands at the same height, the maximum horizontal distance achieved will be:

NOTE: you may find the following trigonometric identity useful in the solution of this question:

(4 marks)

1. A football is kicked with a velocity of 15 m s-1 at angle of 35° to the horizontal. Calculate the maximum horizontal distance achieved by the football if air resistance is ignored.

(2 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_ m

1. A football is kicked with a velocity of 14 m s-1 and achieves a maximum height of 7.00m. Calculate the angle ‘θ’ at which the football is launched. Ignore air resistance.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_ °

**Question 19 (18 marks)**

**Is there a fifth fundamental force of nature? Some ‘weird’ behaviour by muons suggest there might be …**

**All of the activities we undertake in our daily lives are governed by four fundamental forces of nature. We couldn’t play most ball sports without gravity. We couldn’t stick that shopping list to our fridge door without magnetism. We couldn’t treat cancer by radiotherapy without the weak force. Atoms would not exist without the strong force.**

Since the middle of the 20th Century, Physicists have believed that these four forces were ‘it’. Now, some in the Physics community believe they have found signs that a FIFTH fundamental force of nature may exist. The new findings come from some research carried out at a laboratory near Chicago.

The Standard Model describes the way that all objects and particles in the Universe interact with each other and states that these interactions are governed by the four fundamental forces of nature.

For example, charged particles repel and attract each other due to the electromagnetic force. Gravity causes objects to fall.

However, experiments in the US, Japan, and - most recently - from the Large Hadron Collider on the Swiss-French border have found an interaction of muons that is not predicted by the Standard Model. This result provides strong evidence for the existence of an as yet undiscovered sub-atomic particle or new force.

This is clearly a very exciting discovery, because it potentially points to a new future in Physics which may require a rethinking of the Standard Model that includes new laws of Physics, new particles and a new fifth force.

The finding is the latest in a string of promising results from particle physics.

These experiments searched for signs of new phenomena in Physics by studying the behaviour of sub-atomic particles called muons.

The Standard Model predicts that all matter – at its most fundamental level – is built from exquisitely tiny sub-atomic particles that are even smaller than protons and neutrons. These particles cannot be ‘broken down’ further into smaller particles – hence, the description ‘fundamental’.

The muon is one of these fundamental particles.

In the experiments described, muons are accelerated around a particle accelerator to very high speeds and then have a magnetic field applied to them. According to the Standard Model, the magnetic field should make the muons ‘wobble’ at a certain rate.

Guess what? This is not what was observed! The muons ‘wobble rate’ was far greater than expected. The standard Model cannot explain this. Hence, the new Physics!

Other than influencing muon particles, no other effects from this fifth force have been observed. So, not much is known about this force or how it does what it does.

One preliminary school of thought amongst theoretical Physicists is that this force may be connected to an as-yet undiscovered, hypothetical sub-atomic particle like a ‘leptoquark’ or a ‘Z' boson (Z-prime boson)’.

The strong and weak forces are the two fundamental forces that govern the behaviour of sub-atomic particles. It is thought that this fifth force – if it exists - may also play a similar role.

Other Physicists think that a fifth fundamental force might help explain some of the big, unsolved puzzles about the Universe.

One of these puzzles is dark energy. Physicists believe that this phenomenon is responsible for the ever-increasing rate at which the Universe is expanding. It is unknown, however, what dark energy is and how it operates. We just know ‘something’ must be there causing this!! Could this fifth force have properties that could account for this expansion?

Whatever the possibilities, more research needs to be conducted into this mysterious ‘muon-wobble’ and what could be causing it. This discovery has the potential to change the course of modern Physics and vastly increase our understanding of the Universe. Exciting times ahead if you are a Physics fan!!

1. Using data from your Formulae and Data Booklet, calculate the mass of a muon in kilograms (kg).

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_ kg

1. In addition to the more familiar forces of gravity and electromagnetism (which is responsible for electricity and magnetism), the strong and weak forces govern the behaviour of sub-atomic particles.
2. In the table below, state the quark structure of a proton and a neutron (ie – the three quarks). In addition, show how the structure of each of these nucleons determines their charge.

(4 marks)

|  |  |  |
| --- | --- | --- |
| **NUCLEON** | **QUARK STRUCTURE** | **CHARGE** |
| **PROTON** |  |  |
| **NEUTRON** |  |  |

1. Describe the role of the strong force in the formation of the nucleons – protons and neutrons. Name the boson responsible for the mediation of this force in the nucleus.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. A weak force interaction is shown below. One particle is missing.

Use Conservation laws to determine the following properties for the unknown particle.

(3 marks)

|  |  |
| --- | --- |
| Baryon Number |  |
| Lepton Number |  |
| Electric Charge |  |
| Symbol and Name |  |

1. In reality, gravity does not play a very significant role in governing the behaviour of sub-atomic particles. Explain.

(2 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Some Physicists are beginning to think that the observed expansion of the Universe speeding up could be attributed to a ‘fifth fundamental force’. Explain how the increasingly rapid expansion of the Universe could be caused by contrasting the possible properties of this fifth fundamental force with the fundamental force of gravity.

(3 marks)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**END OF EXAMINATION**

**Extra Working Space**

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**Acknowledgements**

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