



PHYSICS

UNIT 3

2019

Name: _____

Teacher: _____

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work: Ten minutes

Working time for the paper: Two hours thirty minutes

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:

- This Question/Answer Booklet; ATAR Physics Formulae and Data Booklet

To be provided by the candidate:

- Standard items: pens, pencils, eraser or correction fluid, ruler, highlighter.
- Special items: Calculators satisfying the conditions set by the SCSA for this subject.

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 notes or other items of a non-personal nature in the examination room. 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 available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short answer	9	9	45	45	30
Section Two: Extended answer	5	5	75	75	50
Section Three: Comprehension and data analysis	2	2	30	30	20
			Total	150	100

Instructions to candidates

- The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2019*. Sitting this examination implies that you agree to abide by these rules.
- Write answers in this Question/Answer Booklet.
- When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.
- You must be careful to confine your responses to the specific questions asked and follow any instructions that are specific to a particular question.
- Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
 - Planning: If you use the spare pages for planning, indicate this clearly.
 - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Refer to the question(s) where you are continuing your work.

Section One: Short response**30% (45 marks)**

This section has **nine (9)** questions. Answer **all** questions. Write your answers in the space provided.

When calculating numerical answers, show your working or reasoning clearly.

Give final answers to three significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of two significant figures and include appropriate units where applicable.

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Suggested working time for this section is 45 minutes.

Question 1

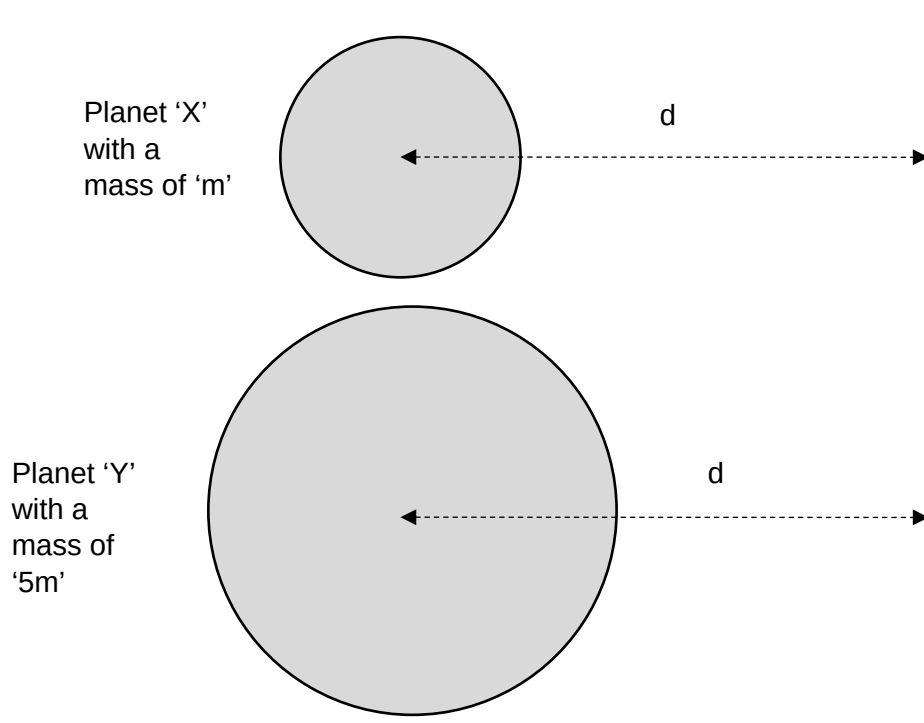
An ammeter was used to measure the current flowing in a DC motor. When the motor is operating normally with the rotor coil rotating freely, the current measured is 2.50 A. However, when the rotor coil is prevented from rotating, this measured current increases sharply to 4.05 A. Explain this observation (no calculations are necessary).

(4 marks)

Question 2

The diagram below shows two planets 'X' and 'Y' which have masses of ' m ' and ' $5m$ ' respectively.

[The measurements described in this question for Planet 'X' and Planet 'Y' are made independently of each other]

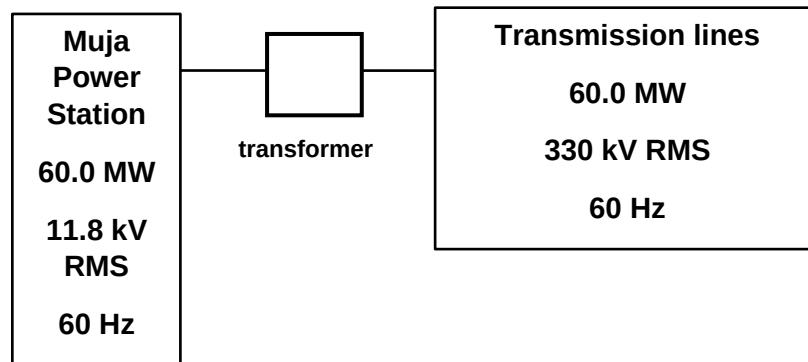


The gravitational field strength is measured at a distance ' d ' from each planet's centre of mass (as shown). The gravitational field strength due to Planet X at distance ' d ' is measured to be 2.5 ms^{-2} . Calculate the gravitational field strength at distance ' d ' from Planet Y.

(4 marks)

Question 3

The generator at the Muja Power Station generates electric power at 60 MW, 11.8 kV RMS. This power is then stepped up by a transformer to a transmission voltage of 330 kV RMS.



- a) Calculate the turns ratio for the step-up transformer described above.

(2 marks)

- b) In the scenario described above, the data indicates an 'ideal' transformer. In reality, no transformer is 'ideal'. Explain. In your answer, describe one (1) factor that prevents the existence of 'ideal' transformers.

(4 marks)

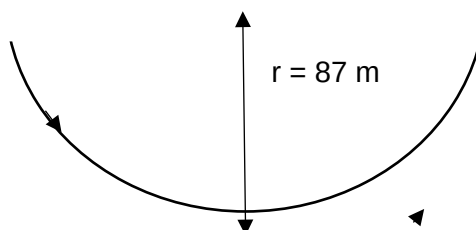
Question 4

Estimate the minimum horizontal force required to tip over a fully-filled 1 litre Coke bottle with a base width of about 7 cm and a height of about 30 cm. Clearly state any assumptions you make while answering this question. Draw any appropriate forces and distances on the diagram.

(4 marks)

**Question 5**

An eagle of mass 55 kg swoops down on its prey. It follows a circular arc of radius 87 m and is travelling at a top speed of 27 ms^{-1} .



- a) Ignoring air resistance, calculate the maximum force experienced by the eagle's wings as it catches its prey.

(3 marks)

- b) Clearly state the point at which this maximum force occurs.

(1 mark)

Question 6

A pair of parallel metal plates, placed in a vacuum, are separated by a distance 4.00 mm and have a potential difference of 1200 V applied between them.

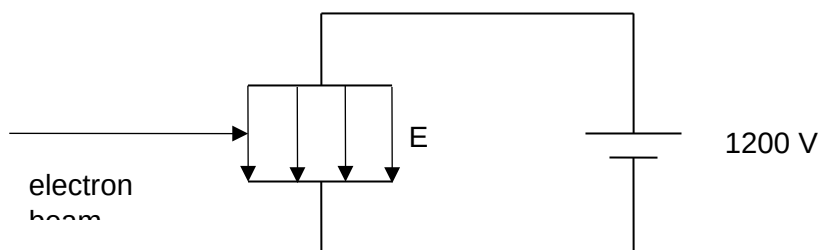
- a) Calculate the magnitude of the electric field between the two plates.

(2 marks)

- b) Calculate the magnitude of the electrostatic force acting on an electron placed between the plates.

(2 marks)

A beam of electrons is fired between the plates at a speed of $4.50 \times 10^6 \text{ ms}^{-1}$ in the direction shown.



A magnetic field is applied to the electron beam sufficient to allow the electron beam to pass between the plates without deviating.

- c) On the diagram, indicate the direction of this magnetic field.

(1 mark)

- d) Hence, calculate the magnitude of the magnetic field required.

(2 marks)

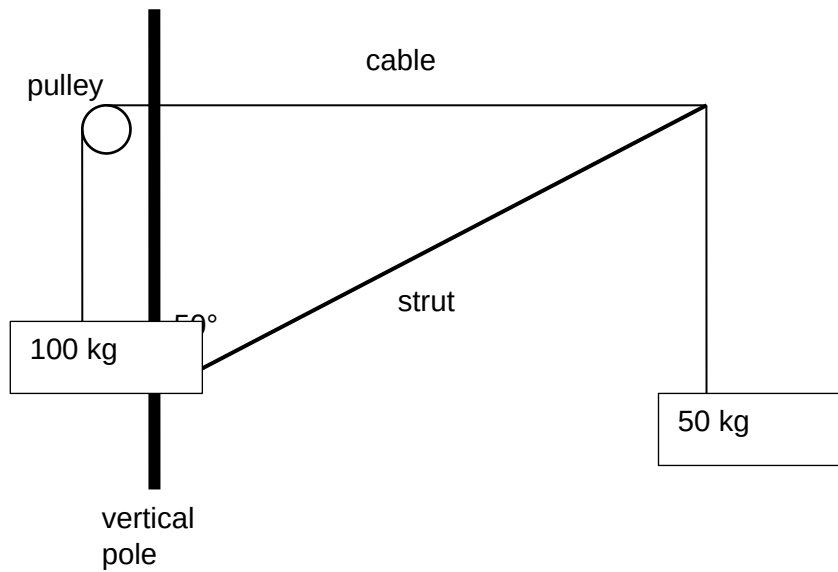
Question 7

A motorbike and rider have a combined mass 325 kg. They are travelling on a road banked at an angle of 32.0° to the horizontal. A force equal to 3000 N up the plane is applied by the engine to the motorbike. Calculate the magnitude of the net acceleration experienced by the motorbike.

(4 marks)

Question 8

The diagram below shows a pulley system designed to raise a mass. At the instant shown, the system can be considered to be in equilibrium.



The strut is uniform and is 2.00m in length; it is attached to a vertical pole by a hinge; and it forms an angle of 50° with the vertical pole as shown. A 50.0kg mass is suspended from the end of the strut as shown. The strut is held in place by a cable attached to its end; the cable runs over the pulley and has a 100kg mass attached to it as shown in the diagram. The length of cable between the pulley and the end of the strut is horizontal.

- a) Calculate the mass of the strut.

(3 marks)

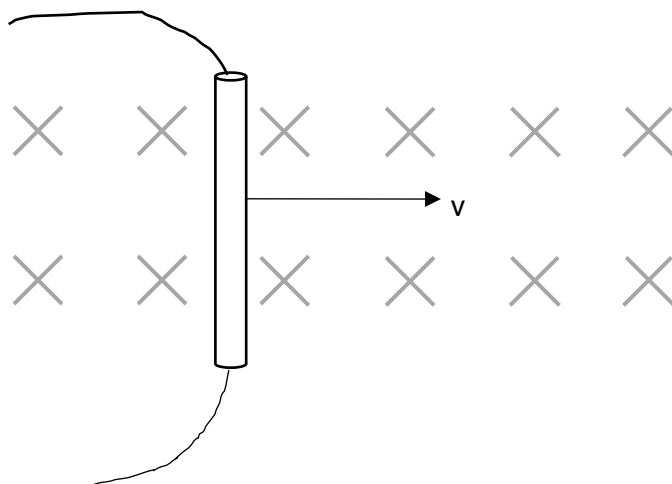
Question 8 is continued on the next page

- b) The strut is hinged at its contact with the vertical pole. Hence, it can rotate and change the size of the angle of 50° . The 100 kg mass is increased in size. In words, explain what happens to the magnitude of angle between the strut and the vertical pole.

(3 marks)

Question 9

An unusual electrical generator consists of a 1.10 m long conducting rod moved with a constant velocity through a magnetic field of strength 1.30 T. The force required to move the conductor in this way is equal to 8.90 N. The ends of the conducting rod are connected to a $1.20\ \Omega$ resistor. This arrangement is shown below.



- a) On the diagram, indicate the direction of conventional current in the conducting rod.

(1)

- b) Calculate the constant velocity 'v' of the conducting rod.

(5)

Section Two: Problem-solving 50% (75 Marks)

This section has **five (5)** questions. You must answer **all** questions. Write your answers in the space provided.

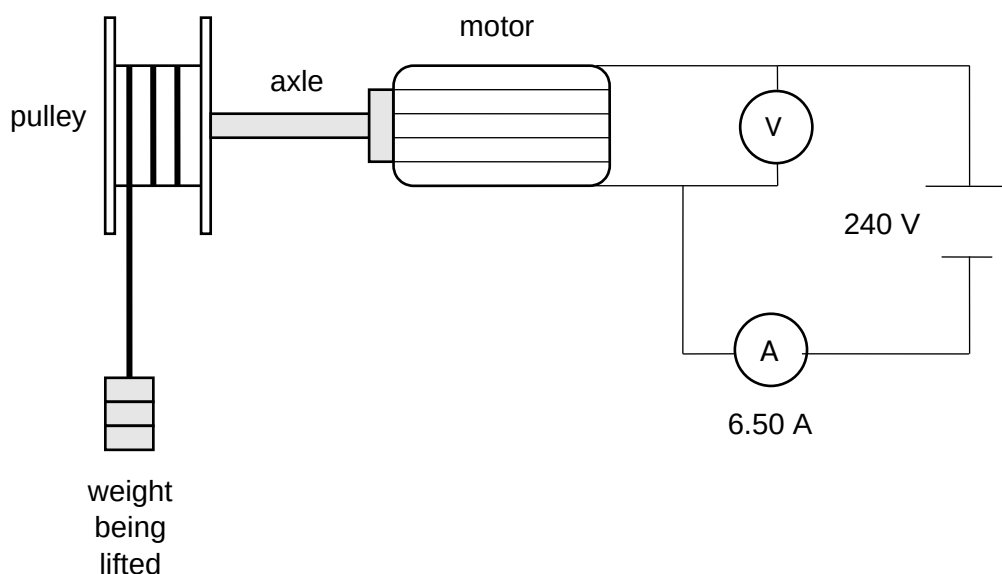
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Suggested working time for this section is 75 minutes.

Question 10**(13marks)**

Electric motors are used to do a variety of tasks. One common use is to lift weights (eg – in a crane or a lift). The input into the motor is electrical energy and the output is the work done in lifting the mass (ie – a gain in gravitational potential energy (ΔE_P)). A diagram outlining this system is shown below.



The DC motor operates at a voltage of 240 V and draws a current of 6.50 A. It is able to lift a mass of 30.0 kg through a vertical height of 3.50 m in 1.05 s.

- a) Calculate the gain in gravitational potential energy (ΔE_p) experienced by the mass and hence, the rate at which the DC motor does work on the mass

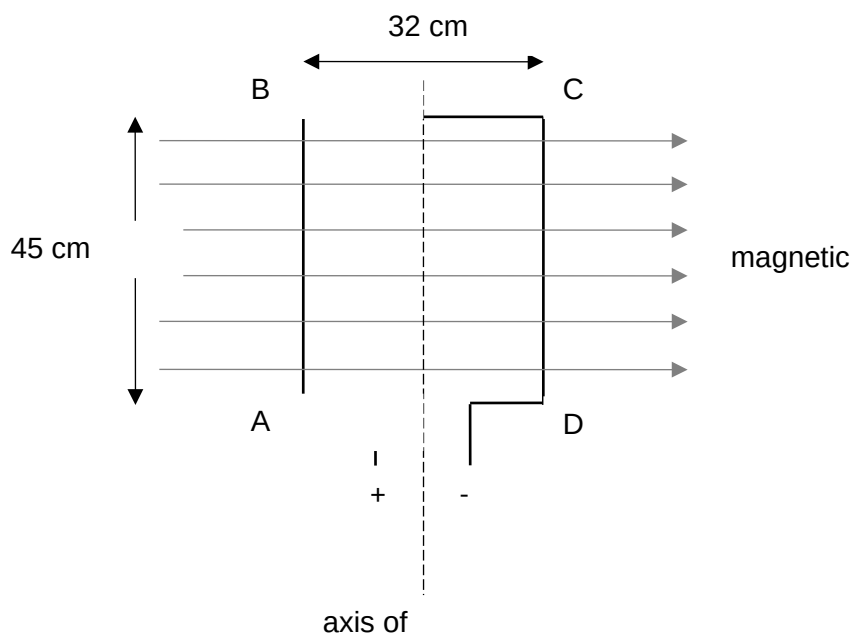
(3)

- b) Calculate the electric power generated by the DC motor and, hence, the percentage efficiency of the electric motor.

[If you were unable to calculate an answer for the rate at which the motor does work on the mass in part (a); use $1.00 \times 10^3 \text{ W}$]

(3)

The pulley has a diameter of 65.0 cm. The DC motor consists of a rectangular 200 turn coil (ABCD) that has the dimensions shown in the diagram below. The coil lies in a magnetic field of strength 'B' Tesla (see diagram).



- c) Given the polarity of the current flowing in the coil, state the direction of the magnetic force experienced by: (2)

(i) side AB.

(ii) Side BC.

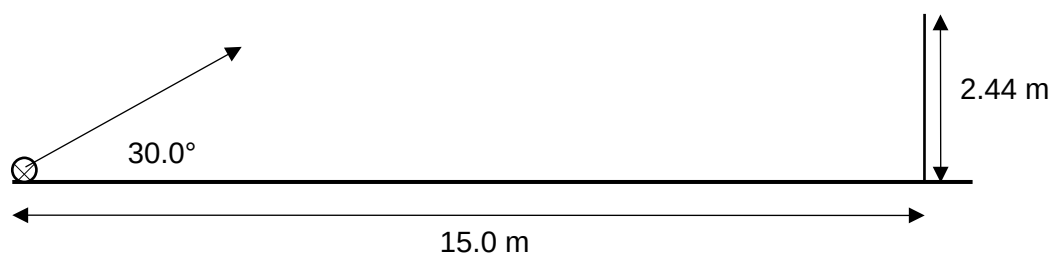
The DC motor raises the 30.0 kg mass at a constant velocity.

- d) Given its dimensions, calculate the maximum torque produced by the DC motor. (3)

- e) Hence, calculate the size of the magnetic field 'B'. [Hint if you were unable to calculate an answer for part (d), use 96.0 Nm] (2)

Question 11**(13 marks)**

A soccer player is shooting at a goal from directly in front of it. The player is 15.0 m from the goal line and kicks the ball with a launch angle of 30.0° to make sure the ball gets over a 'wall' set up by the opposition. The diagram below illustrates this situation. The height of the goal (ie – the crossbar above the ground) is 2.44 m.



The player is trying to launch the ball with a velocity 'u' that allows it pass under the crossbar. For parts (a), (b) and (c), IGNORE the effects of air resistance.

- a) Write down expressions for the horizontal (u_h) and vertical (u_v) components of the launch velocity in terms of 'u' and ' θ '. Show clearly how you obtained these with a vector diagram. (4)

$$u_h = \underline{\hspace{2cm}} \qquad u_v = \underline{\hspace{2cm}}$$

- b) Using horizontal components, show that the mathematical expression for the time taken for the ball to reach the goal line is:

$$t = \frac{17.3}{u} \quad (3)$$

- c) Using the expression derived in part (b), data from the vertical plane, and an appropriate motion formula, calculate the maximum launch velocity ' u ' that allows the ball to pass under the crossbar.
- (4)

- d) If air resistance is taken into account, state how the following would have to change for a successful shot:

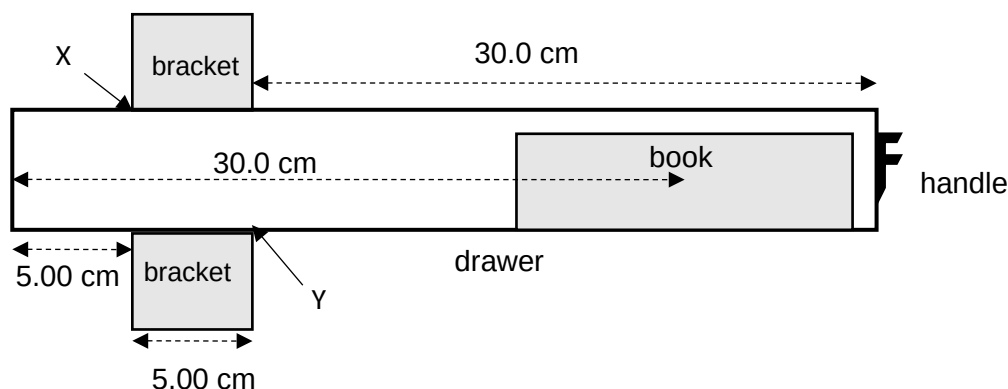
(2)

- (i) Launch velocity ' u ' if launch angle ' θ ' remains at 30° .

- (ii) Launch angle ' θ ' if the launch velocity ' u ' remains at the answer calculated in part (c).

Question 12**(15 marks)**

The diagram below shows the side-on view of a single drawer in a chest of drawers. The drawer is in an extended, open position and a book has been placed inside it as shown. The drawer is held in place by two identical pieces of wood acting as brackets above and below it. The drawer slides in and out between these two brackets when it is pushed and pulled by its handle. Two points, 'X' and 'Y', are labelled on each bracket as shown.



Both the drawer and the book can be considered to be uniform and have masses of 1.20 kg and 0.850 kg respectively. The distance from the left hand edge of the drawer to the centre of mass of the book is measured to be 30.0 cm (as shown). The mass of the handle is insignificant and can be ignored.

The other significant dimensions in this situation are shown.

In this extended position, the drawer is in equilibrium and stationary. It can also be considered to be horizontal.

- a) In the space below, draw a labelled free body diagram showing all the forces acting on the drawer. Make sure you include ' F_X ' and ' F_Y ' – the forces acting at points 'X' and 'Y'.

(4)

b) Given that the drawer is in a state of mechanical equilibrium, calculate:

- (i) the magnitude of the force acting at 'X' (ie – F_x).

(3)

- (ii) the magnitude of the force acting at 'Y' (ie – F_y).

[If you were unable to calculate an answer for part (b) (i), use a value of 58.0 N].

(3)

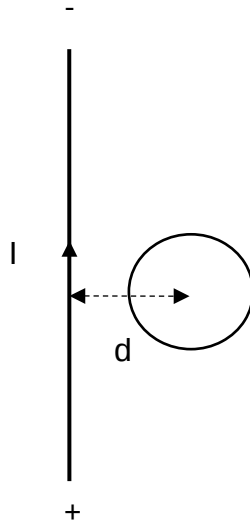
- c) The drawer is slowly pushed back into its unextended position within the chest of drawers by being pushed towards the left by the handle. Describe how the magnitude of forces at 'X' and 'Y' (ie - ' F_x ' and ' F_y ') will change as this drawer is pushed back to its unextended position. Explain your answer.

(5)

Question 13**(18 marks)**

A single coil is placed at a distance 'd' from a current-carrying conductor as shown below. Conventional current (I) is flowing in the straight conductor as indicated in the diagram.

The coil is small enough to assume that the magnetic flux density due to the conductor contained within its area is CONSTANT.



The coil has a radius of 1.00 cm and its centre is positioned at a distance (d) of 5.00 cm from the conductor. The conductor initially carries a current (I) of 0.450 A.

- a) Calculate the magnetic field strength at the centre of the coil.

(3)

- b) Given the assumption described above regarding the magnetic field strength within the area of the coil, calculate the total magnetic flux contained within the coil.
- (3)

- c) The current (I) in the conductor is now increased to 0.650 A in a time of 0.750 s. The coil remains in the same position (ie – its centre remains 5.00 cm from the conductor). Calculate the average EMF generated in the coil during this time. [If you were unable to calculate an answer for part (b), use an answer of 6.00×10^{-10} Wb]
- (5)

- d) On the diagram on the previous page indicate: (i) the direction of the magnetic field due to the current-carrying conductor INSIDE the coil; and (ii) state the direction (ie – clockwise or anticlockwise) of the induced current in the coil. (2)
- e) As the current in the conductor is increased, it is possible to move the coil in a way where NO (zero) EMF is induced. Explain how the coil must be moved so that no EMF is induced. (5)

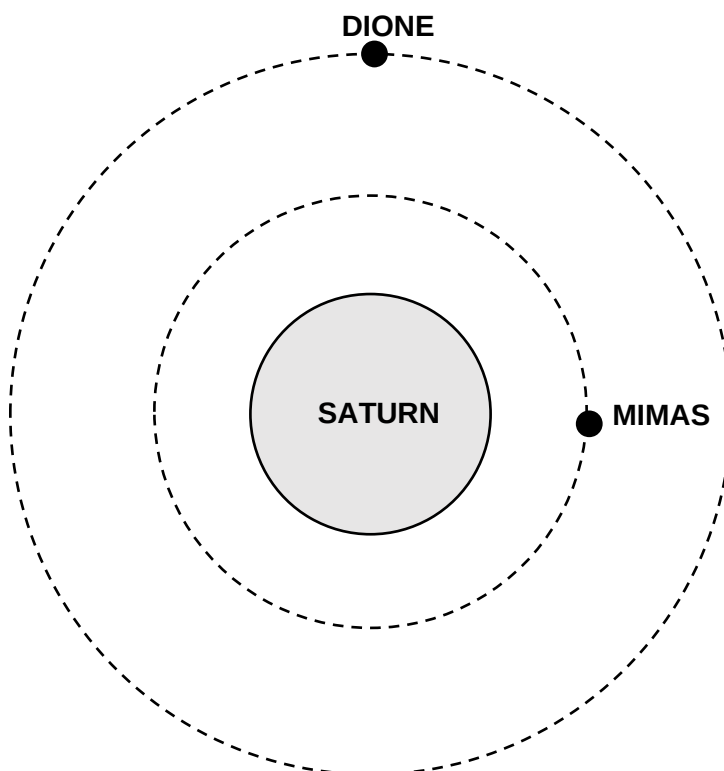
Question 14**(16 marks)**

The moons of Saturn are numerous and diverse – ranging from tiny ‘moonlets’ one kilometre across to the enormous Titan, which is larger than the planet Mercury. Saturn has 62 moons with confirmed orbits – 53 of which are named and only 13 have diameters larger than 50 kilometres. Data for two of the moons are provided below:

NAME	DIAMETER (km)	MASS (kg)	ORBITAL RADIUS (km)	ORBITAL PERIOD (Earth days)
Mimas	396	4.00×10^{19}	1.86×10^5	0.90
Dione	1123	1.10×10^{21}	3.77×10^5	

- a) The diagram below shows Saturn; approximate representations of the orbits of its two moons, Mimas and Dione; and the moons' positions at a particular point in time. On the diagram below, draw two vectors (arrows) that indicate (i) the direction and (ii) strength of the gravitational field due to Saturn's mass at the points indicated. Ignore any gravitational effects the moons' masses may have on the other.

(2)



- b) Using the data provided for Mimas and Dione in the table above – as well as Kepler's 3rd Law - calculate the orbital period for Dione in Earth days.

(4)

- c) Use the data provided for Mimas to calculate the mass of Saturn.

(4)

- d) Which moon has the higher orbital speed - Mimas or Dione? Explain without calculating any values.
- (3)

- e) NASA intends to insert a probe into an orbit around Saturn for scientific observations of its weather. Two students are discussing this probe; one student states: "All of the objects in this probe will be weightless because there are no forces acting on an object when it is in orbit." Is this student correct? Explain your answer.
- (3)

Section Three: Comprehension and Data Analysis**20% (30 Marks)**

This section contains **two (2)** questions. You must answer both questions. Write your answers in the space provided.

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Suggested working time for this section is 30 minutes.

Question 15**(14 marks)****EVIDENCE FOR DARK MATTER**

By examining the light from stars, astronomers are able to measure the rotational (orbital) speeds of stars in our own Milky Way. The distance of each star to the galactic centre around which all the rotations occur (ie – their orbital radii) can also be determined by various means.

If the mass of the Milky Way galaxy was equal to the 'normal' visible matter in the stars seen by astronomers, then the rotational speeds of the stars should vary as predicted by 'Keplerian Motion'. Newton's Laws can be used to predict the stars' speeds from their orbital radius.

However, when the orbital speeds of stars in the Milky Way galaxy are measured we find that no matter the orbital radius, these are virtually constant - they do not decrease as the distance from the galactic centre increases.

One explanation for this phenomenon is that there are huge amounts of unseen 'dark' matter in outer parts of the galaxy causing the stars to orbit more quickly.

The table below contains data for six (6) stars in the Milky Way Galaxy – including our own Sun. The data shows orbital radius (r); predicted orbital speed (v_p); the square of the predicted orbital speed (v_p^2); and the inverse of the orbital radius ($1/r$). Some values are missing in the last two (2) columns.

Star	Orbital Radius (r) ($\times 10^{20}$ m)	Predicted Orbital Speed (v_p) ($\times 10^4$ ms $^{-1}$)	Square of Predicted Orbital Speed (v_p^2) ($\times 10^9$ m 2 s $^{-2}$)	Inverse of Orbital Radius ($1/r$) ($\times 10^{-21}$ m $^{-1}$)
1	0.473	25.5	65.0	21.1
2	1.42	14.7	21.6	7.04
SUN	2.65	10.8		3.77
3	4.54	8.23	6.77	
4	6.34	6.97	4.86	1.58
5	8.57	6.01	3.61	1.17

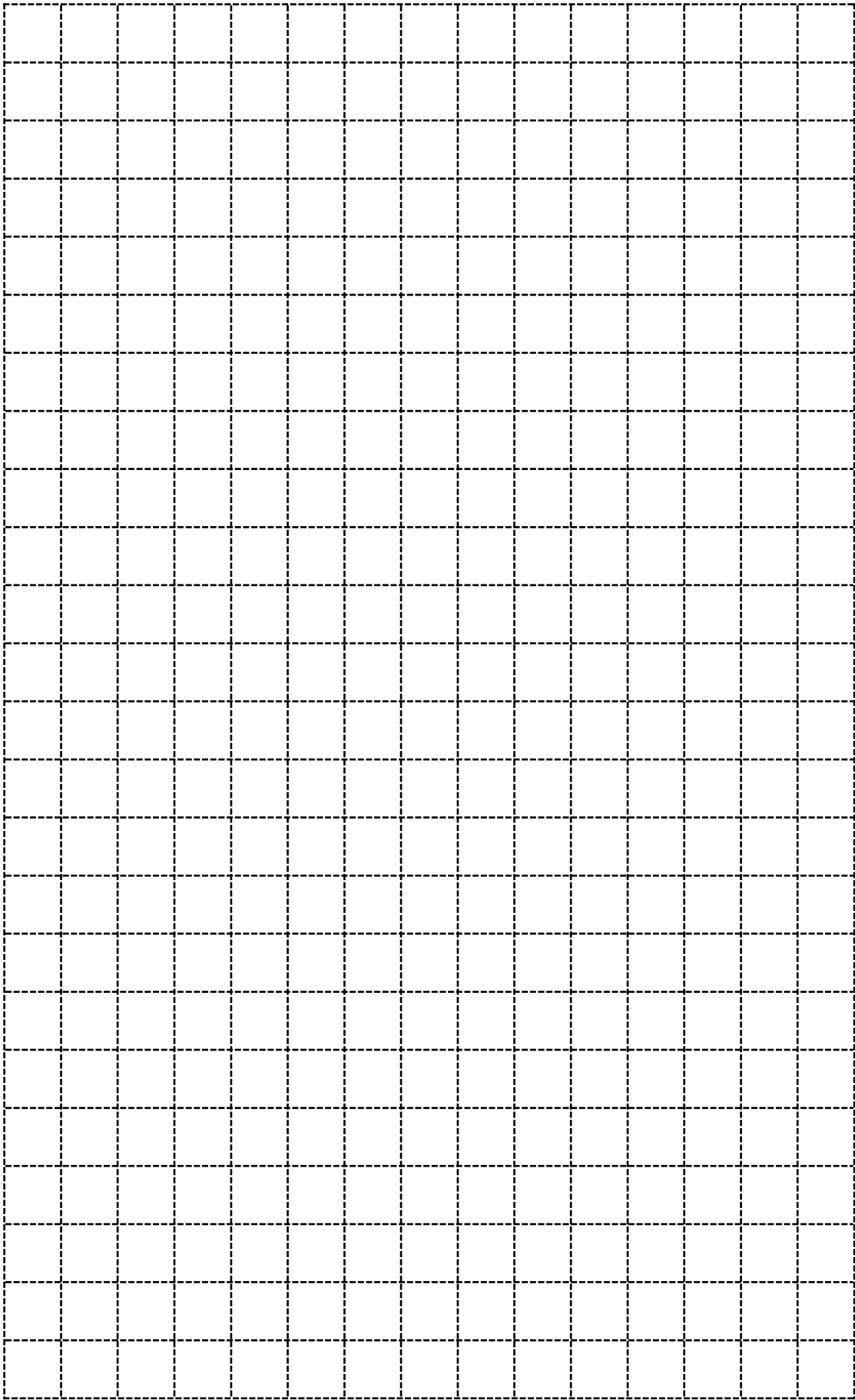
- a) Complete the table by calculating the missing values in the last two columns. (2)
- b) By combining concepts of gravitational force and centripetal force, an expression for orbital speed can be derived. This expression is:

$$v^2 = \frac{Gm}{r}$$

In the space below, show how the expression above is derived.

(2)

- c) On the grid on the next page, plot a graph of **'Square of Predicted Orbital Speed (v_p^2)'** versus **'Inverse of Orbital Radius ($1/r$)'**. Place 'Inverse of Orbital Radius ($1/r$)' on the horizontal axis. Draw a line of best fit for your data. (4)
- d) Calculate the slope of your line of best fit. Include units. (3)
- e) Use the expression derived in part (b) and the slope from part (d) to calculate a predicted value for the mass of the galaxy. (3)



Question 16**(16 marks)****THE LARGE HADRON COLLIDER**

In September, 2008, the CERN particle accelerator complex started up its latest and most powerful addition – the Large Hadron Collider (LHC). This particle accelerator was the most powerful and large of its type – a 27 kilometre ring that accelerates charged particles (normally protons) to speeds approaching the speed of light.

Super conducting magnets (cooled to -271.3°C , so that they can conduct electricity without resistance) bend two beams of protons into near-circular paths travelling in opposite directions before they are caused to collide in detectors.

The proton beams consist of 2808 'bunches' of 1.2×10^{11} protons (at the start of their acceleration in the LHC) and undergo 1 billion collisions per second. The total energy of each proton collision is up to a maximum of 14 TeV (normally about 13 TeV). At these energies, the protons are travelling so quickly that they circumnavigate the 27 km long LHC 11000 times per second.

The fragments and information gained from these collisions provide critical information about the origins of our universe and the nature of matter itself.

ACCELERATING THE PARTICLES

The protons' journey begins in the 'source chamber' – essentially a cylinder of hydrogen gas releases its H-atoms into a strong electric field where protons are separated from their electrons.

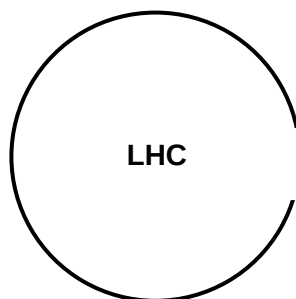
The protons are accelerated to high speeds by very strong electric fields. Initially, this acceleration is achieved in two (2) linear accelerators (LINAC 1 and LINAC 2). By the time the protons leave LINAC 2 and enter the next phase of acceleration (in the PS Booster), they have an energy of 50 MeV.

Subsequent particle acceleration and protons beam energies increase as follows:

- PS Booster accelerates the proton beam to an energy of 1.4 GeV.
- Proton Synchrotron (PS) accelerates the proton beam to an energy of 25 GeV.
- Super Proton Synchrotron (SPS) accelerates the proton beam to an energy of 450 GeV.
- In the Large Hadron Collider (LHC), the proton beam is accelerated for 20 minutes to a maximum energy of 6.5 TeV. The beams are circulated in this ring for several hours under normal operating conditions.

GUIDING THE BEAM IN THE LARGE HADRON COLLIDER (LHC)

The beam is guided in to a near-circular path in the 27 kilometre circumference LHC in high-vacuum tubes by extremely powerful electromagnetic devices (magnets).



Circumfer

ence = 27

There are 9593 magnets in the LHC – varying from single dipoles, quadrupoles, sextupoles, octupoles, decapoles, etc. The strongest magnets consist of 1232 dipoles.

The dipoles are essentially used to guide the trajectory of the beams around the accelerators. The ‘insertion’ quadrupoles are special magnets used to ‘squeeze’ the proton beams and focus them to a size that is so small that the probability of proton collisions are enhanced greatly.

The peak dipole magnetic field strength reaches 7.74 T in the LHC. At a temperature of 1.9 K, the super conducting magnets can carry a current of 11850 A which allows a maximum magnetic field strength of 8.33 T. This temperature is critical to guide the proton beam around the 27 km circumference LHC at an energy of 6.5 TeV without colliding with the sides of the vacuum tubes. At 4.5 K, the magnets could only carry a current of 8500 A and produce a magnetic field strength in the order of 6 T.

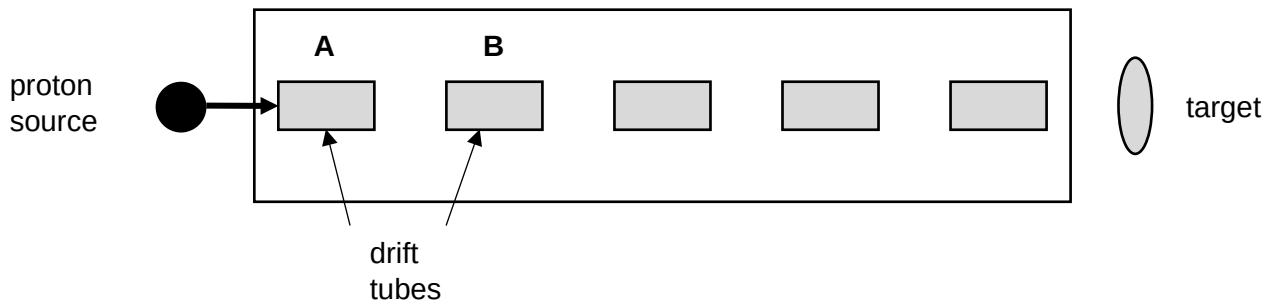
HOW DO WE ‘SEE’ THE PARTICLES PRODUCED BY THE PROTON COLLISIONS?

For each proton collision, the particle physicist’s goal is to count, track and characterise all the other different particles produced in order to reconstruct the collisions process as fully as possible. If the track of a particle can be traced, much valuable information can be discerned about that particle – particularly if the collision takes place in a magnetic field. Characteristics such as charge and momentum can be calculated. Very high momentum particles travel in almost straight lines; very low momentum particles make tighter spirals.

- a) Explain why the H-atoms need to be ionised (ie – protons created) for the operation of the LHC.

(2)

The diagram below shows the structure of the particle accelerators in LINAC 1 and LINAC 2. It consists of 'drift tubes' (where the protons maintain a constant velocity) and 'gaps' between the tubes where the proton acceleration takes place. The proton acceleration occurs due to an alternating electric potential difference between each drift tube.



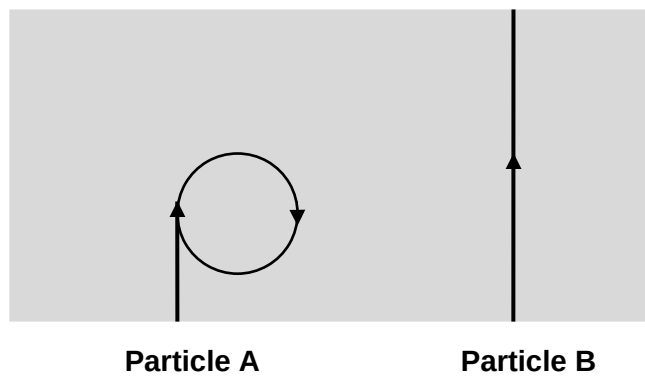
- b) On the two drift tubes that are indicated with arrows ('A' and 'B'), draw two symbols ('+' and '-') to represent the electric potential required to accelerate the proton in the gap between them. (1)
- c) "At these energies, the protons are travelling so quickly that they circumnavigate the 27 km long LHC 11000 times per second."

Use this information to calculate the speed of the protons as they travel around the LHC.

(3)

- d) When the protons leave the two (2) linear accelerators (LINAC 1 and LINAC 2), they have achieved an energy of 50 MeV. Use this information to calculate the speed of the protons as they leave LINAC 2, given that relativistic effects can be ignored. (3)
- e) Explain why changing the temperature of the super conductors (eg – increasing to 4.5 K) will cause protons to collide with the vacuum tubes in the LHC. Include any mathematical expressions that will assist your answer. (4)

The diagram below shows the tracks of two particles (A and B) in a detector.



Both particles have the same sized positive charge.

- f) Use information in the article to describe each particle as either “very high momentum” or “very low momentum”. In the space below the table, explain why the path of Particle ‘B’ is virtually straight despite its positive charge.

(3)

Particle ‘A’	
Particle ‘B’	

End of Section 3

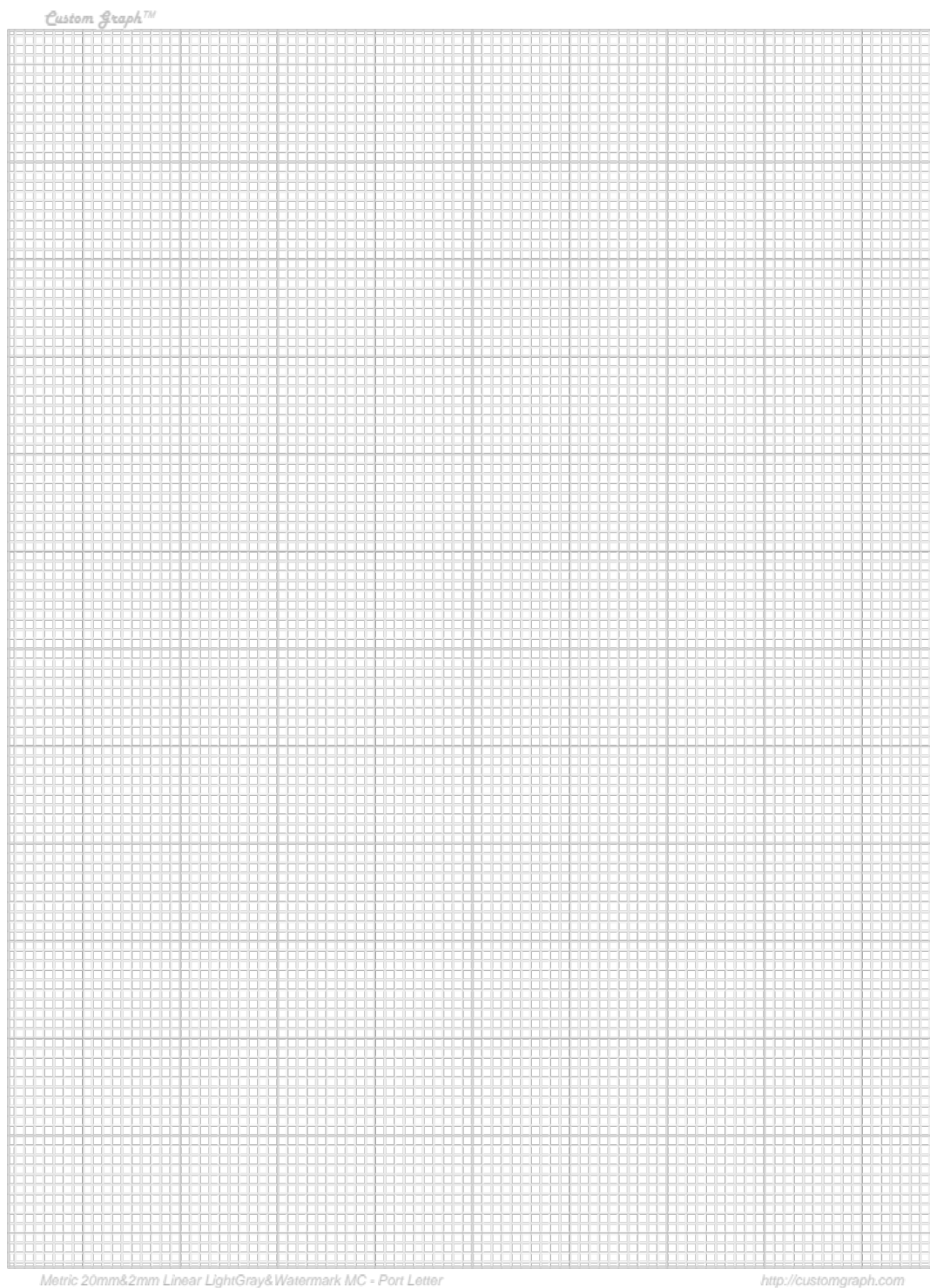
[illegible]

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Additional working space

Additional working space

Additional graph if required.



End of examination

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