## ROSSMOYNE SENIOR HIGH SCHOOL
# SCIENCE

# Semester 1, Examination 2019

# ATAR Physics Unit 3
## Question/Answer Booklet

**Student Number:**     In figures

| | | | | | | | |
|---|---|---|---|---|---|---|---|

In words     _____

_____

## Time allowed for this paper
Reading time before commencing work:     ten minutes
Working time for paper:                                three hours

## 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, correction fluid, ruler, highlighters

Special items:       Calculators satisfying the conditions set by 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 material.  If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

**Circle your Teacher's name:   Mr Holyoake,   Mr Patterson,     Mrs Shashikumar**

## 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 | 11 | 11 | 50 | 52 | 30 |
| Section Two: Extended answer | 6 | 6 | 90 | 87 | 50 |
| Section Three: Comprehension and data analysis | 2 | 2 | 40 | 36 | 20 |
| | | | **Total** | 175 | 100 |

**Instructions to candidates**

1.      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.

2.      Write answers in this Question/Answer Booklet.

3.      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.

4.      You must be careful to confine your responses to the specific questions asked and follow any instructions that are specific to a particular question.

5.      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% (52 marks)**

This section has **eleven (11)** 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 50 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).
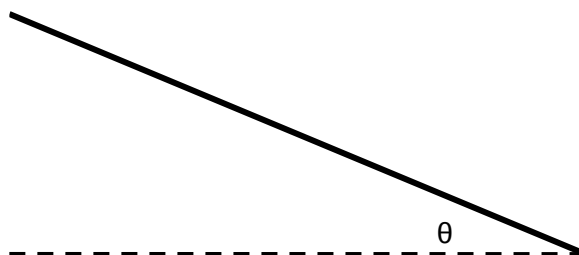
(4 marks)

**Question 2**

At some distance from the centre of a planet, the gravitational field strength is 2.00 m s$^{-2}$. Calculate the gravitational field strength at a distance twice as far from the centre of the planet.

(4 marks)

**Question 3**

A car is able turn in a circular path of radius 'r' at a particular speed 'v' by using a banked road at an angle (θ) to the horizontal. See below.

Banked
curve

θ

Explain why the angle of banking 'θ' of the road needs to increase if the radius of its circular path decreases while maintaining the same speed (v). Include an appropriate mathematical expression and a vector diagram to aid your answer.

(4 marks)

**Question 4**

The generator at the Kwinana Power Station generates electric power at 70.0 MW, 5.80 kV RMS. This power is then stepped up by a transformer to a transmission voltage of 330 kV RMS.
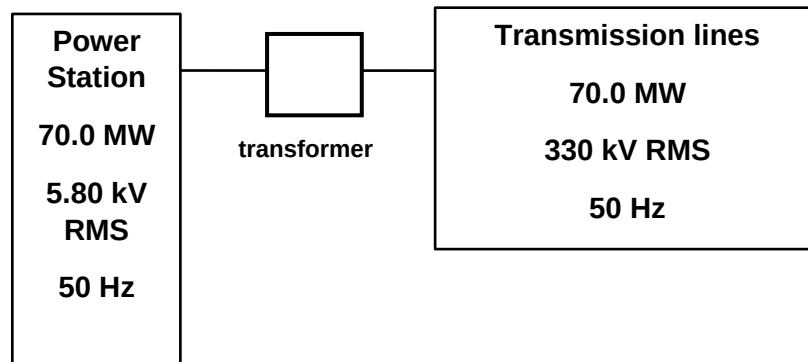


a)      Calculate the turns ratio for the step-up transformer described above.

(2 marks)

b)      In the scenario described above, the data indicates an 'ideal' transformer. In reality, no transformer is 'ideal'. Explain what is assumed for an 'ideal transformer', and why no transformer is ideal.

(4 marks)

**Question 5**

The diagram below is of two asteroids in close proximity. The gravitational field in this region has also been included.
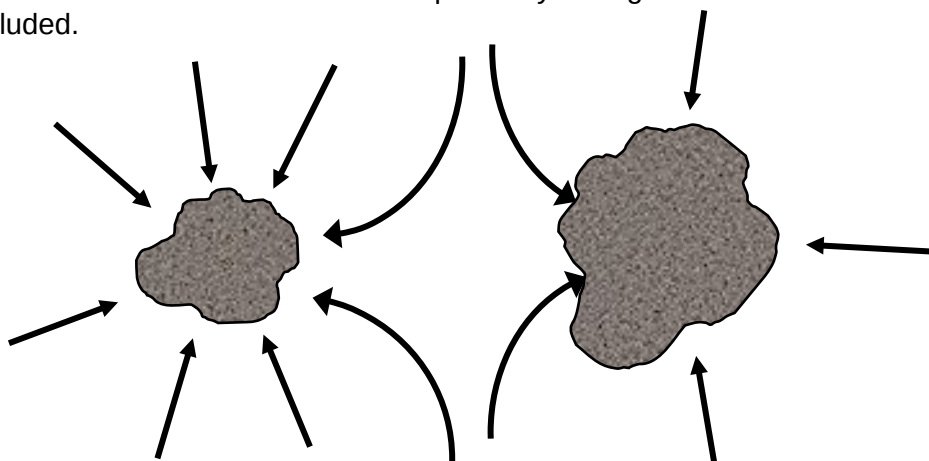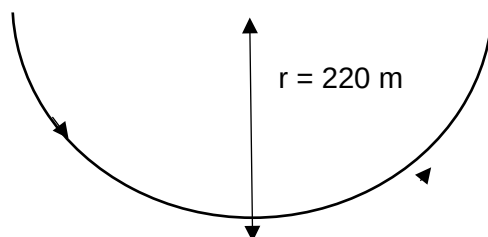


Which asteroid (left or right) has the larger mass? Explain your choice.                    (3 marks)

**Question 6**

A plane of mass 870 kg pulls up from a nosedive. It follows a circular arc of radius 220 m and is travelling at a top speed of 36 ms$^{-1}$.



r = 220 m

a)      Ignoring air resistance, calculate the maximum force experienced by the underside of the plane's wings.

(3 marks)

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

(1 mark)

**Question 7**

A 600 g block on a ramp inclined at 22.00 is accelerating down the ramp at 2.16 m s$^{-2}$. Friction has a significant influence on this block.

(a)     Draw a labelled vector diagram showing the relationship between the physical forces and the net force acting on the block. Include the angle in the diagram.          (3 marks)

(b)     Calculate the frictional force acting on the block.                                (3 marks)

**Question 8**

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 x $10^6$ ms$^{-1}$ in the direction shown.
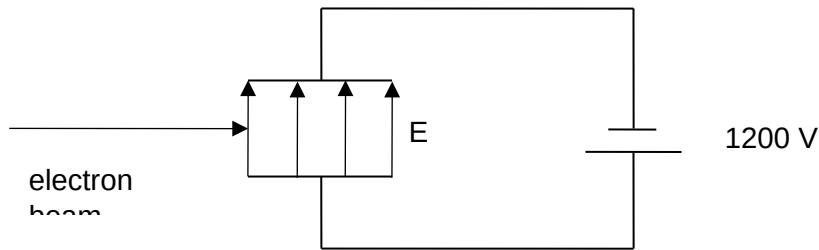


A magnetic field is applied to the electron beam sufficient to allow the electron beam to pass between the plates without deviating.

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

(1 mark)

d)      Hence, calculate the magnitude of the magnetic field required.
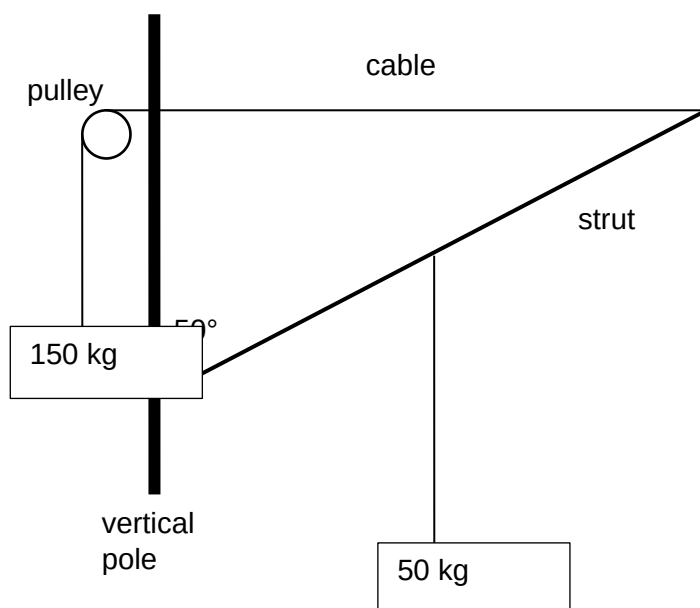
(2 marks)

**Question 9**

Two spheres with equal but opposite electric charge are placed 7.55 cm apart and experience

5.11 × $10^{-4}$ N of attractive force. Calculate the magnitude of the electric charge on each sphere.

(3 marks)

**Question 10**

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 middle of the uniform 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 10 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 150 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 11

An 0.800 m metal rod is moving down through a magnetic field (out of the page) at 12.0 m s$^{-1}$ as
shown in the diagram below. The magnetic flux density is 29.0 mT.
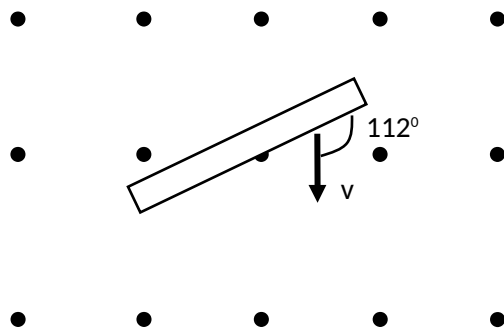


(a)     On the diagram, indicate which region of the rod would accumulate positive charge.

(1 mark)

(b)     Calculate the magnitude of the emf across the rod.                                (4 marks)

**End of Section 1**

**Section Two:  Problem-solving       50% (87 Marks)**

This section has **six (6)** questions.  You must answer **all** questions. Write your answers in the space provided.

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 at the top of the page.

- 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. Fill in the number of the question that you are continuing to answer at the top of the page.

Suggested working time for this section is 90 minutes.

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**Question 12**                                                               **(14 marks)**

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 ($\Delta E_P$)). A diagram outlining this system is shown below.
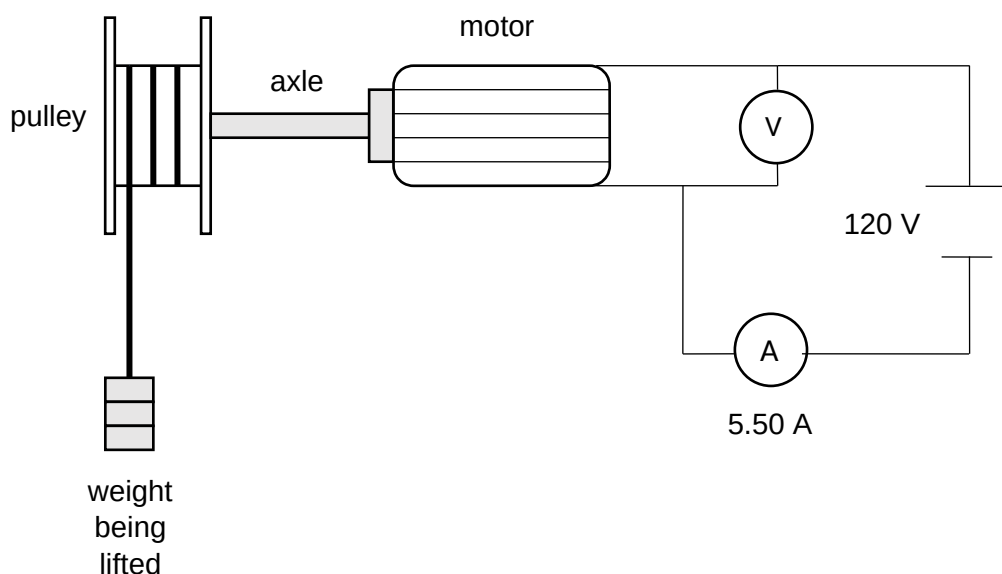


The DC motor operates at a voltage of 120 V and draws a current of 5.50 A. It is able to lift a mass of 15.0 kg through a vertical height of 3.50 m in 1.05 s.

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

                                                                                                            (3 marks)

b)      Calculate the electric power consumed 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 $4.50 \times 10^2$ W]

                                                                                                            (3 marks)

The pulley has a diameter of 65.0 cm. The DC motor consists of a rectangular 240 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).
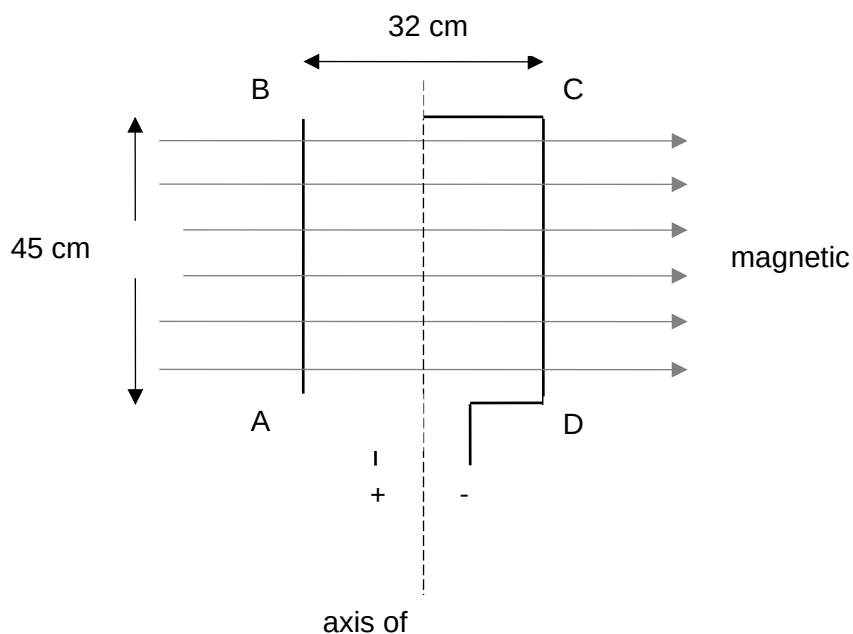
c)      Given the polarity of the current flowing in the coil, state the direction of the magnetic force
        experienced by:

                                                                                          (2 marks)

        (i)      side AB.

        (ii)     Side BC.

d)      The DC motor raises the 30.0 kg mass at a constant velocity. Given its dimensions,
        calculate the maximum torque produced by the DC motor when the coil is parallel to the
        field.

                                                                                          (3 marks)

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 N m]

                                                                                          (3 marks)

**Question 13**                                                                                          **(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° The diagram below illustrates this situation. The height of the goal (ie – the crossbar above the ground) is 2.44 m.
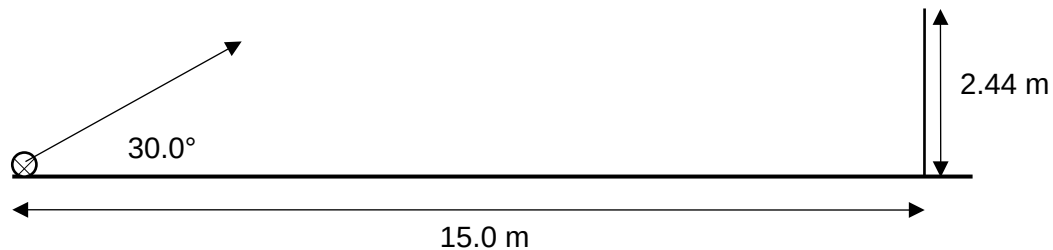


The player is trying to launch the ball with a velocity 'u' that allows it hit the crossbar. For parts (a), (b) and (c), IGNORE the effects of air resistance.

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 marks)

$u_h$ = _____                    $u_v$ = _____

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

$$t = \frac{17.3}{u}$$

(3 marks)

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 hit the crossbar.

(4 marks)

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

(2 marks)

(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 14** **(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.
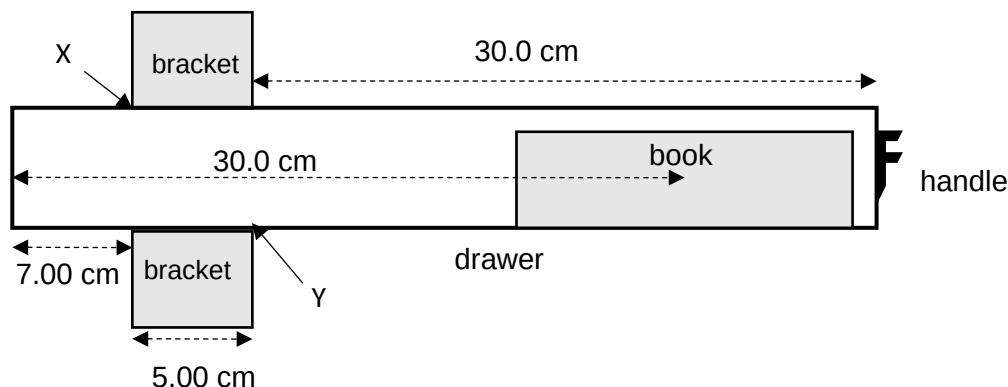


Both the drawer and the book can be considered to be uniform and have masses of 1.20 kg and 0.850 kg respectively. The distance from the left hand edge of the drawer to the centre of mass of the book is measured to be 30.0 cm (as shown). The mass of the handle is insignificant and can be ignored.

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 marks)

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 marks)

(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 marks)

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 marks)

**Question 15**                                                          **(14 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.
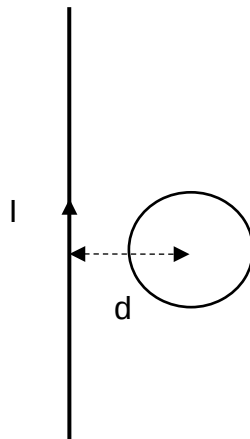


The coil has a radius of 1.00 cm and its centre is positioned at a distance (d) of 5.00 cm from the conductor. The conductor initially carries a current of 2.10 A.

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

(3 marks)

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 marks)

c) The current (I) in the conductor is now increased which increases the flux within the coil to a value of $8.17 \times 10^{-9}$ Wb 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 $6.00 \times 10^{-9}$ Wb]

(3 marks)

d)      Based on the diagram on the previous page state:

        (i)      the direction of the magnetic field due to the current-carrying conductor INSIDE the
                 coil;

        (ii)     the direction of the induced current in the coil due to the change described in part
                 (c).
                                                                                    (2 marks)

e)      It is possible to shift the coil while the current in the conductor is being increased such that
        no EMF is induced in the coil. Explain.
                                                                                    (3 marks)

**Question 16**                                                                          **(15 marks)**

A 20.0 cm long conducting rod forms a circuit with a 3.00 V battery, connected via some loose wires which dangle freely from either end of the rod. The rod is also tethered to a magnet via a pair of strings and can swing freely. Another magnet sits below the rod to create a uniform 0.500 T field. The rod's uniform distributed mass is 0.0900 kg and has a 2.00 Ω resistance. You may assume the mass of the string and loose wires are negligible and the resistance of the loose wires is negligible.
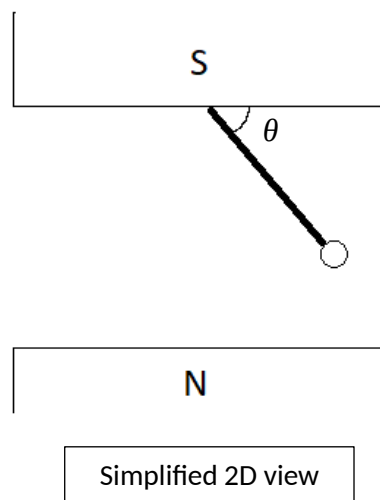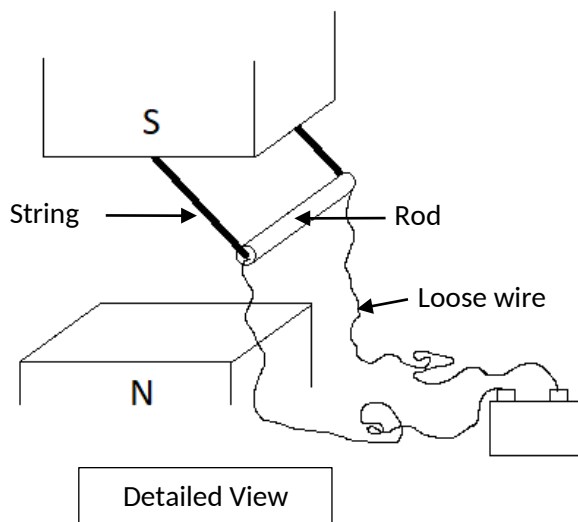


When everything is connected, the rod swings to one side and remains in the position shown in the simplified 2D view.

(a)     By drawing a positive and negative sign, label the polarity of the battery in the
        diagram above.                                                                       (1 mark)

(b)     Calculate the current through the rod.                                               (1 mark)

(c)    Calculate the magnetic force acting on the rod.                          (2 marks)

(d)    Calculate the tension in one of the pieces of string.                     (4 marks)

(e)    Calculate the angle the string makes with the magnet face ($\theta$ in diagram).

(2 marks)

(f)      The battery is removed and the loose wires left dangling, disconnected. The rod swings like a pendulum and comes to a complete stop in 5.60 s. The rod is returned to its starting position, prior to when the battery was removed. The loose wires that were connected to the battery are connected together. The rod is let go, swings like a pendulum but this time comes to a complete stop in 2.90 s. Explain the difference in time.                        (5 marks)

**Question 17**                                                              **(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 | $4.00 \times 10^{19}$ | $1.86 \times 10^5$ | 0.90 |
| Dione | 1123 | $1.10 \times 10^{21}$ | $3.77 \quad 10^5$ | |

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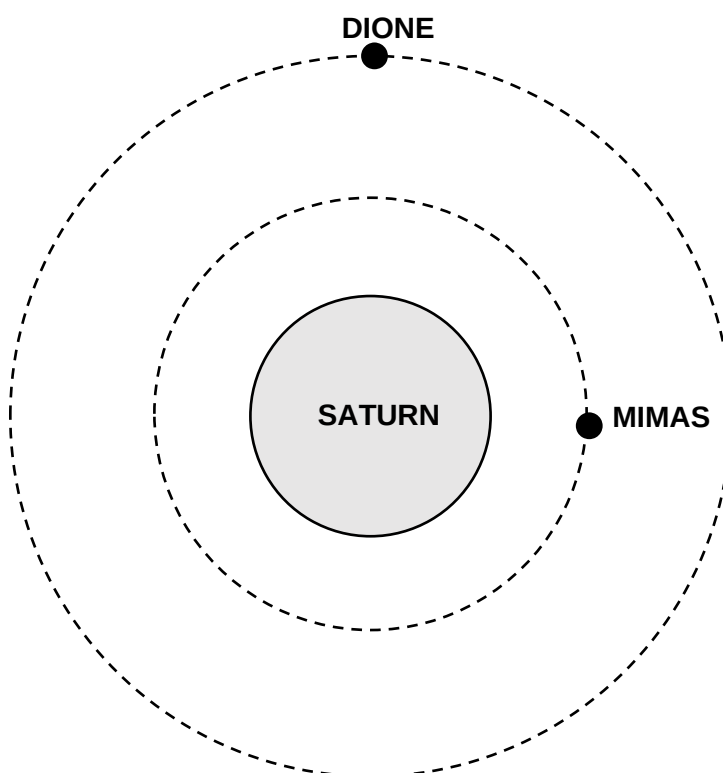
b)      Using the data provided for Mimas and Dione in the table above – as well as Kepler's 3$^{rd}$ Law - calculate the orbital period for Dione in Earth days.

(4 marks)

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

(4 marks)

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

(3 marks)

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 marks)

**End of Section 2**

**Section Three:  Comprehension and Data Analysis**            **20% (36 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 40 minutes.

**Question 18**                                                                         **(18 marks)**

### EVIDENCE FOR DARK MATTER

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

If the mass of the Milky Way galaxy was dominated by the stars and gas seen by astronomers, then the revolution speeds of the stars should vary as predicted by Newton's Laws. One expectation is that the velocity of the star should decrease the further it is from the galactic centre.

However, when the orbital speeds of stars in the Milky Way galaxy are measured we find that no matter the orbital radius, the speed of each star remains a constant 210 km s$^{-1}$.
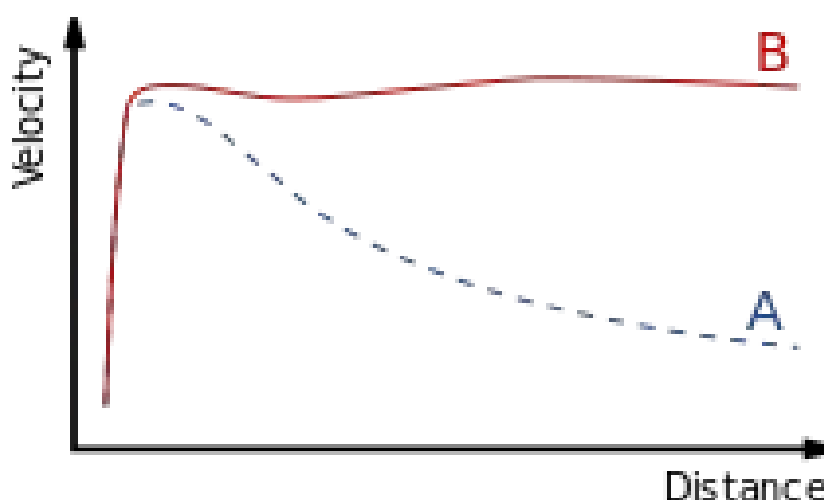


A – Predicted trend of orbital velocity against distance
B – Actual trend of orbital velocity against distance

The preferred theory to explain this result is the presence of 'dark matter'. The Milky Way (and all the universe) is believed to contain much more matter than what we have observed. In addition to stars, gas and planets, there is up to 90% more matter that cannot be seen, does not interact with matter, but does have a gravitational influence. This extra matter is referred to as dark matter and its existence would explain why stars in our galaxy all have the same orbital speed. The dark

matter seems to spread with a fairly uniform density much further from the galactic centre than 'standard' matter does.
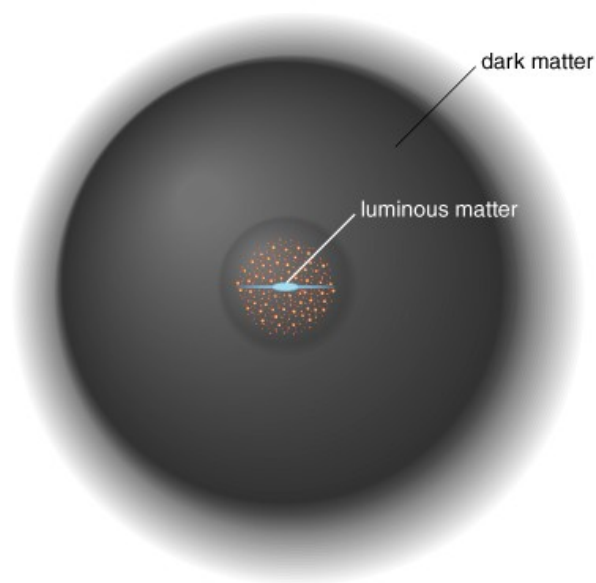


© Addison-Wesley Longman

The simple approach to predicting a star's orbital velocity is to approximate that the galaxy's mass is located in the centre – this is fine when looking at a star near the far edge of the galaxy. However, with 90% of a galaxy's matter being spread out much further than most stars, estimating the mass of the galaxy as a point source no longer is appropriate as the star's are deep inside the mass of the galaxy.

a)     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 marks)

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 ($^1/_r$).

| Star | Orbital Radius (r) (x $10^{20}$ m) | Predicted Orbital Speed ($v_p$) (x $10^4$ ms$^{-1}$) | Square of Predicted Orbital Speed ($v_p^2$) (x $10^9$ m$^2$s$^{-2}$) | Inverse of Orbital Radius ($^1/_r$) (x $10^{-21}$ 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 |

b)    Complete the table by calculating the missing values in the last two columns.

(2 marks)

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.

(5 marks)
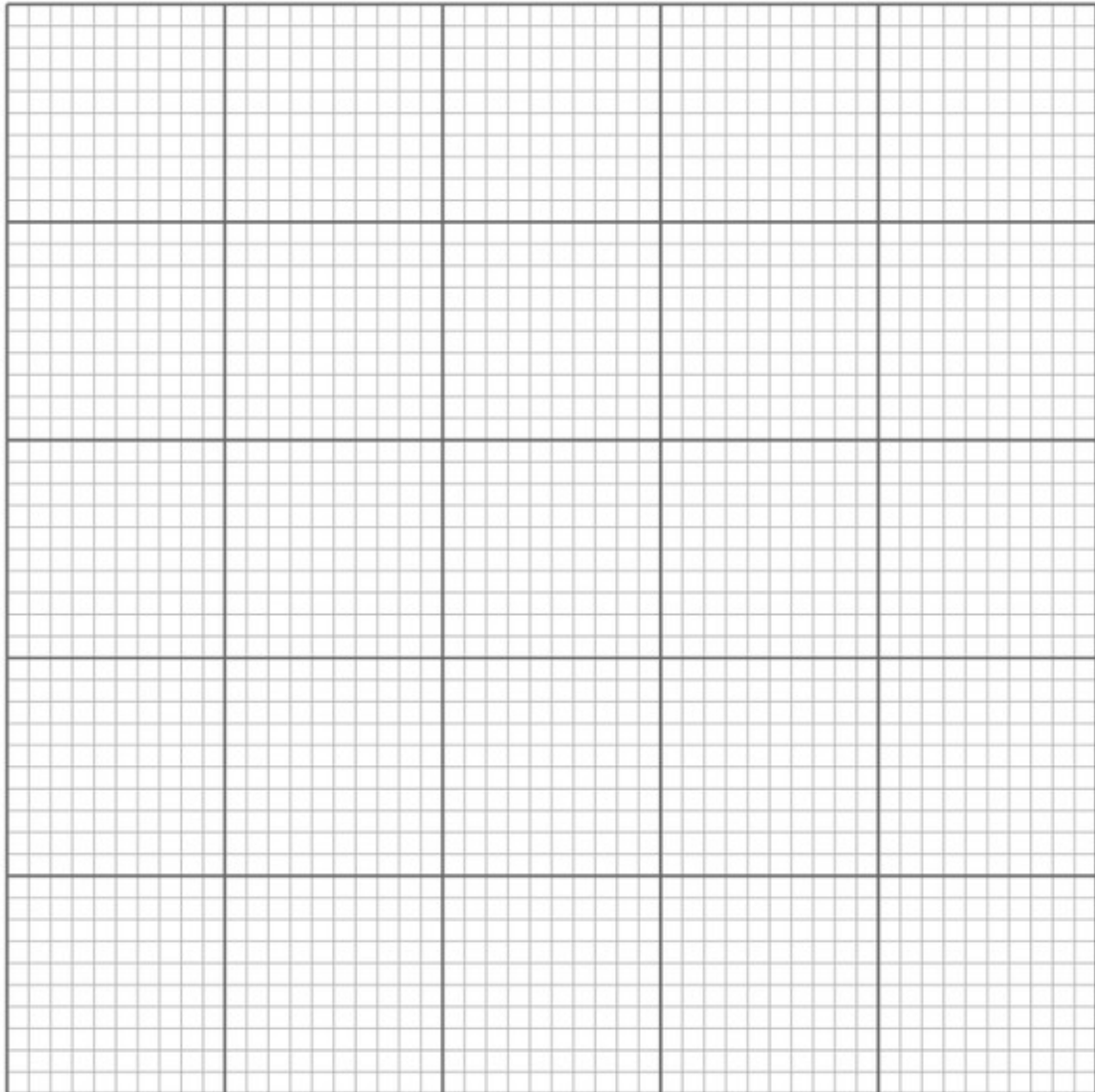
d)      Calculate the slope of your line of best fit. Include units.

(3 marks)

e)    Use the expression derived in part (a) and the slope from part (d) to calculate a predicted value for the mass of the galaxy.

(3 marks)

f)    By referring to gravitational forces acting on a star, explain why the presence of dark matter is required to explain why the orbital speed of stars is independent of orbital distance.

(3 marks)

**Question 19** **(18 marks)**

Metal detectors: a powerful tool to detect hidden metals

Metal detectors are used in civil engineering, archaeology, security, mining and by hobby "detectorists". The design is simple, and credit is given to Gustave Trouve, from France, as the inventor who used a metal detector to locate bullet fragments in patients.

Metal detectors work by transmitting a signal in the form of a magnetic field from a search coil, powered by an electrical supply. Historically, the search coil was round and operated by an AC supply as high as 20 kHz. This is true even if the metal detector was powered by a convenient portable battery- the DC of the battery must be converted into AC. The most powerful detectors produce fields as high as 0.800 T.

The magnetic field induces eddy currents in target metals, which in turn produce their own magnetic fields – this is the return signal. The return signals are detected by another coil in the metal detector which acts as a magnetometer (device for measuring magnetic fields).

Various coil shapes are used for metal detectors, each with distinct advantages. A pair of 'D' shaped coils arranged back to back to form a circle help minimise the effects of mineralisation in soil. Mineralisation is the tendency for some particles in the soil to mimic metals, which will alter the magnetic field signal of the metal detector. The soil in rural northern Australia, with its high iron content has a large mineralisation effect.

A key innovation of metal detector design was the introduction of pulse induction (PI). Rather than using a standard oscillating electric supply, PI detectors produce a relatively large magnetic field but over a much smaller time scale by driving large currents through the search coil. When no target metal is within proximity, the magnetic field in the magnetometer reduces at a uniform rate, producing predictable currents. In the presence of a target metal however, the magnetic field declines at a reduced rate. The time differences are small, but modern electronics allows the difference to be measured to give accurate results. The benefits of a PI mode of detection is that it penetrates deeper into the ground and is also better at ignoring mineralisation in the soil.

If you have ever been on a plane, chances are you walked through a metal detector. These use PI technology. While exact numbers are manufacturer specific, a walk-through PI detector typically sends out 100 pulses a second – each pulse lasting a few microseconds. The magnetic fields are safe to biological matter, even through repeat exposure. This makes metal detectors ideal for the detection of concealed weaponry with no adverse health effects.

(a)    Describe why there are two distinct coils of wire in a metal detector.        (2 marks)

(b)      State one advantage and one disadvantage described by the article when a battery is used
          to power a metal detector.                                                                           (2 marks)

(c)      Explain why a metal detector must use an AC supply.                               (3 marks)

(d)      State the benefit of a pair of 'D' shaped coils and where this type of detector may be used.
                                                                                                                (2 marks)

(e)     An Australian one dollar coin has a 2.50 cm diameter. A powerful metal detector operating
        at 20.0 kHz passes over a one dollar coin, buried just under the surface.

        (i)     Calculate the maximum possible change in flux passing through the face of the coin
                as the metal detector field changes from 0.00 T to its peak field density in the
                presence of the coin.                                                      (2 marks)

        (ii)    Using your answer from part (i), calculate the average induced emf in the coin.
                You may assume the coin behaves like a single coil of wire with an identical cross
                sectional area as the coin and that the flux changes linearly with time. (If you could
                not obtain an answer to part (i), you may use a value of $4.00 \times 10^{-4}$ Wb)
                                                                                           (3 marks)

        (iii)   State two reasons why your answers to part (i) and (ii) could be smaller in practice
                than these theoretical answers.                                            (2 marks)

(f)     Describe why, in the presence of a target metal, the PI magnetic field decreases at a
        reduced rate.                                                          (2 marks)

**End of Section 3**

**END OF EXAM**

**Additional working space**

**Additional working space**

**Additional graph if required.**

**End of examination**