St Mary's Anglican Girls' School

Semester II Exam

2007 Question/Answer Booklet

PHYSICS 12

(Questions marked with a * are for the pre 2010 course)
(Stars have not been placed in the answer key only in the blank question paper)

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 CANDIDATE
Standard Items
Pens, pencils, eraser or correction fluid, ruler.
Special Items
Physical formulae and constants sheet, drawing implements, templates and calculators satisfying the conditions set by the Curriculum Council.

TO BE PROVIDED BY THE SUPERVISOR
This Question/Answer Booklet.
Physical Formulae and Constants sheet.

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. Please check carefully and if you have any unauthorised material with you hand it in to the supervisor BEFORE reading any further.

NAME: ______________________________

Short Answer	Problem Solving	Comprehension	%
/30	/50	/20	/100

STRUCTURE OF THE PAPER

Section	No of questions	No of marks out of 200	Proportion of exam total
A: Short Answers	15	60	30%
B: Problem Solving	6	100	50%
C: Comprehension & Interpretation	2	40	20%

INSTRUCTIONS TO CANDIDATES

Write your answers in the spaces provided beneath each question in sections A and B
The value of each question in section A is four marks.

Note that (where appropriate) answers should be given numerically and they should be evaluated **and not left in fractional or radical form**. Give all numerical **answers to three significant figures** except in the cases for which estimates are required.

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 out will not be awarded full marks**.

Questions containing the instruction **estimate** may give insufficient numerical data for their solution. Candidates should provide appropriate figures to enable an approximate solution to be obtained.

Candidates should remember that when descriptive answers are required, they should be used to display understanding of the aims and objectives of the physics 12 course. A descriptive answer, which addresses the context of a question without displaying an understanding of physics principles, will not attract marks.

Despite an incorrect final result, credit may be obtained for method and working, provided these are **clearly and legibly set out**.

SECTION A : Shorts Answers - 60 Marks (30%)

Attempt ALL 15 questions in this section.
Show all working out. (4 marks each)

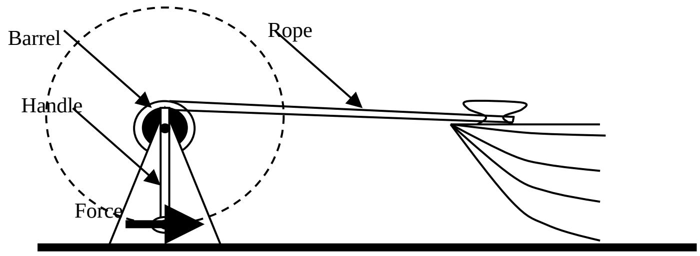
1. In the 1920s people staged bizarre events. One of these events was a piano hurling competition. In a piano hurling competition a piano is launched into the air by a catapult. The catapult releases the piano at an angle of 50.0^0 above the horizontal from a height of 12 m above its base with a speed of 15.0 m s^{-1}. Some spectators insist on standing in front of the proposed landing site. For this reason it is necessary to identify where the piano is most likely to land so that spectators can be positioned sufficiently far in front of the drop zone. How far will the piano land from the base of the catapult?

(4 marks)

2. Neptune has a number of satellites, one of which, Nereid, orbits it once every 360.2 earth days at a mean distance of 5.50×10^6 km from Neptune's centre of mass. What is Neptune's mass?

(4 marks)

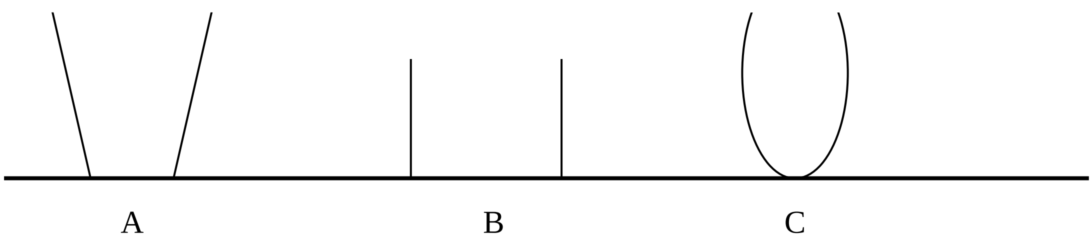
3. A boat is being pulled out of a river using a simple winch. The winch has the following dimensions and configuration…



The barrel has a diameter of 20.0 cm and the handle has a radius of 95.0 cm. The boat must overcome a maximum value of static friction equal to 574 N. What minimum force must be exerted on the handle of the winch to just move the boat?
Note :- the winch has no friction itself.

(4 marks)

4. A person is going shopping for a vase. The vase will contain a large quantity of flowers and can often be placed in locations that experience some windy conditions. Three designs are available (shown below).



a) Which is the most stable design? ______________________________(1 mark)

b) Your answer to part a) is in what kind of equilibrium? ____________(1 mark)

c) What makes this vase the most stable of those on offer?

(2 marks)

____

____

____

***5.** Four similar coiled springs, used in the suspension of a car, each has a length of 50.0 cm before they are fitted to the car. When fitted, and the 1100 kg mass of the car is being supported, each spring has a length of 30.0 cm. Calculate the total amount of elastic potential energy stored in the compressed springs.

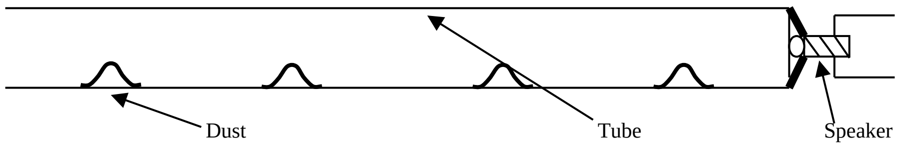
(4 marks)

***6.** A climber, of mass 65.0 kg tests his nylon rope and finds out that when he is suspended at the end of a 20m length of the rope, the rope stretches by 0.35 m. Later at the bottom of a 30.0 m cliff, he has to assist a friend of mass 50.0 kg by carrying her while the rope is hauled from above. By how much will the rope be extended by the total load?

(4 marks)

7. A 1.20 m open pipe is attached to a speaker. The bottom of the pipe has been coated in a thin layer of chalk dust. The speaker is switched on. The sound causes the dust particles in the bottom of the horizontal tube to sweep itself into 4 piles as shown in the diagram.

(4 marks)



What is the frequency of the sound?

8. On a still night in the 1930s (when Perth was smaller and quieter) the elephant at the zoo in South Perth was heard bellowing / trumpeting in Perth city on the other side of the river. A lady, who lived in the city, asked her husband who had been fishing out in the middle of the river at the time, if he had heard anything strange. He said that he had not heard anything at all. The wife then accused him of being at the local tavern instead of going fishing!

If the husband <u>was</u> fishing explain using physics why he could not hear the elephant (or anything else for that matter) but the wife could hear the elephant.

Note :- assume that there were no waves or ripples that night and both husband and wife have equally good hearing. A diagram may assist your explanation.

(4 marks)

***9.** A student is having problems sleeping on the night before their TEE physics exam. Part of the problem is that the cicadas (chirping grasshopper like insects) are singing outside his bedroom window. If the loudness of the average cicada is 70.0 dB at a distance of 4.00 m from the student, how many cicadas will be required to sing together at a distance of 4.00 m from the student for the combined sound to reach the threshold of pain?

Note :- be sure to clearly indicate the decibel level that corresponds to the threshold of pain in your answer.

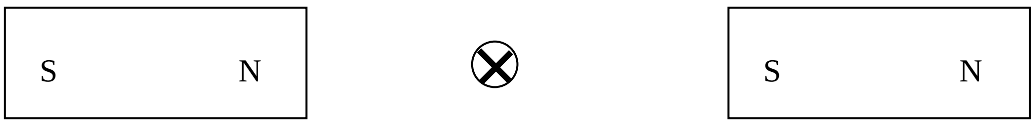
(4 marks)

10. Two cars are parked at some traffic lights waiting for the light to turn green. The sound from the two car engines is heard by the driver in the first car. The driver can hear 16 fluctuations in the loudness of the combined car sounds in 5 seconds. The driver reads his tachometer which indicates that the engine is turning at a rate of 800 rpm (revolutions per minute). When the driver depresses the accelerator slightly, the number of fluctuations in each 5 second period increases to 22 fluctuations. At what speed is the engine in the second car turning (in rpm)?

(4 marks)

11.a) Draw the resultant magnetic field around this wire carrying conventional current into the page and the two magnets

(2 marks)



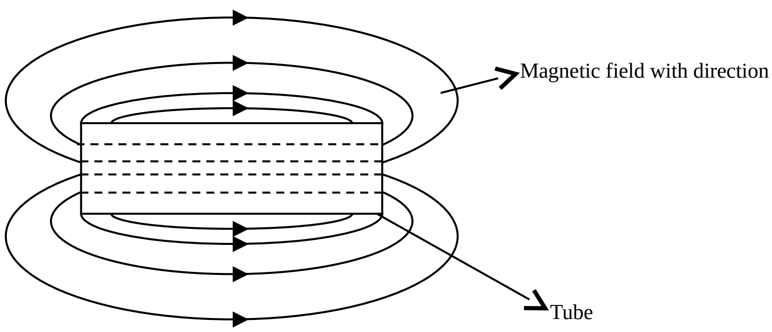
b) Draw on to the solenoid below…

i) wires and a

ii) voltage source

that will produce the following stable magnetic field.

(2 marks)



12a) A 15.0 m flag pole is hit by lightning. The lightning causes a conventional current of 1.00×10^{2} kA to flow out of the ground along the pole towards the clouds. If the horizontal component of the earth's magnetic field is 4.00×10^{-5} T in the vicinity of the flag pole, what force will the flag pole experience?

(2 marks)

b) The flag pole is able to withstand a maximum torque of 400 Nm. If the force exerted due to the current (I) moving through the magnetic field acts half way up the pole, will the flag pole snap? Show calculations to support your answer.

(2 marks)

13a) A 2.00 m metal bar falls with a terminal velocity of 0.5 km s^{-1} above the city of Perth. Perth has a latitude of approximately 32.0^{0}. The bar is orientated in an east - west direction as it falls. The earth's magnetic field has a strength of 5.00×10^{-4}T as it emerges from the earth. What is the magnitude of the voltage induced in the bar as it falls?

(3 marks)

b) Which end of the bar is positive?

(1 mark)

14. A hydro electric power station has an electrical power output of 700 MW. Unfortunately the power station is 300 km from the city it is to supply electrical power to. The builders of the power station decide that they will reticulate (transmit) the electricity to the city on high tension power lines at a voltage of 350 kV. The power lines have an electrical resistance of $4.00 \times 10^{-5}\ \Omega$ per meter of length. What percentage of the original electrical power supplied is <u>lost</u> in transmitting the electricity to the city?

(4 marks)

15. A generator supplies an average voltage of 20.0 V and an average current of 200 mA. What is the peak power supplied by the generator?

(4 marks)

SECTION B : Problem Solving - 100 Marks (50%)

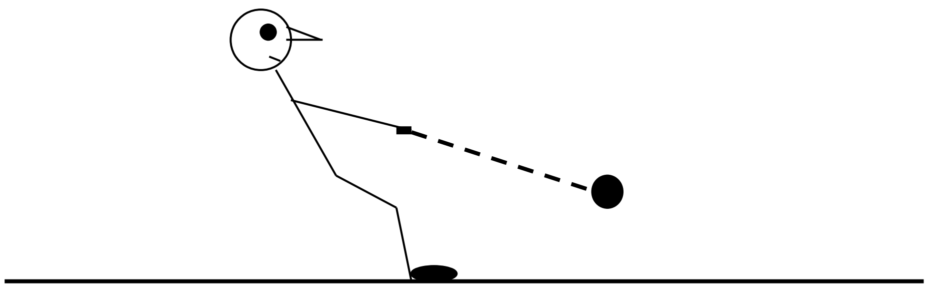
Attempt ALL 8 questions.

1.a) Calculate the centripetal force on a hammer that is being whirled in a horizontal circle of horizontal radius 1.8 m at a steady pace of 10.0 m s^{-1}. The mass of the hammer is 7.30 kg

(2 marks)

b) Draw on the below diagram the forces acting on the hammer.

(2 marks)



c) What is the magnitude of the tension in the chain of the hammer?

(2 marks)

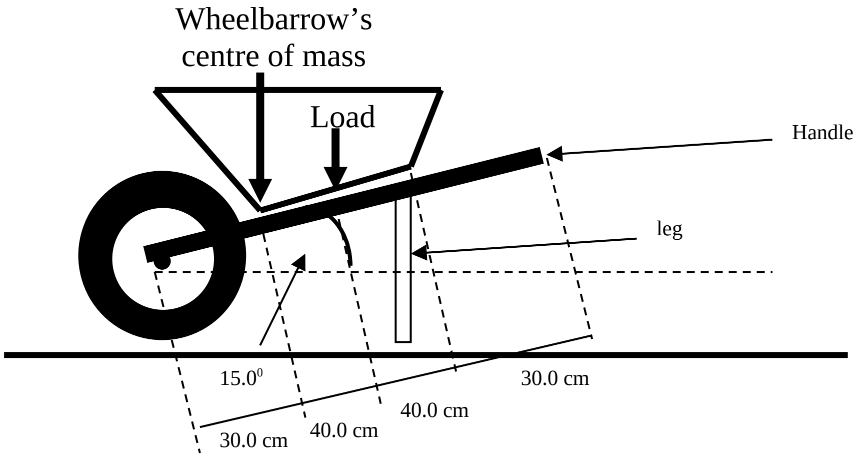
d) What is the angle formed between the chain and the horizontal?

(2 marks)

e) The hammer thrower is in fact also a mass revolving in a circle about a central point. If the hammer thrower has a mass of 130 kg, what is the horizontal radial distance from the hammer thrower to the central point about which he is rotating?

(4 marks)

***2.** A wheelbarrow consists of two simple machines, a wheel / axle and a lever.



a) The load has a mass of 100 kg and the wheelbarrow has a mass of 40.0 kg. What is the magnitude of the force exerted on **each** of the **two** legs of the wheelbarrow?

(5 marks)

b) What is the force of the wheelbarrow and load on the tyre of the wheelbarrow?

(4 marks)

c) A workman sits on the end of one of the handles to have his lunch. What is the maximum mass that the workman (and his lunch) can have without tipping the wheel-barrow clockwise?

(4 marks)

3. A hunting horn is a brass musical instrument which consists of a long pipe coiled in a circle. The horn player buzzes their lips at one end of the pipe (into a mouthpiece) and a musical note comes out the other end. Both ends of the pipe are classified as open ends.

a) Traditional hunting horns were 12 foot (3.60m) long. What is the lowest frequency the pipe is able to produce?

(4 marks)

b) The hunting horn player buzzes her lips with a frequency of 1.20×10^3 Hz while attempting to play the instrument. Will this frequency cause resonance? Explain why or why not with the support of a calculation.

(4 marks)

c) After having too much wine in the forest the hunting horn players enjoyed playing a trick on the king and nobles in the hunting party. They would play (buzz) a note into the horn at such a high frequency that the humans could not hear it but the dogs could. If the upper threshold of hearing for humans in the 12th century was 18 000 Hz, what is the lowest overtone that the horn player could play to set the dogs barking without the humans hearing the sound?

(4 marks)

4. Light produced by sprinkling potassium chloride into a bunsen flame is a bright lilac colour. When this light is viewed through a spectroscope, it is seen to contain two lines corresponding to wavelengths of 766.5 nm and 769.9 nm. These lines are caused by electrons of two separate energy levels dropping into a common lower energy level.

Note :- You will need to use these values for constants…

$h = 6.626 \times 10^{-34}$ J s^{-1}

$c = 2.998 \times 10^{8}$ m s^{-1}.

a) How have the electrons in the potassium atoms been excited?

(2 marks)

b) What frequencies do the above wavelengths correspond to?

(2 marks)

c) Calculate the difference between these energy levels in electron volts.

(3 marks)

d) The shorter wavelength of light, when measured has an intensity of 60 W m^{-2}. How many energy level transitions must occur each second to produce this amount of energy (light) spread over a surface area of 1.00 m^2?

(3 marks)

e) Lilac is actually a combination of at least 2 colours. At which coloured end of the visual spectrum is the 769.9 nm wavelength most closely associated?

(1 mark)

____

f) Explain how you came to your conclusion in part e) above

(1 mark)

g) Potassium chloride is now dissolved in a jar of water. An incandescent light globe is placed behind the jar. Light from the light globe that has passed through the jar is then passed through a prism to produce a spectrum. What type of spectrum has been produced?

(1 mark)

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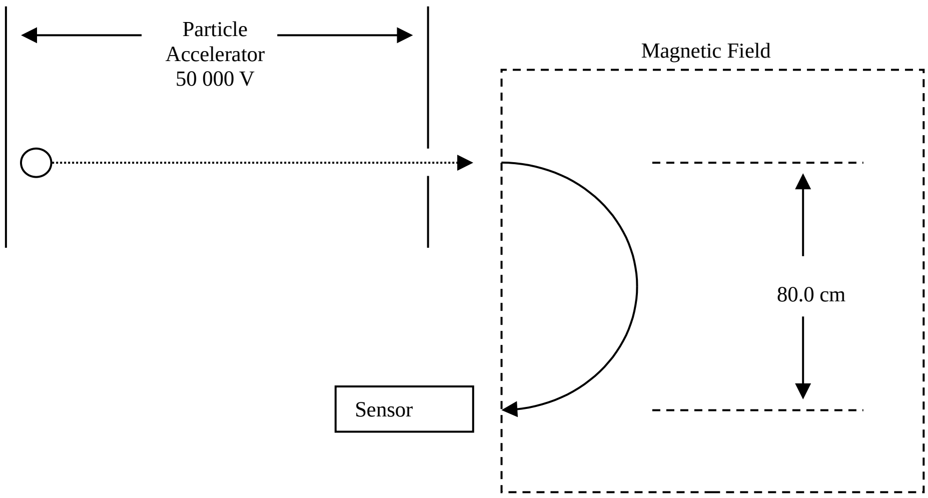
5. A helium - 4 atom has one of its electrons removed to give it a positive charge (i.e. ${}^{4}_{2}He^{+}$). It is then accelerated through a potential difference of 50 000 V in a particle accelerator.



a) If the positively charged helium atom has a mass of 6.6438 x 10^{-27} kg, what is the velocity of the positively charged helium atom as it leaves the accelerator?

(4 marks)

b) The helium nucleus now enters a magnetic field. **Draw onto the diagram above** the direction of the magnetic field if the atom is to turn in a clockwise direction.

(1 mark)

c) A sensor is set up at a distance of 80.0 cm to the right of the position where the atom enters the field. What is the field strength required to turn the atom into the sensor?

(4 marks)

d) The laboratory in which the mass spectrometer is set up is on the equator where the earth's magnetic field runs parallel with the ground. If the diagram shown on the previous page is a top view diagram and north is at the top of the page, what is the overall (net) effect of the earth's magnetic field on the positioning of the sensor? Explain?

(3 marks)

6. A scientist aims to build a 100 % efficient transformer. What are 4 of the major problems the scientist must overcome if the transformer is to be as efficient as possible and how will they solve these problems?

(4 marks)

Problem	Solution

b) Assume that the scientist succeeds in building the perfectly efficient transformer. The scientist inputs 20 V of AC electricity from a 500 W power supply. The transformer has a N_s / N_p turn ratio of 2 : 5. What is the output current from the secondary coil?

(3 marks)

c) What is the resistance of the secondary coil?

(2 marks)

d) Is this a step up or a step down transformer?

(1 mark)

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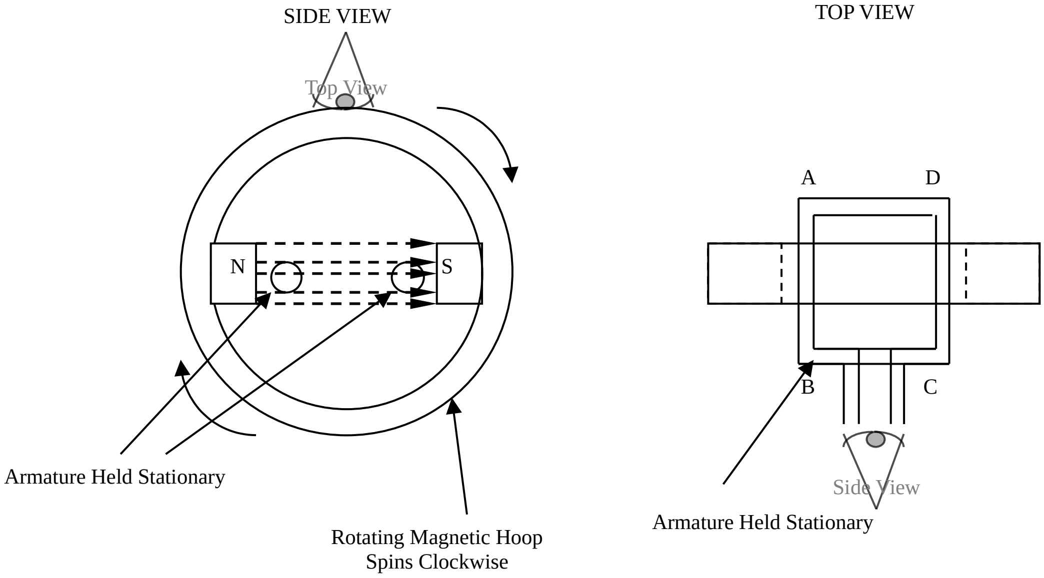
e) The transformer is now turned around and the 20 V is supplied to the original secondary side of the transformer by the 500 W power supply. What is the resistance of the original primary side of the transformer?

(3 marks)

7. A new experimental alternator is being designed. The alternator has no commutators. The design of the alternator is shown below.



a) If the magnetic hoop is moving in a clockwise direction in which direction will the **positive** charges in the armature side A-B experience a force when viewed in the top view diagram? (Note :- also draw the direction of the current on the diagram to remove any ambiguity)

(1 mark)

____

b) The magnetic hoop spins at a rate of 450 RPM (revolutions per minute). What is the frequency of the rotation?

(1 mark)

c) The armature has 340 turns. The magnetic flux density between the sides of the magnetic hoop is 0.08 T. The area inside the armature is 200 cm^2. What is the magnitude of the peak voltage induced in the armature?

(3 marks)

d) Name three ways that the amount of voltage produced by the alternator can be increased.

(3 marks)

(i) ____________________

(ii) ____________________

(iii) ____________________

e) Is the current produced by the armature direct or alternating current? Explain why.

(2 marks)

f) Can the opposite type of current be created by this machine? If so explain how?

(1 mark)

g) The alternator is now stopped and the armature is now connected to a 60.0 Hz alternating voltage source. At a particular moment in time, when the coil and the magnetic hoop are in the positions shown in the diagram on the previous page, the voltage source is connected, causing conventional current to flow in the armature (shown in the top view diagram) in a clockwise direction. This will cause the magnet to spin. Will it spin clockwise or anticlockwise as viewed in the side view diagram?

(1 mark)

____

h) How can you make the magnet spin faster?

(1 mark)

8. Small DC electric motors which use a permanent magnet to produce the magnetic field generate a "back EMF" when they rotate. This "back EMF" opposes the voltage applied to the motor. If the motor stops, because of a heavy load being applied to it, the current will increase because there will be no "back – EMF".

A researcher applies a fixed voltage of **12V DC** to a small permanent magnet DC electric motor. By varying the load on the motor shaft they are able to reduce the speed of the motor and measure the current at various speeds.

Some of the results are tabulated below.

Result Number	1	2	3	4	5
Motor Speed (S) (RPM)	0	200	400	600	800
Current drawn by motor (mA)	550	515	270	140	0

a) Convert the above table to S.I. units in the table below.

(2 marks)

Result Number	Unit	1	2	3	4	5
Motor Speed (S)						
Current drawn by motor						

b) What is the independent and what is the dependant variable?

(1 mark)

Independent ____

Dependent ____

c) Plot the data on your graphics calculator. Are there any outliers in the data? If so which result number(s) is / are outliers? Take steps to deal with the outlier(s).

(1 mark)

Is there an outlier? ____________________________________

Result Number ____________________________________

d) What is the mathematical equation relating the two variables?

(1 mark)

e) Estimate the resistance of the motor's armature winding. Please notice that this is best done using the data relating to when the motor is stalled (not moving) and hence there is no "back EMF".

(3 marks)

f) The back EMF of the motor (V_{back}) is related to actual resultant voltage pushing the current along the armature of the motor by the formula $V_{resultant} = 12 - V_{back}$. Rearrange the mathematical equation you have found relating the variables I and S, so that it now relates $V_{resultant}$ and S.

(4 marks)

SECTION C : Comprehension and Interpretation - 40 Marks (20%)

Read the passages below carefully and answer all of the questions at the end of the passages. Candidates are reminded of the need for correct English and clear and precise presentation of answers. Diagrams (sketches), equations and/or numerical results should be included as appropriate.

Show all working out for questions requiring numerical answers.

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1. London Eye

[20 marks]

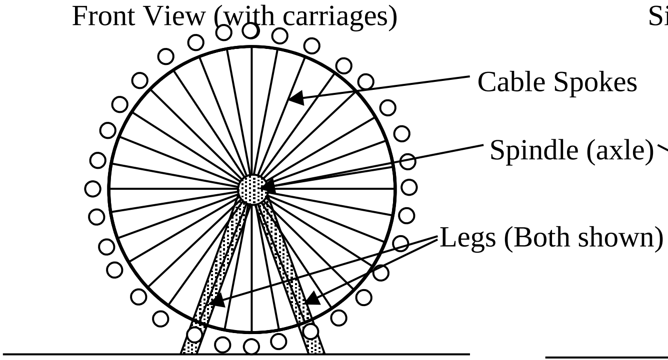


Figure 1

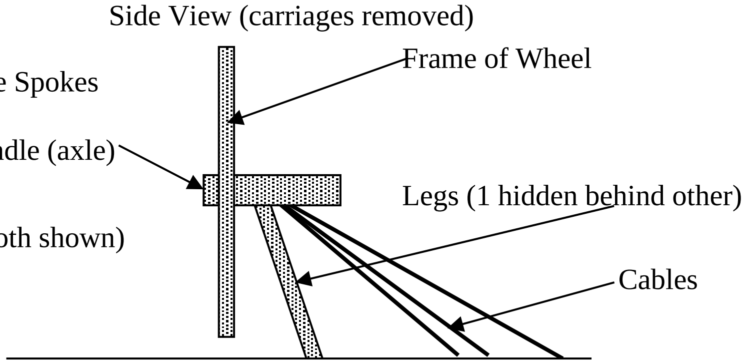


Figure 2

The London Eye was built to mark the millennium. It is the largest observation wheel ever built and from its highest point 135 m above the ground, visitors can see for 42 km.

The design and manufacture involved many people. As well as the many jobs for civil and structural engineers, there were jobs for mechanical engineers, such as designing the drive mechanism, and for electrical engineers, such as supplying the drive energy and the lighting.

The first task for the structural engineer was to calculate all the forces acting on the structure: the weight of the component parts (called self-weight); the people who have to be carried; and the wind. After calculating the forces, the engineer had to evaluate stresses in the different parts of the structure and check they were safe. To do this required knowledge of how to calculate the stresses in cables, columns and beams. Once the forces were known, the appropriate materials could be chosen.

Figure 1 shows a side view of the wheel supported by the two legs, which lie one behind the other in this diagram. Three supporting cables are shown (the cables for the other leg are directly behind these). Although the problem is really one in three dimensions, we can get an idea of the forces in the legs and cables by considering the two-dimensional cross-section. Most of the weight is taken by two main cables for each leg and one other cable. If we simplify the problem by looking at a cross section, with one leg and one main cable we can calculate the forces by taking moments and resolving horizontally and vertically. (Figure 3)

Simplified Cross Sectional Diagram

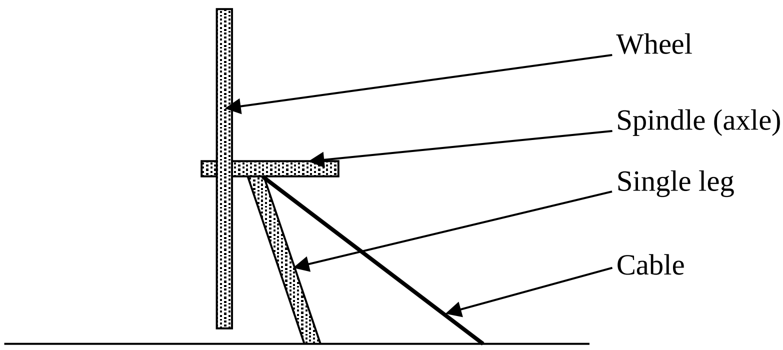


Figure 3

The mass of the rim and the capsules is about 1000 tonnes. When the capsules are fully loaded, we have the added mass of the people. The wheel has thirty-two capsules with a capacity for 25 people in each. The other load to be considered is the weight of the spindle. This is a cylinder 23 m long. It is 2.1 m in diameter with walls 30 cm thick and a weight 200 tonnes.

The wheel has a natural resonance frequency and it is important that it is not set in resonance by the wind or by fluctuations in the wind, which can be up to about 40 m s^{-1} at the top of the wheel. Engineers were able to calculate the natural frequency of the wheel using the formula:

$$f = 0.5\,\pi\,(\text{stiffness} / \text{mass})^{½}$$

Where …

- the **stiffness** was 2 x 10^6 N m^{-1}
- **m** in kg was the mass
- **f** was the frequency.

Actual Diagram

As the wheel rotates, the tension in individual cables changes. This means that the natural frequency will change. A cable at the top of the wheel will have lower resonant frequency than one at the bottom. The London Eye is driven around at a slow speed, 0.26 m s^{-1} at the capsule position, and so does not have to stop to allow people to board. The mechanical engineers chose a drive system based on tyres gripping the edge of the wheel rim. There is a main wheel drive at rim level which has 16 rubber-tyred wheels to supply 200 kN traction.

The yield strength of steel is normally about 350 MPa, depending on the type of steel. The cables are made from very strong steel with a yield strength of 1 000 MPa. For safety, the compressive stress on the legs must be much less than the yield strength of the steel.

Questions

1. Are the cables in compression or tension? Explain with the help of a diagram.

(2 marks)

2. Are the legs in compression or tension? Explain with the help of a diagram.

(2 marks)

3. Is the mass of the people significant when calculating the forces on the wheel? Explain with reference to the other forces on the wheel.

(3 marks)

4. How could the wheel be protected against resonant frequencies of wind, which may cause the wheel to sway dangerously?

(2 marks)

5. Why would the natural frequency of the wheel be different at the bottom of the wheel to the top of the wheel?

(3 marks)

6. Estimate the centripetal acceleration of the wheel at the capsule position?

(3 marks)

*7. Why must the compressive stress on the legs be less than the yield strength of steel?

(3 marks)

8. Calculate the natural frequency of the wheel.

(2 marks)

2. Ferromagnetism & Hysteresis Loops

excerpt from Edward Hughes

[20 marks]

Paragraph 1

As long ago as 1823, Andre-Marie Ampere suggested that the increase in the magnetic flux of an iron current-carrying conductor might be due to electric currents circulating within the molecules of the iron. Subsequent discoveries have confirmed this suggestion.

Paragraph 2

An electron moving around a nucleus of an atom can also be thought to spin about its own axis - somewhat like a gyroscope and the magnetic characteristics of iron appear to be due mainly to this electron 'spin'. The movement of an electron around a circular path is equivalent to a minute current flowing in a circular ring. In an iron atom, four more electrons spin around in one direction than in the reverse direction, and the axes of spin of these electrons are parallel with one another; consequently, the effect is equivalent to four current rings producing magnetic flux in a certain direction.

Paragraph 3

The iron atoms are grouped together in 'domains', each about 0.1mm in width; and in any one domain the magnetic axes of all the atoms are parallel with one another. In an unmagnetised bar of iron, the magnetic axes of different domains are in various directions so that their magnetizing effects cancel one another. Between adjacent domains there is a region or 'wall' about 10^{-4} mm thick, within which the direction of the magnetic axes of the atoms changes gradually from that of the axes in one domain to that of the axes in the adjacent domain.

Paragraph 4

For five elements (Fe, Co, Ni, Cd and Dy) a special effect occurs which permits a specimen to achieve a high degree of magnetic alignment in spite of the randomizing tendency of the thermal motions of the atoms. In such materials, described as ferromagnetic, a special form of interaction called exchange coupling occurs between adjacent atoms, coupling their magnetic fields together in a parallel manner. If the temperature is raised above a certain critical value, called the Curie temperature, the exchange coupling suddenly disappears and the materials become simply paramagnetic. For iron the Curie temperature is 1043 K

Paragraph 5

When an unmagnetised bar of iron is moved into a current-carrying solenoid, there are sudden tiny increments of the magnetic flux as the magnetic axes of the various domains are orientated so that they coincide with the direction of the magnetic field due to the current in the solenoid. This phenomenon is known as the Barkhausen effect. This increasing magnetic alignment within an increasing external magnetic field is illustrated below in the magnetization curve of iron.

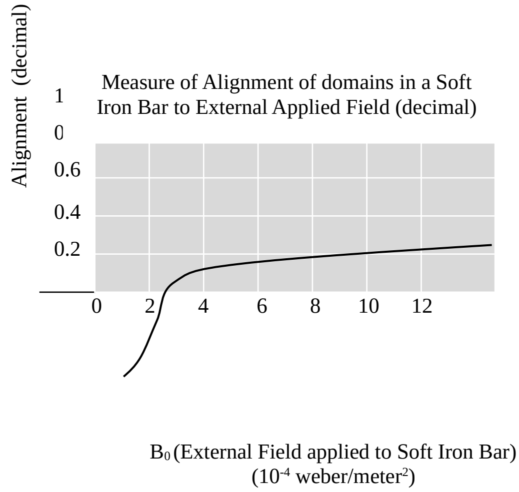


Figure 1

Paragraph 6

Interestingly, the magnetization curves for ferromagnetic materials do not retrace themselves as we increase and decrease the figure below, which displays this lack of retraceability (called a hysteresis loop) for a ferromagnetic material.

Hysteresis loop of a ferromagnetic material

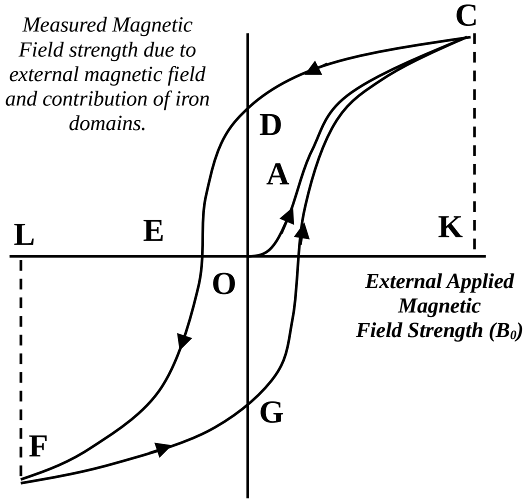


Figure 2

Paragraph 7

We begin at point O with unmagnetised iron. Increasing the external magnetic field (B_0) on the iron brings us to point C along path A. The external magnetic field (B_0) is now reduced back to zero but we find ourselves at point D. the external magnetic field (B_0) is now reversed and its magnitude increased until we reach point F. Decreasing B_0 to zero leads us to point G, and finally increasing B in the forward direction brings us back to point C. A disturbance in the alignment of the domains necessitates the expenditure of energy in taking a specimen of iron through a cycle of magnetization.

Paragraph 8

Paramagnetic materials exhibit a weaker form of magnetism due to fact that magnetic alignment is by individual atoms. Hence thermal agitation resulting in collisions or vibrations (depending on whether the substance is a gas or solid) can seriously interfere with alignment. No domains are found in these materials as they fail to couple with adjacent atoms.

Questions

1. Explain the origin of magnetism in a magnetic material. (paragraph 1 and 2).

(2 marks)

2. What is a domain? (paragraph 3).

(2 marks)

3. Explain at a microscopic level, why a ferromagnetic material is different to a paramagnetic material. (paragraph 4)

(2 marks)

4. A ferromagnetic material loses its magnetic nature if it is heated above its Curie temperature. Explain why. (paragraph 4)

(2 marks)

5. Based on your interpretation of figure 1, at what external magnetic field strength are the domains within the soft iron bar re aligning themselves **most** rapidly? (Figure 1)

(1 mark)

6. For the hysteresis loop shown in figure 2, at point D the external applied magnetic field (horizontal axis) is zero yet the measured magnetic flux (vertical axis) is not. What does this imply? (Figure 2)

(2 marks)

7. At what letter in figure 2, is the resultant magnetic field strength zero despite an applied external field not being zero? (Figure 2)

(1 mark)

8. A scientist wishes to determine the contribution of the soft iron domains **only** to the total field at the point C. Mathematically, what should they do? (Figure 2)

(1 mark)

9. The magnetization cycle results in the ferromagnetic material becoming warm. Why is the ferromagnetic material releasing heat energy? (paragraph 7)

(2 marks)

10. Would you expect paramagnetic substances at cold temperatures to be more strongly or weakly attracted to magnets? Why? (paragraph 8)

(2 marks)

11. In what common electrical device do hysteresis loops occur frequently?

(1 mark)

12. What is the difference between a hysteresis loop and an eddy current?

(2 marks)

END OF EXAM

St Mary's Anglican Girls' School

Semester II Exam

2007 Question/Answer Booklet

PHYSICS 12

Answers

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 CANDIDATE
Standard Items
Pens, pencils, eraser or correction fluid, ruler.
Special Items
Physical formulae and constants sheet, drawing implements, templates and calculators satisfying the conditions set by the Curriculum Council.

TO BE PROVIDED BY THE SUPERVISOR
This Question/Answer Booklet.
Physical Formulae and Constants sheet.

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. Please check carefully and if you have any unauthorised material with you hand it in to the supervisor BEFORE reading any further.

NAME: ____________________

Short Answer	Problem Solving	Comprehension	%
/30	/50	/20	/100

STRUCTURE OF THE PAPER

Section	No of questions	No of marks out of 200	Proportion of exam total
A: Short Answers	15	60	30%
B: Problem Solving	6	100	50%
C: Comprehension & Interpretation	2	40	20%

INSTRUCTIONS TO CANDIDATES

Write your answers in the spaces provided beneath each question in sections A and B
The value of each question in section A is four marks.

Note that (where appropriate) answers should be given numerically and they should be evaluated **and not left in fractional or radical form**. Give all numerical **answers to three significant figures** except in the cases for which estimates are required.

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 out will not be awarded full marks**.

Questions containing the instruction **estimate** may give insufficient numerical data for their solution. Candidates should provide appropriate figures to enable an approximate solution to be obtained.

Candidates should remember that when descriptive answers are required, they should be used to display understanding of the aims and objectives of the physics 12 course. A descriptive answer, which addresses the context of a question without displaying an understanding of physics principles, will not attract marks.

Despite an incorrect final result, credit may be obtained for method and working, provided these are **clearly and legibly set out**.

SECTION A : Shorts Answers - 60 Marks (30%)

Attempt ALL 15 questions in this section.
Show all working out. (4 marks each)

1. In the 1920s people staged bizarre events. One of these events was a piano hurling competition. In a piano hurling competition a piano is launched into the air by a catapult. The catapult releases the piano at an angle of 50.0^0 above the horizontal from a height of 12 m above its base with a speed of 15.0 m s^{-1}. Some spectators insist on standing in front of the proposed landing site. For this reason it is necessary to identify where the piano is most likely to land so that spectators can be positioned sufficiently far in front of the drop zone. How far will the piano land from the base of the catapult?

(4 marks)

s_h = ?

V	H
u_v = 15 sin 50^0 $s_v = ut + ½ at^2$ -12 = (15 sin (50) x t) + ½ (-9.8) t^2 t = 3.127 s	u_h = 15 Cos 50 t = 3.127 s_h = ? s = v x t s_h = 15 cos (50) x 3.127 s_h = 30.16 m s_h = 30.2 m in front of the base.

2. Neptune has a number of satellites, one of which, Nereid, orbits it once every 360.2 earth days at a mean distance of 5.50 x 10^6 km from Neptune's centre of mass. What is Neptune's mass?

(4 marks)

$v^2/r = G\ m / r^2$

v = 2 π r / T

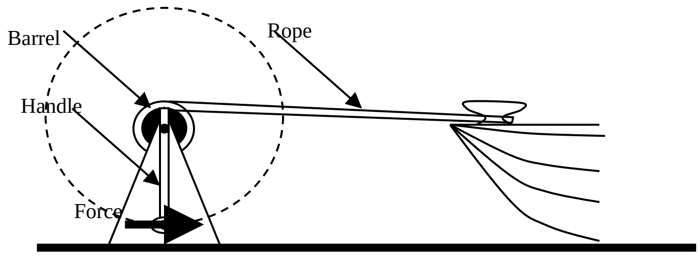
v = 2 π 5.50 x 10^9 / 360.2 x 24 x 60 x 60

v = 1110.4

$m = v^2 r / G$

$m = 1.02 \times 10^{26}$ kg

3. A boat is being pulled out of a river using a simple winch. The winch has the following dimensions and configuration…



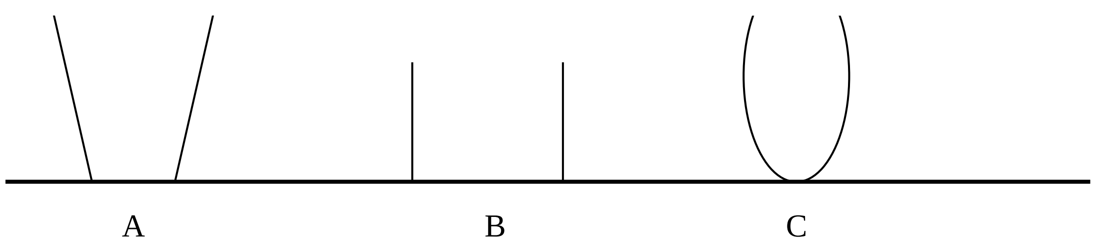
The barrel has a diameter of 20.0 cm and the handle has a radius of 95.0 cm. The boat must overcome a maximum value of static friction equal to 574 N. What minimum force must be exerted on the handle of the winch to just move the boat? Note :- the winch has no friction itself.

(4 marks)

Sum or the torques clock = sum of the torque anti
0.1 * 574 = 0.95 * F

F = 60.4 N

4. A person is going shopping for a vase. The vase will contain a large quantity of flowers and can often be placed in locations that experience some windy conditions. Three designs are available (shown below).



A B C

a) Which is the most stable design? B__________________ (1 mark)

b) Your answer to part a) is in what kind of equilibrium? Stable (static)(1 mark)

c) What makes this vase the most stable of those on offer?

(2 marks)

Low center of mass and large base

5. Four similar coiled springs, used in the suspension of a car, each has a length of 50.0 cm before they are fitted to the car. When fitted, and the 1100 kg mass of the car is being supported, each spring has a length of 30.0 cm. Calculate the total amount of elastic potential energy stored in the compressed springs.

(4 marks)

$l_0 = 0.5$ m
$l = 0.3$ m

$\Delta l = x = 0.2$ m (1)

$F = k x$
$F = 1100 \times 9.8 / 4$
$F = 2695$ N on each spring (1)
$k = F / x$
$k = 13475$ N/m (1)
$E = ½ k x^2$
$E = .5 \times 13475 \times .2^2 =$ **2.70×10^2 J** (1) times by 4 = **1.08×10^3 J**

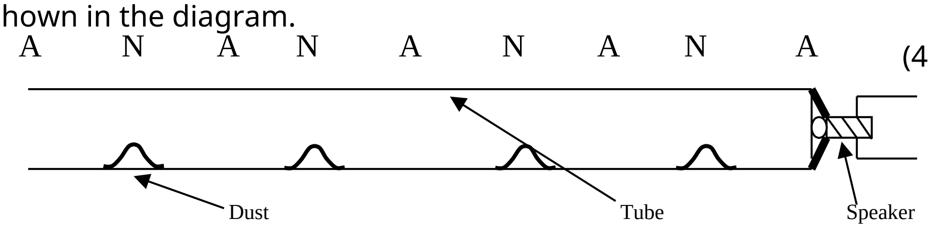
6. A climber, of mass 65.0 kg tests his nylon rope and finds out that when he is suspended at the end of a 20m length of the rope, the rope stretches by 0.35 m. Later at the bottom of a 30.0 m cliff, he has to assist a friend of mass 50.0 kg by carrying her while the rope is hauled from above. By how much will the rope be extended by the total load?

(4 marks)

Don't use Hooke's Law because the l_0 is not the same between the two situations
You therefore have to use the Young's modulus formula

Situation 1	Situation 2
$x = 0.35$ $mg = 65 \times 9.8$ $Y = \frac{F l}{A x}$ $YA = 637 \times 20 / 0.35$ $YA = 3.64 \times 10^4$ Nm^2	$Y A = \frac{F l}{x}$ $3.64 \times 10^4 = \frac{115 \times 9.8 \times 30}{x}$ $x = 0.929$ m

7. A 1.20 m open pipe is attached to a speaker. The bottom of the pipe has been coated in a thin layer of chalk dust. The speaker is switched on. The sound causes the dust particles in the bottom of the horizontal tube to sweep itself into 4 piles as shown in the diagram.



(4 marks)

What is the frequency of the sound?

L = 1.2 m
n = 4 (1)

f = nv / 2l (1)

f = 4 x 346 / 2 x 1.2 (1)

f = 577 Hz (1)

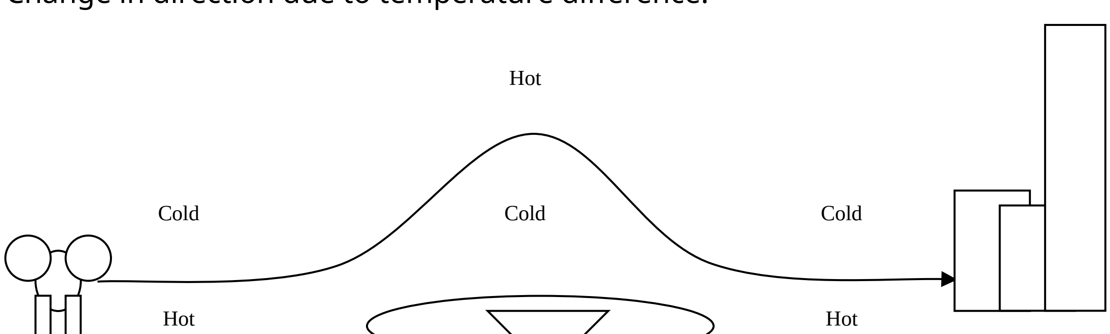
8. On a still night in the 1930s (when Perth was smaller and quieter) the elephant at the zoo in South Perth was heard bellowing / trumpeting in Perth city on the other side of the river. A lady, who lived in the city, asked her husband who had been fishing out in the middle of the river at the time, if he had heard anything strange. He said that he had not heard anything at all. The wife then accused him of being at the local tavern instead of going fishing!

If the husband <u>was</u> fishing explain using physics why he could not hear the elephant (or anything else for that matter) but the wife could hear the elephant.

Note :- assume that there were no waves or ripples that night and both husband and wife have equally good hearing. A diagram may assist your explanation.

(4 marks)

Refraction
Change in direction due to temperature difference.



9. A student is having problems sleeping on the night before their TEE physics exam. Part of the problem is that the cicadas (chirping grasshopper like insects) are singing outside his bedroom window. If the loudness of the average cicada is 70.0 dB at a distance of 4.00 m from the student, how many cicadas will be required to sing together at a distance of 4.00 m from the student for the combined sound to reach the threshold of pain?

Note :- be sure to clearly indicate the decibel level that corresponds to the threshold of pain in your answer.

(4 marks)

L = threshold of pain = 120 dB (1

$120 = 10 \log (I_{pain} / 1 \times 10^{-12})$

$I = 1\ W\ m^{-2}$ **(1)**

$L_{1\ cicada} = 10 \log (I_{1\ cicada} / 1 \times 10^{-12})$

$70 = 10 \log (I_{1\ cicada} / 1 \times 10^{-12})$

$I_{1\ cicada} = 1 \times 10^{-5}\ W\ m^{-2}$ **(1)**

N^o of cicadas = $I_{pain} / I_{1\ cicada}$

$1 / 1 \times 10^{-5}$

1.00×10^5 cicadas **(1)**

. Two cars are parked at some traffic lights waiting for the light to turn green. The sound from the two car engines is heard by the driver in the first car. The driver can hear 16 fluctuations in the loudness of the combined car sounds in 5 seconds. The driver reads his tachometer which indicates that the engine is turning at a rate of 800 rpm (revolutions per minute). When the driver depresses the accelerator slightly, the number of fluctuations in each 5 second period increases to 22 fluctuations. At what speed is the engine in the second car turning (in rpm)?

(4 marks)

$f_{Beat} = 16 / 5 = 3.2$ Hz (1)

$f_1 = 800 / 60 = 13.33333$ Hz (1)

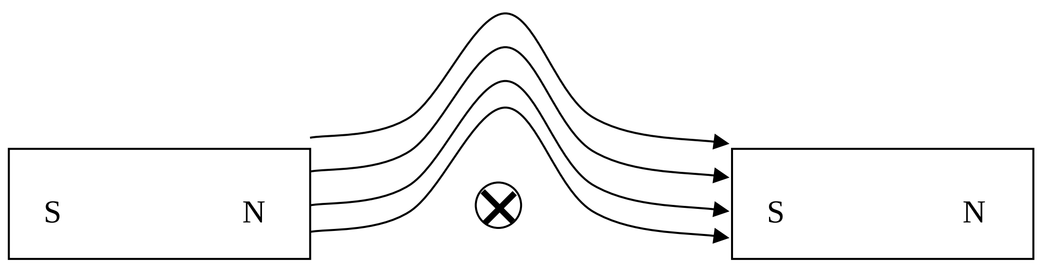
f_2 = ?13.3333 + or – 3.2 = 16.533333 Hz or 10.133333 Hz (1)

When f1 increases the beat frequency increases indicating that the second frequency is lower then the first frequency.

Hence the answer is 10.13 Hz = 608 RPM (1)

11.a) Draw the <u>resultant</u> magnetic field around this wire carrying conventional current into the page and the two magnets

(2 marks)



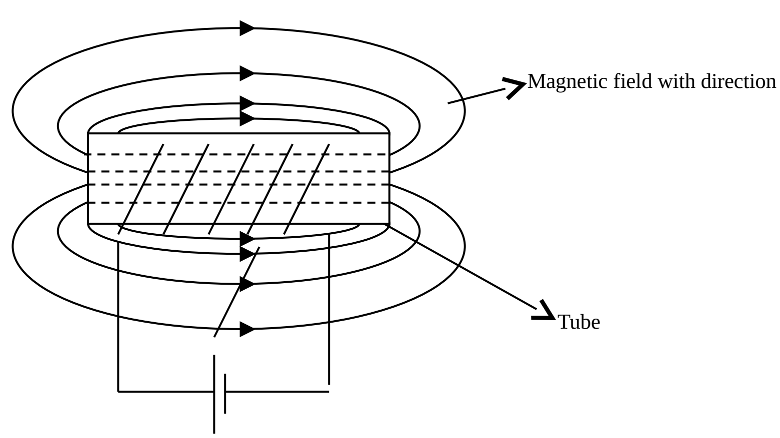
b) Draw on to the solenoid below…

i) wires and a

ii) voltage source

that will produce the following stable magnetic field.

(2 marks)



12a) A 15.0 m flag pole is hit by lightning. The lightning causes a conventional current of 1.00×10^2 kA to flow out of the ground along the pole towards the clouds. If the horizontal component of the earth's magnetic field is 4.00×10^{-5} T in the vicinity of the flag pole, what force will the flag pole experience?

(2 marks)

F = I L B
$F = 100000 \times 15 \times 4 \times 10^{-5}$ (1)
F = 60 N **(1)**

b) The flag pole is able to withstand a maximum torque of 400 Nm. If the force exerted due to the current (I) moving through the magnetic field acts half way up the pole, will the flag pole snap? Show calculations to support your answer.

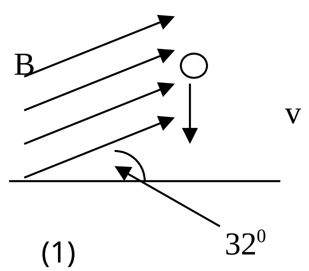
(2 marks)

M = rF
M = (15/2) x 60

M = 450 N m **(1)**
450 N m > 400 Nm so snaps (1)

13a) A 2.00 m metal bar falls with a terminal velocity of 0.5 km s^{-1} above the city of Perth. Perth has a latitude of approximately 32.0^0. The bar is orientated in an east - west direction as it falls. The earth's magnetic field has a strength of 5.00×10^{-4}T as it emerges from the earth. What is the magnitude of the voltage induced in the bar as it falls?

(3 marks)



V = nlvB (1)

$V = 1 \times 2 \times 500 \times 5 \times 10^{-4} \cos 32^0$ (1)

V = 0.424 V **(1)**

b) Which end of the bar is positive?

(1 mark)

East

14. A hydro electric power station has an electrical power output of 700 MW. Unfortunately the power station is 300 km from the city it is to supply electrical power to. The builders of the power station decide that they will reticulate (transmit) the electricity to the city on high tension power lines at a voltage of 350 kV. The power lines have an electrical resistance of $4.00 \times 10^{-5}\ \Omega$ per meter of length. What percentage of the original electrical power supplied is lost in transmitting the electricity to the city?

(4 marks)

Total resistance of power line is $4 \times 10^{-5} \times 300\,000$ = **12 ohms (1)**

$P = V I$

$700 \times 10^6 = 350 \times 10^3 \times I$

I = 2000 A (1)

$P_{loss} = I^2 R$

$P_{loss} = 2000^2 \times 12$

$P_{loss} = 4.8 \times 10^7$ (1)

$\% = (4.8 \times 10^7 / 700 \times 10^6) \times 100$

6.86 % (1)

15. A generator supplies an average voltage of 20.0 V and an average current of 200 mA. What is the peak power supplied by the generator?

(4 marks)

$V_{peek} = V_{ave} \times \sqrt{2}$ (1)

$I_{peek} = I_{ave} \times \sqrt{2}$ (1)

$P = V \times I$ (1)

$P_{peek} = V_{ave} \times \sqrt{2} \times I_{ave} \times \sqrt{2}$

$P_{peek} = 20 \times \sqrt{2} \times 0.2 \times \sqrt{2}$

$P_{peek} = 8$ W (1)

SECTION B : Problem Solving - 100 Marks (50%)

Attempt ALL 8 questions.

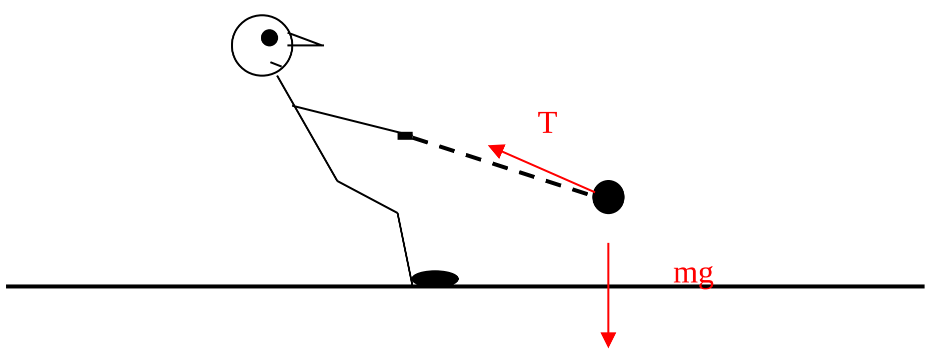
1.a) Calculate the centripetal force on a hammer that is being whirled in a horizontal circle of horizontal radius 1.8 m at a steady pace of 10.0 m s^{-1}. The mass of the hammer is 7.30 kg

(2 marks)

$F_c = m\,v^2 / r$ (1)
$F_c = 7.3\ 10^2 / 1.8$
$F_c = 7.3\ 10^2 / 1.8$
$F_c = 4.06 \times 10^2$ N towards the center of the circle. (1)

b) Draw on the below diagram the forces acting on the hammer.

(2 marks)



c) What is the magnitude of the tension in the chain of the hammer?

(2 marks)

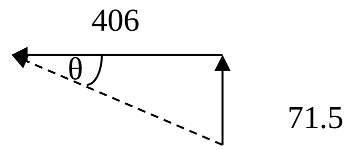
V	H
$\sum F_v = 0$ $mg = T_v$ $7.3 \times 9.8 = Tv$ $Tv = 71.5$ N (1)	$\sum F_h = Fc$ $T_h = Fc$ $T_h = 406$ N

$T = \sqrt{(71.5^2 + 406^2)}$

T = 412 N along the chain. (1)

d) What is the angle formed between the chain and the horizontal?

(2 marks)



Tan θ = 71.5 / 406
θ = Arc Tan (71.5 / 406)
θ = 10.0 ^{0} below the horizontal.

e) The hammer thrower is in fact also a mass revolving in a circle about a central point. If the hammer thrower has a mass of 130 kg, what is the horizontal radial distance from the hammer thrower to the central point about which he is rotating?

(4 marks)

Fc on hammer = Fc on the hammer thrower.

$Fc = mv^2 / r$ (1)

$$406 = 130 \frac{(2\pi r)^2}{T^2 r}$$ (1)

$$406 = 130 \frac{(2\pi)^2 r}{T^2}$$

T hammer = T hammer thrower

T hammer = 2 π r / v

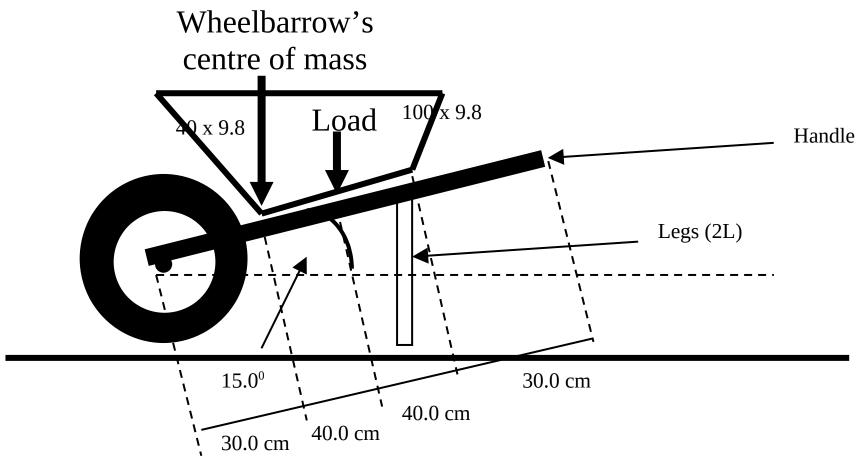
T hammer = 2 x π x 1.8 / 10

T hammer = 1.13 s = T hammer thrower (1)

$$406 = 130 \frac{(2\pi)^2 r}{1.13^2}$$

$r = 1.01 \times 10^{-1}$ m (1)

2. A wheelbarrow consists of two simple machines, a wheel / axle and a lever.



a) The load has a mass of 100 kg and the wheelbarrow has a mass of 40.0 kg. What is the magnitude of the force exerted on **each** of the **two** legs of the wheelbarrow?

(5 marks)

$\Sigma M_c = \Sigma M_a$ (1)
Pivot about the wheel's axle

[40 x 9.8 x 0.3 cos (15)] + [100 x 9.8 x 0.7 cos (15)] = [2 L x 1.10 x cos (15)]
(3 sets of numbers)

[40 x 9.8 x 0.3] + [100 x 9.8 x 0.7] = [2 L x 1.10]

117.6 + 686 = L 2.2

L = 3.65 x 10^2 N (1)

b) What is the force of the wheelbarrow and load on the tyre of the wheelbarrow?

(4 marks)

(all the cos 15 degrees cancel)
Σ F up = Σ F down (1)

F tyre + 2 x F leg = Load + wheelbarrows weight

F tyre + 2 x 3.65 x 10^2 = (100 x 9.8) + (40 x 9.8) (2 left and right side)

F tyre + 730 = (980) + (392)

F barrow on tyre = 642 N down **(1)**

c) A workman sits on the end of one of the handles to have his lunch. What is the maximum mass that the workman (and his lunch) can have without tipping the wheel-barrow clockwise?

(4 marks)

Take moments (pivot) about the legs of the wheel barrow.

Ignore cos 15 degrees because they all cancel

$\Sigma M_c = \Sigma M_a$ (1)

[40 x 9.8 x 0.8] + [100 x 9.8 x 0.4] = [Mass of builder x 9.8 x 0.3]

(2 sets of numbers)

313.6 + 392 = M x L 2.94

m = 2.40 x 10^2 kg **(1)**

3. A hunting horn is a brass musical instrument which consists of a long pipe coiled in a circle. The horn player buzzes their lips at one end of the pipe (into a mouthpiece) and a musical note comes out the other end. Both ends of the pipe are classified as open ends.

a) Traditional hunting horns were 12 foot (3.60m) long. What is the lowest frequency the pipe is able to produce?

(4 marks)

$f = n\,v/(2l)$ (2)

$f = 1 \times 346/(2 \times 3.6)$ (1)

$f = 48.1$ Hz (1)

b) The hunting horn player buzzes her lips with a frequency of 1.20×10^3 Hz while attempting to play the instrument. Will this frequency cause resonance? Explain why or why not with the support of a calculation.

(4 marks)

$f = n\,v/(2l)$ (1)

$1200 = n\,346/(2 \times 3.6)$ (1)

$n = 24.97$

$n = 25.0$ (1)

Yes this note will produce resonance. (1)

c) After having too much wine in the forest the hunting horn players enjoyed playing a trick on the king and nobles in the hunting party. They would play (buzz) a note into the horn at such a high frequency that the humans could not hear it but the dogs could. If the upper threshold of hearing for humans in the 12th century was 18 000 Hz, what is the lowest overtone that the horn player could play to set the dogs barking without the humans hearing the sound?

(4 marks)

$f = n\,v/(2l)$ (1)

$18\,000 = n\,346 / (2 \times 3.6)$ (1)

$n = 374.5$ = harmonic

$n = 375$ harmonic (1)

$n = 374^{th}$ overtone (1)

4. Light produced by sprinkling potassium chloride into a bunsen flame is a bright lilac colour. When this light is viewed through a spectroscope, it is seen to contain two lines corresponding to wavelengths of 766.5 nm and 769.9 nm. These lines are caused by electrons of two separate energy levels dropping into a common lower energy level.

Note :- You will need to use these values for constants…
$h = 6.626 \times 10^{-34}$ J s^{-1}
$c = 2.998 \times 10^{8}$ m s^{-1}.

a) How have the electrons in the potassium atoms been excited?

(2 marks)

Thermal Excitation

Gas particles have collided with the KCl causing electrons around the K and /or Cl atoms to be dislodged and moved to higher energy levels.

b) What frequencies do the above wavelengths correspond to?

(2 marks)

Calc 1	Calc 2
$c = f \times \lambda$ $2.998 \times 10^{8} = f \times 766.5 \times 10^{-9}$ **$f = 3.91 \times 10^{14}$ Hz**	$c = f \times \lambda$ $2.998 \times 10^{8} = f \times 769.9 \times 10^{-9}$ **$f = 3.89 \times 10^{14}$ Hz**

c) Calculate the difference between these energy levels in electron volts.

(3 marks)

Calc 1	Calc 2
$E = h f$ $E = 6.626 \times 10^{-34} \times 3.91 \times 10^{14}$ **$E = 2.59 \times 10^{-19}$ J**	$c = f \times \lambda$ $E = 6.626 \times 10^{-34} \times 3.89 \times 10^{14}$ **$E = 2.58 \times 10^{-19}$ J**

Difference = 0.01×10^{-19} J = **6.25×10^{-3} eV**

d) The shorter wavelength of light, when measured has an intensity of 60 W m^{-2}. How many energy level transitions must occur each second to produce this amount of energy (light) spread over a surface area of 1.00 m^2?

(3 marks)

I = P / A

$$I = \frac{E}{t\ A}$$

E = I x t x A
E = 60 x 1 x 1

E = 60 J (1)
Number = 60 / 2.59 x 10^{-19} (1)

Number = 60 / 2.59 x 10^{-19}

Number = 2.32 x 10^{20} Transitions. (1)

e) Lilac is actually a combination of at least 2 colours. At which coloured end of the visual spectrum is the 769.9 nm wavelength most closely associated?

(1 mark)

Red

f) Explain how you came to your conclusion in part e) above

(1 mark)

The visual spectrum ranges from **red at the 700 nm wavelength** end to violet at the 400 nm wavelength range.

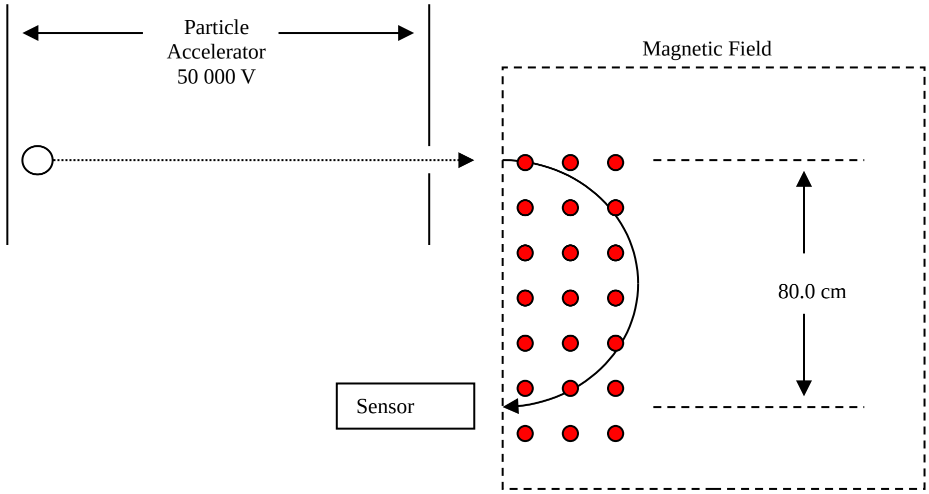
769.9 nm is closer to the red end of the visual spectrum.

g) Potassium chloride is now dissolved in a jar of water. An incandescent light globe is placed behind the jar. Light from the light globe that has passed through the jar is then passed through a prism to produce a spectrum. What type of spectrum has been produced?

(1 mark)

accept band absorption or line absorption.

5. A helium - 4 atom has one of its electrons removed to give it a positive charge (i.e. ${}^{4}_{2}He^{+}$). It is then accelerated through a potential difference of 50 000 V in a particle accelerator.



a) If the positively charged helium atom has a mass of 6.6438×10^{-27} kg, what is the velocity of the positively charged helium atom as it leaves the accelerator?

(4 marks)

$qV = ½ mv^2$ (1)

$1.6 \times 10^{-19} \times 50\,000 = 0.5 \times 6.6438 \times 10^{-27}\, v^2$ (2)

v = 1.55 x 10⁶ m/s

b) The helium nucleus now enters a magnetic field. **Draw onto the diagram above** the direction of the magnetic field if the atom is to turn in a clockwise direction.

(1 mark)

c) A sensor is set up at a distance of 80.0 cm to the right of the position where the atom enters the field. What is the field strength required to turn the atom into the sensor?

(4 marks)

$mv^2 / r = qvB$ (1)

$mv / r = qB$

$\dfrac{6.6438 \times 10^{-27} \times \mathbf{1.55 \times 10^{6}}}{0.4} = \mathbf{1.6 \times 10^{-19} \times B}$ (2)

$B = 1.61 \times 10^{-1}$ T (1)

d) The laboratory in which the mass spectrometer is set up is on the equator where the earth's magnetic field runs parallel with the ground. If the diagram shown on the previous page is a top view diagram and north is at the top of the page, what is the overall (net) effect of the earth's magnetic field on the positioning of the sensor? Explain?

(3 marks)

No overall effect (1)

Deflect nucleus upwards a s it travels to the right (1)

Deflects nucleus downwards as it travels to the left (1)

Both upward and downward deflections are equal and opposite and so cancel out producing no net effect.

6. A scientist aims to build a 100 % efficient transformer. What are 4 of the major problems the scientist must overcome if the transformer is to be as efficient as possible and how will they solve these problems?

(4 marks)

Problem	**Solution**
B Field leaks	Soft iron core
Eddy current is in soft iron	laminates
Resistance in windings	Use low resistance copper wires
Heat generated increases resistance	Heat sink to remove heat

b) Assume that the scientist succeeds in building the perfectly efficient transformer. The scientist inputs 20 V of AC electricity from a 500 W power supply. The transformer has a N_s / N_p turn ratio of 2 : 5. What is the output current from the secondary coil?

(3 marks)

$\frac{Vp}{Vs} = \frac{Np}{Ns}$ (1)

$\frac{20}{?} = \frac{5}{2}$

Vs = 8 V **(1)**

P = V x I

500 = 8 x I

I = 62.5 A (1)

c) What is the resistance of the secondary coil?

(2 marks)

P = 500W

V = 8 V

I = ?

R = ?

$P = V^2 / R$

$500 = 20^2 / R$

R = 1.28 x 10^{-1} Ω

d) Is this a step up or a step down transformer?

(1 mark)

Step down

e) The transformer is now turned around and the 20 V is supplied to the original secondary side of the transformer by the 500 W power supply. What is the resistance of the original primary side of the transformer?

(3 marks)

V = 50 V

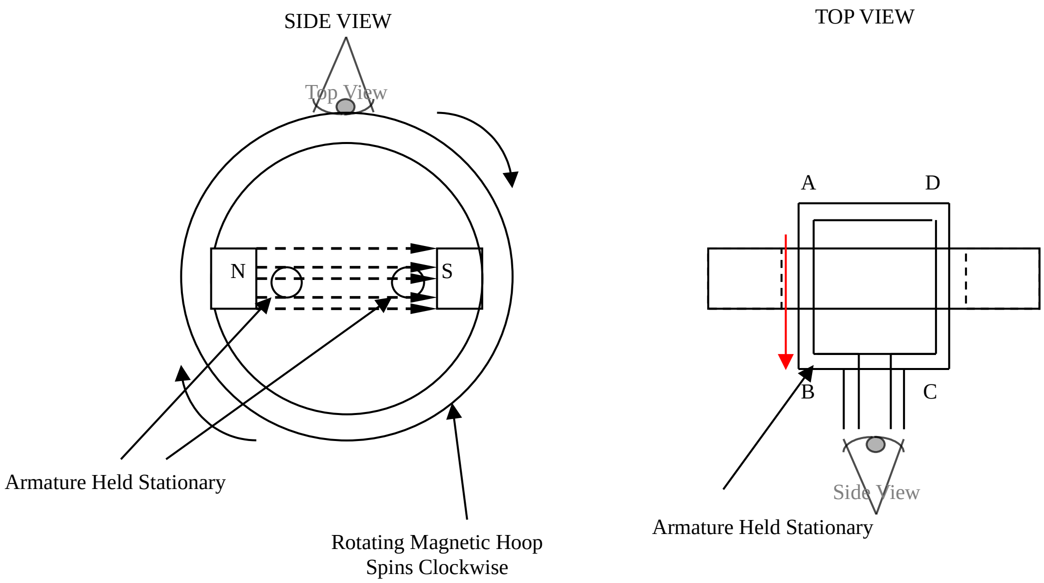
P = 500

$P = V^2 / R$

$500 = 50^2 / R$

R = 5.00 Ω

7. A new experimental alternator is being designed. The alternator has no commutators. The design of the alternator is shown below.



a) If the magnetic hoop is moving in a clockwise direction in which direction will the **positive** charges in the armature side A-B experience a force when viewed in the top view diagram? (Note :- also draw the direction of the current on the diagram to remove any ambiguity)

(1 mark)

Towards B

b) The magnetic hoop spins at a rate of 450 RPM (revolutions per minute). What is the frequency of the rotation?

(1 mark)

f = 450 / 60

f = 7.5 Hz

c) The armature has 340 turns. The magnetic flux density between the sides of the magnetic hoop is 0.08 T. The area inside the armature is 200 cm^2. What is the magnitude of the RMS voltage induced in the armature?

(3 marks)

Emf = nBAω sin ωt
Emf_{peak} = nBAf2π
Emf_{peak} = nBAf2π
Emf_{peak} = 340 x 0.08 x 200 x 10^{-4} x 7.5 x 2 x π
Emf_{peak} = 25.6 V
Emf_{RMS} = 25.6 V / √ 2

Emf_{RMS} = **18.1 V**

d) Name three ways that the amount of voltage produced by the alternator can be increased.

(3 marks)

(i) increase speed (Rpm)____

(ii) Increase field strength____

(iii) Increase number of turns____

e) Is the current produced by the armature direct or alternating current? Explain why.

(2 marks)

AC

No split ring commutator so the current induced in the armature (AC)is fed directly to the external circuit

f) Can the opposite type of current be created by this machine? If so explain how?

(1 mark)

No

No commutator can be fitted to this machine and so no split ring commutator can be used to rectify the current.

(can use diodes)

g) The alternator is now stopped and the armature is now connected to a 60.0 Hz alternating voltage source. At a particular moment in time, when the coil and the magnetic hoop are in the positions shown in the diagram on the previous page, the voltage source is connected, causing conventional current to flow in the armature (shown in the top view diagram) in a clockwise direction. This will cause the magnet to spin. Will it spin clockwise or anticlockwise as viewed in the side view diagram?

(1 mark)

Clockwise

h) How can you make the magnet spin faster?

(1 mark)

increase frequency of the applied voltage

8. Small DC electric motors which use a permanent magnet to produce the magnetic field generate a "back EMF" when they rotate. This "back EMF" opposes the voltage applied to the motor. If the motor stops, because of a heavy load being applied to it, the current will increase because there will be no "back – EMF".

A researcher applies a fixed voltage of **12V DC** to a small permanent magnet DC electric motor. By varying the load on the motor shaft they are able to reduce the speed of the motor and measure the current at various speeds.

Some of the results are tabulated below.

Result Number	1	2	3	4	5
Motor Speed (S) (RPM)	0	200	400	600	800
Current drawn by motor (mA)	550	515	270	140	0

a) Convert the above table to S.I. units in the table below.

(2 marks)

Result Number	Unit	1	2	3	4	5
Motor Speed (S)	Hz	0	3.33	6.67	10	13.33
Current drawn by motor	A	0.550	0.515	0.270	0.140	0

b) What is the independent and what is the dependant variable?

(1 mark)

Independent Current or Motor Speed – accept either

Dependent Motor Speed or Current – accept either

c) Plot the data on your graphics calculator. Are there any outliers in the data? If so which result number(s) is / are outliers? Take steps to deal with the outlier(s).

(1 mark)

Is there an outlier? Yes____

Result Number 2 (0.515 A, 3.33Hz)

d) What is the mathematical equation relating the two variables?

(1 mark)

Speed = -24.3 (current) + 13.33 (1)

outlier not removed S = -21.8 (I) + 13.11 (0)

Or

Current = -4.11×10^{-2} (Speed) + 0.549 (1)

outlier not removed I = -4.42×10^{-2} (S) + 0.590 (0)

e) Estimate the resistance of the motor's armature winding. Please notice that this is best done using the data relating to when the motor is stalled (not moving) and hence there is no "back EMF".

(3 marks)

V = 12 V

I = 0.550 A

R = ?

V = IR (1)

12 = 0.55 x R (1)

R = 21.8 Ω (1)

f) The back EMF of the motor (V_{back}) is related to actual resultant voltage pushing the current along the armature of the motor by the formula $V_{resultant}$ = 12 – V_{back}. Rearrange the mathematical equation you have found relating the variables I and S, so that it now relates $V_{resultant}$ and S.

(4 marks)

$V_{resultant} = I R$ (1)

$12 – V_{back} = I \; 21.8$ (1)

$$\frac{12 – V_{back}}{21.8} = I$$

Substitute above into formula …

Speed (S)= -24.3 (current(I)) + 13.33

Speed = -24.3 (12 - V_{back} / 21.8) + 13.33 (2)

Or

Substitute above into formula …

Current (I) = -4.11 x 10^{-2} (Speed (S)) + 0.549

(12 - V_{back} / 21.8) = -4.11 x 10^{-2} (Speed) + 0.549

SECTION C : Comprehension and Interpretation - 40 Marks (20%)

Read the passages below carefully and answer all of the questions at the end of the passages. Candidates are reminded of the need for correct English and clear and precise presentation of answers. Diagrams (sketches), equations and/or numerical results should be included as appropriate.

Show all working out for questions requiring numerical answers.

1. London Eye

[20 marks]

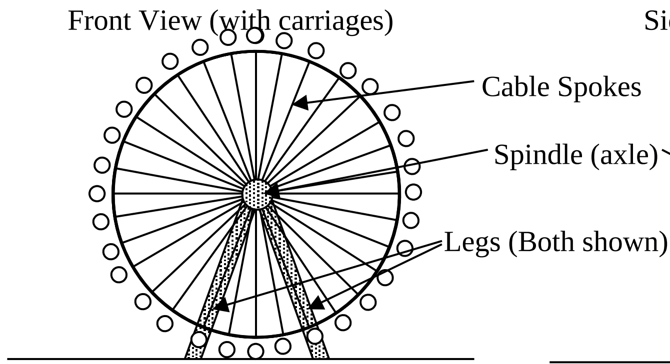


Figure 1

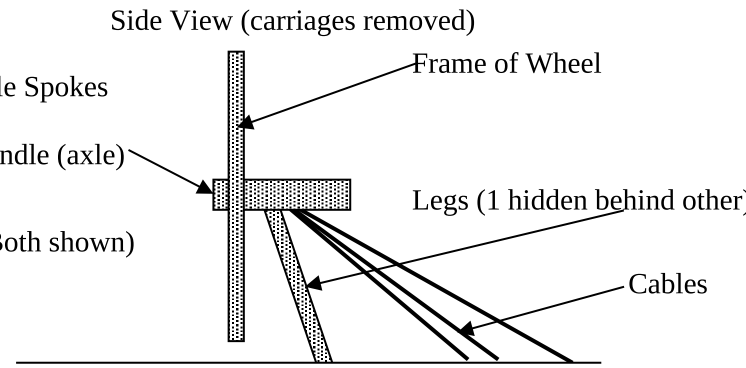


Figure 2

The London Eye was built to mark the millennium. It is the largest observation wheel ever built and from its highest point 135 m above the ground, visitors can see for 42 km.

The design and manufacture involved many people. As well as the many jobs for civil and structural engineers, there were jobs for mechanical engineers, such as designing the drive mechanism, and for electrical engineers, such as supplying the drive energy and the lighting.

The first task for the structural engineer was to calculate all the forces acting on the structure: the weight of the component parts (called self-weight); the people who have to be carried; and the wind. After calculating the forces, the engineer had to evaluate stresses in the different parts of the structure and check they were safe. To do this required knowledge of how to calculate the stresses in cables, columns and beams. Once the forces were known, the appropriate materials could be chosen.

Figure 1 shows a side view of the wheel supported by the two legs, which lie one behind the other in this diagram. Three supporting cables are shown (the cables for the other leg are directly behind these). Although the problem is really one in three dimensions, we can get an idea of the forces in the legs and cables by considering the two-dimensional cross-section. Most of the weight is taken by two main cables for each leg and one other cable. If we simplify the problem by looking at a cross section, with one leg and one main cable we can calculate the forces by taking moments and resolving horizontally and vertically. (Figure 3)

Simplified Cross Sectional Diagram

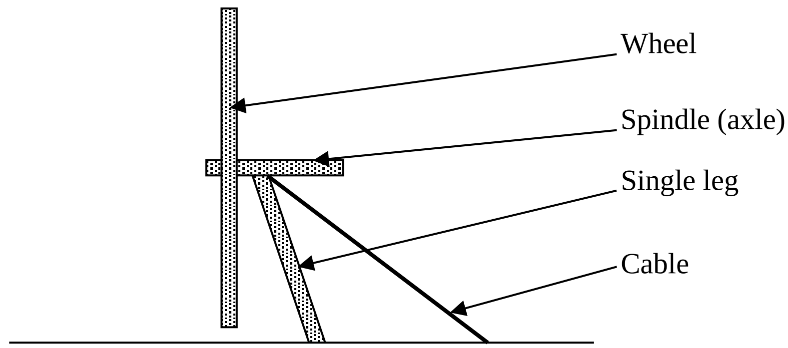


Figure 3

The mass of the rim and the capsules is about 1000 tonnes. When the capsules are fully loaded, we have the added mass of the people. The wheel has thirty-two capsules with a capacity for 25 people in each. The other load to be considered is the weight of the spindle. This is a cylinder 23 m long. It is 2.1 m in diameter with walls 30 cm thick and a weight 200 tonnes.

The wheel has a natural resonance frequency and it is important that it is not set in resonance by the wind or by fluctuations in the wind, which can be up to about 40 m s^{-1} at the top of the wheel. Engineers were able to calculate the natural frequency of the wheel using the formula:

$$f = 0.5\,\pi\,(\text{stiffness} / \text{mass})^{1/2}$$

Where …

- the **stiffness** was 2 x 10^{6} N m^{-1}
- **m** in kg was the mass
- **f** was the frequency.

Actual Diagram

As the wheel rotates, the tension in individual cables changes. This means that the natural frequency will change. A cable at the top of the wheel will have lower resonant frequency than one at the bottom. The London Eye is driven around at a slow speed, 0.26 m s^{-1} at the capsule position, and so does not have to stop to allow people to board. The mechanical engineers chose a drive system based on tyres gripping the edge of the wheel rim. There is a main wheel drive at rim level which has 16 rubber-tyred wheels to supply 200 kN traction.

The yield strength of steel is normally about 350 MPa, depending on the type of steel. The cables are made from very strong steel with a yield strength of 1 000 MPa. For safety, the compressive stress on the legs must be much less than the yield strength of the steel.

Questions

1. Are the cables in compression or tension? Explain with the help of a diagram.

(2 marks)

Tension (1)

Diagram and explanation (1)

2. Are the legs in compression or tension? Explain with the help of a diagram.

(2 marks)

mostly compression (there is some bending) (1)

Diagram and explanation (1)

3. Is the mass of the people significant when calculating the forces on the wheel? Explain with reference to the other forces on the wheel.

(3 marks)

Calculate the mass of the people if the wheel was full

32 capsules x 25 people each x 100 kg per person (over estimate?)

80 000 kg (1)

= 80 Tonnes

other parts = 1 200 tonnes (1 200 000 kg) (1)

only 7 % approx so not very significant (compare) (1)

4. How could the wheel be protected against resonant frequencies of wind, which may cause the wheel to sway dangerously?

(2 marks)

Alter the tension in the wheel spokes according to wind conditions. (2)

Change how the cars are loaded to alter the tension in the spokes. (2)
Remove energy from the wheel to stop the build up of energy stored in the wheel (2)
Anything reasonable.

5. Why would the natural frequency of the wheel be different at the bottom of the wheel to the top of the wheel?

(3 marks)

Diagrams (1)

The spokes are in tension at the bottom because they are supporting the full weight of the wheel (mg is in opposite direction to F centripetal) (1)

The spokes are almost in compression at the top because the rim is pushing towards the center of the wheel a the top (mg is in the same direction as the force centripetal) (1)

6. Estimate the centripetal acceleration of the wheel at the capsule position?

(3 marks)

$F_{centripetal} = m v^2 / r$
$a_{centripetal} = v^2 / r$ *(1)*
r = *approximately* $\frac{1}{2} \times 135 = 67.5$ m *(1)*
$v = 0.26$ m/s
$a = 0.26^2 / 67.5$
$a = 1.00 \times 10^{-3}$ m/s^2 towards the center of the circle. (1)

7. Why must the compressive stress on the legs be less than the yield strength of steel?

(3 marks)

The yield strength is the boundary force at which the substance goes beyond the elastic limit and into the plastic region of the metal

If the legs yield they will either permanently deform (change shape) or break depending on whether the metal is brittle.

This will alter the distribution of the forces in the structure and could ultimately cause the wheel to fail (collapse).

8. Calculate the natural frequency of the wheel.

(2 marks)

Mass 1	**or**	**Mass 2**
$f = 0.5\ \pi\ (stiffness\ /\ mass)^{½}$ *$f = ½ \times 3.142 \times (2 \times 10^6 / 1\ 000\ 000)^{½}$ (1)* *f = 2.22 Hz (1)*		*$f = 0.5\ \pi\ (stiffness\ /\ mass)^{½}$* *$f = ½ \times 3.142 \times (2 \times 10^6 / 1\ 200\ 000)^{½}$ (1)* *f = 2.02 Hz (1)*

2. Ferromagnetism & Hysteresis Loops

excerpt from Edward Hughes

[20 marks]

Paragraph 1

As long ago as 1823, Andre-Marie Ampere suggested that the increase in the magnetic flux of an iron current-carrying conductor might be due to electric currents circulating within the molecules of the iron. Subsequent discoveries have confirmed this suggestion.

Paragraph 2

An electron moving around a nucleus of an atom can also be thought to spin about its own axis - somewhat like a gyroscope and the magnetic characteristics of iron appear to be due mainly to this electron 'spin'. The movement of an electron around a circular path is equivalent to a minute current flowing in a circular ring. In an iron atom, four more electrons spin around in one direction than in the reverse direction, and the axes of spin of these electrons are parallel with one another; consequently, the effect is equivalent to four current rings producing magnetic flux in a certain direction.

Paragraph 3

The iron atoms are grouped together in 'domains', each about 0.1mm in width; and in any one domain the magnetic axes of all the atoms are parallel with one another. In an unmagnetised bar of iron, the magnetic axes of different domains are in various directions so that their magnetizing effects cancel one another. Between adjacent domains there is a region or 'wall' about 10^{-4} mm thick, within which the direction of the magnetic axes of the atoms changes gradually from that of the axes in one domain to that of the axes in the adjacent domain.

Paragraph 4

For five elements (Fe, Co, Ni, Cd and Dy) a special effect occurs which permits a specimen to achieve a high degree of magnetic alignment in spite of the randomizing tendency of the thermal motions of the atoms. In such materials, described as ferromagnetic, a special form of interaction called exchange coupling occurs between adjacent atoms, coupling their magnetic fields together in a parallel manner. If the temperature is raised above a certain critical value, called the Curie temperature, the exchange coupling suddenly disappears and the materials become simply paramagnetic. For iron the Curie temperature is 1043 K

Paragraph 5

When an unmagnetised bar of iron is moved into a current-carrying solenoid, there are sudden tiny increments of the magnetic flux as the magnetic axes of the various domains are orientated so that they coincide with the direction of the magnetic field due to the current in the solenoid. This phenomenon is known as the Barkhausen effect. This increasing magnetic alignment within an increasing external magnetic field is illustrated below in the magnetization curve of iron.

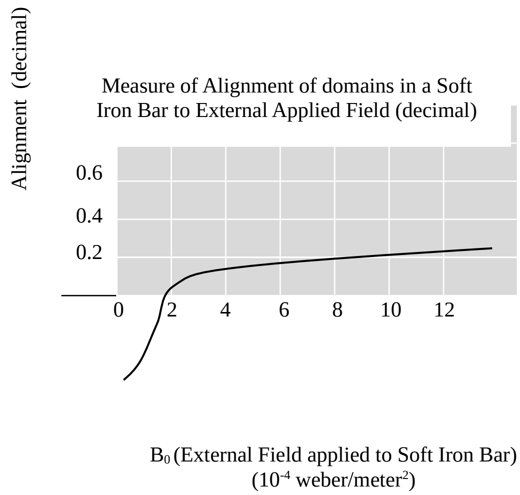


Figure 1

Paragraph 6

Interestingly, the magnetization curves for ferromagnetic materials do not retrace themselves as we increase and decrease the ext e below, which displays this lack of retraceability (called a hysteresis loop) for a ferromagnetic material.

Hysteresis loop of a ferromagnetic material

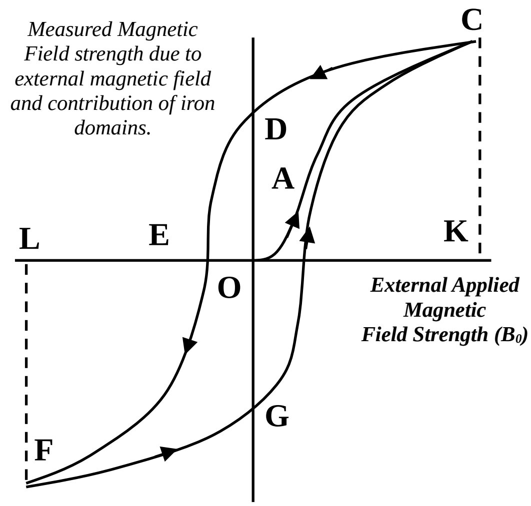


Figure 2

Paragraph 7

We begin at point O with unmagnetised iron. Increasing the external magnetic field (B_0) on the iron brings us to point C along path A. The external magnetic field (B_0) is now reduced back to zero but we find ourselves at point D. the external magnetic field (B_0) is now reversed and its magnitude increased until we reach point F. Decreasing B_0 to zero leads us to point G, and finally increasing B in the forward direction brings us back to point C. A disturbance in the alignment of the domains necessitates the expenditure of energy in taking a specimen of iron through a cycle of magnetization.

Paragraph 8

Paramagnetic materials exhibit a weaker form of magnetism due to fact that magnetic alignment is by individual atoms. Hence thermal agitation resulting in collisions or vibrations (depending on whether the substance is a gas or solid) can seriously interfere with alignment. No domains are found in these materials as they fail to couple with adjacent atoms.

Questions

1. Explain the origin of magnetism in a magnetic material. (paragraph 1 and 2).
(2 marks)

magnetic materials contain **domains** that are **aligned**

2. What is a domain? (paragraph 3).
(2 marks)

A set of atoms that have there electron spins aligned resulting in a magnetic field

3. Explain at a microscopic level, why a ferromagnetic material is different to a paramagnetic material. (paragraph 4)

(2 marks)

paramagnetic materials have electron spins but the atoms do not align
Ferro magnetic materials do have electron spins that align and the atoms align

4. A ferromagnetic material loses its magnetic nature if it is heated above its Curie temperature. Explain why. (paragraph 4)

(2 marks)

Above the Curie temperature the atoms lose there alignment resulting in the loss of magnetic coupling between atoms

5. Based on your interpretation of figure 1, at what external magnetic field strength are the domains within the soft iron bar re aligning themselves **most** rapidly? (Figure 1)

(1 mark)

The slope of the line is greatest at the x axis data point = to 1.5×10^{-4} T

6. For the hysteresis loop shown in figure 2, at point D the external applied magnetic field (horizontal axis) is zero yet the measured magnetic flux (vertical axis) is not. What does this imply? (Figure 2)

(2 marks)

The Domains within the material have all been partially aligned with each other resulting in a net external magnetic field

7. At what letter in figure 2, is the resultant magnetic field strength zero despite an applied external field not being zero? (Figure 2)

(1 mark)

E

8. A scientist wishes to determine the contribution of the soft iron domains **only** to the total field at the point C. Mathematically, what should they do? (Figure 2)

(1 mark)

Subtract off the external field K from the resultant field C in order to identify the contribution of the domains

9. The magnetization cycle results in the ferromagnetic material becoming warm. Why is the ferromagnetic material releasing heat energy? (paragraph 7)

(2 marks)

Energy is required to realign the domains of the material. This realignment causes the domains of the material to collide with each other resulting in heat.

10. Would you expect paramagnetic substances at cold temperatures to be more strongly or weakly attracted to magnets? Why? (paragraph 8)

(2 marks)

More attracted to magnets.
Below their Curie temperature, paramagnetic substance undergo magnetic coupling to produce domains and so become ferromagnetic

11. In what common electrical device do hysteresis loops occur frequently?

(1 mark)

Transformers

12. What is the difference between a hysteresis loop and an eddy current?

(2 marks)

Hysteriesis = oscillation of domains

Eddy currents = circular currents executed by charged particles in magnetic fields.

END OF EXAM