PHYSICS

YEAR 12

STAGE 3

Wesley College

Name: ___________________________

Teacher: _________________________

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work: Ten minutes
Working time for the paper: Three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:

- This Question/Answer Booklet; Formula and Constants sheet

To be provided by the candidate:

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

IMPORTANT NOTE TO CANDIDATES

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short answer	13	13	50	54	30
Section Two: Extended answer	7	7	90	90	50
Section Three: Comprehension and data analysis	2	2	40	36	20
			Total	180	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2013.* 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% (54 Marks)**

This section has **13** questions. Answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 50 minutes.

Question 1

A straight wire of length 250 mm carries a current of 4.50 A is placed in a uniform magnetic field. The wire experiences an electromagnetic force of 5.48×10^{-2} N. Calculate the magnitude of flux density perpendicular to the wire.

(2)

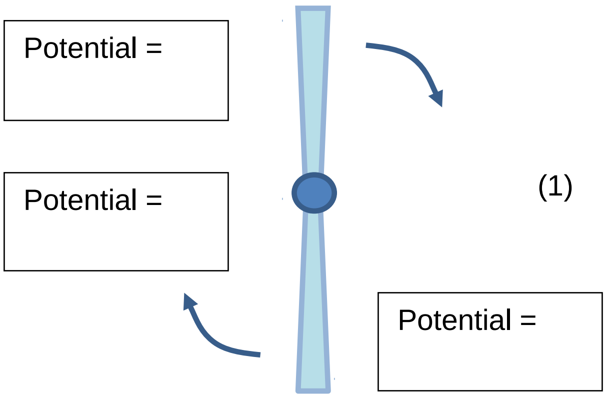
Question 2

An ice hockey puck slides at 21.0 m s^{-1} South-West, hits a goal post and rebounds at 20.0 m s^{-1} North-West. Calculate the change in velocity of the ice hockey puck. You must refer to a vector diagram and state both magnitude and direction in your response.

(4)

Question 3

The metal rotor blades of a helicopter are shown in the diagram as viewed from above. The helicopter is in Perth where the Earth's magnetic field points upwards with an angle of dip of 66° to the horizon. The blades are turning clockwise.



a. Identify areas of positive or negative electric potential as indicated in the diagram. (1)

b. Explain how a potential difference is established in this situation.

(3)

Question 4

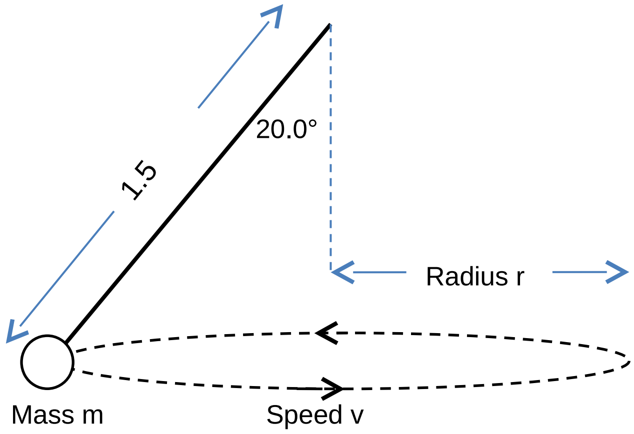
The diagram shows object A falling at a constant speed of 2.00 m s^{-1} towards the ground and object B accelerating at 9.80 m s^{-2} towards the ground. What is the acceleration of object B relative to object A? Explain briefly.

(3)

Question 5

A ball of mass **m**, suspended from a ceiling moves along a horizontal circle of radius **r** at a constant speed **v**. The string connecting the mass to the ceiling makes an angle of 20.0° to the vertical. The string has a length of 1.50 metres.

Calculate the time taken for the ball to make one revolution.



(4)

Question 6

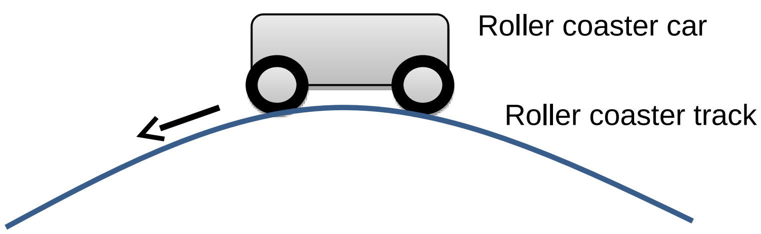
A battery supplies current to a DC electric motor in an electric drill. When the motor is allowed to spin freely the revolutions per second are high and the current measured is very low. When the motor in the drill is put under load by drilling a hole, the revolutions per second decrease and the current in the motor increases. Explain why the current is different in each situation.

(3)

Question 7

A roller coaster car of mass 800 kg is going over the apex of a circular section of track. The car has a speed of 6.00 m s^{-1}. Calculate the radius of the curve for the car to experience a normal reaction force of 4000 N from the track. You must refer to a vector diagram in your answer.

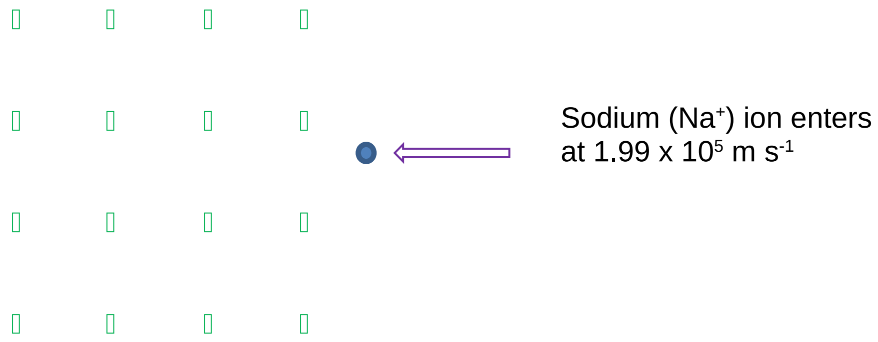
Vector diagram



(4)

Question 8

A sodium ion with a single positive charge and a mass of mass 3.82 x 10^{-26} kg enters a uniform magnetic field of flux density 0.258 T at a speed of 1.99 x 10^{5} m s^{-1} as shown in the diagram below.



a. Calculate the magnetic force acting on the sodium ion.

(2)

b. Sketch an arrow on the diagram and label it "deflection" to indicate which direction the sodium ion will be deflected.

(1)

c. Calculate the radius of the deflected path.

(3)

Question 9

An astronomer is viewing light from a star in a distant galaxy.

a. Explain how the astronomer can use the light that passed through the relatively cool outer layer of a star to predict its chemical composition.

(2)

b. What is it about the spectrum of the starlight that tells the astronomer that the galaxy is receding?

(2)

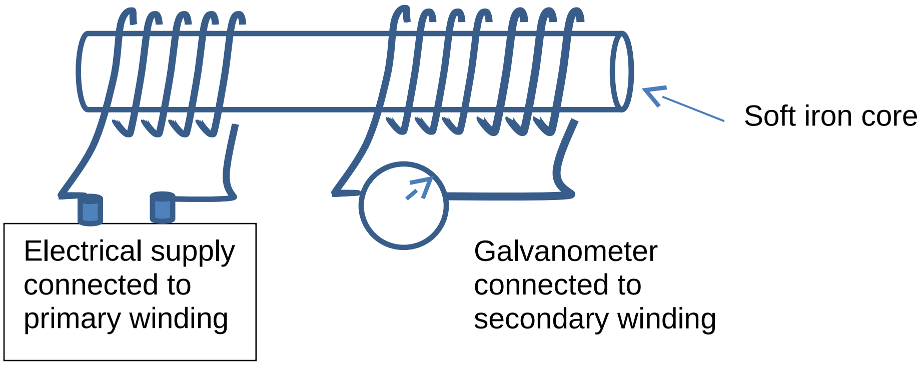
c. When compared to a galaxy that is closer to Earth, Hubble's Law tells us that the closer galaxy is likely to be:
(Circle a response and briefly explain)

(2)

Approaching Receding at the same speed Receding faster Receding slower

Question 10

A simple transformer design is shown in the diagram.

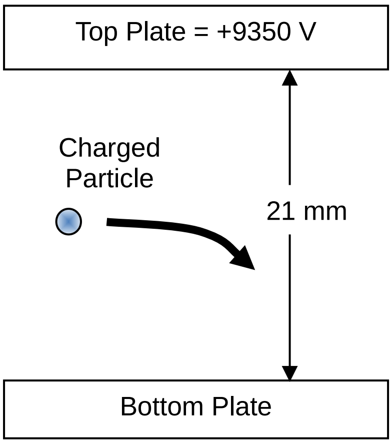


a. Explain, with reference to Faraday's Law, how emf can be established in the secondary coil. (2)

b. Explain the function of the soft iron core. (1)

c. How will the magnitude of the voltage on the secondary winding compare to the voltage on the primary winding? (1)

Question 11



A positively charged particle enters a region between two parallel plates set at different voltages. The distance between the plates is 21.0 mm. The electric field strength in the region between the plates is 3.50×10^{5} V m^{-1}.

a. Calculate the voltage of the bottom plate.

(3)

b. The charged particle experiences a force of magnitude 1.40×10^{-11} N that causes it to deflect towards the bottom plate. Determine the magnitude of charge of the particle.

(2)

c. Use five lines with arrowheads to indicate the uniform electric field in the region between the plates.

(1)

i.

Question 12

In the Standard Model hadrons are particles that are composed of quarks. A baryon is composed of three quarks e.g. utb. A meson is composed of two quarks – one quark is normal matter and the other is an antimatter quark e.g. $d\bar{s}$. A table of quarks is shown below left.

Complete the table below right by giving examples of quark combinations that could make the hadrons described.

(4)

Quark	Charge (e)
Up (u)	$+\frac{2}{3}$
Down (d)	$-\frac{1}{3}$
Top (t)	$+\frac{2}{3}$
Bottom (b)	$-\frac{1}{3}$
Charm (c)	$+\frac{2}{3}$
Strange (s)	$-\frac{1}{3}$

Hadron	Charge (e)	Examples of Quark combination
A positively charged baryon	+2	
A neutral baryon	0	
A negatively charged meson	-1	
A positively charged meson	+1	

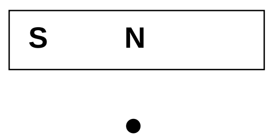
Question 13

(4)

a) The diagram at right shows a permanent magnet and a wire carrying current.

i. Sketch 6 lines to indicate the field of the magnet.

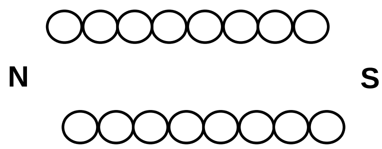
ii. Indicate on the diagram the direction of magnetic force acting on the wire with an arrow labelled “force”.



b) The diagram at right shows a cross section of a powered solenoid. The magnetic polarity at each end of the solenoid is shown.

ii. Show on the diagram, the direction of current that will establish this field.

iii. Sketch 3 magnetic field lines within the solenoid core.



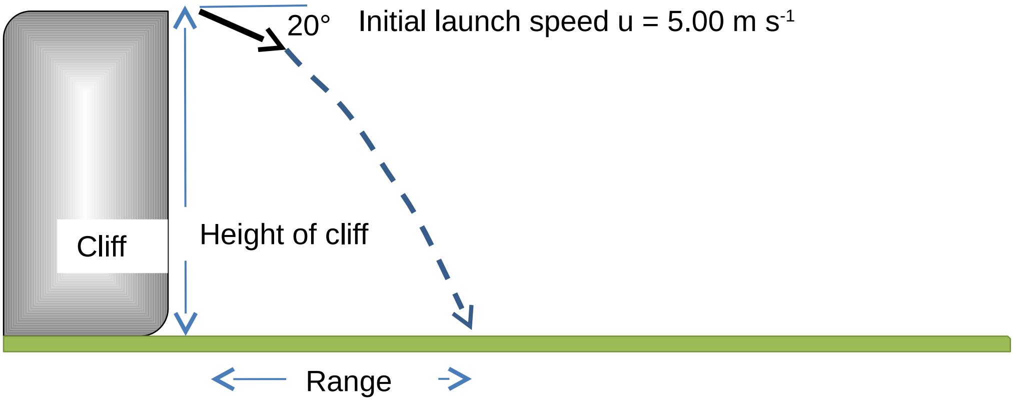
End of Section One

Section Two: Problem-solving **50% (90 Marks)**

This section has **seven (7)** questions. You must answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 90 minutes.

Question 14 (13 marks)

A physics student observes a stone of mass 380 g being catapulted from the top of a cliff. The stone takes a time of 4.00 s to reach the ground. The initial launch speed u is at an angle of 20.0° below the horizontal. You may ignore air resistance for the calculations.



a. Calculate the height of the cliff.

(3)

b. Calculate the horizontal range of the stone.

(3)

c. Calculate the kinetic energy of the stone after 3 seconds.

(4)

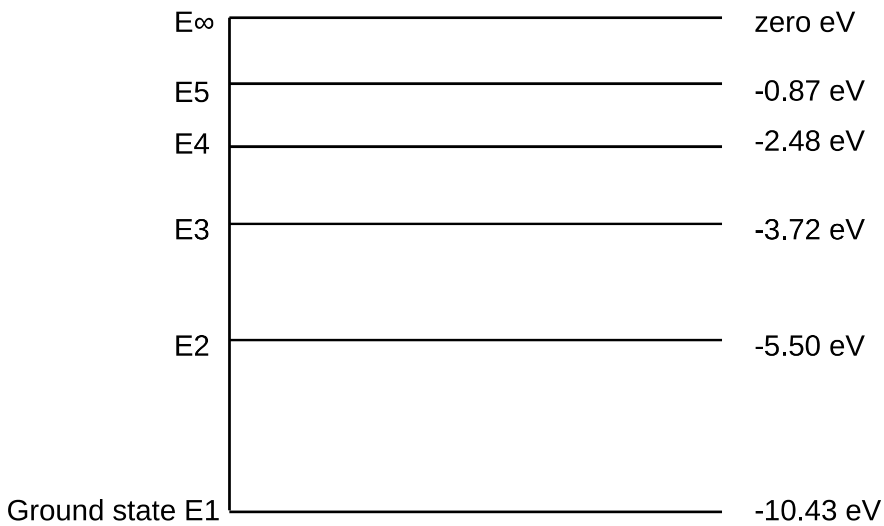
d. The final velocity of the stone is achieved as the stone reaches ground level. If the stone had been catapulted at the same launch speed but at an angle of 20° above the horizontal how would the magnitude of final velocity compare to a launch 20° below the horizontal. Circle a response and explain briefly.

(3)

final velocity greater   final velocity the same   final velocity less

Question 15 (16 marks)

A fluorescent light contains low pressure mercury vapour. When atoms of mercury are bombarded by high speed electrons they emit Ultraviolet photons. These UV photons strike a coating on the inside of the lamp causing it to fluoresce and emit visible light. The diagram below details some of the energy levels for Mercury.



a. Calculate the minimum speed of a bombarding electron that could ionise a ground state mercury atom.

(4)

b. Is it possible for a mercury atom to absorb a 10.5 eV photon? Explain briefly.

(2)

c. Explain why the mercury atom can emit several photon wavelengths but not a continuous emission spectrum.

(3)

d. The mercury atom can also emit a visible 772 nm photon. Identify the transition on the diagram with an arrow and label the transition “772 nm photon”. You must provide supporting calculations to justify your answer.

(4)

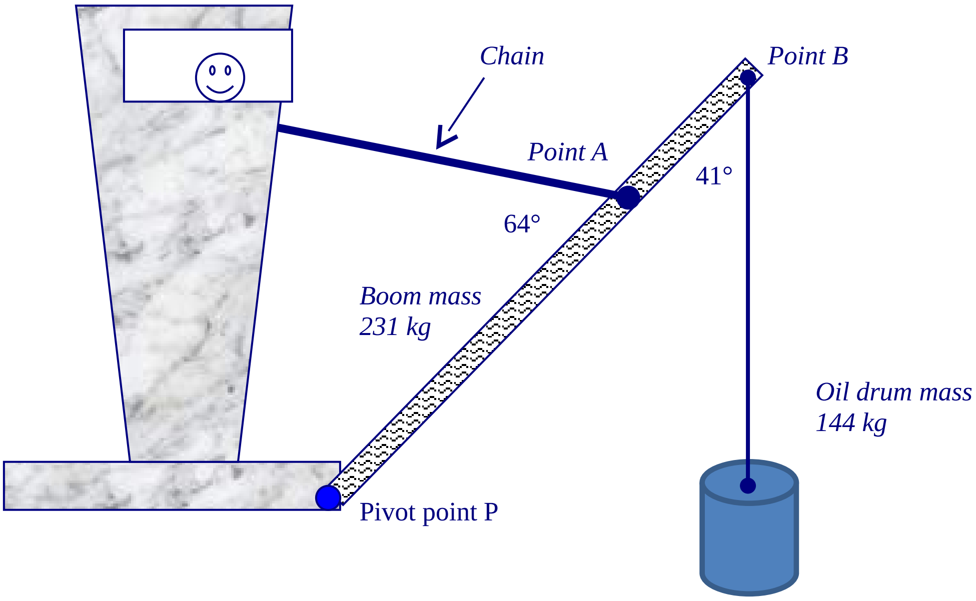
e. When UV photons strike the phosphor coating on the inside of the lamp the coating “fluoresces”. Explain this process with reference to a simple energy level diagram.

(3)

Question 16 (9 marks)

A crane at Fremantle port is unloading an oil drum from a ship.

- The boom of the crane has a mass of 231 kg and is pivoted at point P.
- The oil drum of mass 144 kg is suspended from point B. Its rope makes an angle of 41° with the boom.
- A chain attached at point A is holding the boom in position. The distance from P to A is 3.80 m.
- The chain makes an angle of 64° with the boom.
- The boom has a length of 4.50 m from P to B with uniform mass distribution.



a. Demonstrate by calculation that the tension in the chain = 2.20×10^3 N.

(4)

b. Calculate the magnitude of the **reaction force** acting on the boom from the pivot. (3)

c. Calculate the direction of the **reaction force** acting on the boom from the pivot. (2)

Question 17 (12 marks)

A circular coil is placed in the uniform magnetic field between 2 magnetic poles such that the plane of the coil is perpendicular to the field lines. The circular coil has a diameter of 16.0 cm and is made from 150 turns of wire. The magnetic field has a flux density of 186 mT. The right edge of the coil is initially 2 cm from the limit of the field. The coil is moved to the right at a constant speed of 40 cm s^{-1} for 0.500 seconds.

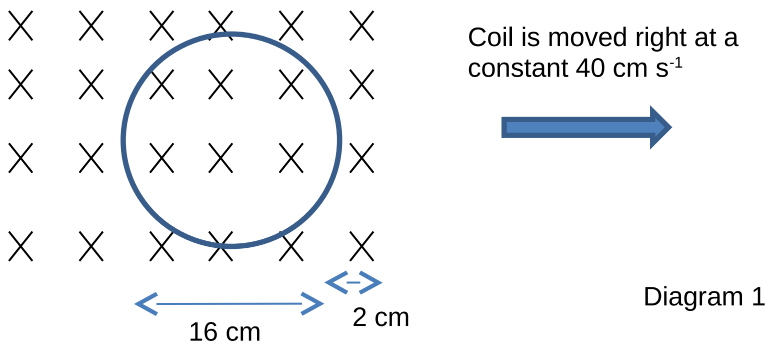


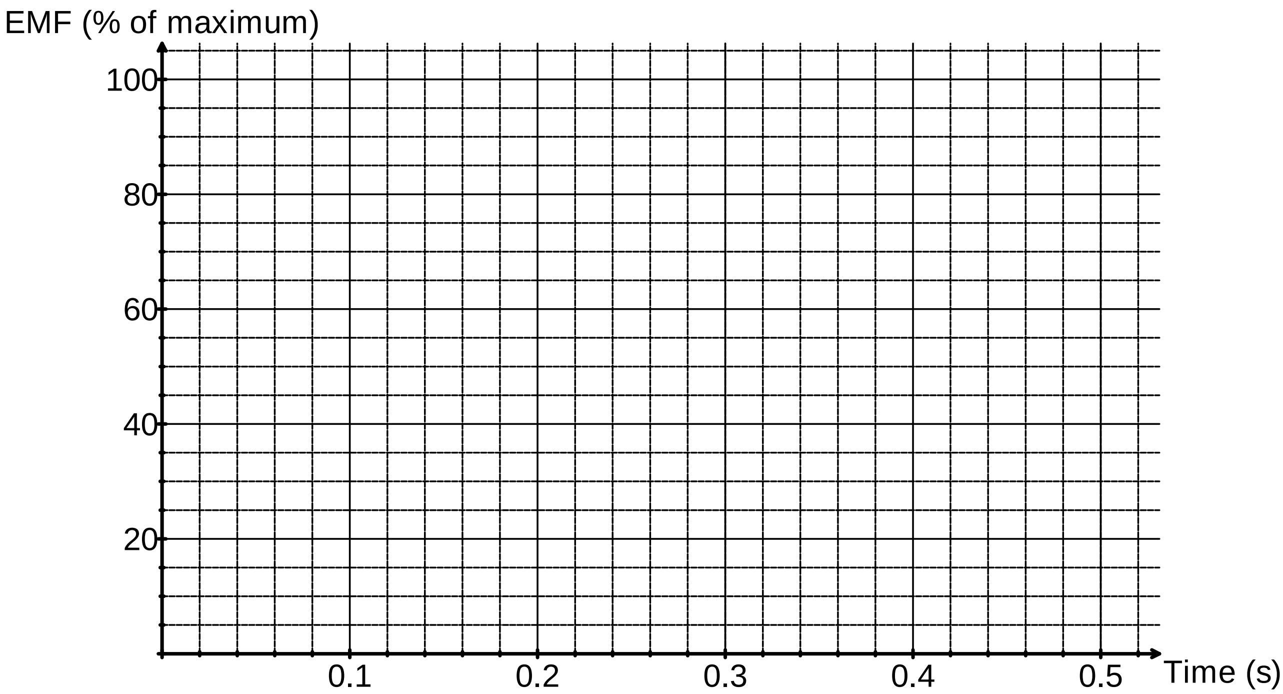
Diagram 1

a. Calculate the magnetic flux enclosed by the coil when it is fully within the magnetic field.

(2)

b. Calculate the time it takes for the coil to completely leave the magnetic field and then use this to determine the **average** value of induced emf as the coil is removed from the field

(4)



c. On the graph above sketch the approximate shape of the emf versus time as the circular coil is moved right from the start position shown in diagram 1. Briefly explain the shape of your graph. (4)

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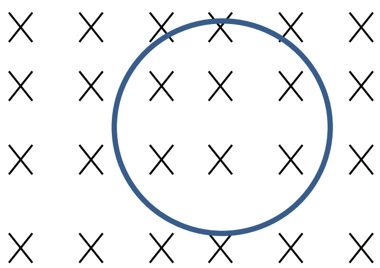
The diagram below shows the circular coil in the magnetic field in another experiment.

d. Show the direction of induced current if the magnetic flux density increases. Draw an arrow on the coil to indicate current direction and label it 'current'. Briefly explain your answer. (2)



Magnetic Flux
Density is increased

Question 18 (16 marks)

Kepler-186f is a planet in orbit around the red dwarf star Kepler-186. A full public announcement about the planet was made by NASA on 17 April 2014. It is the first discovery of a planet with a similar radius to that of Earth in the habitable zone of another star.

Kepler-186f is a distance of 151 ± 18 parsecs from Earth (1 parsec = 3.26 Light Years). It has an orbital radius of 0.391 AU from its host star (The Astronomical Unit (AU) = Sun-Earth distance). It has an orbital period of 129.9 days.

a) Calculate the speed of Kepler-186f around its host star

(3)

b) Calculate the mass of the host star Kepler-186 based on the information given.

(5)

c) The mass of the planet Kepler-186f is difficult to estimate and is thought to be in a range of 32% to 377% the mass of the Earth. Explain whether or not this high degree of uncertainty affects estimates for the mass of the host star.

(3)

d) Calculate the percentage uncertainty (relative uncertainty) for the distance from Earth to Kepler-186f.

(2)

e) The SETI institute (Search for Extra-Terrestrial Intelligence) in California started to listen to radio emissions from Kepler-186f in April 2014. As yet, no signals attributable to intelligent life have been detected. If such a signal was detected in 2014 what would be the latest year in Earth history that the signal was transmitted from Kepler-186f?

(3)

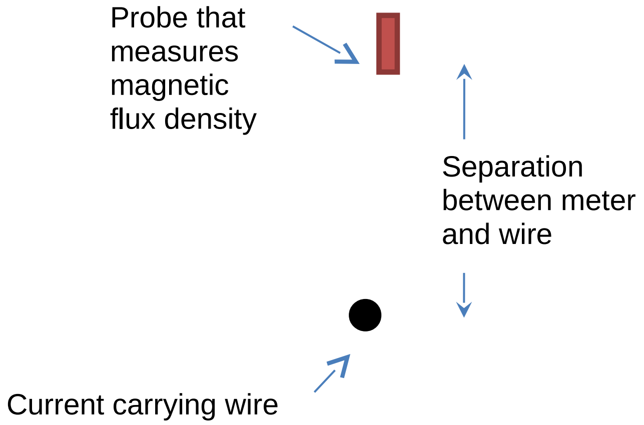
Question 19 (16 marks)

Some university students are investigating the circular magnetic field formed around a long straight wire carrying electrical current. They use a probe that measures magnetic flux density at different radii of separation from the wire.

The students know that the magnetic flux density decreases with increasing distance from the wire.

The students put a 90 cm straight length of wire between two clamps such that no objects (other than the probe) are closer than 40 cm to the centre of the wire.

A steady current of 2200 A is fed into the wire from an external power supply.



The probe that measures magnetic flux density is placed at set distances from the middle of the wire and measurements recorded.

The students analyse the difficulty obtaining a precise measurement of magnetic flux density and decide to record this data with an uncertainty of ±7%.

The magnetic flux density B, due to a current I, passing in a wire is given by the expression:

$$B = \frac{\mu_0 I}{2\pi r}$$

Where, μ_0 = the permeability of free space ($H\ m^{-1}$), which is a measure of the extent to which the surrounding medium reinforces the magnetic field.

r = radius of separation (m)

The results obtained are as follows:

Radius of separation (m)	$\frac{1}{r}$ **(m^{-1})**	**Magnetic Flux Density ($\times 10^{-3}$ T)**
0.065	15.4	6.70 ± 0.47
0.080		5.90
0.100		4.50
0.125		3.50
0.200		2.10
0.500		0.90 ± 0.06

Answer the following questions:

a. Complete the second column of the table 1/r , so that you can plot a straight line graph. One value has been done for you.

(1)

b. Complete the third column of the table **(Magnetic Flux Density)** to include the uncertainty for each measurement. Two values have been done for you.

(1)

c. Plot a graph of Magnetic Flux Density (B) on the vertical axis versus 1/r on the horizontal axis. You must include a line of best fit and error bars.

If you need to make a second attempt, spare graph paper is at the end of this question. Indicate clearly if you have used the second graph and cancel the working on the first graph.

(6)

d. Calculate the gradient of your line of best fit from your graph showing all working.

(3)

e. Determine the value of μ_0, the permeability of free space, from the value of the gradient that you obtained. (If you could not determine the gradient use the numerical value 4.40 x 10^{-4}).

(3)

f. Describe a possible source of experimental error in this experiment.

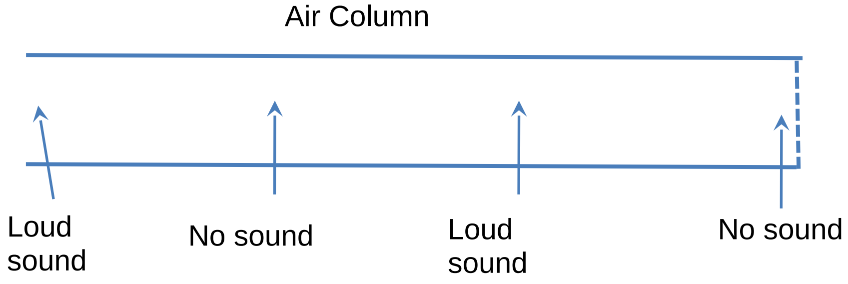
(2)

Spare graph paper

(3)

Question 20 (8 marks)

The diagram shows a closed air column that is resonating because a standing wave has formed inside it. A small microphone is slid inside the pipe from the left hand side without interfering with the standing wave. The microphone has detected loud regions and regions with no sound associated with this standing wave.



a) Sketch the standing wave that forms within this air column.

(1)

b) Explain briefly why there are loud regions and regions with no sound.

(2)

c) The air column has an effective length of 36.0 cm. The speed of sound in air is 346 m s^{-1}. Calculate the frequency of this standing wave.

(3)

d) Calculate the frequency produced by the air column if it were vibrating in its fundamental mode.

(2)

End of Section 2

Section Three: Comprehension 20% (36 Marks)

This section contains **two (2)** questions. You must answer both questions. Write your answers in the space provided. Suggested working time for this section is 40 minutes.

Question 21 The speed of mechanical waves (18 marks)

Mechanical waves travel through material media by causing particles to vibrate. If one part of the medium is disturbed, the speed at which this disturbance is passed on depends on two properties of the medium.

Density: A denser medium has more mass per unit volume to set in motion and so responds more slowly to a disturbance. When one particle vibrates it exerts a force on its neighbours along the bonds that join them and they respond accordingly. If there is more mass to move the force will achieve a smaller acceleration.

Stiffness (Elasticity): If the bonds between the particles are stiff then disturbances between particles are transferred more effectively.

A more detailed analysis shows that in many cases:

The speed (v) of a mechanical wave is proportional to $\sqrt{\frac{stiffness\ factor}{density\ factor}}$

The density and stiffness factors take different forms in different circumstance. Some examples are shown here:

Longitudinal waves in a solid rod, $v = \sqrt{\frac{Y}{\rho}}$

Where
Y = Young's Modulus (Pa),
ρ=density (kg m^{-3}) = $\frac{mass}{volume}$

Sound waves in a gas, $v = \sqrt{\frac{\gamma.R.T}{M}}$

Where
R = molar gas constant 8.314472 (J K^{-1}mol^{-1})
T = absolute temperature kelvin (0°C = 273 K)
γ = a constant
M = the molar mass in kg mol^{-1}

Measuring the speed of sound in a metal rod

If a metal rod is dropped vertically onto a metal plate it will bounce. The rod arrives at the metal plate and the two metals will stay in contact for the time it takes a compression pulse to travel up the rod, reflect from the top and travel back down. The returning pulse pushes the rod away from the base plate.

The rod and the base plate are made part of an electric circuit. When they make contact they trigger a high frequency electric signal (25 kHz) to be recorded on an oscilloscope until contact is broken. By analysing the number of transverse electric waves on the oscilloscope the contact time can be determined. By using this data with the length of the rod, the speed of the compression pulse can be calculated. The speed of sound in an iron rod can be deduced using this method.

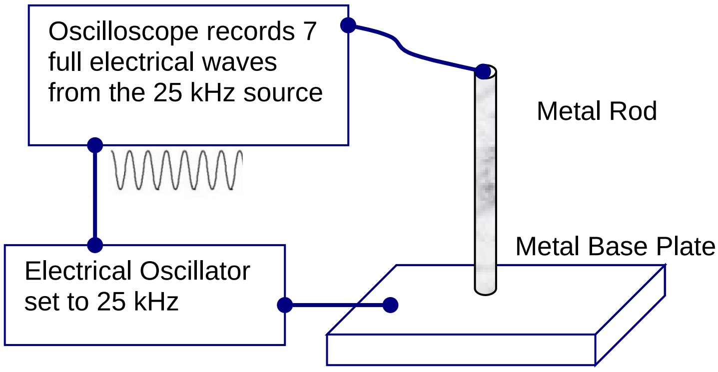


Diagram 1
Experiment to determine the speed of sound in a Metal Rod

The rod is dropped onto the base plate

Answer the following questions

a) Two of Newton's Laws are referred to in the paragraph about density. State which laws are referred to and how the physics described in the paragraph is linked to the laws.

(2)

b) The passage clearly states that as material density increases then the speed of sound will decrease. Explain why sound travels faster in a solid compared to a gas when the solid has much higher density.

(3)

c) Calculate the speed of sound in helium at 25°C (298 K). For helium γ = 1.67 and the molar mass= 0.004. (3)

d) The speed of sound in air increases with temperature. Explain what physical property of air is changing with an increase in temperature.

(2)

e) An aluminium rod of length 80 cm and diameter 2.40 cm has a mass of 977 grams. Young's Modulus for aluminium is 70 $\times 10^9$ Pa. Calculate the speed of sound in the aluminium rod.

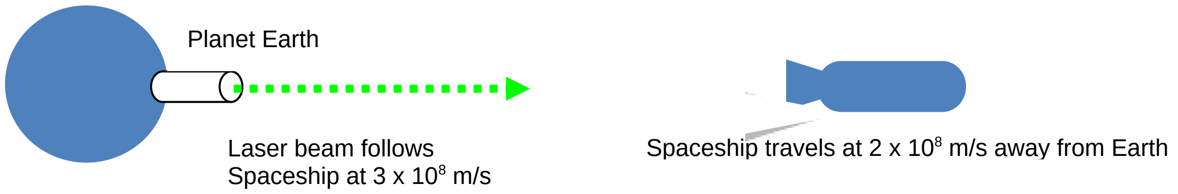
(4)

f) For the experiment to determine the speed of sound in a metal rod, a speed of 5200 m s^{-1} was determined for a steel rod. Calculate the length of the steel rod if 7 full waves were recorded on the oscilloscope. *(Refer to Diagram 1).*

(4)

Question 22 Einstein's theory of Special Relativity – Time Dilation (18 marks)

Imagine that you are a stationary observer and your friend flies away from you in a spaceship at 2.00×10^8 m s^{-1}. You then shine a laser beam at your friend's spaceship. The laser beam travels towards the spaceship at 3.00×10^8 m s^{-1}. Using simple arithmetic you think that the light is travelling towards the spaceship at a net velocity of 1.00×10^8 m s^{-1}. But the principle of relativity says that if your friend measures the speed of the laser beam from her spaceship she sees it travelling at 3.00×10^8 m s^{-1} relative to her. This raises an important question.



How can the light gain 1.00×10^8 m s^{-1} towards the spaceship as measured by you but be travelling at 3.00×10^8 m s^{-1} relative to the spaceship as measured by your friend on the spaceship? The answer is it can do both if your friend's seconds last longer than yours.

In special relativity, moving clocks run slow in the sense that the observed time between ticks is taking more time. The rate that time passes is taking longer.

The speed of light in a vacuum does not vary when viewed by any observer travelling at any speed. If Einstein's theory of special relativity is correct then time runs slower for moving objects compared to the time duration experienced by stationary observers.

Time dilation can be calculated using the formula:

$$t_v = \gamma . t_0$$

Where γ is the Lorentz contraction given by:

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

t_v = time between "clock ticks" on a moving object

t_0 = time between "clock ticks" in stationary reference frame
The units of time are arbitrary but must be the same for t and t_0

v = the speed of moving object (m s^{-1})

c = speed of light in a vacuum (m s^{-1})

The slowing of time has been tested by NASA by comparing 2 identical atomic clocks. One was left on Earth and the other sent into high speed orbits around Earth. The time that passed for the orbiting clock was less than that of the Earth based clock.

a) A spaceship is travelling directly towards the Sun at 1.40×10^8 m s^{-1}. Light is travelling from the Sun towards the spaceship at 3.00×10^8 m s^{-1}. What is the speed of light from the Sun relative to a pilot on the spaceship?

(1)

b) A spaceship travels away from Earth at 85% of the speed of light. A NASA technician on Earth calculates that ship will travel for 8 years at this speed. Calculate how much time will elapse on the spaceship as viewed from Earth. Give your answer in years to 2 decimal places.

(4)

c) Describe what happens to the magnitude of the Lorentz contraction (γ) as v approaches the speed of light.

(2)

d) What happens to time inside a spaceship (as viewed from Earth) if the speed of the spaceship relative to the Earth approaches the speed of light?

(2)

e) Does Einstein's theory of special relativity allow for objects to travel faster than the speed of light? Justify your answer by making reference to the Lorentz contraction (γ).

(3)

f) Determine the speed a spaceship must travel such that 23 years of time passes on the moving spaceship whilst 230 years passes for an observer on Earth.

(4)

g) The manufacturers of the satellites deliberately build in a correction to the rate at which the clocks tick so that they run a little fast before they are put into orbit. Explain why they do this.

(2)

End of questions

Additional working space

Additional working space

End of Examination