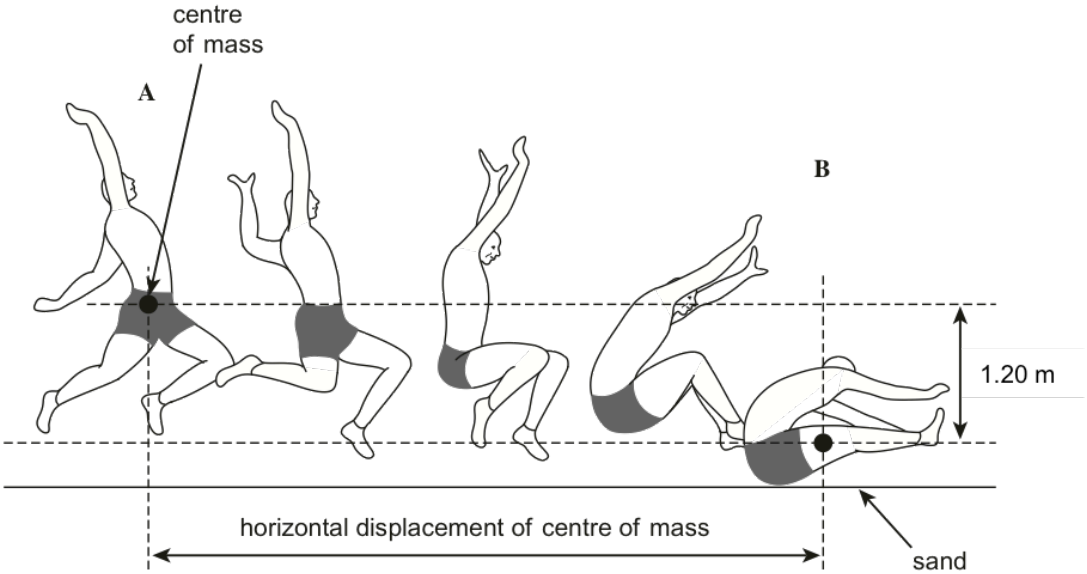
Question 1 **(4 marks)**

The diagram below shows the path of a long jumper from half-way through a jump at position A, to position B when contact is made with the sand on the ground.



During this part of the jump, the centre of mass of the athlete falls 1.20 m.

The athlete is moving horizontally at A with a velocity of 8.50 ms^{-1}. Calculate the magnitude of horizontal displacement of the athlete's centre of mass from A to B.

Vertical :

$$s = ut + \frac{1}{2}at^2$$ (1)

$$1.2 = \frac{1}{2}(9.8)t^2$$ (½)

$$t = 0.495s$$ (½)

Horizontal :

$$s = vt$$ (½)

$$s = (8.5)(0.495)$$ (½)

$$s = 4.21m$$ (1)

Question 2 **(3 marks)**

A piece of wire is placed in a magnetic field of 19.6 mT and experiences a force of 17.0 x 10^{-3} N when a current of 2.40 A flows through it. Calculate the length of the wire.

$$F = IlB \quad (1)$$

$$17\times10^{-3} = (2.4)(19.6\times10^{-3})l \quad (1)$$

$$l = 0.361m \quad (1)$$

Question 3 **(4 marks)**

Explain how an opera singer can break a glass using only their voice and name the phenomena that causes this to happen.

- The singer sings at the same frequency as the natural frequency of the glass.
- The glass oscillates with increasing amplitude
- Until the glass cannot maintain its shape.
- This effect is called resonance.

Question 4 **(4 marks)**

Quarks are a group of fundamental particles that make up matter, including particles such as the kaon, K^+.

Quarks have the following properties:

Quark	Charge
Up	+ 2/3 e
Down	- 1/3 e
Charm	+ 2/3 e
Strange	- 1/3 e
Top	+ 2/3 e
Bottom	- 1/3 e

(a) Using the information in the table above determine the correct quark structure of the K^+. Circle your chosen answer.

(1 mark)

$u\bar{s}$ us $s\bar{u}$

(b) The K^+ is classified as a meson, rather than a baryon. State why this is the case.

(2 marks)

- The kaon is made of 2 quarks.
- Mesons are made of 2 quarks, whereas baryons are made of 3.

(c) What is the quark makeup of the antiparticle of a K^+?

(1 mark)

$\bar{u}s$

Question 5 **(3 marks)**

Calculate the energy produced if a chicken, of mass 3.00 kg, is converted entirely to electromagnetic radiation.

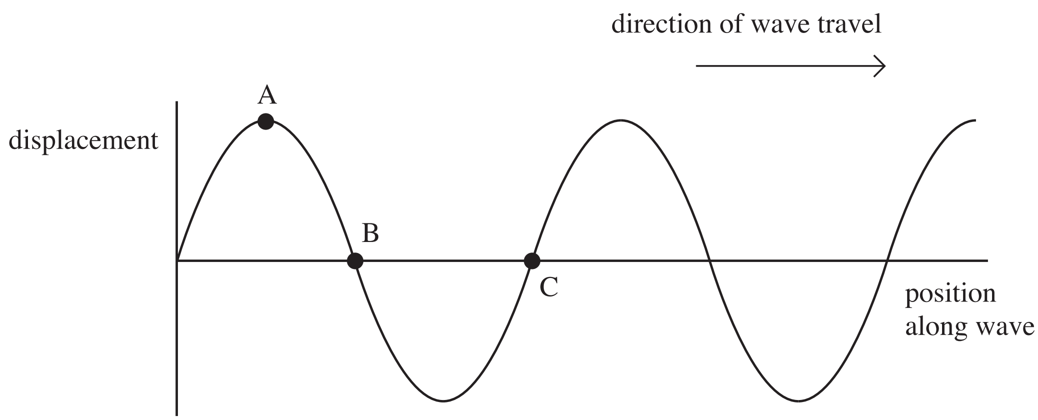
$$E = mc^2 \quad ①$$

$$E = (3)(3 \times 10^8)^2 \quad ①$$

$$E = 2.70 \times 10^{17} J \quad ①$$

Question 6 **(3 marks)**

The graph below shows the displacement of particles at a given instant, for different positions along a transverse wave.



(a) State the phase difference between:

(2 marks)

(i) points A and B on the wave.

90°

(ii) points A and C on the wave.

90° or 270°

(b) State the direction of the motion of the particle at point B

(1 mark)

Up

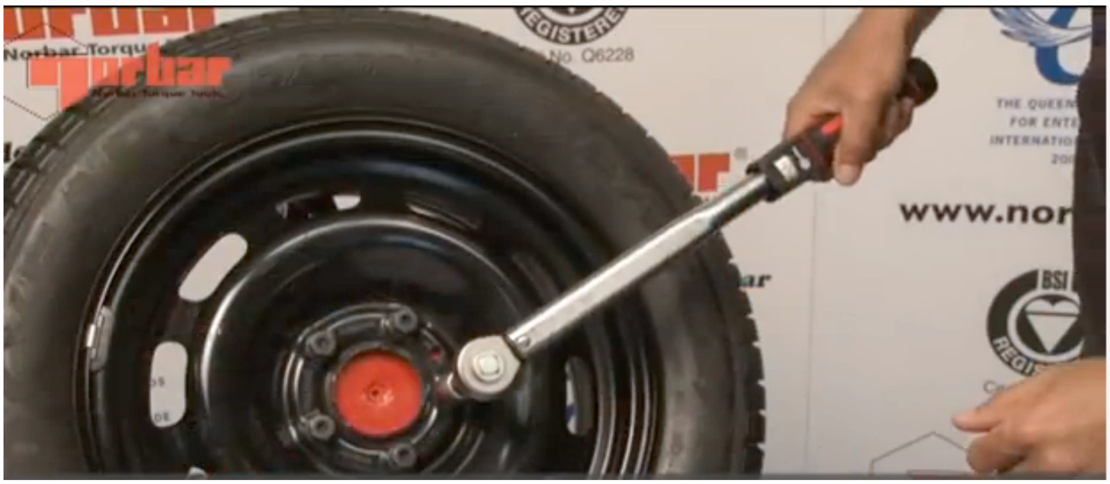
Question 7 **(2 marks)**

An earth bound physicist and an astronaut are having a discussion as to how the astronaut can measure the speed of his rocketship using only a single ruler. The astronaut will be travelling at approximately 0.8c. The astronaut thinks that he should take the ruler so that he can measure its length contraction. Explain if the astronaut's reasoning is correct.

- This will not work.
- There will be no relative motion between the astronaut and the ruler.

Question 8 **(5 marks)**

A torque wrench is used to tighten the bolts on a tyre. If the wrench is set to deliver 100 Nm of torque, estimate the magnitude of force that must be applied at the handle of the torque wrench, as shown in the diagram below. It can be assumed that the force is applied at 90.0° to the handle. State any estimations.



Estimate hand width: 0.10 m (1)

Length of spanner: 4 x 0.1 = 0.4 m (1)

$\tau = Fr\sin\theta$ (1)

$100 = F(0.4)$ (1)

$F = 2.5\times10^2 N$ (1)

Accept 0.08-0.12 m for length of hand.

Accept range of force: 2.0×10^2 - 3.1×10^2

Question 9 **(4 marks)**

Analysis of the redshifts from many distant galaxies led Edwin Hubble to a significant conclusion. Outline Hubble's conclusions and how these suggest that our universe started in an event called the Big Bang.

- Galaxies that are further way have been redshifted more.
- This means they are receeding at a higher velocity than ones closer to us.
- This mean that the universe is expanding.
- An expanding universe must have started from a singularity: a single moment in spacetime.

Question 10 **(4 marks)**

An electron is accelerated towards a positively charged conductive plate through a potential difference of 25.0 kV. Calculate the speed of the electron as it reaches the positive plate.

$W = Vq$ (½)

$W = (25 \times 10^{3})(1.6 \times 10^{19})$ (½)

$W = 4.00 \times 10^{-15} J$ (1)

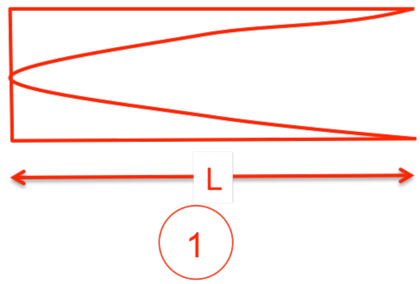
$E_k = \frac{1}{2}mv^2$ (½)

$4.00 \times 10^{-15} = \frac{1}{2}(9.11 \times 10^{-31})v^2$ (½)

$v = 9.37 \times 10^{7} ms^{-1}$ (1)

Question 11 **(4 marks)**

A narrow glass tube, 0.500 m long, is sealed at its bottom end. A loudspeaker, that is connected to a signal generator, is placed over the open end of the tube. A tone with a gradually increasing frequency is played through the loudspeaker. If a loud resonance is first heard at 172 Hz, calculate the speed of sound in the room. Sketch a diagram to support your reasoning.



$$L = \frac{n\lambda}{4}$$ (½)

$$0.5 = \frac{(1)\lambda}{4}$$

$$\lambda = 2.00m$$ (1)

$$v = f\lambda$$ (½)

$$v = (172)(2)$$

$$v = 344ms^{-1}$$ (1)

Question 12 **(3 marks)**

Calculate the gravitational force acting on the planet Mercury from the Sun, given that the mean Sun-Mercury distance is 57.9 x 10^6 km and the mass of Mercury is 3.29 x 10^{23} kg.

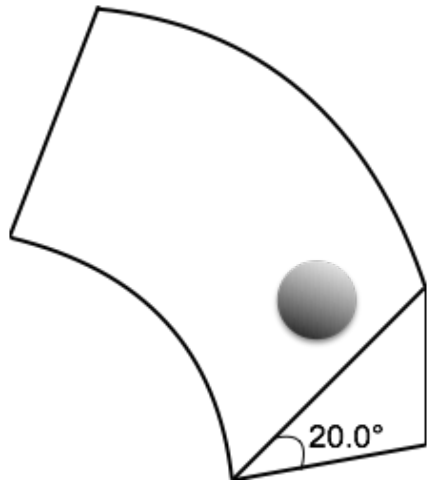
$$F_g = G\frac{m_1 m_2}{r^2}$$ (1)

$$F = \frac{(6.67\times10^{-11})(1.99\times10^{30})(3.29\times10^{23})}{(57.9\times10^{9})^2}$$ (1)

$$F = 1.30\times10^{22}N$$ towards the Sun (1)

Question 13 **(5 marks)**

A children's game is based around the movement of a marble. In one part the marble rolls around a circular path that is banked at 20.0° to the horizontal. A child playing the game wants to see if he can make the marble roll at a constant horizontal level around the bank.



The marble he uses has a mass of 5.00 g. Calculate the speed at which the marble must be travelling in order to complete the curve if the radius of curvature of the path is 30.0 cm.

$$\Sigma F = ma$$ (½)

$$F_c = \frac{mv^2}{r}$$ (½)

$$\Sigma F_{vertical} = 0 = mg - F_{N_{vertical}}$$ (½)

$$\Sigma F_{horizontal} = F_c = F_{N_{horizontal}}$$ (½)

$$\tan\theta = \frac{F_{N_{horizontal}}}{F_{N_{vertical}}} = \frac{mv^2}{mgr} = \frac{v^2}{gr}$$ (1)

$$v = \sqrt{(9.8)(0.3)(\tan 20)}$$ (1)

$$v = 1.03ms^{-1}$$ (1)

Question 14 **(6 marks)**

The two images below show spectra for the same element in different conditions. See extra colour images provided.

Image 1:

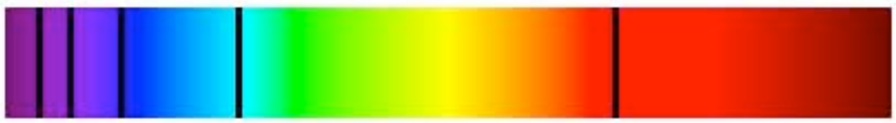


Image 2:

(a) State what type of spectrum each image shows.

(2 marks)

Image 1: Line absorption spectrum

Image 2: Line emission spectrum

(b) Explain how image 1 has been formed.

(4 marks)

- White light shines through a cold, dense gas.
- Electrons become excited when they absorb photons with a specific frequency.
- The frequencies that are absorbed correspond to the difference in energy levels for that atom.
- Those frequencies of light do not appear in the spectrum, and are seen as black lines instead.

END OF SECTION

YEAR 12
PHYSICS STAGE 3
TRIAL EXAMINATION 2015

Section Two: Problem-Solving

This section has **eight (8)** questions. Answer **all** questions. Write your answers in the space provided.

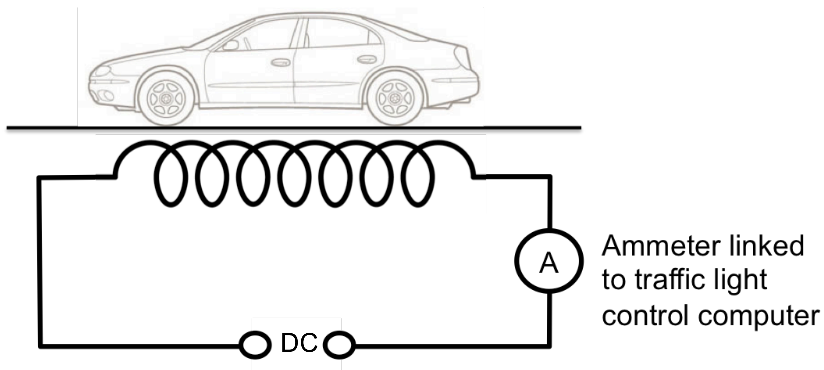
Suggested working time for this section is **90 minutes**.

NAME:____

Question 1 **(12 marks)**

Inductive-loop traffic detectors are used in traffic light systems to determine when a car arrives at a junction. They are made of loops of wire buried just below the surface of the road which are connected across a DC power supply of constant potential difference.

A diagram showing the loops under the surface of the road is shown below.



(a) State what will happen to the reading on the ammeter when a car starts to drive over the loop.

(1 mark)

It will decrease.

(b) Explain your answer to part (a).

(5 marks)

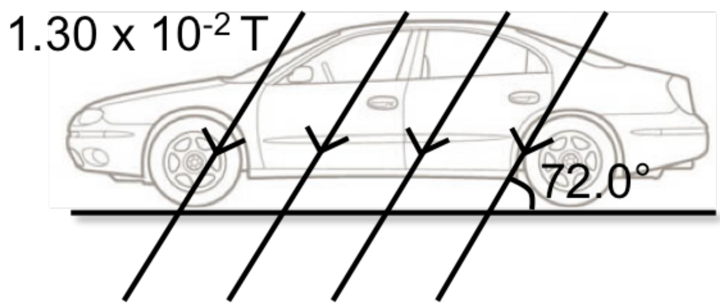
- The current carrying loop of wire will have a magnetic field associated with it. The car is made from metal and so is a conductor.
- As the car moves over the magnetic field, there will be a changing magnetic flux within the body of the car.
- Faraday's Law states that an emf will be induced in the car that is proportional to the rate of change of magnetic flux.
- Lenz's Law states that this induced emf (and hence magnetic field) will be in such a direction as to oppose the change that initially caused it.
- This induced magnetic field will retard the motion of the charges in the coil, reducing the current in the coil.

(c) If a car remains stationary over the loop, state what effect this will have on the reading of the ammeter and explain your reasoning.

(3 marks)

- The ammeter reading will show no change from the normal reading.
- There is no motion of the car relative to the magnetic field.
- So no induced emf (or current)

In one such device the idealised field from part of the solenoid is shown below. A car of length 2.30 m and width 1.50 m drives at a constant speed above the section of solenoid.



(d) Assuming the car behaves like a sheet of metal, calculate the amount of flux that it interacts with.

(3 marks)

$$\Phi = BA$$ (1)

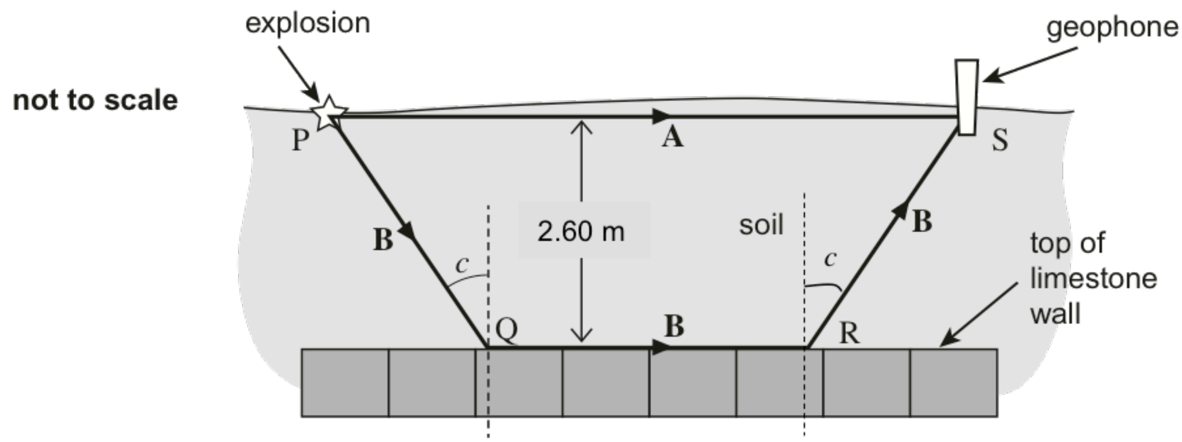
$$\Phi = (1.3\times10^{-2}\sin 72)(2.3)(1.5)$$ (1)

$$\Phi = 4.27\times10^{-2}\,Wb$$ (1)

Question 2 **(13 marks)**

The diagram below illustrates a geophone being used to detect sound waves generated by a small surface explosion on an archeological site. An explosion is detonated at ground level 2.60 m above a buried limestone wall. The most direct path, A, for the sound is along the soil surface. Another sound wave, following path B, meets and leaves the limestone at angle c, which is 37.0° to the vertical. This wave is refracted into the limestone and travels along the top edge of the wall, within the limestone.

Speed of sound in soil = 1.80 km s^{-1}
Speed of sound in limestone = 3.00 km s^{-1}



The length of path A is 9.80 m.

(a) Calculate the time taken for the sound to reach the geophone along path A.

(2 marks)

$s = vt$ (1)

$9.8 = 1.8 \times 10^{3} t$

$t = 5.44 \times 10^{-3} s$ (1)

(b) Determine the lengths PQ, QR and RS and use these to find the time taken for the sound to reach the geophone along path B.

(5 marks)

$PQ = RS$

$PQ\cos 37 = 2.6$ (½)

$PQ = 3.26m$ (1)

$QR = 9.8 - (2)(2.6\tan 37)$ (½)

$QR = 5.88m$ (1)

$s = vt$

$(3.26) = (1.8 \times 10^3)t_{PQ}$ (½)

$t_{PQ} = t_{RS} = 1.81 \times 10^{-3}s$

$5.88 = (3 \times 10^3)t_{QR}$ (½)

$t_{QR} = 1.96 \times 10^{-3}s$

$t = (2)(1.81 \times 10^{-3}) + (1.96 \times 10^{-3})$

$t = 5.58 \times 10^{-3}s$ (1)

(c) The wavelength of the sound in the soil is 190 m. Calculate the wavelength of the sound in the limestone.

(4 marks)

$v = f\lambda$ (1)

$f_{soil} = f_{limestone}$ (1)

$$\frac{v_s}{\lambda_s} = \frac{v_l}{\lambda_l}$$

$$\frac{1800}{190} = \frac{3000}{\lambda_l}$$ (1)

$\lambda_l = 317m$ (1)

The speed of sound in a medium can be calculated using the following formula:

$$v = \sqrt{\frac{B}{\rho}}$$

Where B is the bulk modulus of the material and ρ is the density

The table below shows properties of limestone and soil:

	Limestone	Soil
ρ (kgm^{-3})	1.50×10^3	1.20×10^3
B (Nm^{-2})	84.0×10^9	23.0×10^8

(d) Explain why the speed of sound in limestone is significantly greater than in soil.

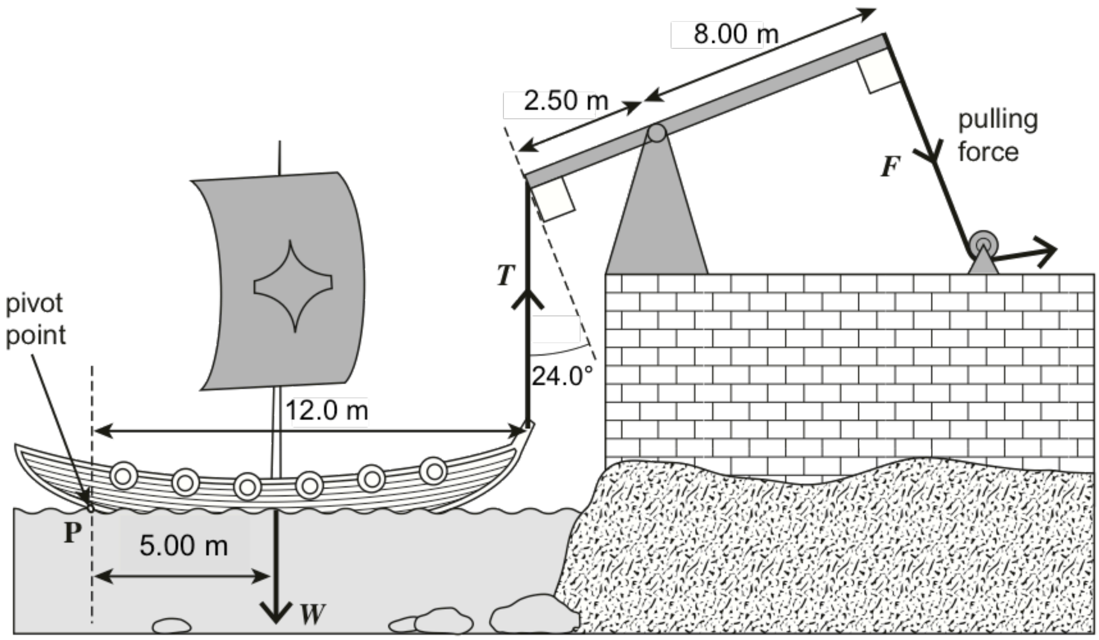
(2 marks)

- Speed of sound is proportional to the ratio of B:ρ
- Although the values of ρ are similar for both materials, the bulk modulus of the limestone is an order of magnitude larger than that of the soil, meaning the ratio will be larger and hence the speed.

No marks awarded if tried to justify with density.

Question 3 **(7 marks)**

Huge levers may have been used to sink ships in Roman times. A possible system is shown below where a rope is hooked on to the front of the ship and the lever is pulled by several men. The weight of the ship is 3.40 x 10^4 N.



(a) Calculate the magnitude of the minimum vertical force, T, required to start to raise the front of the ship.

(3 marks)

½ ½

$\tau = Fr\sin\theta \qquad \Sigma\tau_{cw} = \Sigma\tau_{acw}$

$(5)(3.4 \times 10^4) = (12)T$ 1

$T = 1.42 \times 10^4 N$ 1

(b) Calculate the magnitude of minimum force, *F*, that must be exerted to start to raise the front of the ship.

(4 marks)

½ ½

$$\tau = Fr\sin\theta \qquad \Sigma\tau_{cw} = \Sigma\tau_{acw}$$

1

$$(T\cos 24)(2.5) = (8)F$$

$$F = \frac{(2.5)(1.42\times10^{4})(\cos 24)}{8} \quad (1)$$

$$F = 4.05\times10^{3}\,N \quad (1)$$

Question 4 **(16 marks)**

A fluorescent tube is filled with mercury vapour at low pressure. A current is passed through the tube, exciting the mercury atoms. After the mercury atoms have been excited they emit photons. These photons interact with the coating on the inside of the fluorescent tube to emit visible light.

(a) State which part of the electromagnetic spectrum the photons emitted from the mercury atoms are from.

(1 mark)

Ultraviolet (accept UV)

(b) Describe what is meant by an excited mercury atom.

(1 mark)

An atom that has an electron that has been raised above its ground state.

(c) Explain how the mercury atoms in the fluorescent tube become excited.

(2 marks)

- Fast moving electrons (accept charge/current) flow through the tube.
- They collide with the mercury atoms transferring energy to the electrons and exciting the atom.

(d) Explain why the excited mercury atoms emit photons of characteristic frequencies.

(3 marks)

- The difference between the energy levels of each element are different (characteristic of the element).
- The excited mercury atoms will decay by emitting photons that have energy equal to the difference between energy levels.
- Each of these photons will have a characteristic frequency that is related to the difference in energy between the levels, as E=hf.

(e) The wavelength of some of the photons emitted by excited mercury atoms is 254 nm. Calculate the energy of the photons in electron volts (eV).

(4 marks)

$$E = hf \quad and \quad v = f\lambda \quad OR \quad E = \frac{hv}{\lambda}$$ (1)

$$E = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{254 \times 10^{-9}}$$ (½)

$$E = 7.83 \times 10^{-19} J$$ (1)

$$\frac{7.83 \times 10^{-19}}{1.6 \times 10^{-19}} = 4.89 eV$$ (1)

(½)

(f) Explain, with the aid of a diagram, how the coating on the inside of a fluorescent tube emits visible light.

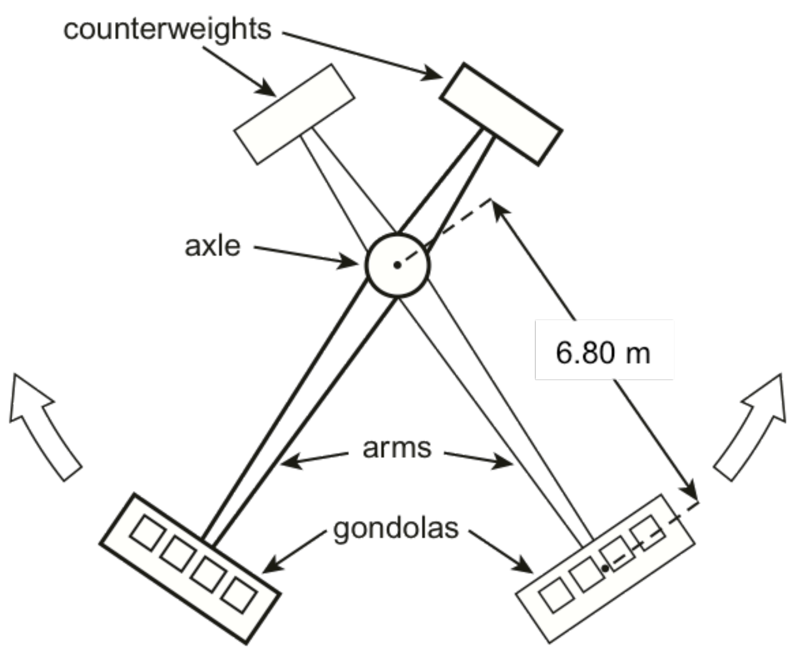
(5 marks)

- The electrons in the atoms of the coating absorb the UV photons and are excited to a high level.
- The atoms decay back to their ground state in multiple steps, the difference in energy between these levels is lower
- As $E=hc/\lambda$, as the energy decreases the wavelength of the photons emitted increases
- These photons are more likely to be in the visible part of the spectrum.

+1 for appropriate diagram

Question 5 **(12 marks)**

In a theme park ride, shown below, passengers are seated in a pair of gondolas that move in vertical circles in opposite directions. Each gondola system includes the gondola, a very heavy counterweight and the arm on which it is mounted. The distance between the centre of the axle and the centre of mass of a gondola is 6.80 m.



(a) Explain how the counterweights can be effective, even though the arms on which they are mounted are shorter than the arms carrying the gondolas.

(3 marks)

- The purpose of the counterweights is to provide additional torque to maintain the circular motion of the ride (and to reduce the power output required from the motor to spin the gondolas).
- The counterweights still effective because they are very heavy.
- τ = Fr, if the radius decreases but the mass (F) increases, the torque will be the same.

The ride starts from rest with both gondolas at the bottom. A motor is used to accelerate each gondola system uniformly from rest to a speed of 9.50 ms^{-1}. The gondolas then move in a circular at a constant speed of 9.50 ms^{-1}.

(b) Calculate the centripetal force exerted on a passenger of mass 86.0 kg when the gondolas are moving at constant speed.

(3 marks)

$$F_c = \frac{mv^2}{r} \quad (1)$$

$$F_c = \frac{(86)(9.5^2)}{6.8} \quad (1)$$

$$F_c = 1.14 \times 10^3 N \ towards\ centre \quad (1)$$

(c) Calculate the normal force exerted on the passenger by his or her seat when the gondola is at the top of its circular path.

(4 marks)

$$\Sigma F = ma = ma_c \quad (1)$$

$$-F_N - mg = -\frac{mv^2}{r} \quad (1)$$

$$F_N = \frac{mv^2}{r} - mg$$

$$= 1140 - (86)(9.8) \quad (1)$$

$$= 297\ N \quad downwards \quad (1)$$

(d) Describe how the magnitude of this normal force varies during one complete rotation of the gondola.

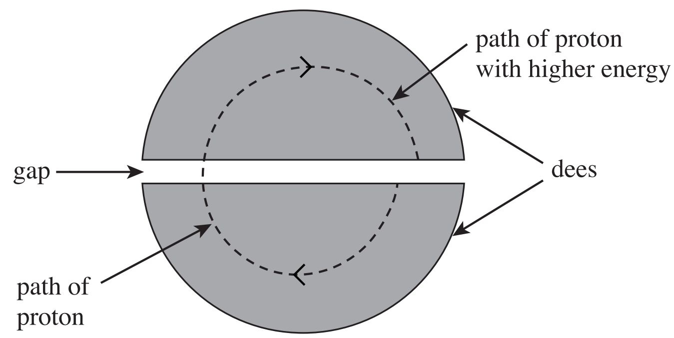
(2 marks)

- The normal force is at a minimum at the top of the rotation
- and increases to a maximum at the bottom of the rotation.

Question 6 **(9 marks)**

A cyclotron is a piece of equipment that is designed to produce high energy protons. In order to do this, the protons pass repeatedly between two hollow D-shaped containers called 'dees'.

The protons are acted on by a uniform magnetic field over the whole area of the dees. Each proton moves in a semi-circular path at constant speed when inside a dee. There is an alternating electric field applied between the dees, so that every time a proton crosses the gap it is accelerated.



(a) State the direction in which the magnetic field should be applied in order for the protons to travel along the semicircular paths inside each of the dees as shown.

(1 mark)

Out of the page

In a particular cyclotron the flux density of the uniform magnetic field is 0.480 T.

(b) Calculate the speed of a proton when the radius of its path inside the dee is 190 mm.

(5 marks)

$F_c = \frac{mv^2}{r}$ (½) $\quad F = qvB$ (½)

$\frac{mv^2}{r} = qvB$ (1)

$v = \frac{qBr}{m}$

$v = \frac{(1.6 \times 10^{-19})(0.48)(0.19)}{1.67 \times 10^{-27}}$ (1)

$v = 8.74 \times 10^6 ms^{-1}$ (1)

(c) Calculate the time taken for this proton to travel at constant speed in a semi-circular path of radius 190 mm inside the dee.

(3 marks)

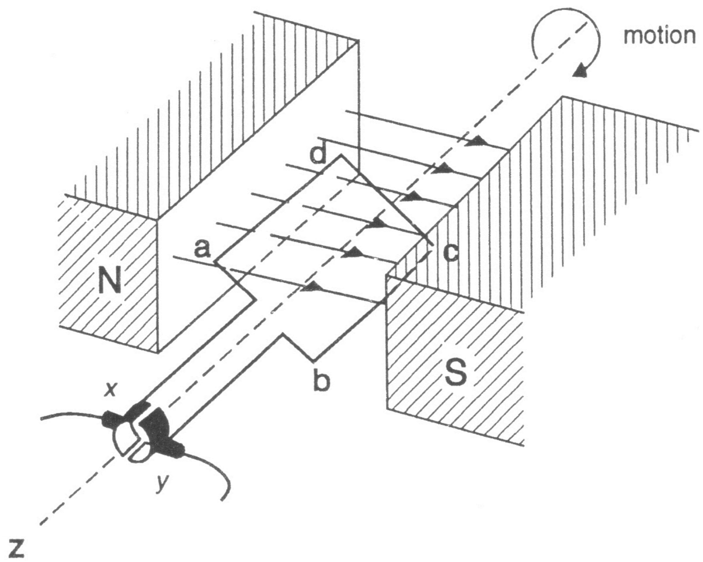
$$s = vt \quad \text{(½)} \qquad s_{semicircle} = \frac{2\pi r}{2} \quad \text{(½)}$$

$$t = \frac{\pi r}{v} = \frac{\pi(0.19)}{8.74 \times 10^{6}} \quad \text{(1)}$$

$$t = 6.83 \times 10^{-8}\, s \quad \text{(1)}$$

Question 7 **(10 marks)**

The diagram below shows a model DC motor. A battery is connected between *x* and *y* (see diagram). The coil is now rotated continuously in the same direction.



(a) State the name of the device located between *x* and *y* and explain its purpose.

(2 marks)

- Split ring commutator (spelling must be correct)
- Changes the direction of current through the circuit every half cycle (0.5 marks)
- To ensure the coil keeps spinning in one direction (0.5 marks)

(b) State how the terminals of the battery should be connected to *x* and *y* to make the coil rotate clockwise as viewed from Z.

(1 mark)

y is connected to the positive terminal, x is connected to the negative terminal

The coil *abcd* of the motor is formed from 50.0 turns of wire. Each turn is rectangular, having length 5.00 cm (sides *ad* and *bc*) and width 3.00 cm (sides *cd* and *ab*). The magnetic field can be assumed to be uniform and have a value of 48.0 mT.

(c) Calculate the force on the side *ad* of the when the coil is in the orientation shown above and the current in the coil is 2.00 A.

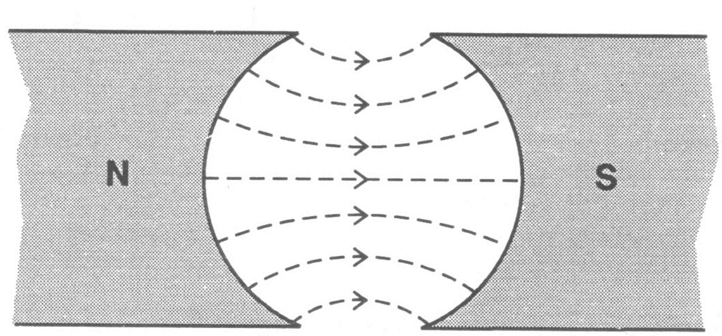
(4 marks)

$$F = NIlB \quad (1)$$

$$F = (50)(2)(0.05)(48 \times 10^{-3}) \quad (1)$$

$$F = 0.240 N \text{ up} \quad (1)$$

Curving the pole pieces of a magnet produces the magnetic field as shown below.



(d) State the effect that curving the pole pieces has on the average toque produced by the motor. Explain your reasoning.

(3 marks)

- The average torque will be greater with curved pole pieces than without.
- Curving the pole pieces means that the magnetic field is parallel to the plane of the coil for the majority of the rotation.
- As the force due to the magnetic field will always be perpendicular to the magnetic field, this will mean that the force is perpendicular to the arm of the rotor for more of the cycle. As $\tau = rF_{\perp}$ this will maximise the torque in the cycle (as r and F are perpendicular for longer).

Question 8 **(11 marks)**

A satellite of mass 2.52 x10^3 kg is at a height of 1.39 × 10^7 m above the surface of the Earth.

(a) Calculate the gravitational force of the Earth attracting the satellite.

(3 marks)

$$F = G\frac{m_1 m_2}{r^2} \quad (1)$$

$$F = 6.67\times10^{-11}\frac{(2.52\times10^3)(5.97\times10^{24})}{(1.39\times10^7 + 6.38\times10^6)^2} \quad (1)$$

$$F = 2.44\times10^3 N \text{ towards Earth} \quad (1)$$

(b) The satellite in part (a) is in a circular polar orbit. Calculate the number of times the satellite would travel around the Earth every 24 hours.

(5 marks)

$$F_c = \frac{mv^2}{r} \quad (1) \qquad v = \frac{2\pi r}{T} \quad (1)$$

$$v = \sqrt{\frac{F_c r}{m}} = \frac{2\pi r}{T}$$

$$\sqrt{\frac{(2.44\times10^3)(1.39\times10^7 + 6.38\times10^6)}{2.52\times10^3}} = \frac{2\pi(1.39\times10^7 + 6.38\times10^6)}{T} \quad (1)$$

$$T = 2.88\times10^4 s \quad (1)$$

$$\frac{(24)(60)(60)}{2.88\times10^4} = 3.00 \quad (1)$$

3 times in 24 hours

(c) A solar panel on the satellite's wing has not been connected properly and falls off so that the overall mass of the satellite is less. Describe how this will affect the motion of the satellite, making reference to appropriate formulae.

(3 marks)

- The motion of the satellite will not be affected.
- The velocity of the satellite depends on the radius of the orbit and the mass of the Earth, both of which are constant.
- As shown by the formulae below:

$$F_g = G\frac{Mm}{r^2} \qquad F_c = \frac{mv^2}{r}$$

$$G\frac{M\cancel{m}}{r^{\cancel{2}}} = \frac{\cancel{m}v^2}{\cancel{r}}$$

$$v = \sqrt{\frac{GM}{r}}$$

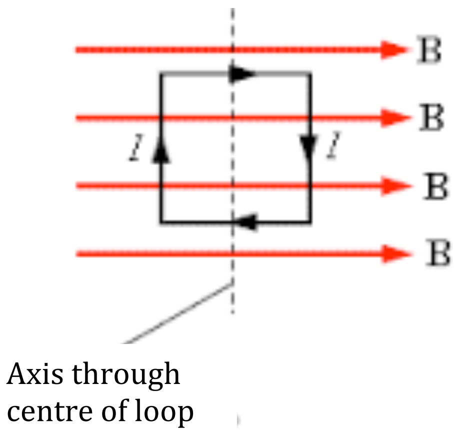
END OF SECTION

Question 1 **(21 marks)**

Nuclear Magnetic Resonance Spectroscopy

Nuclear Magnetic Resonance (NMR) was discovered in 1946 and is a powerful research tool in a variety of fields including physics, chemistry and biochemistry. In more recent times it has been developed into an important and widely used medical imaging technique.

If we place a loop of wire carrying an electric current in a magnetic field, such as in the diagram below, it will experience a torque on it. This is called a **magnetic moment**. If allowed to rotate freely, the plane of the loop would align itself with the magnetic field.



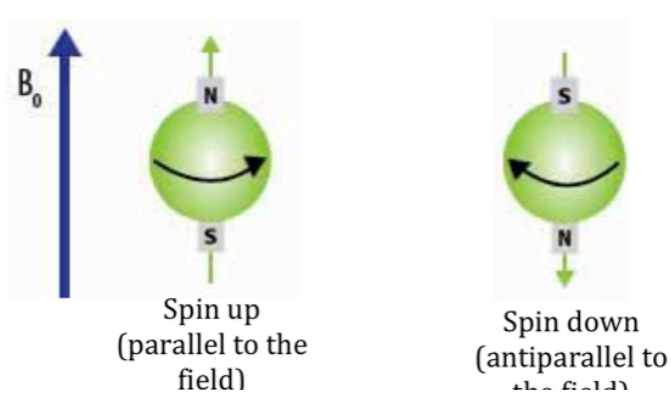
This principle can be applied to electrons in an atom.

As electrons in atoms orbit the nucleus, they also act as tiny current loops with an associated property called **spin**. This property acts like the magnetic moment of a current loop. Spin can take on one of two values:

1. Spin up – parallel to the field

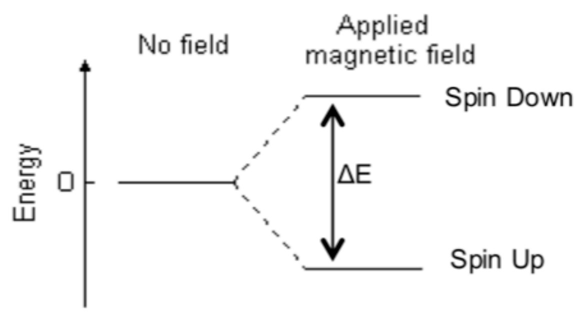
2. Spin down – antiparallel to the field

These states can be visualised as arrows pointing up and down, as shown in the diagram below.



Nuclei also exhibit these magnetic properties. Hydrogen, the simplest nuclei, consists of a single proton. Its spin, like that of an electron, can only take on two values when placed in a magnetic field: spin up and spin down.

When a magnetic field is present, the energy level of the nucleus splits into two levels, as shown in the diagram below, with the spin up having the lower energy.



The difference in energy between these two levels is proportional to the total magnetic field,

$$\Delta E = kB_T$$

Where B_T is the total magnetic field at the nucleus and k is a proportionality constant that is different for different nuclides.

In a standard NMR setup, the sample to be examined is placed in a static magnetic field. A radiofrequency (RF) pulse of electromagnetic radiation is applied to the samples.

If the frequency of this pulse corresponds precisely to the energy difference between the two energy levels so that;

$$hf = \Delta E = kB_T$$

the photons of the RF beam are absorbed, exciting many of the nuclei from the lower state to the upper state. This is termed a resonance phenomenon, as it is similar in principle to resonance in sound waves, hence the name ‘nuclear magnetic resonance’.

(a) Explain why this can be considered a resonance phenomenon.

(2 marks)

- Only specific frequencies lead to a large number of excitations.
- Similar to large amplitude oscillations at an object's natural frequency during sound resonance

For producing medically useful NMR images (often called MRI or magnetic resonance imaging), the element most often used is hydrogen since it is the most common element in the human body and gives the strongest NMR signals. The formation of a two-dimensional or three-dimensional image can be done by measuring the intensity of the absorbed and/or re-emitted radiation from many different points of the body. But how can we determine from what part of the body a photon comes?

One technique is to give the magnetic field a gradient, so instead of applying a uniform magnetic field, it is made to vary with position across the width of the sample or patient.

(b) Explain how the graduated magnetic field would this allow you to work which part of the sample a photon was emitted from.

(3 marks)

- The frequency of the photon that will be absorbed and emitted is proportional to the magnetic field at that point.
- If the magnetic field varies, it can be calculated the frequency of the photon that will be detected from that point of the magnetic field
- Which can be relocated back.

The following data was collected when investigating the energy emitted from a particular nuclide at different magnetic field strengths:

ΔE ($\times 10^{-9}$ eV)	B (T)	f ($\times 10^{6}$ Hz)
7.24	2.21	1.75
21.7	5.78	5.24
29.0	7.91	7.00
43.4	12.3	10.5
57.9	16.2	14.0
72.4	19.4	17.5

(c) Process the data in order to plot a graph of f vs B.

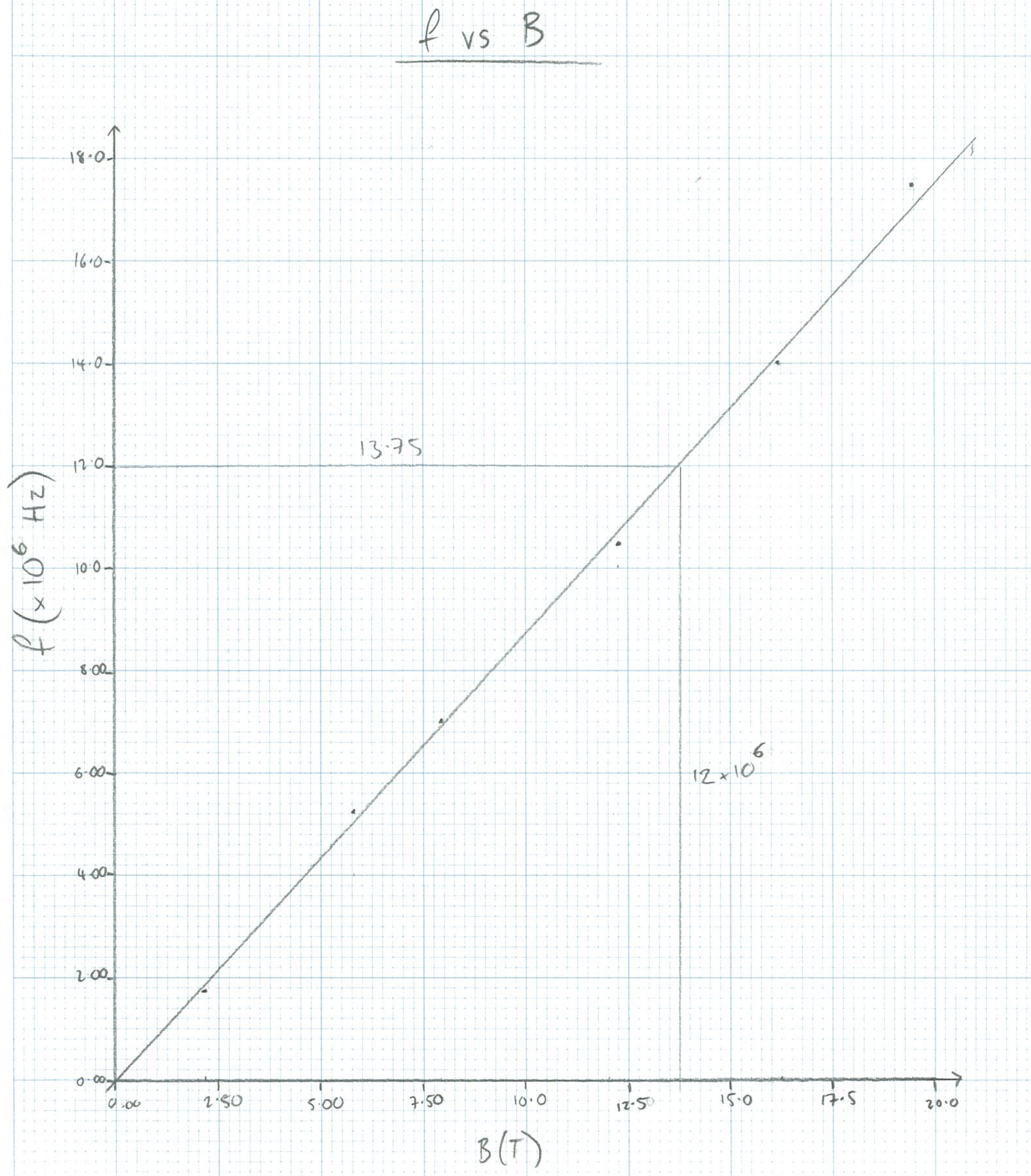
(5 marks)

Heading
Unit
3 Sig figs
2 x marks for values
-1 if not converted to J first

(d) Plot a graph of f vs B on the graph paper provided.

(5 marks)

Title
Axis labels, units & arrows
Linear scale
Points
Line of best fit



f vs B
f (× 10^6 Hz)
B (T)
18.0
16.0
14.0
12.0
10.0
8.00
6.00
4.00
2.00
0.00
0.00
2.50
5.00
7.50
10.0
12.50
15.0
17.5
20.0
13.75
12 × 10^6

(e) Determine the gradient of the graph.

(3 marks)

Triangle drawn on graph (1)

Gradient = (Rise / Run) = 12 x 10^6 / 13.75 = 8.73 x 10^5 HzT^{-1} (1) (1)

(f) Use your gradient to calculate the value of k for this nuclide. Include units in your answer.

(3 marks)

$$hf = kB_T$$

$$f = \frac{k}{h}B_T$$

gradient = k / h (1)

k = 8.73 x 10^5 x 6.63 x 10^{-34} = 5.79 x 10^{-28} J T^{-1} (1) (1)

- 1 for no units

Question 2 **(15 marks)**

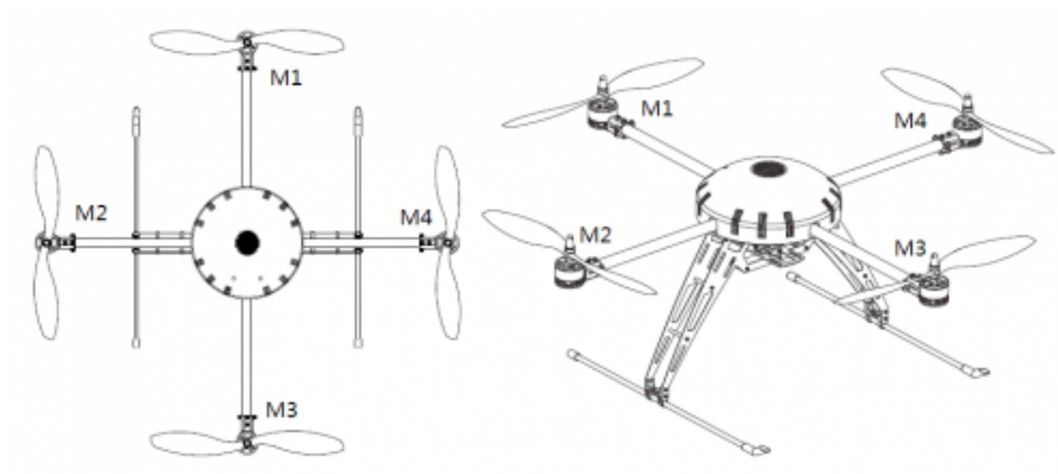
The Physics of Drones – The Quadcopter Revolution

Drones, or 'quadcopters' are popular devices that have some level of autonomy meaning they can fly, hover, or navigate without input from a pilot or remote control.

Drones need multiple horizontal rotors in order to achieve the level of control necessary for the unmanned aerial vehicle to be self-reliant. The rotors generate a lift force as they rotate, with a faster rotation generating more lift.

If one of the rotors fails, the aircraft can still stay aloft with the remaining rotors working together to compensate. In addition, the more rotors that you have, the more lift an aircraft will generate, allowing it to carry a heavier load, something that comes in handy when you're attaching a camera to a drone.

The diagram below shows the structure of a drone as viewed from above and from the side.



(a) Based on the information in the diagram, state how each rotor would have to change the speed of its rotation to maintain the same altitude if rotor M3 were to fail. Explain your answer.

(4 marks)

M1 – must slow down:

Otherwise a turning effect will be created around the centre of the drone as M3 no longer balances it.

M2 & M4 – speed up:

Must provide enough lift force to overcome weight of drone.

It takes a source of potential difference to get the rotors spinning. Drones typically come with a removable battery that provides around 12 minutes of flight time. Many drone makers sell alternative batteries, which can provide up to 25 minutes of flight. However, greater potential difference means more weight.

(b) Compare the rate of energy transfer for a heavier drone to a lighter one. Explain your reasoning.

(2 marks)

A heavier drone will transfer energy at a higher rate than a lighter one.

It has to do more work every second to maintain the same altitude.

(c) A battery salesperson states that “a battery which is twice as heavy will provide twice as much flight time”. Is the salesperson correct? Explain your answer.

(2 marks)

No, the salesperson is not correct.

The heavier battery will transfer energy at a greater rate so will run down faster than a lighter on.

Drones require a controller that needs to communicate with the drone. They often operate using radio waves. Drones are typically run by 2.40 GHz ultra high frequency radio waves.

(d) Concerns have been raised about the use of mobile phones (which operate using microwaves) whilst operating drones, based on their operating frequency. Suggest why this may be the case.

(2 marks)

- The operating frequency of mobile phones is in the same range as the drone controllers.
- This may cause interference.

When it comes to flying, onboard sensors keep drones in the air. For instance, an altimeter lets the drone know its altitude. When you set the aircraft to hover in place, a chip will tell the drone to maintain that height. Meanwhile, ultrasonic sensors tell the drone how close it is to the ground.

A drone is programmed to assume the speed of sound in air is 340 ms^{-1}. In a test flight, an ultrasound signal is sent from the drone and received back at the drone after a time interval of 2.15 s.

(e) Calculate the height the drone is above the ground.

(3 marks)

$s = vt$ (1)

$s = 340 \times 2.15 = 731$ m (1)

$731 / 2 = 366$ m (1)

(f) Explain why the calculated height is not likely to be accurate.

(2 marks)

- The speed of sound will not remain constant
- as the altitude increases, and air pressure drops.

OR

- The speed of sound will not remain constant
- as the air temperature changes.

END OF SECTION