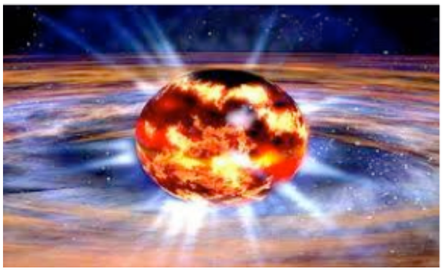
SECTION A (Short Answer – worth 60 marks or 30% of total for paper)

Answer all 14 questions in the spaces provided.

Question 1



A star larger than our Sun may collapse near the end of its life to form a super dense **neutron star** with a mass up to 3 times that of our Sun packed into a sphere with a diameter of only about 20 km.

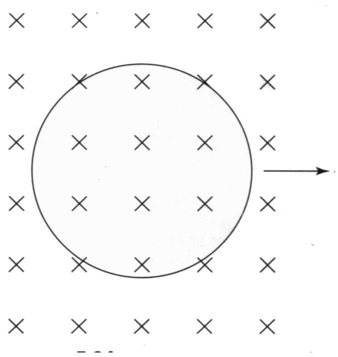
Estimate the gravitational field strength at the surface of such a neutron star.

(3 marks)

Question 2

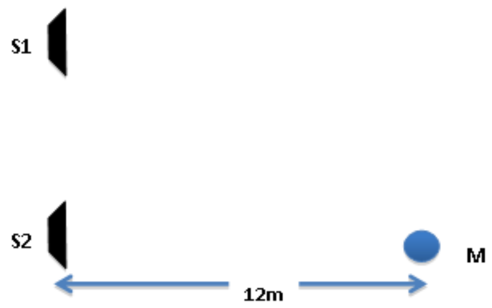
The coil of wire shown below is quickly withdrawn from the magnetic field. Which way does current flow around the coil as it is removed from the field? Briefly explain your answer.

(3 marks)



Question 3

Two loudspeakers (S1 and S2) are connected in phase to a frequency generator. A microphone M is placed 12 m directly in front of speaker S2. The frequency of the sound generated is varied so that the microphone detects a series of maximum and minimum intensity sounds. The lowest frequency at which a **minimum** intensity sound is detected at the microphone is 173 Hz.



(a) Explain how this minimum intensity sound is produced. **(2 marks)**

(b) Calculate the distance between the two speakers. **(3 marks)**

Question 4

A car is driving west along Hay St in the city at 60 km/hr. It has a vertical aerial of length 1.2 m. The magnetic field of the Earth in Perth has a strength of 54μT at an angle of 66° above the horizontal.

(a) The aerial is only cutting through a component of the Earth's magnetic field. Find the size and direction of this component.

(2 marks)

(b) Calculate the emf induced across the length of the aerial as the car drives west, and state whether the top of the aerial acquires a positive or negative charge.

(3 marks)

Question 5

An aircraft attempts to land along a north-south aligned landing strip. It approaches from the south and has an air speed of 133km hr^{-1}. The wind is blowing from the west at 45.0km hr^{-1}. Draw a vector diagram to show the direction the aircraft needs to head and calculate its actual velocity, in ms^{-1}, relative to the runway. **Show all workings**.

(5 marks)

Question 6

The images below show hydrogen spectra.

Image 1: Bright lines on a black background.

Image 2: Dark lines on a continuous spectrum.

For each, name the type of spectrum and how it is created. **(4 marks)**

Image 1 spectrum type: ____

Created: ____

____

____

Image 2 spectrum type: ____

Created: ____

____

____

Question 7

Shown below are three diagrams A, B and C representing fields. Use the diagrams to fill in the blanks in the following sentences. Any field diagram can be used more than once.

(5 marks)

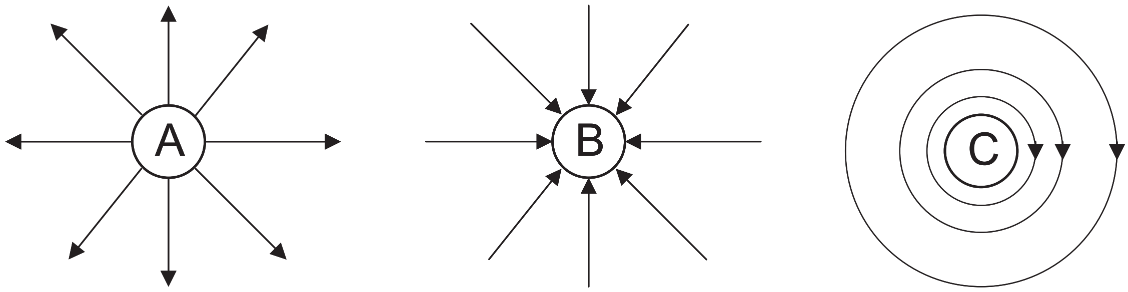


Diagram __________ could represent the gravitational field of a mass.

Diagram __________ could represent the electric field around a positively charged particle.

Diagram __________ could represent the electric field of a negatively charged particle.

Diagram __________ could represent the magnetic field around a current carrying

conductor that is directed ______________ the page.

Question 8

Briefly describe the relationship between the mass and energy of an accelerating object as it approaches, but cannot exceed, the speed of light in a vacuum, *c*.

(3 marks)

___

___

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___

___

___

___

Question 9

A battery recharger is used to charge up a car battery that has gone flat. The battery recharger transforms power from the 240 V domestic power supply down to 14 V to be applied across the terminals of the car battery; this lowered voltage pushes a current of 3.6 A through the car battery while it is recharging.

(a) Briefly describe how the transformer inside the battery recharger enables the 240 V input to be reduced down to the 14 V applied across the terminals of the car battery (a basic sketch of a transformer would be useful in your description).

(3 marks)

(b) Calculate the power and current drawn from the domestic power supply by the battery recharger while in operation (assume it is 100% efficient).

(2 marks)

Question 10

In 1865 James Clerk Maxwell established that light was an electromagnetic wave that propagated at 3×10^8 m/s through a vacuum. Scientists then proposed that there was an invisible, up to now undetected, electromagnetic "aether" that filled the vacuum of space and through which light travelled.

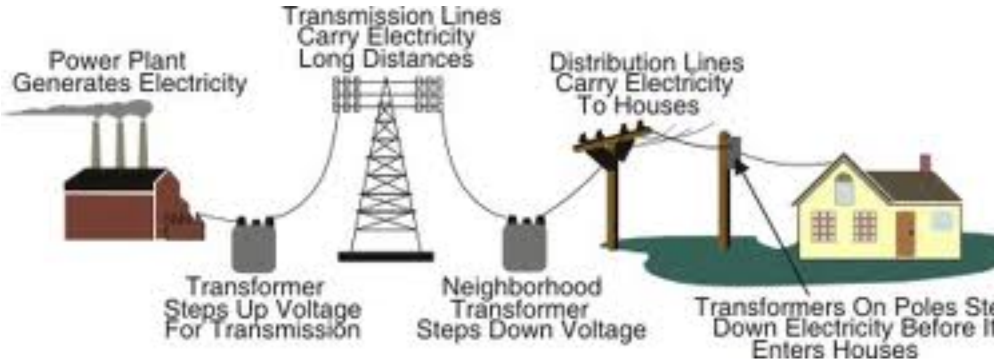
(a) Give two reasons why these scientists considered the existence of this "aether" to be essential. **(2 marks)**

(b) Albert Einstein proposed a radical way to deal with the problem of the speed of light through a vacuum. State the two essential features (postulates) that provided the foundation of his special theory of relativity.

(2 marks)

Question 11

An electrical power plant can generate a maximum power of 50.0 MW, which is stepped up to 67.0kV before transmission alonglines of length 25 km and total resistance 2.50 Ω. Calculate:



(a) the current in the transmission lines at maximum power.

(1 mark)

(b) the voltage input to the neighbourhood transformer at the end of the transmission lines (at maximum power).

(2 marks)

(c) the percentage power loss along the transmission lines (at maximum power).

(2 marks)

Question 12

A roller coaster carriage passes over the crest of a hill of radius 12.0 m at sufficient speed to make the passengers feel only half of their usual weight at the crest.

(a) On the photograph at right, draw labelled arrows to show the forces acting on a carriage of the roller coaster as it passes over the crest of the hill.

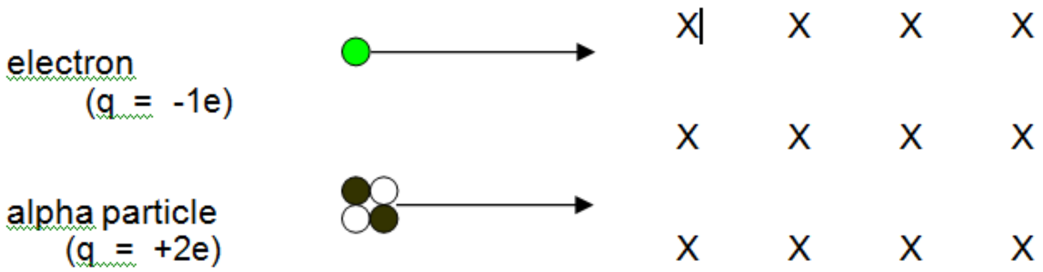
(2 marks)

(b) Calculate the speed of the carriage at the top of the crest given the passengers only experience half of their usual weight at that point.

(2 marks)

Question 13

An electron and an alpha particle moving with equal velocities both enter a region of magnetic field as shown below. (the mass of an alpha particle is 6.64 x 10 $^{-27}$ kg)



(a) Indicate the direction of the force on each particle as it passes through the field.
(1 mark)

(b) Which of these particles will experience the greatest force and why?
(2 marks)

(c) Which of these particles will experience the greatest acceleration and why?
(2 marks)

Question 14

One of the largest moons in the solar system, Titan, orbits the planet Saturn. Titan has a mass of 1.35 x 10^{23} kg and a diameter of 5150 km (about 1.5 times larger than Earth's Moon), and orbits Saturn at an average orbital radius of 1.22 million km with an orbital period of 15.95 days. Use this information to calculate the mass of Saturn.

(4 marks)

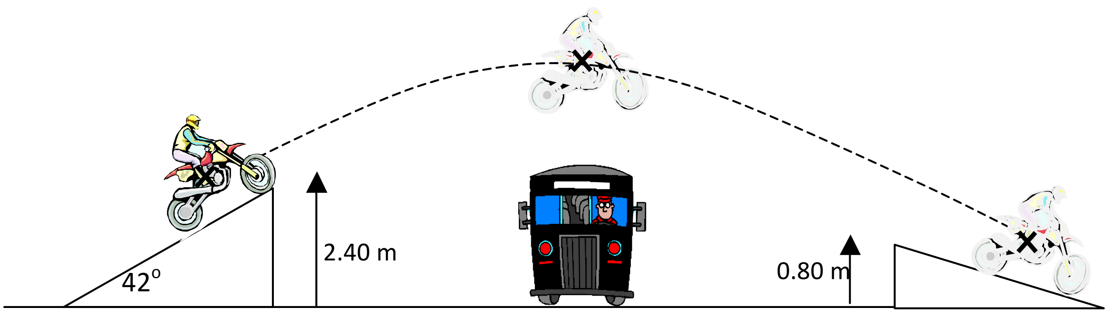
End of Section One

SECTION TWO **(Extended Answer – worth 100 marks or 50% of total for paper)**

This section has **eight (8) questions**. You must **answer all questions**. Write your answers in the spaces provided.

Question 15

Bec likes to jump over buses on her trail bike. In an exhibition one day she drives her motorcycle up a ramp, over a bus and lands safely on the ramp at the other side. The left hand ramp has an incline of 42° and when she takes off the centre of gravity of her and her machine is 2.4 m above the ground. Her speed at this point is 45 km h^{-1}.



a) How fast is the height of her machine above the ground increasing in a vertical direction when she takes off?

(2 marks)

b) What is the maximum height reached by Bec and her bike (centre of gravity) above the ground?

(3 marks)

The motorcyclist and her machine lands on another ramp at the other side of the bus, at which point the centre of mass of the combination is 0.80 m above the ground.

c) What is the vertical speed of the motorcycle when Bec lands?

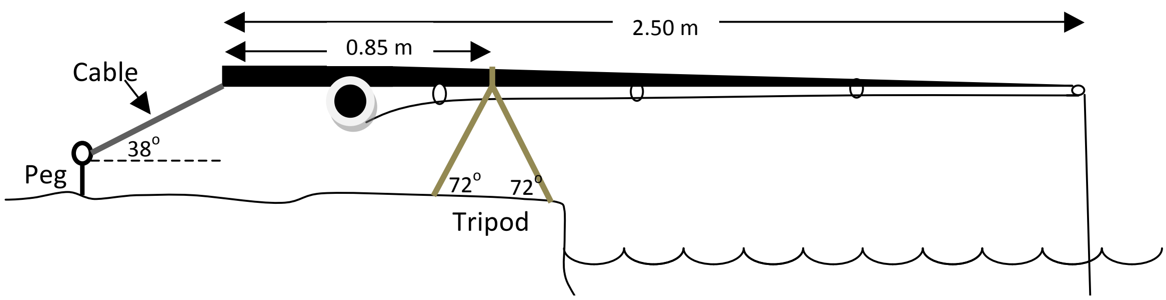
(3 marks)

d) Calculate how far away horizontally the motorcycle is from its take-off position when it lands.

(4 marks)

Question 16

Genevieve decides to go fishing one day with her new rod and tripod. She sits on the banks of the Swan River and sets up the 900 gram rod with the tripod close to the bank and a cable at the left hand end anchored into the ground with a tent peg. The centre of mass of the rod is 1.00 m from the left hand end of the rod. She has not caught a fish yet!



a) Draw in and name all the forces acting on the rod, using arrows to indicate direction.

(2 marks)

b) Explain why Genevieve needs to secure the end of the rod with a peg and a cable.

(2 marks)

c) Genevieve eventually manages to hook a 1.50 kg fish on the end of her line. Calculate the **vertical** force that the cable has to exert to keep the rod in a horizontal position.

(3 marks)

d) If the cable makes an angle of 38° to the ground, calculate the total force of tension needed in the cable when the fish is caught.

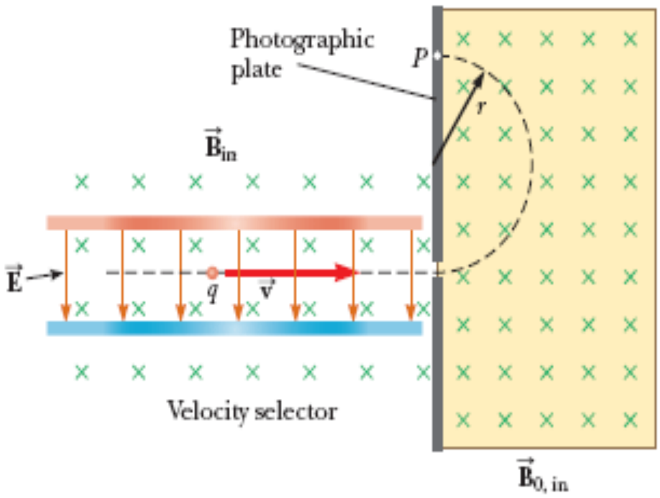
(2 marks)

e) If the legs of the tripod make an angle of 72° to the ground, calculate the compressive force in each leg of the tripod when the fish is on the end of the line.

(4 marks)

Question 17

In a mass spectrometer the radius of curvature of an ion's path in the magnetic field can be used to determine the mass of the ion. In the diagram at right, ions travel through a velocity selector before passing through a slit and entering the main chamber of the machine, where they move in a semi-circular path until they hit the photographic plate at point P.



Sodium ions of charge +1e and with a speed of 8.5×10^4 m/s are selected to enter the main chamber where the magnetic field is of strength 0.075 T. They are measured to move in semi-circular paths of radius 28.4 cm.

a) By considering the directions of the magnetic and electric fields in the velocity selector, as shown above, explain how the velocity selector allows sodium ions of a particular speed only to travel un-deflected and pass through the slit into the main chamber.

(3 marks)

b) The radius (r) of the semi-circular path of the ions in the magnetic field of the main chamber is given by the formula

$$r = \frac{m\,v}{q\,B}$$

where m is the mass of an ion, v is their speed, q is their charge and B is the strength of the magnetic field. Derive this formula using formulas from the Formula Sheet.

(3 marks)

c) Use the formula derived above to calculate the mass of a sodium ion.

(2 marks)

d) Find the mass number of these sodium ions (use the mass of a proton from the Formula Sheet for the mass of a nucleon).

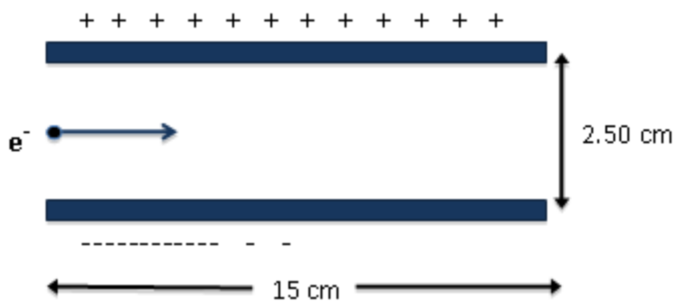
(1 mark)

e) Calcium ions of mass number 40 and charge +2e are now used in the mass spectrometer with all other settings unchanged. Find the radius of the semi-circular path of these calcium ions.

(2 marks)

Question 18

An electron enters the gap between two oppositely charged parallel plates while moving horizontally and parallel to the plates at a speed of 1.2×10^8 m/s, as shown in the diagram at right. The gap between the plates is 2.50 cm wide and 15.0 cm long, and the potential difference between the plates is 2400 V.



a) Find the strength and direction of the electric field in the region between the charged parallel plates.

(2 marks)

b) Calculate the magnitude of the electric force acting on the electron as it moves between the plates, and the size and direction of its resulting acceleration.

(3 marks)

c) Why could we ignore the weight of the electron in determining the net force acting on it and hence its acceleration?

(2 marks)

d) Calculate the time it takes for the electron to move through the gap between the parallel plates.

(2 marks)

e) Determine the vertical displacement of the electron as it moves through the gap between the parallel plates. (use an acceleration of 1.50 x 10^{15} m/s^2 if no answer from part (b))

(2 marks)

f) Find the final velocity (magnitude and direction) of the electron as it exits the gap between the parallel plates.

(3 marks)

Question 19

A domestic microwave oven is rated at 500 W and uses a frequency of 2500 MHz.

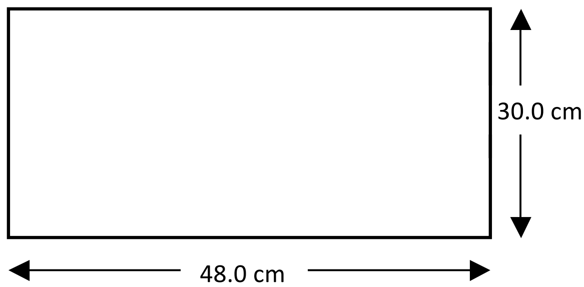
a) How many photons would be produced in the 50 seconds it takes to heat a mug of coffee in the microwave oven?

(3 marks)

The microwaves emitted inside a microwave oven can form standing waves as they are reflected off the metal walls. The distance between the left and right hand walls of the microwave is 48.0 cm and the distance from the top to the bottom is 30.0 cm.

b) Calculate the wavelength of the microwaves and use the results to draw shapes on the diagram below to illustrate the standing wave existing inside the oven.

(2 marks)

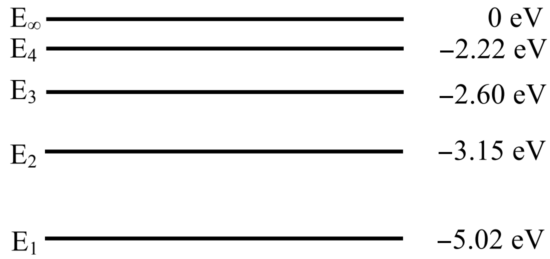


When a solution of calcium chloride is sprayed onto a Bunsen burner flame, a red colour is produced (due to the calcium atoms). With a solution of copper chloride a green colour is produced (due to the copper atoms).

c) Explain why calcium and copper produce different coloured flames. Include an energy diagram.

(3 marks)

The diagram shows the energy levels for an element X. E_1 is the lowest energy state that an electron in this element can have.



d) Explain why gaseous elements in a flame only give out a series of coloured lines in their spectrum and not a complete spread of colours of the rainbow.

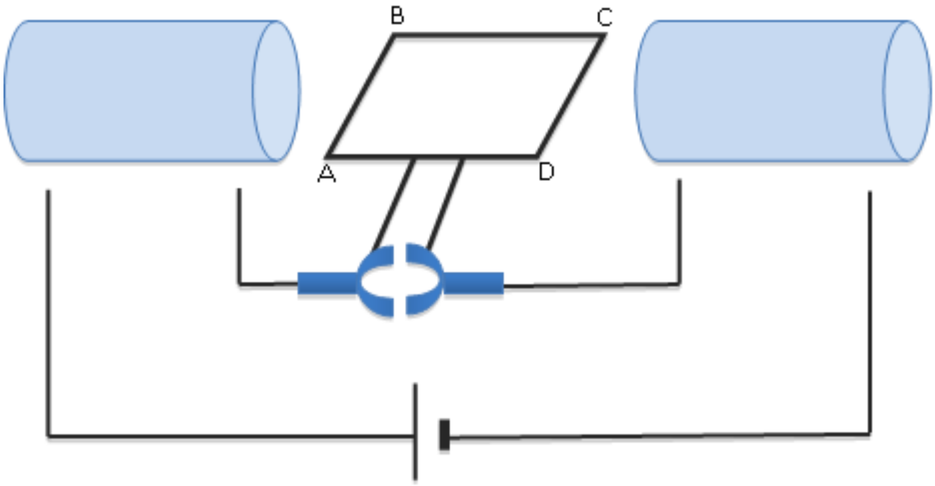
(3 marks)

e) Calculate the wavelength of the spectral line produced when a transition occurs between energy levels E_3 and E_2.

(4 marks)

Question 20

A DC motor is designed with electromagnets either side of a square (5cm x 5cm) loop ABCD containing 150 turns of copper wire. The electromagnets are wired in series with the coil so that the current from the battery goes through the left electromagnet, through the coil, through the right electromagnet and then back to the battery.



a) Draw the wiring around the electromagnets so that the left electromagnet has a north end facing the coil and the right electromagnet has a south end facing the coil.

(2 marks)

b) Use arrows in the diagram above to show the direction of the magnetic forces acting on the sides of the coil.

(1 mark)

c) Complete the table below by circling the correct option for the directions of the current and the magnetic force on **side AB** of the coil when it has rotated from the position shown above by the amount indicated in the first column.

(2 marks)

Amount of rotation (degrees)	Current Direction	Magnetic Force Direction
90°	A to B B to A None	Up Down None
180°	A to B B to A None	Up Down None

d) When the motor is first turned on, it draws a current of 30 A from the battery and produces 3.6 Nm of torque. Determine the strength of the magnetic field in the region between the two electromagnets.

(2 marks)

e) Explain why the current drawn from the battery is initially very large, when the motor is first turned on, but decreases steadily as the motor builds up rotational speed.

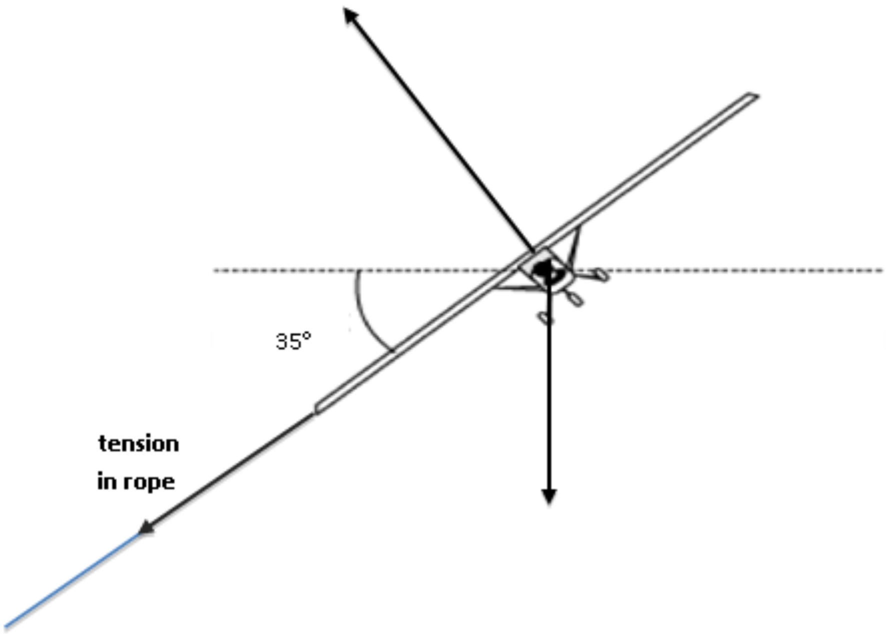
(3 marks)

f) This design of motor will also work with an AC input. Briefly explain why.

(2 marks)

Question 21

The diagram below shows a cross-section view of a model aeroplane as it flies in a horizontal circle at the end of a light rope. The wings of the aeroplane are banked at an angle of 35°to the horizontal.



a) On the cross-section view above, label the two other important forces that are shown acting on the model aeroplane as it flies around in a horizontal circle.

(2 marks)

b) Given that the tension in the rope is 16 N and the force perpendicular to the wings of the aeroplane is 28 N, calculate the size of the centripetal force acting on the aeroplane.

(3 marks)

c) Determine the mass of the model aeroplane.

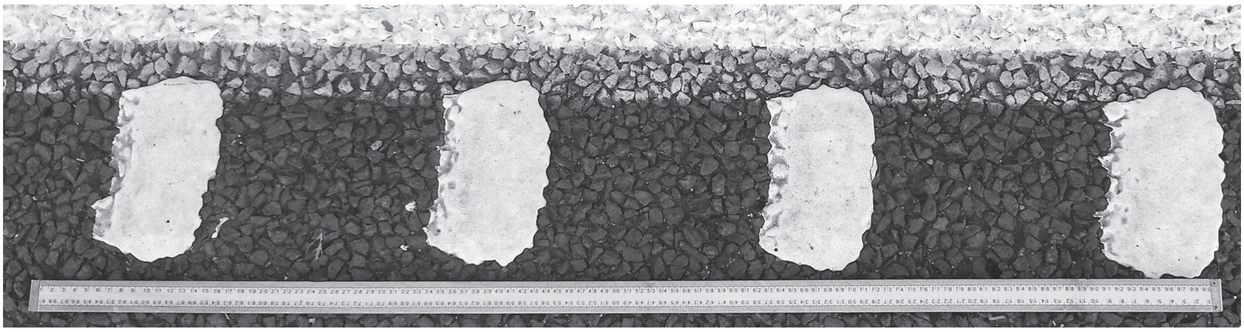
(3 marks)

d) What is the speed of the aeroplane given it flies in a circle with a radius of 12 m?

(2 marks)

Question 22

Along the sides of some roads are rumble strips made of raised painted markers that are intended to get a driver's attention if a car strays across them. One part of the strip is photographed below. A metre ruler has been included to give an idea of scale.



a) Estimate the frequency of vibration if a car is travelling at 95 km h^{-1}. Use appropriate significant figures and unit for the value. Show **all assumptions and working.**

(5 marks)

b) An old car slows down to stop on the side of the road. As it crosses the rumble strip, the frequency of sound decreases along with the speed and the vibrations cause the dashboard to rattle. The intensity of the vibration of the dashboard varies and becomes very loud at one particular frequency. Explain this phenomenon, using appropriate physics terminology and concepts. **(4 marks)**

c) In another car, a test frequency with a constant frequency and amplitude is being played on the radio. This test signal matches closely the frequency produced when driving over the rumble strip at constant speed. Despite both sounds maintaining a constant frequency and amplitude, fluctuation in amplitude can be heard by the car's occupants, for whom the sounds grow louder and quieter. Explain this phenomenon, using appropriate physics terminology and concepts. **(4 marks)**

End of Section Two

SECTION THREE **(Comprehension and Data Analysis – worth 40 marks or 20% of total for paper)**

This section has **TWO** questions. Answer **all parts of both questions**. Write your answers in the spaces provided.

Question 23 **THE COMPTON EFFECT**

Paragraph 1

The Compton Effect is one of the more remarkable discoveries in modern physics. Young had shown that light could diffracted, which convinced everyone that this was the end of the controversy about whether light was a wave or consisted of particles, as contended by Newton. In this context, the Compton Effect was quite unexpected, and it made it necessary to revise the theories of electromagnetic radiation.

Paragraph 2

It was well known that particles such as electrons have a momentum given by p = mv. In the development of his theory of relativity, Albert Einstein found it necessary to assign photons a momentum given by p = h/λ, where h is Planck's constant and λ is the wavelength of the photon. This is something that Young had never anticipated. Experiments confirmed that this relationship is true.

Paragraph 3

One of the applications of this property is in the phenomenon of Compton scattering. In this process, a photon collides with a stationary electron, after which the electron and the photon fly off in different directions. One of the laws of physics is that momentum has to be conserved. When you consider the momentum in the x and y directions, there are limitations on the final directions the scattered electron and photon can go. In addition, the total energy of the electron and the photon has to be the same before and after the collision.

Putting this all together, it comes out that:

$$\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_0 c}(1 - \cos\theta)$$

λ_i = wavelength of the incident photon

λ_f = wavelength of the scattered photon

h = Planck's constant

m_0 = mass of the electron

c = velocity of light

θ = the angle at the photon is scattered

The equation shows that the photon loses energy in the scattering process, and that the larger the angle of scatter, the larger the energy lost.

Paragraph 4

This discovery that photons have momentum has some rather interesting consequences. One is that photons reflected from a surface create a force on the surface. One of the more imaginative proposals that has been made is to construct giant solar sailboats with huge sails, that could be used to assist travel in the solar system. There are some technical difficulties, but one of the great advantages of such a sailboat is that the Sun provides the driving force and no fuel is necessary.

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a) Does Compton scattering demonstrate the wave nature or the particle nature of radiation? Justify your answer.

(2 marks)

b) Which will have the smaller momentum, a gamma ray or an ultraviolet photon? State your reason.

(3 marks)

c) Calculate the momentum of a photon with energy of 105 keV.

(3 marks)

d) Through what angle must a photon be scattered in order for it to have the lowest possible amount of energy after it is scattered? Justify your answer.

(3 marks)

e) A photon with an energy of 1.76 x 10^{-14} J is scattered at an angle of 60^{o}. What is the energy of the scattered electron? [**Hint: use the relationship given in paragraph 3 of the passage**].

(5 marks)

f) Explain why reflection of photons from a surface should exert a force on the surface (paragraph 4). Show using a diagram the direction of the force on the sail of a solar sailboat.

(4 marks)

Question 24 **WHAT IS THE UNIVERSE MADE OF?**

Adapted from: Science News, 23/04/2011, Vol. 179 Issue 9, p24-25 by Alexandra Witze

Read the article and then answer the questions that follow.

In ancient times, listing the ingredients of the universe was simple: earth, air, fire and water. Today, scientists know that naming all of that, plus everything else familiar in everyday life, leaves out 95 percent of the cosmos's contents'.

From the atoms that make up an astronomer, to the glass and steel of a telescope, to the hot plasma of the stars above -- all ordinary stuff accounts for less than 5 percent of the mass and energy in the universe. "All the visible world that we see around us is just the tip of the iceberg," says Joshua Frieman, an astrophysicist at the University of Chicago and the Fermi National Accelerator Laboratory in Batavia, Ill.

The rest is, quite literally, dark. Nearly one-quarter of the universe's composition is as-yet-unidentified material called dark matter. The remaining 70 percent or so is a mysterious entity known as *dark energy* that pervades all of space, pushing it apart at an ever-faster rate.

A different matter

Dark matter made its debut in 1933, when Swiss astronomer Fritz Zwicky measured the velocities of galaxies in a group known as the Coma cluster and found them moving at different rates than expected. Some unseen and large amount of "dunkle Materie," he proposed in German, must exist, exerting its gravitational effects on the galaxies within the cluster.

Astronomer Vera Rubin confirmed dark matter's existence in the 1970s, after she and colleagues had measured the speeds of stars rotating around the centres of dozens of galaxies. She found that, counter intuitively, stars on the galaxies' outer fringes moved just as rapidly as those closer in - as if Pluto orbited the sun as quickly as Mercury. Rubin's work demonstrated that each galaxy must be embedded in some much larger gravitational scaffold.

The leading candidate for a dark matter particle is the vaguely named "weakly interacting massive particle," or WIMP. Such particles would be "weakly interacting" because they rarely affect ordinary matter, and "massive" because they must exceed the mass of most known particles, possibly weighing in at as much as 1,000 times the mass of the proton. But nobody has yet definitively detected a WIMP, despite decades of experiments designed to spot one.

Mysterious forces

Spotting dark matter may prove to be easier than understanding dark energy, whose mysteries make scientists feel like mental wimps.

Albert Einstein unknowingly ushered dark energy onto the stage in 1917, while modifying his new equations of general relativity. Einstein wondered why gravity didn't make the universe contract in on itself, like a balloon with the air sucked out of it. In 1929, though, Edwin Hubble solved Einstein's problem by reporting that distant galaxies were flying away from each other. The universe, Hubble showed, was expanding. It had been zooming outward ever since the Big Bang gave birth to it. Something funny was going on, giving the cosmos a repulsive push. So in 1998 Michael Turner, a cosmologist at the University of Chicago, dubbed the thing "funny energy" at first, before settling on "dark energy."

a) According to the article, all matter that we can observe makes up only 5% of the content of the Universe. What constitutes the other 95%? **(2 marks)**

b) What observations did Fritz Zwicky make for him to theorise about the presence of “dunkle Materie” (translates to “Dark Matter” in English)? **(3 marks)**

c) How did Vera Rubin confirm the existence of dark matter in 1970? **(4 marks)**

d) Astronomers have theorized the existence of WIMPS (weakly interacting massive particles). Why do astronomers believe the particles must be massive? **(3 marks)**

e) In 1917, Einstein pondered the fact that the Universe doesn't contract in on itself. Why do you think Einstein would have expected the Universe to contract? **(2 marks)**

f) Why is the concept of "Dark Energy" necessary for our current understanding of astronomy? **(2 marks)**

g) Our galaxy, the Milky Way contains approximately 300 billion stars. Assuming that our solar system is 26,000 light years from the centre of the galaxy, **estimate** the amount of mass that would need to be present at the centre of the galaxy (excluding the possibility of dark matter) for our sun to orbit the centre of the galaxy once every 225 million years. **(4 marks)**

END OF QUESTIONS

END OF EXAMINATION