Government of **Western Australia**
Curriculum Council

Western Australian Certificate of Education
Sample Examination, 2010

Question/Answer Booklet

PHYSICS
Stage 3

Please place your student identification label in this box

Student Number: In figures

In words

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

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer Booklet
Formulae and Constants Sheet

To be provided by the candidate
Standard items: pens, pencils, eraser, correction fluid, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set by the Curriculum Council for this course

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 response	13	13	50	54	30
Section Two: Problem-solving	7	7	90	90	50
Section Three: Comprehension	2	2	40	36	20
					100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2010.* Sitting this examination implies that you agree to abide by these rules.

2. Write answers in this Question/Answer Booklet.

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

4. Working or reasoning should be clearly shown when calculating or estimating answers.

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 at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Section One: Short response **30% (54 Marks)**

This section has **13** questions. Answer **all** questions. Write your answers in the space provided.

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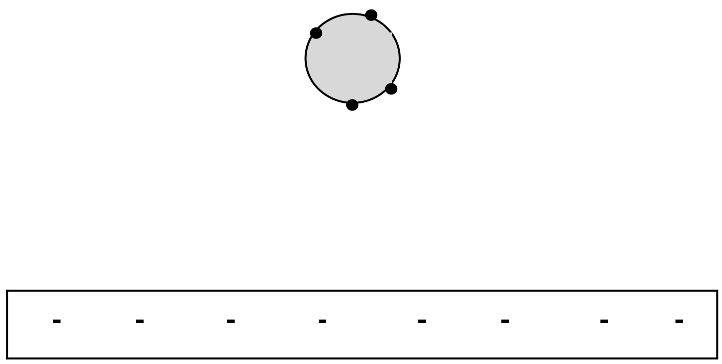
Suggested working time for this section is 50 minutes.

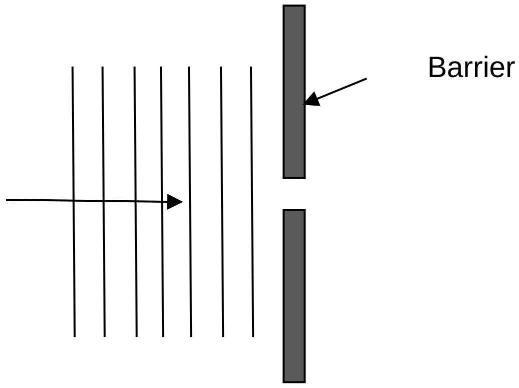
Question 1 **(3 marks)**

A positively charged metal sphere is located above a negatively charged conducting plate as shown in the diagram. Sketch the electric field lines between the charged sphere and the plate, using the four dots on the sphere as starting points.



Question 2 **(3 marks)**

The following diagram shows wavefronts approaching a gap in a barrier.



(a) Complete the diagram showing the wavefronts after they pass through the gap.
(2 marks)

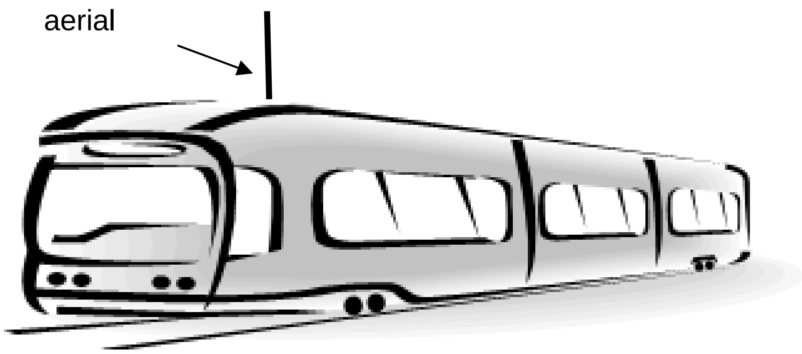
(b) Identify the type of wave shown in the diagram above by circling the correct answer.
(1 mark)

(i) sound waves (ii) light waves (iii) could be either sound or light

Question 3 **(4 marks)**

A student is investigating the emf induced along a metal rod moving in the Earth's magnetic field. The 3.00 m long rod is clamped, vertically upright, to the top of a train and is electrically insulated from the train. The train is moving at 72.0 km h^{-1} west in a region where the Earth's magnetic field is horizontal and has magnitude 5.00×10^{-5} T.

(a) Calculate the value of the induced emf, showing your working. (3 marks)



(b) Which part of the aerial will develop a positive charge? Circle the correct answer. (1 mark)

(i) top (ii) bottom (iii) there is not enough information supplied

Question 4 **(3 marks)**

The resolving power of any telescope defines whether an observer can clearly see two distant stars as two separate images. An angle of 10^{-5} radians between two clear images is considered to be the minimum acceptable. This angle is denoted by Φ in the equation

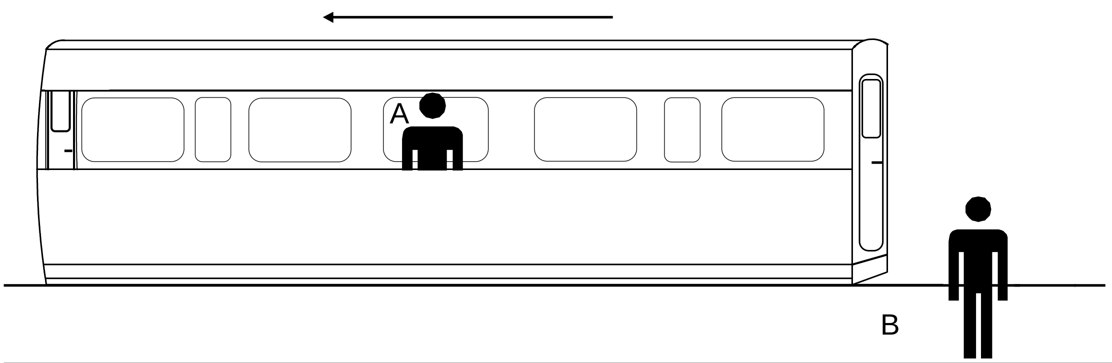
$$\Phi = \frac{\lambda}{D}$$

where λ is the wavelength of the radiation received and
D is the diameter of the receiving dish or antenna

An optical telescope with a 10 m diameter dish can collect useful information in the optical range of wavelengths. The proposed Square Kilometre Array radio wave telescope, intended to detect electromagnetic radiation at a wavelength of 21 cm, needs to cover an area of hundreds of square kilometres. Explain this difference.

Question 5 **(5 marks)**

Train moving at very high velocity



An observer at position A at the midpoint of a train carriage (a moving frame of reference), sends light signals to the front and back of the carriage at the same time. These light beams open doors at each end of the carriage. Another observer at position B is stationary on the platform, watching the train moving away from him at high velocity.

(a) Does observer A see the doors in the carriage open simultaneously, or at different times? (1 mark)

(b) Does observer B see the doors in the carriage open simultaneously, or at different times? (2 marks)

(c) If the observations are different, whose observation is correct? Explain your reasoning. (2 marks)

Question 6 **(4 marks)**

The force that holds the protons and neutrons together in the nucleus is known as the strong nuclear force. This force only acts on particles known as hadrons of which protons and neutrons are members. Hadrons are thought to be made up of quarks having non integer charges. All hadrons are made of three quarks.

These quarks have different charges. The up quark has a charge of $+\frac{2}{3}e$ while the down quark has a charge of $-\frac{1}{3}e$. 'e' is the charge on an electron.

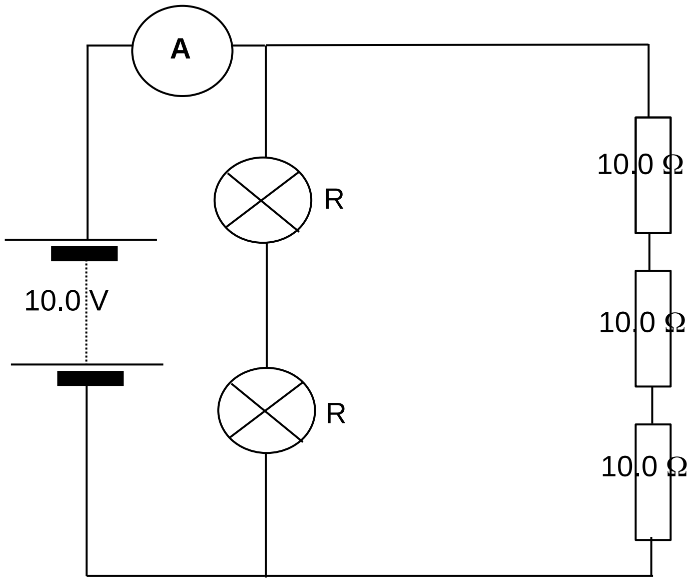
(a) List the quarks in a proton and justify your answer. (2 marks)

(b) List the quarks in a neutron and justify your answer. (2 marks)

Question 7 **(4 marks)**

In the circuit shown below the lamps are identical to each other. The ammeter reads 1.33 A.

Calculate the resistance of one lamp.



Question 8 **(4 marks)**

While on holiday in the United States, Max purchased a hair dryer marked

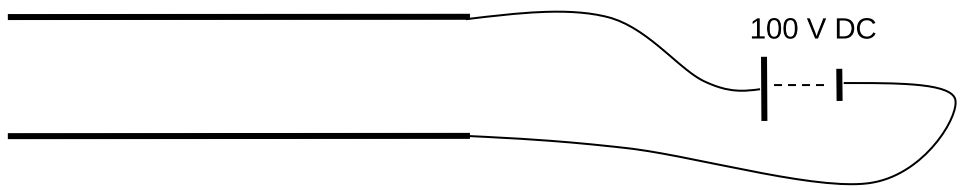
120 V, 1200 W.

(a) If Max wants to use the hair dryer in Australia where the electricity is supplied at 240 V, what power will it draw from the mains? Assume the resistance of the heater coil is constant. (3 marks)

(b) Suggest how the hair dryer in (a) could safely operate at its specified power in Australia. (1 mark)

Question 9 **(4 marks)**

A cathode ray oscilloscope contains two parallel plates, AB and CD, with a high voltage (potential difference) across them as shown below.



(a) Draw the electric field pattern between the plates AB and CD. (2 marks)

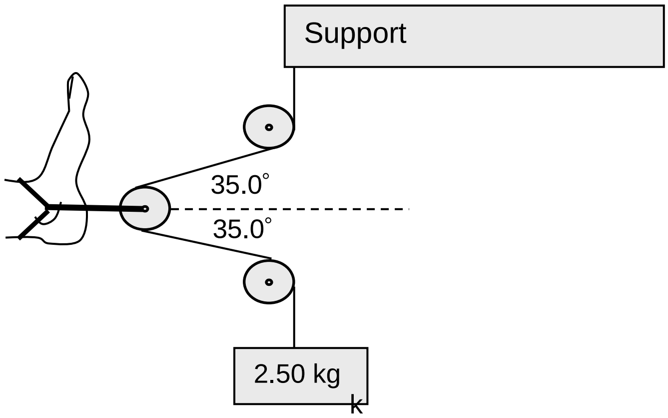
(b) Calculate the electric field intensity if the battery has a voltage of 100 V DC and the plate separation is 2.00 cm. (2 marks)

Question 10 **(4 marks)**

A compact disc spins at 4000 revolutions per minute, and has a radius of 6.00×10^{-2} m. A dust particle of mass 1.00×10^{-4} kg rests on the outer edge of the disc. Calculate the magnitude of the frictional force required to prevent the dust particle from flying off the spinning disc.

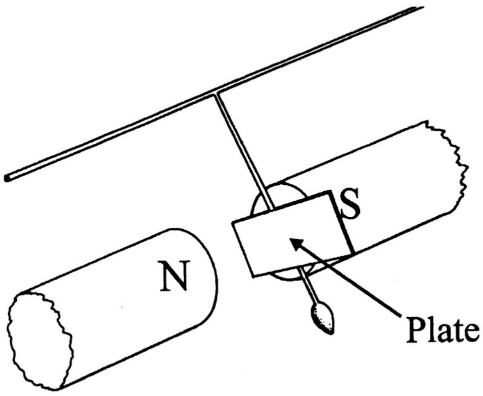
Question 11 **(4 marks)**

A traction device uses three pulleys to apply a horizontal force to a patient's foot as shown in the figure below. A single string goes around the three fixed pulleys. One end of the string is tied to a 2.50 kg load and the other end is tied to a rigid support. The middle pulley is attached to the patient's ankle and pulls it as shown. Calculate the magnitude of the force exerted on the patient's ankle. Assume that the pulleys are frictionless.



Question 12 **(3 marks)**

An oscillating pendulum has an aluminium plate attached to it that passes between opposite magnetic poles as shown.



(a) Describe what would happen to the aluminium plate as it swings between the poles. (2 marks)

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(b) How would your observations change if the aluminium plate is replaced with an identically-shaped iron plate? (1 mark)

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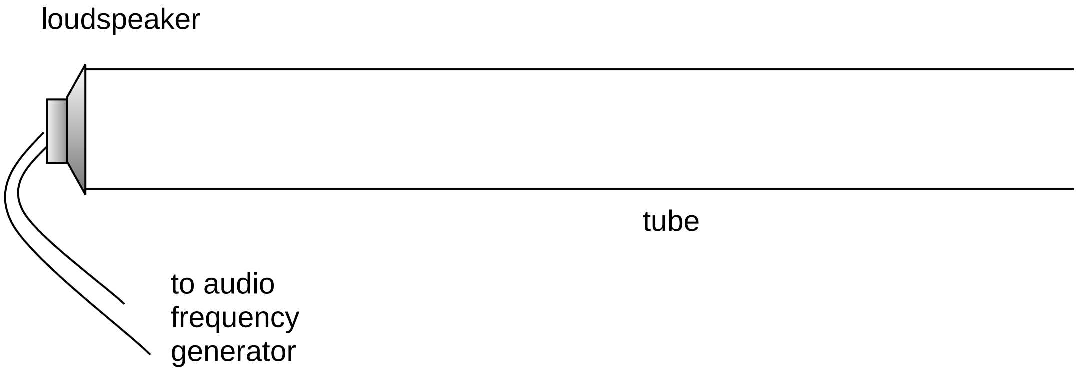
Question 13 **(8 marks)**

A metal tube, open at both ends, has a small loudspeaker fitted over one end. The speaker is connected to an audio frequency generator. The note produced by the speaker is altered slowly until resonance is detected.



(a) Does the vibrating speaker cone act as a displacement node, or a displacement antinode? (1 mark)

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(b) Using the axes above, draw a displacement versus distance graph for the standing wave produced at the fundamental frequency. (2 marks)

(c) How would resonance be detected in this case? (1 mark)

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(d) If the fundamental resonant frequency is 173 Hz and the speed of sound in the tube is 346 m s^{-1}, calculate the length of the tube. (2 marks)

(e) How would the resonant frequency change if you used a longer tube? Explain. (2 marks)

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.

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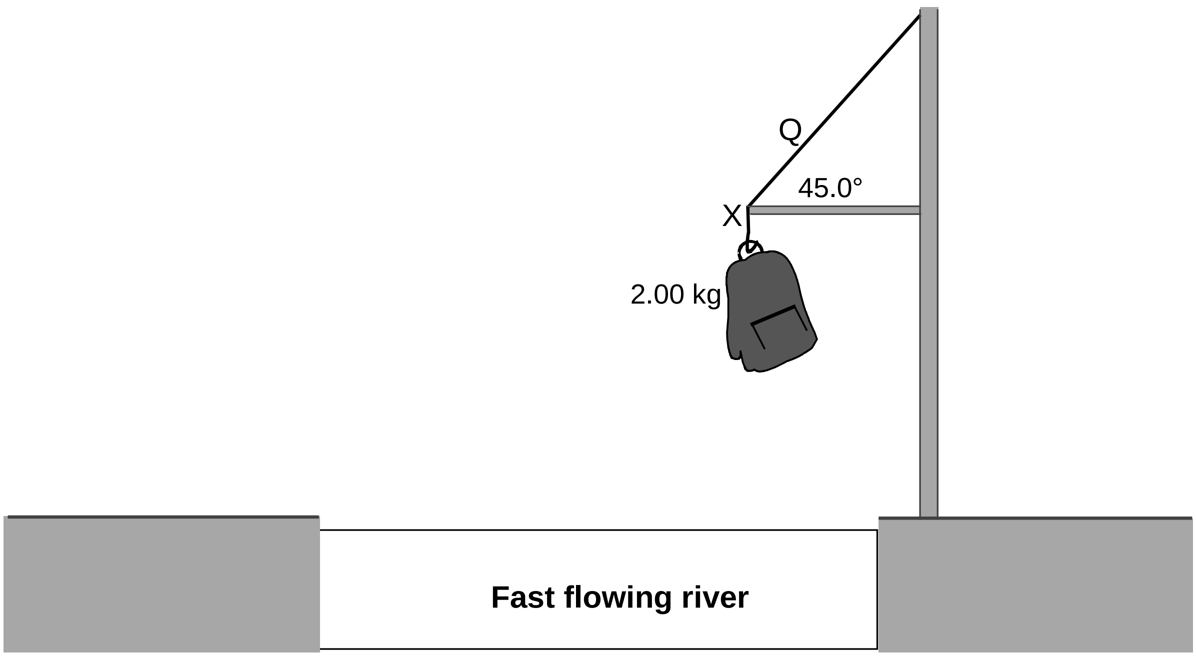
Suggested working time for this section is 90 minutes.

Question 14 (13 marks)

A survival course requires trainees to retrieve a ration pack of mass 2.00 kg suspended from a rope above a fast flowing river, as shown in the diagram below.

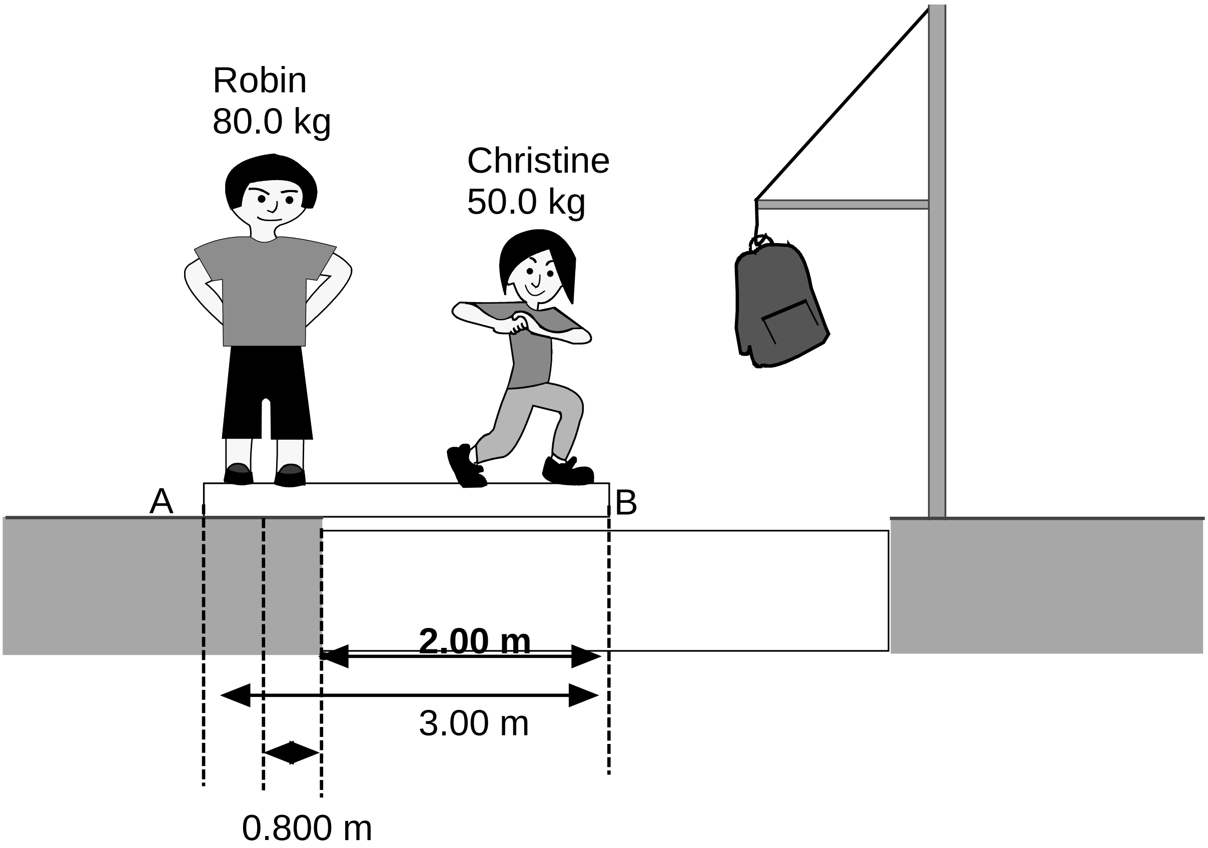


(a) Determine the net force acting on the suspended pack. (1 mark)

(b) On the diagram, draw vectors to represent the forces acting at point X. Ignore any frictional forces that might act at X. (3 marks)

(c) Calculate the tension in the rope at the point marked Q. (3 marks)

(d) Robin, a trainee whose mass is 80.0 kg, is unable to reach the hanging mass. Robin suggests to a friend, Christine, that they could use a 3.00 m long uniform plank of mass 12.0 kg as shown below.

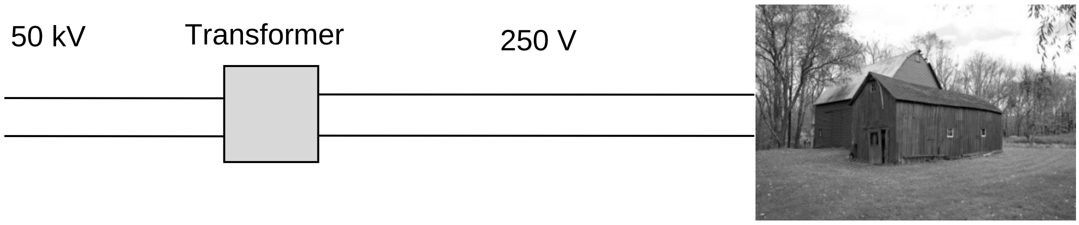


Robin stands so that his centre of mass is 0.200 m from end A of the plank. With Robin holding down one end, the plank extends over the river bank by 2.00 m. Christine, of mass 50.0 kg, walks out along the plank toward end B.

Calculate how far Christine can safely walk along the plank. (6 marks)

Question 15 **(12 marks)**

A farmhouse is supplied electricity from a transformer 3.00 km away. The input voltage of the transformer is 50.0 kV and the output voltage of the transformer is 250 V. When an electric heater is used inside the farmhouse the measured voltage across the heater is 220 V. The resistance of the heater is 40.0 Ω.



(a) Calculate the turns ratio of the transformer. (1 mark)

(b) Calculate the current to the heater. (2 marks)

(c) Calculate the power of the heater. (2 marks)

(d) Calculate the resistance of the cables supplying electricity to the farmhouse. (2 marks)

(e) Calculate the amount of energy dissipated as heat in the cables every second.
(3 marks)

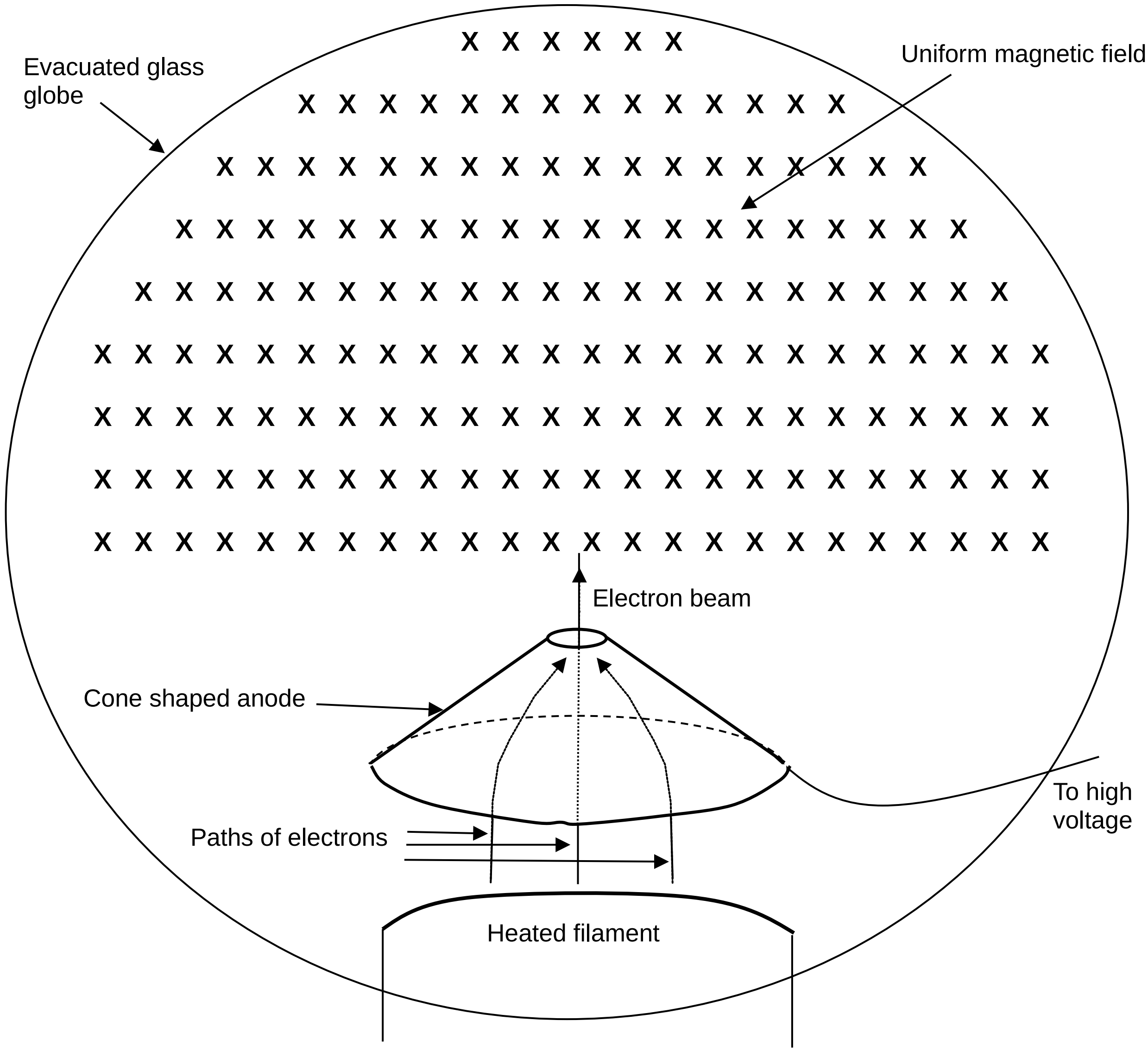
(f) A petrol station is further away from the transformer than the farmhouse. Compare the voltage available at the petrol station to the voltage available at the farmhouse. Explain your reasoning. (2 marks)

Question 16 **(15 marks)**

The diagram below shows a glass globe containing a heated filament that emits electrons by thermionic emission. Initially, the space inside globe is a vacuum. The electrons are attracted to, and then pass through, a hollow conical anode. This forms a narrow beam of electrons.

The electron beam then enters a region of uniform magnetic field. The magnitude of this field can be changed.

This device can be used for a range of experiments.



(a) Is the anode positively or negatively charged? Explain your answer. (2 marks)

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(b) Show clearly on the diagram the trajectory of the electron beam whilst in the uniform magnetic field. (2 marks)

(c) Using the equation $F = Bqv$ and an equation for circular motion, show that $r = \dfrac{mv}{Bq}$.
Show your working. (3 marks)

(d) One experiment using this apparatus gives the following experimental measurements:
electron speed = 2.00×10^{7} m s^{-1}
magnetic field strength = 1.20×10^{-3} T
radius of electron path = 10.0 cm.

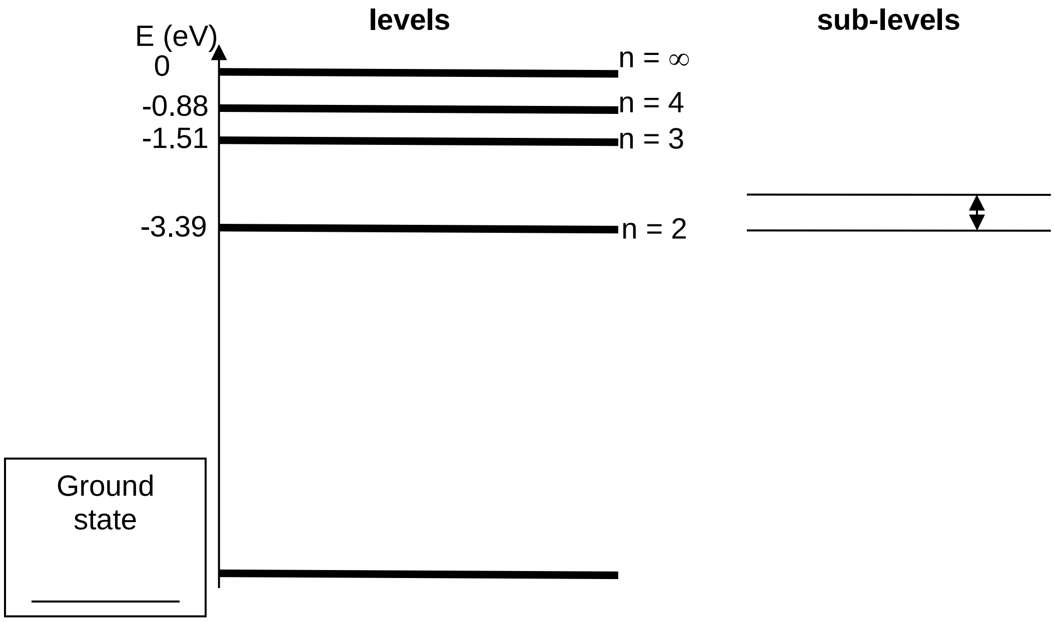
Use these values to calculate the charge to mass ratio $\dfrac{e}{m}$ for an electron. (4 marks)

(e) If the glass bulb is filled with neon gas, a glowing pink ring appears within the globe when the electron beam is turned on. Explain why this glowing ring appears. (3 marks)

(f) Suggest how could the colour of the glowing ring could be changed. (1 mark)

Question 17 **(14 marks)**

The diagram below shows some of the possible electron energy levels in a hydrogen atom.
The ionisation energy for a hydrogen atom is 13.6 eV.



(a) Mark the value of the ground state of hydrogen in the box labelled 'ground state'. (1 mark)

(b) Explain what is meant by the term 'ionisation energy'. (2 marks)

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(c) Light from a hydrogen discharge tube can be seen as a line emission spectrum. Using a labelled diagram, describe what a line emission spectrum looks like. (3 marks)

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The diagram on page 22 is based on the Bohr model, which is the simplest model of the hydrogen atom. In more physically accurate (and more complex) models the $n = 2$ energy level is split into two sub-levels. An electron making a transition between these sub-levels emits a photon with a wavelength of 21 cm.

(d) Calculate the energy difference (in eV) between the two n = 2 sub-levels. (3 marks)

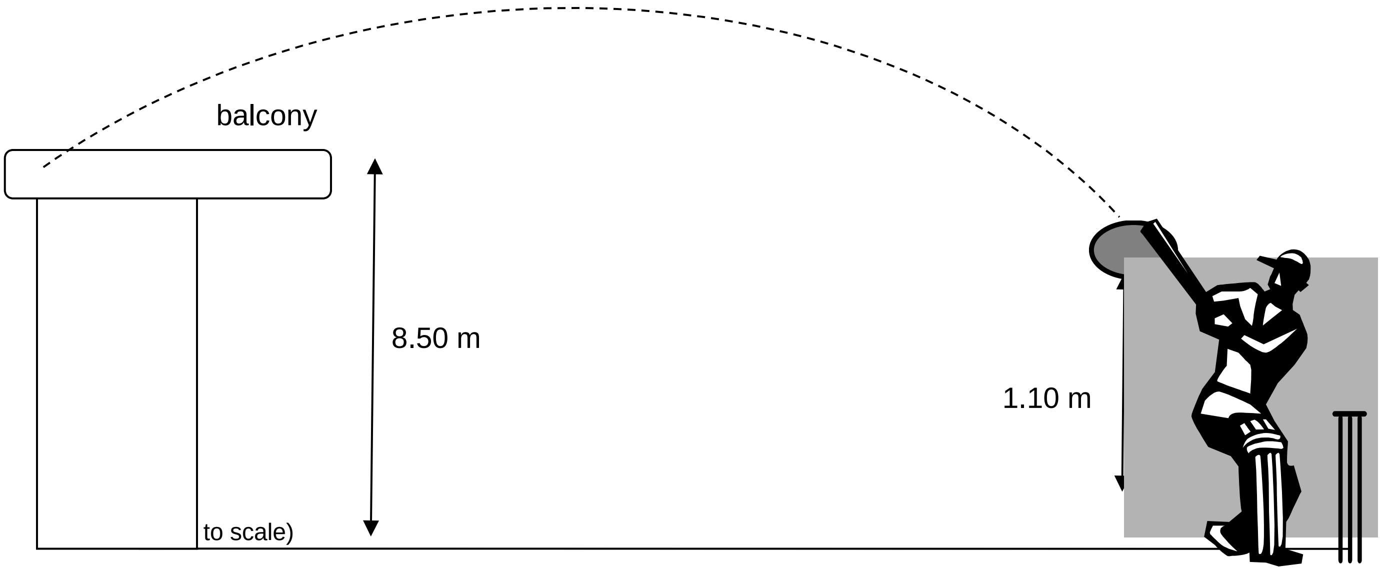
This 21 cm wavelength in the hydrogen spectrum is used by radio astronomers to measure the velocities of stars and galaxies.

(e) Describe the difference you would expect to see between a hydrogen spectrum emitted by a galaxy that is not moving toward or away from our galaxy, and a hydrogen spectrum emitted by a galaxy moving away from our own. (2 marks)

(f) How does your answer to (e) provide evidence for the Big Bang model of the formation of the Universe? (3 marks)

Question 18 **(15 marks)**

During a cricket match a cricket ball is hit with an initial velocity of 45.0 m s^{-1} at an angle of 30.0^{o} to the horizontal from a height of 1.10 m above the ground. It lands in the spectators' balcony which is 8.50 m above the ground.



(a) Calculate the horizontal and vertical components of the cricket ball's initial velocity. (2 marks)

(b) Determine the final vertical displacement of the ball. (1 mark)

(c) Calculate the vertical velocity component of the ball when it lands in the spectators' balcony. (3 marks)

(d) Calculate the time of flight of the ball. (3 marks)

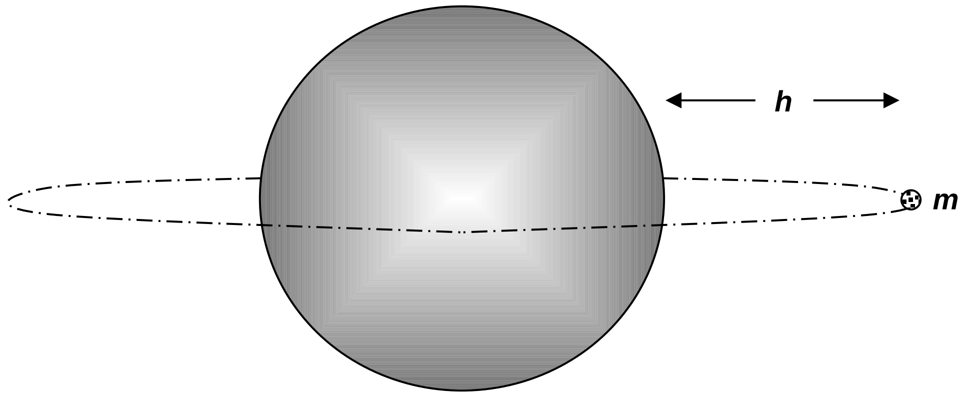
(e) Calculate the horizontal distance between the batsman and the point where the ball landed on the spectators' balcony. (2 marks)

If you are unable to complete (d) use value of 4.10 s for time of flight for this question.

(f) Calculate the maximum height the ball achieved relative to the ground. (4 marks)

Question 19 **(10 marks)**

A satellite of mass ***m*** follows a circular orbit around the Earth, at constant speed and at an altitude ***h*** above the Earth's surface as shown below.



(a) Determine the orbital period of the satellite if it appears stationary above a fixed point on the Earth's equator. (1 mark)

(b) Calculate the height ***h*** of the satellite above the surface of the Earth. (6 marks)

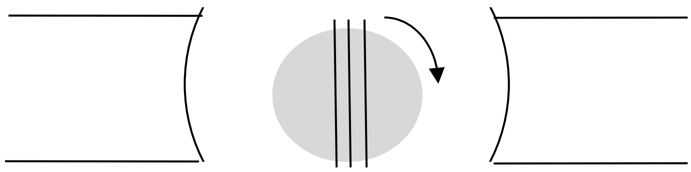
(c) If the mass of the satellite is doubled, how will this affect its orbital radius? Give a reason for your answer. (2 marks)

(d) Name one use or application of geostationary satellites. (1 mark)

Question 20 **(11 marks)**

A student is conducting an experiment to investigate the properties of generators. She rotates a coil in a magnetic field as shown and, using a computer data-logger, generates a graph of the output emf from the coil versus time. The experimental arrangement and her graph of the output emf are shown below.

Experimental arrangement (diagram and photograph):



Graph of the emf generated versus time:

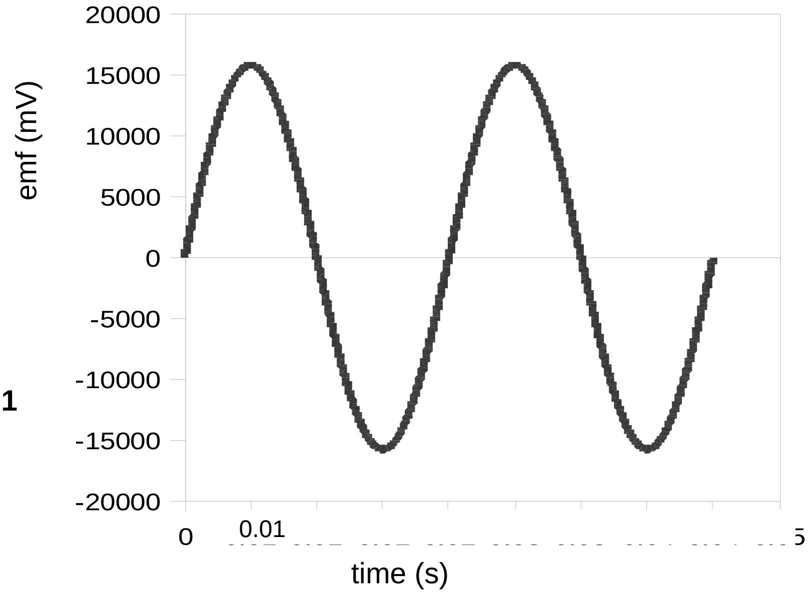


Figure 1

(a) Explain why an emf is generated in the coil. (3 marks)

(b) Explain why the graph of the output voltage takes the form shown. (2 marks)

(c) To increase the output from the generator, the coil can be wound on a material that becomes magnetic in the presence of a magnetic field but loses its magnetism when the field is removed. Explain why it is better to use this type of material rather than a material that can become a permanent magnet. (2 marks)

(d) The student then makes some changes to her experiment and produces the two graphs of output emf versus time as shown below. For each graph, describe one change she could make to her original equipment to produce the output emf shown. (4 marks)

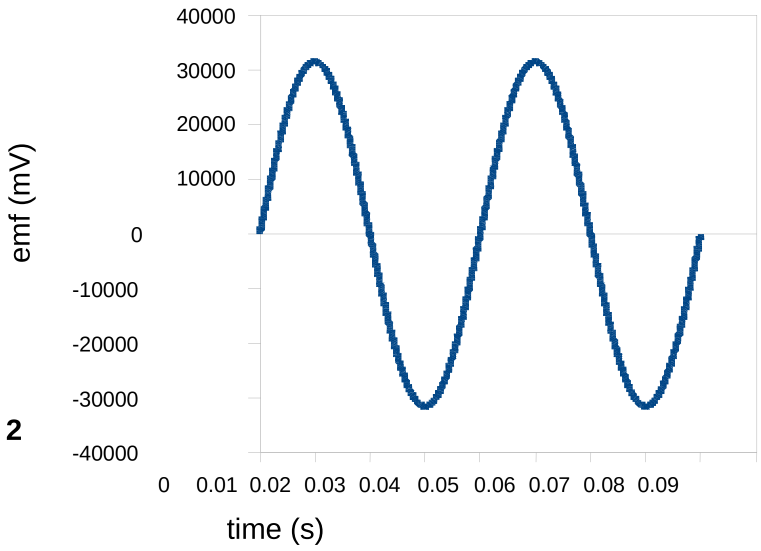


Figure 2

Change 1: ____

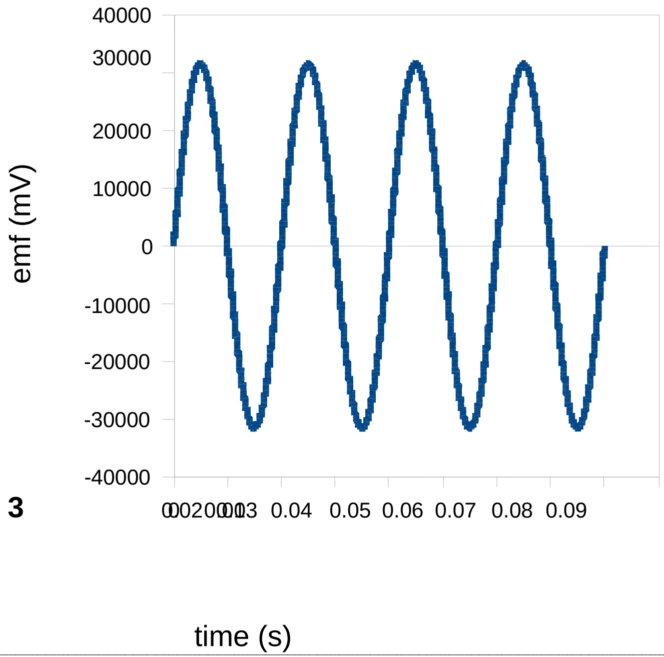


Figure 3

Change 2: ____

End of Section Two

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Section Three: Comprehension **20% (36 Marks)**

This section contains **two (2)** questions. You must answer both questions. Write your answers in the space provided.

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Suggested working time for this section is 40 minutes.

Question 21 **(18 marks)**

Black Holes

Anything on the surface of a large body (for example a planet) is affected by the gravitational field surrounding that body and to escape from the surface an object must move very quickly. The force of gravity will slow such an object but providing it is moving fast enough it can escape, that is, move sufficiently far away from the large body that the gravitational pull never manages to slow the escaping object's velocity to zero.

The minimum velocity needed to leave a surface is called the escape velocity and the equation used to calculate it is

$$v = \sqrt{\frac{2GM_E}{r_E}}$$

Imagine all the matter of the Sun, a ball of gas (mainly hydrogen and helium) with radius 6.96×10^8 m, squeezed together, so that it has a radius of only 2420 km. The Sun would now be a 'white dwarf' and its gases would have become a mixture of atomic nuclei and loose electrons.

Compressing the Sun even more would cause the electrons to fuse into the nuclei leaving nothing but neutrons. The Sun would be a 'neutron star' with a radius of 7250 m. The escape velocity of a neutron star is 1.93×10^8 m s^{-1}. It is hard to imagine anything being able to achieve such huge velocities but light would be able to escape since it travels at 3×10^8 m s^{-1}.

If the Sun continued to shrink past the neutron star stage the escape velocity would increase, eventually, to the speed of light. Then nothing, not even light, would be able to escape from the Sun's surface. Anything can fall into such an object, but nothing can escape. It is a 'black hole'.

The critical radius at which a neutron star becomes a black hole is given by the formula

$$r = \frac{2GM}{c^2}$$

In fact our Sun is too small to become a black hole. Stars more massive than the Sun explode before they begin to collapse, losing some of their mass. If the amount of mass remaining after such an explosion is more than 3.2 times the mass of our Sun, the collapsing star will become a black hole.

Black holes are difficult to detect. They neither emit nor reflect light, are very small and are very long distances from our own planet. The only way we can detect a black hole is to watch out for something falling into it. In general, objects falling toward black holes emit X-rays. If a black hole has a lot of matter falling into it there will be lots of X-rays emitted – enough for astronomers to detect.

The first black hole to be detected was Cygnus X-1. Initially, an X-ray source detected in the constellation Cygnus was found to be close (in astronomical terms) to the star HD-226868, a giant star 30 times more massive than the Sun. HD-226868 is one component of a binary star system. These two stars orbit their centre of mass every 5.6 days. The X-rays come from the other star, named Cygnus X-1.

The motion of HD-226868 shows that Cygnus X-1 is 5 to 8 times the mass of our Sun. A normal star of this mass should be visible with an optical telescope at that distance. However, no optical telescope has ever detected a star in the spot where the X-rays come from. Since Cygnus X-1 has at least 5 times more mass than the Sun, it is too massive to be anything other than a black hole.

(a) Calculate the escape velocity from the Earth. (3 marks)

(b) Describe how the strength of the gravitational field changes as you move further away from a planet. (2 marks)

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(c) Calculate the radius of a black hole having the same mass as the Sun. Using this radius, calculate the density of the black hole. Assume that the black hole is spherical and that its density is given by mass divided by volume. The volume of a sphere is given by

$$V = \frac{4\pi r^3}{3}$$

(4 marks)

(d) The X-rays emitted from Cygnus X-1 had wavelengths in the range 10–150 nm. Calculate the energy of a 10 nm X-ray photon. (3 marks)

(e) Is the centre of mass of the binary star system closer to Cygnus X-1 or to HD-226868?. Justify your answer. (3 marks)

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(f) HD-228686 is continually losing mass at an estimated rate of 2.5×10^{-6} solar masses per year, creating a stellar wind. Calculate how long it will take HD-228686 to lose a mass equivalent to the mass of the Sun. (3 marks)

Question 22 **(18 marks)**

When source of waves moves, the waves it emits change frequency relative to a stationary observer. This applies to both transverse and longitudinal (sound) waves. As a car moves away from you the frequency of the sound you hear is lower than the frequency it is emitting. A similar effect using radar waves is used by police to measure the speed of cars.

Thus if a source of electromagnetic waves such as a star is moving away from an observer on Earth then the frequencies of the lines in the star's emitted electromagnetic spectrum are shifted to lower values. This is known as red shift.

In 1920, Edwin Hubble measured the red shifts of several galaxies and discovered that most galaxies are moving away from the Earth, suggesting that the Universe is expanding. Hubble also found that the further away a galaxy is, the larger its red shift; that is, the faster it is moving.

The following data together with the associated errors were recorded by Hubble at Mount Wilson in California in the 1940s using an optical telescope.

Object name	Speed of recession ($\times 10^4$ km s^{-1})	Distance ($\times 10^6$ light years)
Virgo	0.2 ± 0.1	10.2
Corona Borealis	2.4 ± 0.2	400
Hydra	6.2 ± 0.3	1100
Kip	4.8 ± 0.2	900

(a) Graph these data on the graph paper below, including error bars. Plot recession speed (y-axis) against distance (x-axis) and draw a line of best fit. (5 marks)

If you wish to have a second attempt at this item, the grid is repeated on page 43. Indicate clearly on this page if you have used the second grid and cancel the working on the grid on this page.

(b) Use the graph to predict the recession speed of a galaxy that is 710 × 10^6 light years from Earth. (2 marks)

(c) Hubble's Law can be stated as

$$v_{galaxy} = (H_o)(distance)$$

where the term H_o is called Hubble's constant.

Use your graph to calculate a value for H_o. Take care with the units. (4 marks)

(d) The shift in wavelength $\Delta\lambda$ due to recession of a spectral line of wavelength λ is given by the formula

$$v_{galaxy} = \left(\frac{\Delta\lambda}{\lambda}\right)c$$

where c is the speed of light, 3 × 10^8 m $s^{-1.}$

A line in the spectrum of ionised calcium has wavelength 393.3 nm when measured in the laboratory. When similar light from the elliptical galaxy NGC 4889 is measured its wavelength is 401.8 nm.

Determine the recession speed of this galaxy. (3 marks)

(e) Edwin Hubble could estimate the age of the Universe from his data by calculating the time for which one of the galaxies has been receding. Determine Hubble's value for the age of the Universe by using the data for Corona Borealis. (4 marks)

End of questions

Additional working space

Additional working space

Additional working space

Additional working space

ACKNOWLEDGEMENTS

Question 21 Text adapted from: Asimov, I. (1995). Black holes. In J. Carey (Ed.), *The Faber book of science* (pp. 420–422). London: Faber & Faber.

Question 22 Astronomical data source: Serway, R., Beichner, R., & Jewett, J. (2000). *Physics for scientists and engineers* (5th ed.). Philadelphia: Saunders College Publications, p. 1541.