Western Australian Certificate of Education

Practice Examination

Question/ Answer Booklet

STEP UP IN EDUCATION

PHYSICS Unit 3 and 4

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 Data Booklet

To be provided by the candidate

Standard items:	pens, pencils, sharpener, correction fluid/tape, eraser, ruler, highlighters
Special items:	up to three non-programmable calculators approved for use in the WACE examinations, drawing templates, drawing compass and a protractor

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	14	14	50	54	30
Section Two: Problem-solving	7	7	90	90	50
Section Three: Comprehension	2	2	40	36	20
				Total	**100**

Instructions to candidates

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.

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

This section has **14** questions. Answer **all** questions. Write your answers in the spaces provided.

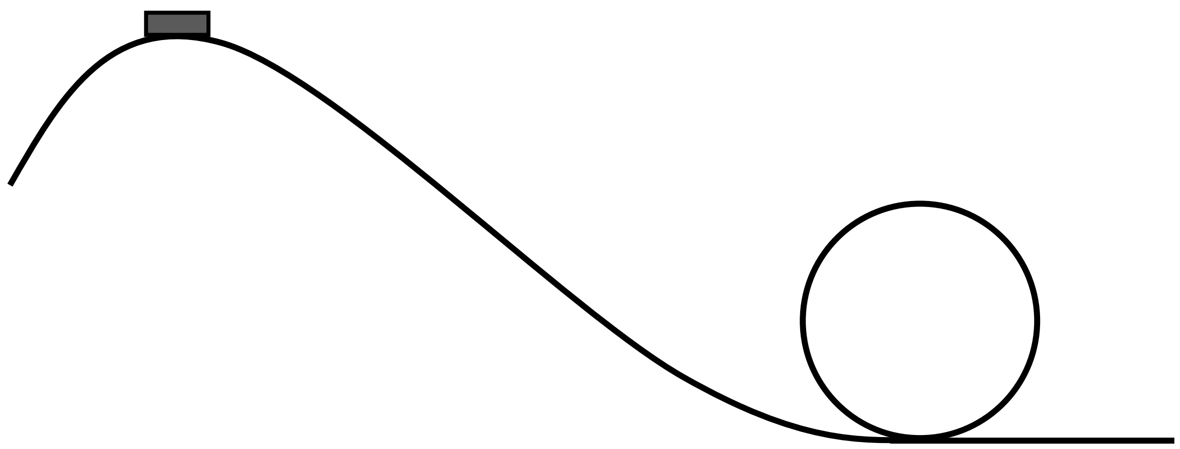
When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

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.

Suggested working time: 50 minutes.

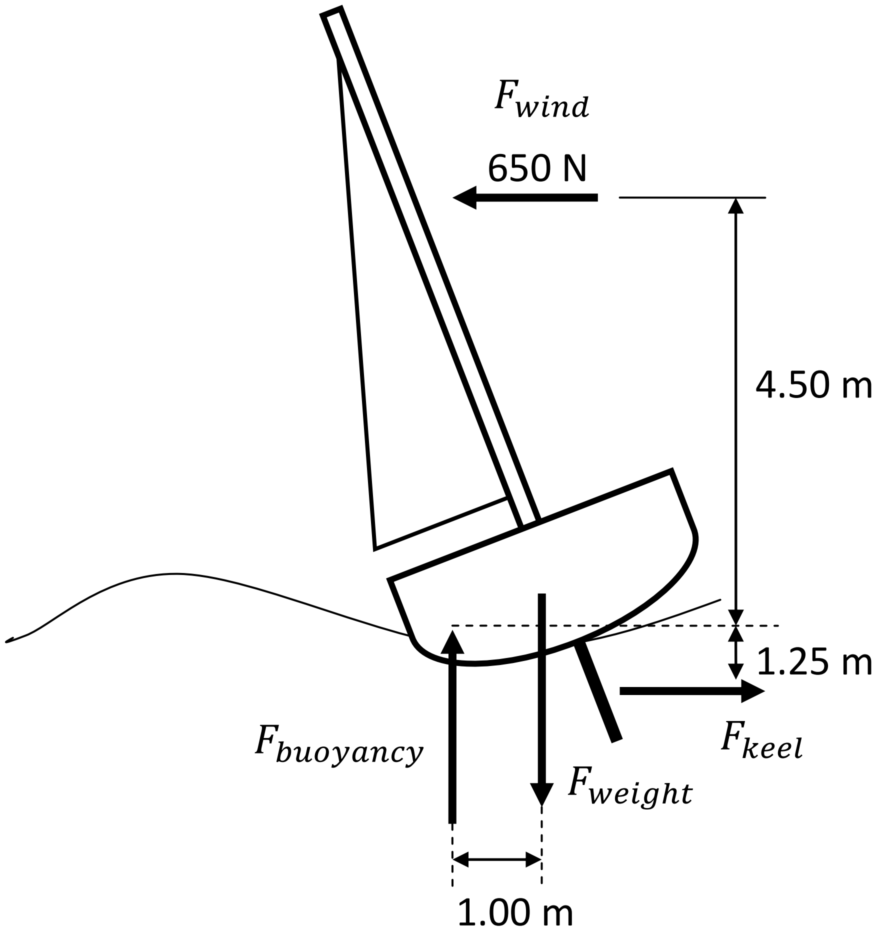
Question 1 **(5 marks)**

A rollercoaster is at the peak of its track and moving at 4.00 ms^{-1}. It races to the bottom and then performs a vertical loop that has a 6.80 m radius. Calculate how high the peak of the rollercoaster is above the base of the ride if the rollercoaster only just manages to make it around the vertical loop.



Question 2 **(6 marks)**

Four forces (wind, weight, keel and buoyancy) acting on a sailboat keep it in equilibrium. Use the free body diagram provided to calculate the mass of the sailboat.



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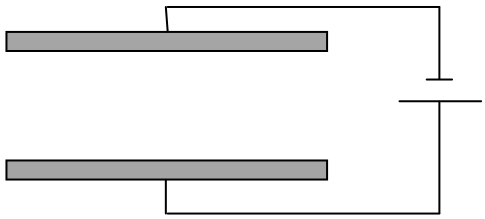
Question 3 **(4 marks)**

A pair of parallel plates is separated by 85.0 mm and has a 275 V potential applied across them.



Calculate the force that would be applied to an ion that had lost 2 electrons when placed between the two plates.

Question 4 **(3 marks)**

A horizontal power line carries a 3.50×10^2 A to the south through a region where the Earth's magnetic field is 58.0 μT inclined at 28.0^0. Calculate the magnitude of the force per metre acting on the power line.

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Question 5 **(4 marks)**

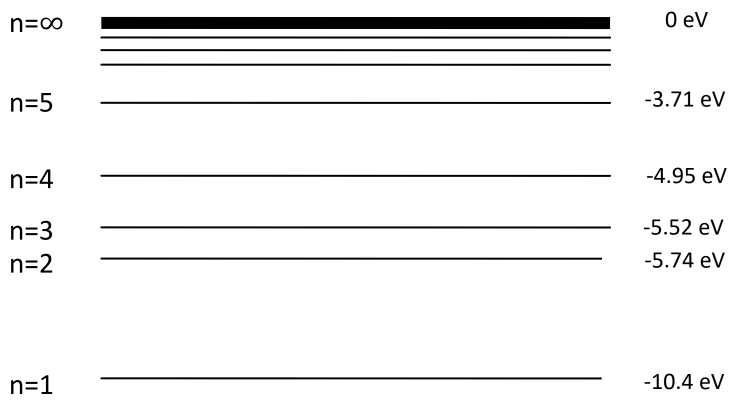
The photoelectric effect experiment involves shining a monochromatic light source onto a target metal. Explain how the photoelectric effect experiment provides supporting evidence for the particle nature of light.

Question 6 **(4 marks)**

A step down transformer with a 340:1 winding ratio supplies power to a 160 V, 250 W load. The transformer is 96.0 % efficient. What is the current in the primary windings of the transformer?

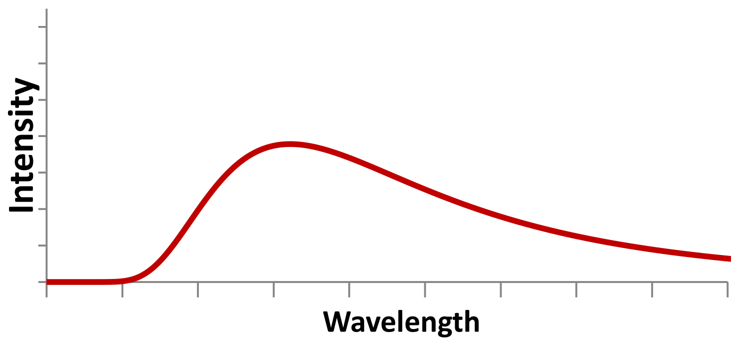
Question 7 **(4 marks)**

A ground state electron in a mercury atom was bombarded with a 12.2 eV electron. 90.0 % of the energy was passed onto the ground state electron. Calculate the speed of the ground state electron after the collision.



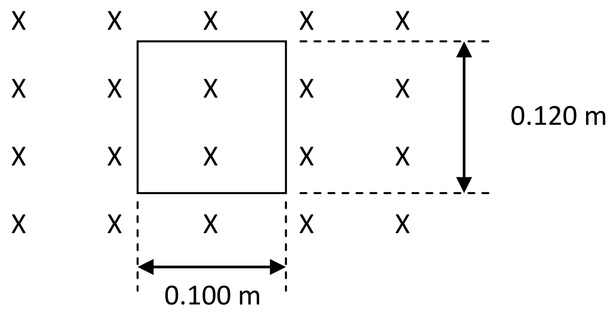
Question 8 **(3 marks)**

The black body spectrum shown below is for a yellow star. Draw in the black body spectrum you would expect for a hotter blue star on the same axes.



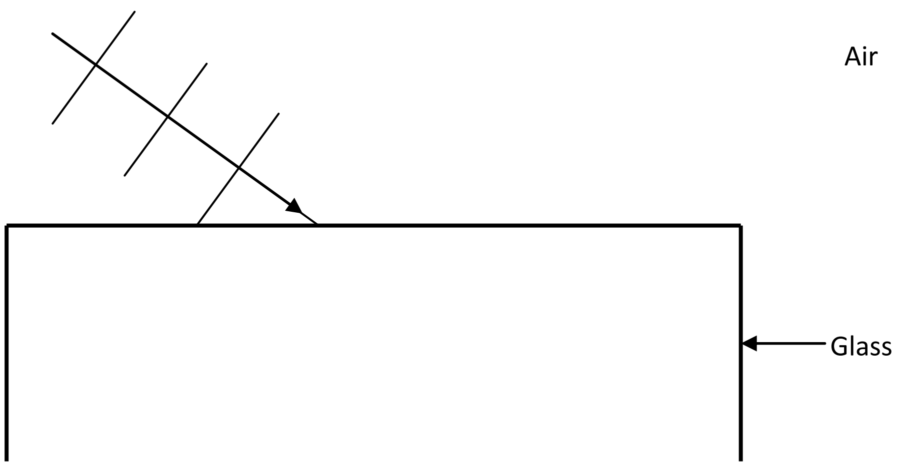
Question 9 **(4 marks)**

The cross sectional area of the copper coil shown in the diagram is perpendicular to a 32.0 mT field. The magnetic field is reversed within 2.00×10^{-2} s interval. The internal resistance of the copper wire is 4.50 Ω. Calculate the current flowing in the wires during the field change. On the coil show the direction the current would flow using an arrow.



Question 10 **(4 marks)**

When light is incident upon the boundary between air and glass most of it refracts but a small amount also reflects. On the diagram below, complete the ray and wave fronts for the light which partially reflects and partially refracts.



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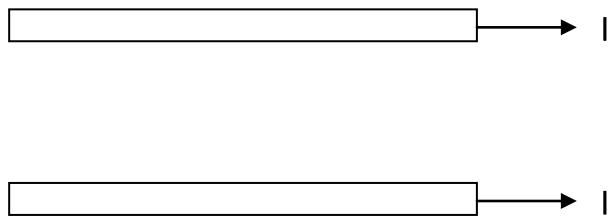
Question 11 **(3 marks)**

Two long, parallel wires are separated by a small distance. Each has a current flowing through them in the same direction. Draw the direction of the force each wire has exerted upon it by the other and label these forces with an "F". Describe how you determined the direction of the force applied to the top wire on the page.



Question 12 **(4 marks)**

For each of the samples described below, state the type of spectrum observed using the terms line, band, continuous, absorption and/or emission.

i. Burning a salt ________________________________

ii. Hydrogen gas discharge tube ________________________________

iii. Toaster element while heated ________________________________

iv. Solar spectrum viewed from Earth ________________________________

Question 13 **(3 marks)**

Describe the relationship between the terms hadron, baryon, meson and quark.

Question 14 **(3 marks)**

The following reaction is proposed to occur for positively charged pions (π^+) at high energy levels. A pion is a meson composed of up and down quarks and antiquarks only.

$$\pi^+ \rightarrow \pi^0 + e^+ + \overline{\nu_e}$$

Check for conservation of baryon number, lepton number and electric charge for this proposed reaction.

End of Section 1

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

This section has **7** questions. Answer **all** questions. Write your answers in the spaces provided.

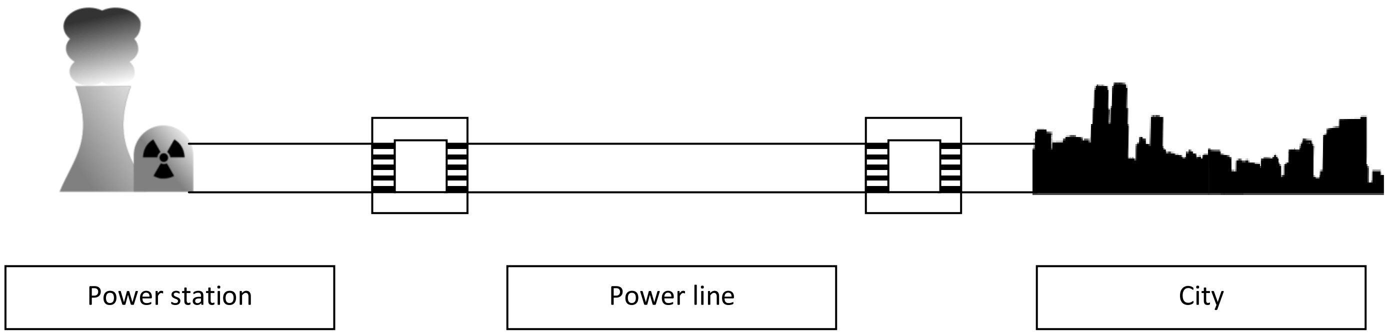
When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

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.

Suggested working time: 90 minutes.

Question 15 **(13 marks)**

A small city requires 300 MW of power during peak periods. The power station that supplies the power operates at 720 V before being stepped up to 32.0 kV ready for transmission. The power line between the power station and city is 23.0 km long and has an 18.0 Ω resistance. The power line at the city side is connected to a step down transformer with a turns ratio of 126:1. Both transformers are 95% efficient.



a) The step up transformer has 100 turns on the primary side. How many turns will the secondary side have? [2 marks]

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b) The city operates at 240 V. What is the voltage on the primary side of the step down transformer? [2 marks]

c) Calculate the voltage drop across the power line. [1 mark]

d) Calculate the power lost through the power line. [2 marks]

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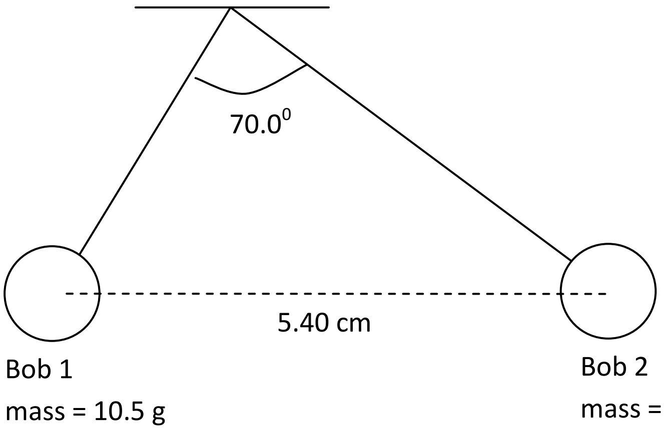
e) How much power does the power station produce to meet the requirements of the town during peak periods? [4 marks]

f) Suggest two methods to minimise the power loss through the power line. [2 marks]

Question 16 **(12 marks)**

Two bobs are tethered via separate strings to the same frictionless hook in the ceiling. The bobs each have a $+13.0 \times 10^{-8}$ C electric charge. The bobs hang from the hook in the arrangement shown in the diagram below. Note that one string is longer than the other and the bobs have different masses but lie along the same horizontal plane.



a) In the space below, draw a vector diagram showing the relationship between all the forces acting on bob 1. (2 marks)

b) Calculate the electrostatic force applied to bob 1 by bob 2. (2 marks)

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c) Calculate the tension in the string attached to bob 1, including direction. (3 marks)

d) Calculate the mass of bob 2. You may assume the string has negligible mass. (5 marks)

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Question 17 **(18 marks)**

Dr. Emily is performing particle accelerator experiments aboard a spaceship that is moving past Earth at 0.800 c. Dr. Emily is observing protons move from the front of the spaceship to the back at 0.900 c. This distance covered by the protons, as measured by Dr. Emily, is 33.0 m.

a) Calculate the time observed by Dr. Emily for the proton to reach the back of the spaceship. (2 marks)

b) Calculate the velocity of the protons as observed by an Earth based observer. (4 marks)

c) Compare the energy of the protons as measured by Dr. Emily and the Earth based observer. (4 marks)

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d) How far is the front of the spaceship from the back as observed by the Earth based observer? (3 marks)

e) What is the proper time for the journey of the protons from the front of the spaceship to the back? (3 marks)

f) Explain why Dr. Emily and the Earth based observer disagree about the mass of the protons. (2 marks)

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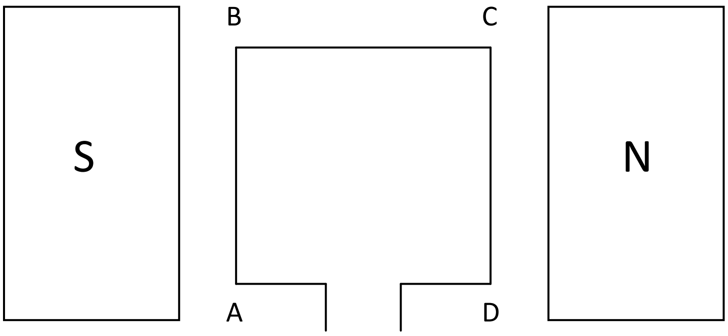
Question 18 **(12 marks)**

A cordless drill attached to a skateboard's axle makes for a cheap way to produce an electric skateboard.

Image used with permission www.inspiredtomake.com

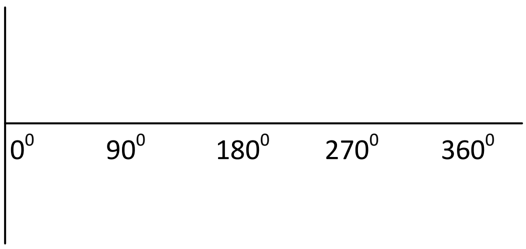
The design of the drill's motor is shown below.



Windings	250
Side AB	4.20 cm
Side BC	3.10 cm
Flux density	19.0 mT
Armature current	645 mA

a) Calculate the torque produced by the motor. (3 marks)

b) Complete a sketch of the torque output for the motor as the winding rotates from the position shown in the diagram over a 360^0 range. (3 marks)



c) When the skateboard was placed on the ground and the rider stood on it, the drill was not able to cause the wheels to turn. The drill also became very hot. Describe why the drill gets hotter when the wheels do not turn compared to when they do. (3 marks)

d) List three specific design changes to the drill that may allow it to turn the wheels while the rider stands on the skateboard. (3 marks)

Question 19 **(10 marks)**

Voyager 2 travelled passed Neptune in 1989 and discovered several new moons. A table of properties for two of these moons and Neptune is given below.

Body	Orbital radius around Neptune (m)	Mean body diameter (m)	Mass (kg)
Neptune	-	2.48×10^{7}	1.02×10^{26}
Larissa	7.35×10^{7}	2.04×10^{5}	4.20×10^{18}
Proteus	1.18×10^{8}	4.20×10^{5}	4.40×10^{19}

a) Calculate the gravitational field strength on the surface of Neptune, ignoring any effects from the moons. (2 marks)

b) Calculate the orbital period for Larissa. (2 marks)

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c) Calculate the net force acting on Larisa when Neptune, Larisa and Proteus form a straight line configuration. (6 marks)

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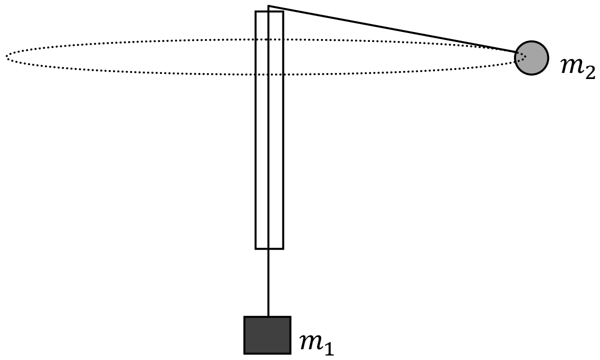
Question 20 **(14 marks)**

It is possible to measure the gravitational field strength of the Earth using a variety of experiments. Two students experimentally obtain a value by spinning a bob around in a horizontal circle.



The centripetal force allowing the bob (m_2) to maintain its circular path is provided by the tension in the string, supplied through the weight force of a hanging mass (m_1).

$$F_c = F_g$$

$$\frac{m_2 v^2}{r} = m_1 g$$

The string connecting the two masses is free to move up and down in the tube, allowing the radius of the swing to be controlled by the velocity of the bob. A faster swing increases the radius such that the centripetal force always matches the weight force. The students controlled the masses; the hanging mass (m_1) was 500 g and the revolving bob (m_2) was 94.0 g.

a) Draw a vector diagram in the space below showing the relationship between the physical forces acting on the ball and the centripetal force. (2 marks)

b) The students estimate a ±10% error for their time measurement. Complete the entries in the table below. (3 marks)

Radius (m)	Time for one revolution (s)	Velocity (ms^{-1})	Velocity^2 (m^2s^{-2})	Uncertainty of velocity^2 (m^2s^{-2})
0.30	0.50	3.8	14	±2.8
0.50	0.66			
0.80	0.78			
1.10	1.0			
1.60	1.1			

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c) Plot the relationship between the radius and velocity on the grid below. You should choose suitable variables for the axes such that the relationship is linear. Include error bars in your plot. (4 marks)

d) Calculate the gradient of the line of best fit. Include units. (3 marks)

e) Using the gradient, determine the gravitational field strength affecting the experiment. (2 marks)

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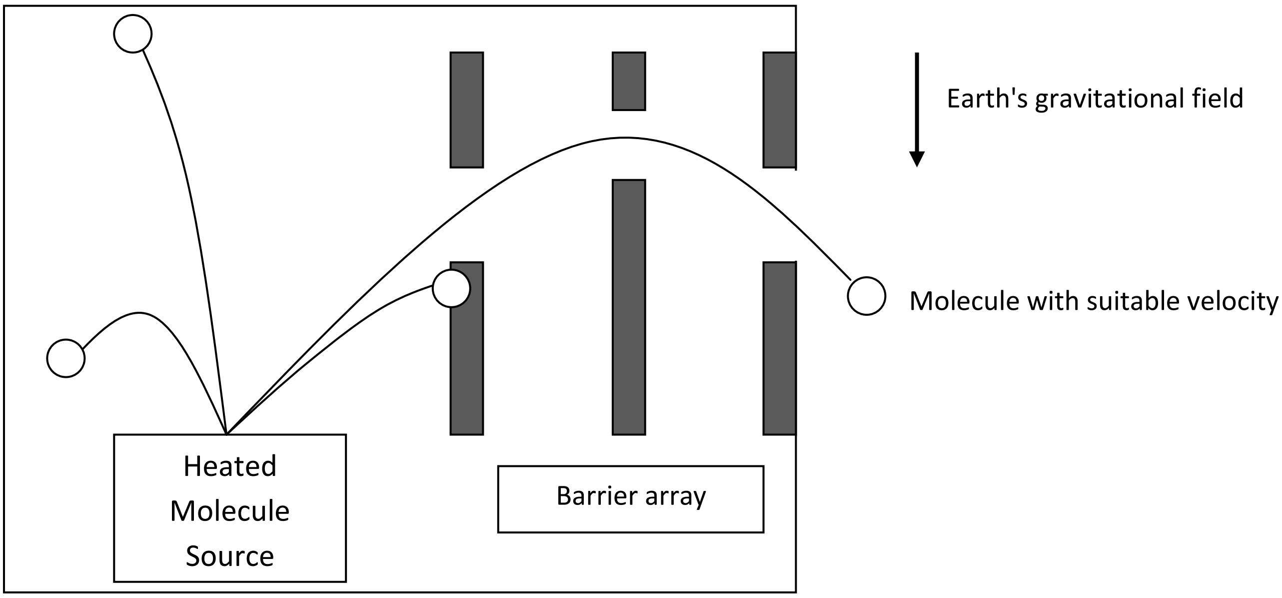
Question 21 **(11 marks)**

A velocity selector is a device capable of emitting particles moving at a very specific, and often adjustable, speed. This is achieved using electric and magnetic fields for charged particles. These fields cannot affect neutral molecules. A velocity selector for neutral molecules is based on taking a source of molecules with a range of kinetic energies and the using the effect of the Earth's gravitational field on the path these molecules will follow to isolate a particular speed.



An array of barriers, each with a single slit, are used to block the majority of the molecules released from a heated source. Only those molecules with a suitable kinetic energy and initial direction of motion are able to pass through all slits and escape the velocity selector. The molecules used in the velocity selector above have a 2.66×10^{-26} kg mass.

a) The middle slit in the diagram is 24.0 cm higher than the top of the heated molecule source. Only molecules that escape moving at 22.0^0 above the horizontal have the right trajectory to pass through all slits. Calculate the initial speed of these molecules. (3 marks)

Question 21 (continued)

b) If the molecule source was replaced with heavier molecules, describe what effect this would have on both the kinetic energy and velocity of the molecules that are able to pass through all slits and escape the velocity selector. (2 marks)

c) Calculate the de Broglie wavelength of the molecules as they are emitted from the heated molecule source that will have a suitable initial velocity required to escape the velocity selector. (2 marks)

d) Explain why the de Broglie wavelength of a molecule changes throughout its motion through the velocity selector. (2 marks)

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e) The slits are made narrower to help ensure the range of velocities able to escape through all the slits is minimised. This however can lead to the beam of escaping molecules spreading out as it leaves the velocity selector. Describe why this occurs. (2 marks)

End of Section 2

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

This section has **2** questions. Answer **both** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

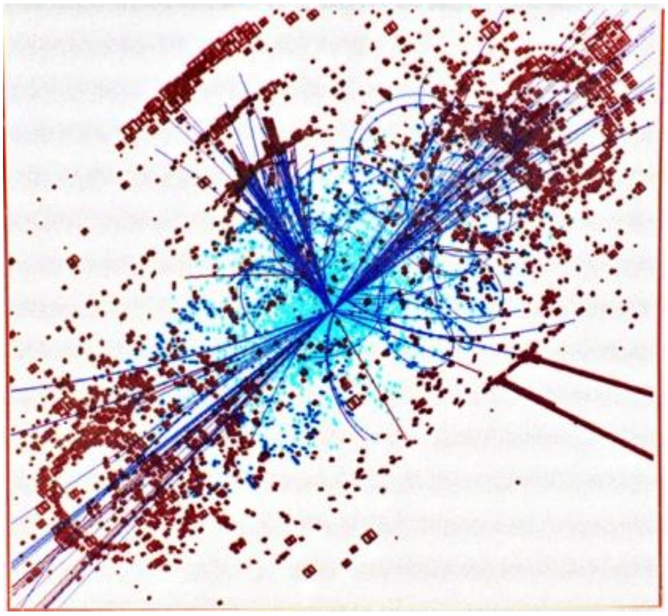
When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Suggested working time: 40 minutes.

Question 22 **(18 marks)**

One of the many roles of particle accelerators is to test the theories of the Standard Model. Particles are accelerated up to very high speeds before they are made to collide. The outcomes of the collisions can include the production of unstable, heavier fundamental particles. The only issue that remains is how to detect the particles produced in these collisions.

The collision between the white cue ball and the pyramid of coloured balls in a game of billiards projects all the balls out in straight lines. Particle collisions are no different; the particles that result from the collision of high speed particles tend to travel in straight lines and obey the conservation of momentum. However, charged particles moving through an external magnetic field follow curved lines. The momentum of the particle will affect the curvature of the path the particle follows.



An example of track lines generated by software after a high speed collision.
http://cds.cern.ch/record/628469 (License: CC-BY-SA-4.0) By CERN.

Surrounding the location of the collision are several detectors, designed to measure specific properties of the particles produced. These include tracking devices, calorimeters and various particle-identification detectors.

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Tracking devices

These monitor the positions of electrically charged particles via their interaction with a suitable substance as they move through the substance. This substance may be superheated liquid hydrogen (as in a bubble chamber) or based on more recent technologies such as strips of semiconductors. The tracking device picks up the position of the electrically charged particles and software is used to reconstruct the paths, called track lines, these particles followed. By applying an external magnetic field the charged particles will follow a curved path rather than a straight one. The momentum of the particle can be calculated from knowledge of the magnetic field density and the radius of curvature.

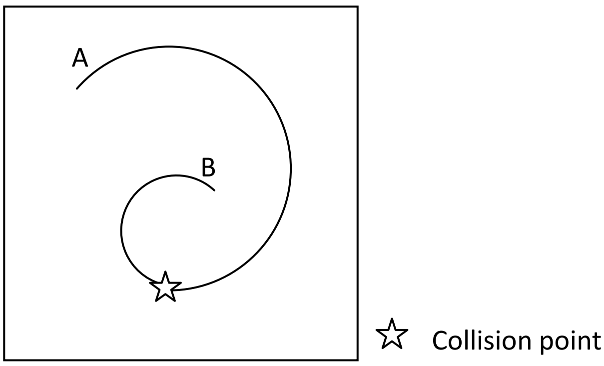
Calorimeters

A calorimeter is used to measure the energy of a particle produced within the collision. Calorimeters absorb the energy of the particles and therefore bring them to a complete stop. Electromagnetic calorimeters are capable of measuring the energy of particles that interact via the electromagnetic force while hadronic calorimeters measure the energy of particles that interact via the strong nuclear force.

Particle-identification detectors

There are many types of particle-identification detectors that focus on measuring properties such as spin and electric charge. A useful property to detect is the rest mass of a particle. If a particle moves faster than the speed of light through a physical medium it will emit a special type of electromagnetic radiation called Cherenkov radiation. The angle of emission of Cherenkov radiation depends on the velocity of the particle. Using knowledge of the particle's momentum (from the tracking device) and velocity (from the Cherenkov detector) allows the rest mass of the particle to be calculated.

a) The track lines of two identically charged particles as they move through a magnetic field are shown below. State which particle (A or B) has more momentum. With reference to a suitable formula, describe how you determined your answer. (3 marks)



Question 22 (continued)

b) How is it possible to create heavier particles from the collision of lighter ones? (2 marks)

c) In modern particle detectors the different detector types are layered over each other like an onion. Explain why the calorimeter must be placed on the outer layer. (2 marks)

d) Neutrinos are not detected by tracking devices nor easily detected by calorimeters. Suggest a reason for this. (2 marks)

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e) Only one type of calorimeter is useful for the detection of a tau. Explain which one is suitable. (2 marks)

f) Explain, using relevant formula to assist, why it is necessary to use both a tracking device and calorimeter to determine the rest mass of a particle produced by the collision. (5 marks)

g) Describe why knowing the rest mass of a particle produced by these high speed collisions is useful in the study of the Standard Model. (2 marks)

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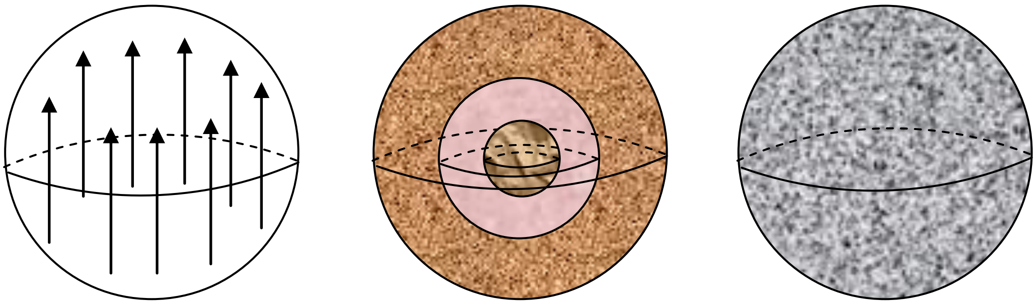
Question 23 **(18 marks)**

What is at the edge of the universe? Many cosmologists agree that the universe is expanding. But that leads naturally to the question of expanding into what? The Big Bang theory suggests that the universe was once a much hotter and denser form of what it is today. Many people imagine the Big Bang similar to the explosion of a bomb; galaxies and stars flung away in all directions from some central point. While the name "Big Bang" leads to this type of imagery, this interpretation is wrong.

The expansion of the universe is due to the expansion of space itself. Einstein's general relativity, a generalisation of special relativity that includes the laws of gravitation, predicts that space and time (spacetime) can be manipulated to expand, shrink and even fold like a rubber balloon. These manipulations of spacetime are influenced by the presence of matter and energy. While this does not answer the original question, it does lead us down the right path.

One of the core concepts of modern cosmology is that the universe is homogenous and isotropic. Cosmological models require the universe to be the same everywhere (homogenous) and to appear the same in all directions (isotropic). The diagram below helps to visualise the differences between homogeneity and isotropy. Consider an observer positioned at the centre of each of the spheres shown below.



a) Homogenous
Not isotropic

b) Not homogenous
Isotropic

c) Homogenous
Isotropic

In sphere (a), the observer would see the same composition everywhere within the sphere. However, looking up gives a different perspective than looking down. In sphere (b) the sphere looks the same in all directions but its composition is not uniform. Sphere (c) has a uniform composition and appears the same in all directions.

Astronomical observations have revealed that galaxies are receding from Earth which is described by Hubble's law. This might be because Earth is near the centre of the universe and the Big Bang event is like a bomb that has flung all galaxies away from us. But there are two issues with this idea. The probability of Earth being at the centre of the universe is mind bogglingly small. The other issue is isotropy cannot be maintained. Consider an observer at the edge of sphere (c) which represents the universe. This observer would not perceive the universe to be isotropic; there is stuff inside the universe but no stuff out of it.

If the universe is homogenous and isotropic there can be no edge. For all observers to measure galaxies receding according to Hubble's law requires the universe to be infinitely large and space itself to be expanding, increasing the distance between all the galaxies. At least this is the assumption. It is not possible to confirm the infinite nature of the universe because there is a limit to how deep into the universe we can see. As described by the Big Bang theory, the universe is 13.7 billion years old. The very first light in the universe has had a finite time to cross the span of space and reach Earth. There is just no way to observe anything further because not enough time has passed for the light to reach Earth. Earth is surrounded by a universe we can see and beyond this

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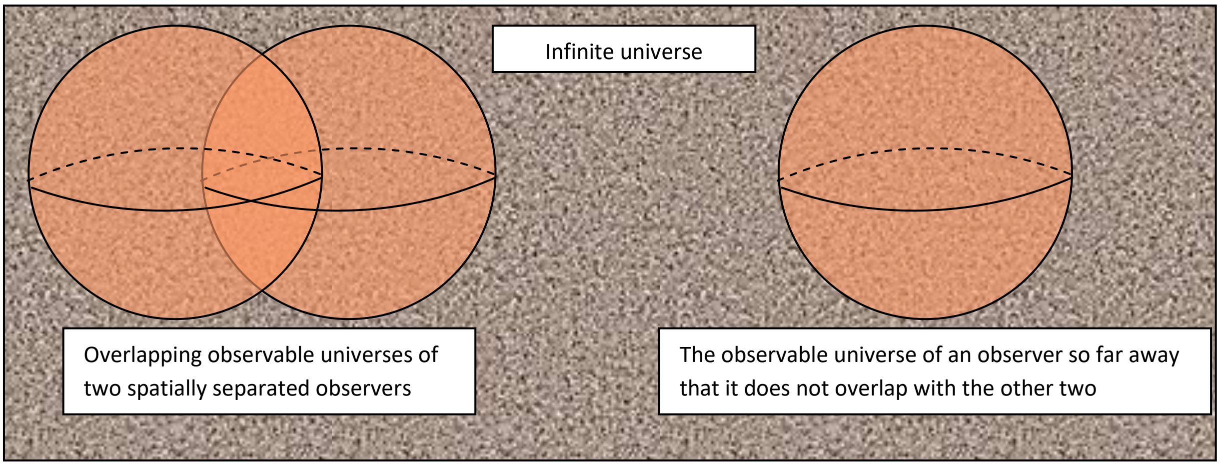
distance is the universe we cannot see. We refer to our little universe inside this boundary as the observable universe. We can argue that sphere (c), with Earth at the centre, is our observable universe. Every other observer is at the centre of their own observable universe which may or may not overlap with our own.



If the universe is 13.7 billion years old, at first glance one might assume the observable universe has a 13.7 billion light year radius. However, because of the expansion of space, the light that was produced 13.7 billion years ago and is only just reaching Earth originated from a source that is now closer to 42 billion light years away. This boundary is called the past horizon; we cannot see any further into space beyond this boundary and it encases our observable universe.

There is also a theoretical future horizon. There may be objects in the universe that are far enough away that the space between them and us expands so rapidly there will be no way for any light produced by these objects to ever reach Earth. We will never see this far nor be able to communicate with anything further than the future horizon.

So to answer the original question, there is no edge of the universe. The universe is infinitely large, always has been.... and it is expanding.

a) Describe what an observable universe is. (1 mark)

b) What is the diameter of our observable universe? (2 mark)

c) When looking at objects at the edge of our observable universe, how far into the past are we observing? (1 mark)

d) Describe what isotropic means in the context of the universe and why there can be no edge to the universe if the universe is isotropic. (2 marks)

e) Explain. in the context of the Big Bang theory why observations made on Earth cannot give us a picture of the entire universe. (3 marks)

f) Hubble's law reveals that the **further** away a galaxy is, the **more** red shifted its light. Explain this observation in the context of the expansion of the universe. (3 marks)

g) Has the past horizon always been at the same distance from Earth? Justify your response. (3 marks)

h) Cosmologists are uncertain about whether the expansion of space will continue. If the expansion of space was to halt, explain what would happen to the future horizon. (3 marks)

End of questions