South Australian Certificate of Education

Stage 2 Physics

Sample Examination Questions

1. (a) Using $E_K = \frac{1}{2}mv^2$, show that electrons with a speed of $v = 4.1 \times 10^7 \text{ m s}^{-1}$ have a kinetic energy of $7.7 \times 10^{-16} \text{ J}$.

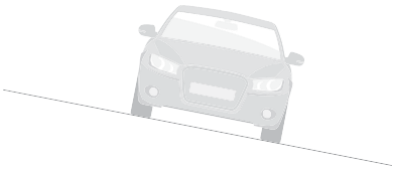
(1 mark)

(b) The electrons gained this kinetic energy by moving through a potential difference.

Determine the potential difference that increased the kinetic energy of the electrons by $7.7 \times 10^{-16} \text{ J}$.

(2 marks)

2. The diagram below shows a vehicle travelling on a road, around a banked curve.



Source: adapted from © Elena Tumanova | Dreamstime.com

(a) On the diagram above:

(i) draw and label a vector to show the normal force, $\vec{F}_{N}$, on the vehicle (1 mark)

(ii) draw and label the horizontal and vertical components of the normal force vector.

(2 marks)

(b) Under some conditions, the friction between the vehicle's tyres and the road is almost zero.

Explain how the vehicle would be able to travel in a circular path around the banked curve without relying on friction.

(2 marks)

3. The Earth's magnetic field deflects protons that are emitted by the Sun.

A proton is travelling towards the Earth at a speed of $4.3 \times 10^{7}\ \text{m s}^{-1}$. The velocity of the proton is perpendicular to the Earth's magnetic field at a point where the field has a strength of $3.2 \times 10^{-5}\ \text{T}$.

(a) Show that the magnitude of the magnetic force on the proton is $2.2 \times 10^{-16}\ \text{N}$.

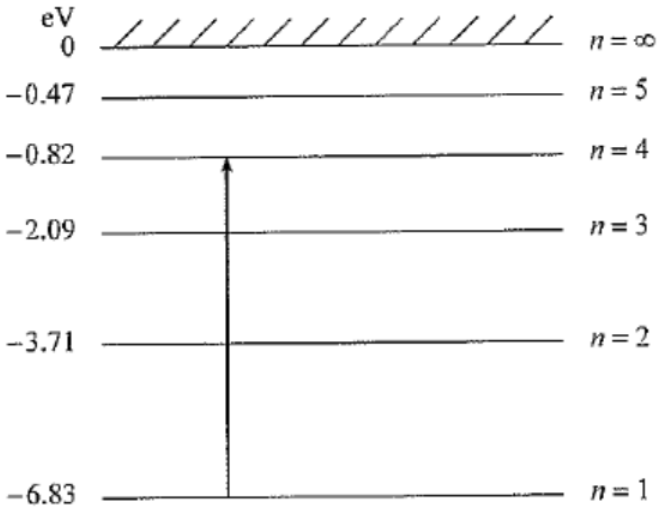
(1 mark)

(b) The magnetic force causes the proton to travel in a circular path.

Calculate the radius of this circular path.

(2 marks)

4. The diagram below shows some of the energy levels of an atom.



[*This diagram is not drawn to scale.*]

(a) The atom absorbed a photon and was raised from the ground state to the $n = 4$ excited state, as shown in the diagram above.

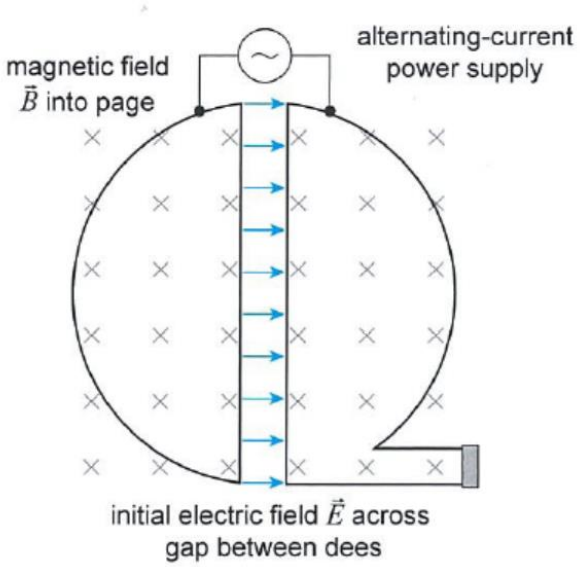
Calculate the frequency of the photon that was absorbed.

(3 marks)

(b) The atom underwent fluorescence.

On the diagram above, show *one* possible set of transitions for the fluorescence from the $n = 4$ excited state. (1 mark)

5. In a cyclotron, ions are accelerated to high speeds. The magnetic field within the dees causes the ions to travel in circular paths so that they repeatedly pass through the electric field across the gap between the dees.



[*This diagram is not drawn to scale.*]

(a) An alternating-current power supply is used to create the electric field across the gap between the dees.

Explain why it is necessary for the electric field to continuously reverse direction.

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_____ (2 marks)

(b) Explain why the ions do not gain kinetic energy when inside the dees.

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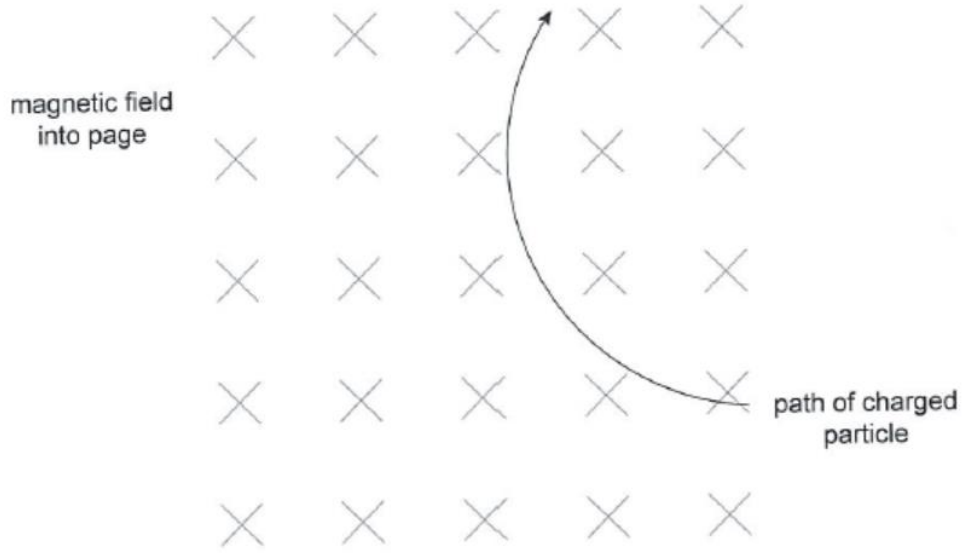
_____ (2 marks)

6. A charged particle enters a uniform magnetic field that is directed into the page, as shown in the diagram below. The velocity of the charged particle is perpendicular to the magnetic field.



(a) Explain why this particle travels with uniform circular motion.

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_____ (3 marks)

(b) Determine the sign of the charge of this particle.

_____ (1 mark)

7. Sigma particles are baryons. One particular Sigma particle consists of two up quarks and one strange quark.

Determine the charge of this Sigma particle.

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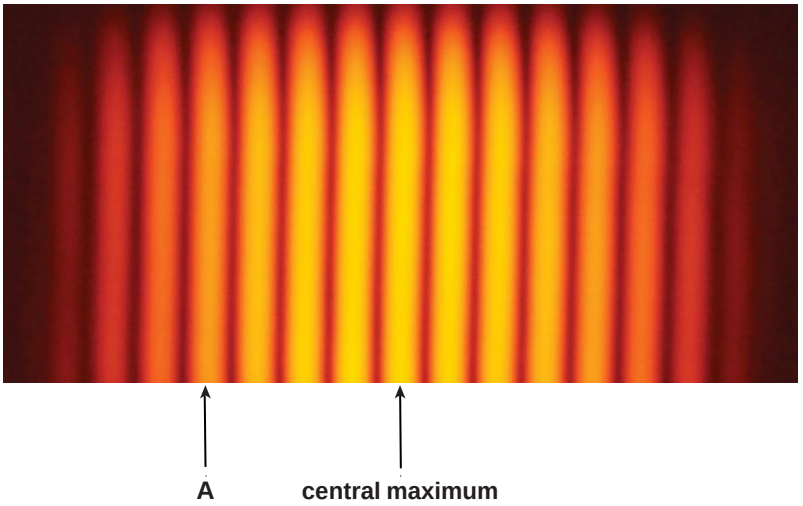
_____ (2 marks)

8. The image below shows a two-slit interference pattern.



Source: adapted from Kuiper, P 2010, 'File:SodiumD two double slits.jpg', *Wikimedia Commons, the free media repository*, viewed 26 February 2019, https://commons.wikimedia.org

Explain how the bright fringe labelled **A** was produced.

(3 marks)

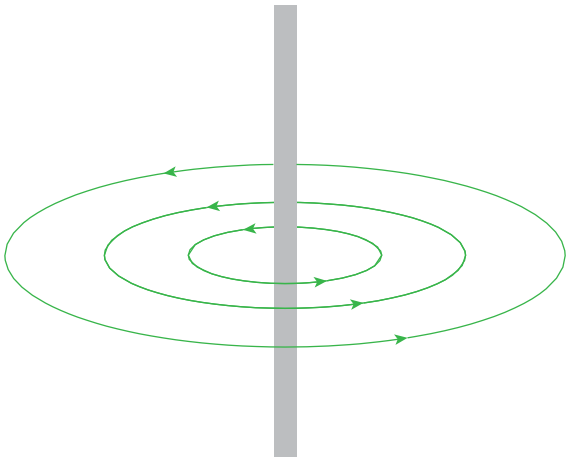
9. A particular solenoid is made up of 100 conducting loops. The solenoid is positioned within an external magnetic field of magnitude $3.2 \times 10^{-4}\,\text{T}$. The area of the loops perpendicular to the magnetic field is $2.8 \times 10^{-3}\,\text{m}^2$.

   The strength of the magnetic field is decreased to zero in a time of $6.4 \times 10^{-5}\,\text{s}$.

   Determine the electromotive force (*emf)* induced in the solenoid during this time.

(3 marks)

10. The diagram below shows the magnetic field lines produced by an electric current flowing in a straight conductor.



[*This diagram is not drawn to scale.*]

(a) *On the diagram above*, show the direction of the current that produces these magnetic field lines. (1 mark)

(b) A current of 0.57A is flowing in the straight conductor.

Calculate the magnitude of the magnetic field $0.012\ \text{m}$ from this conductor.

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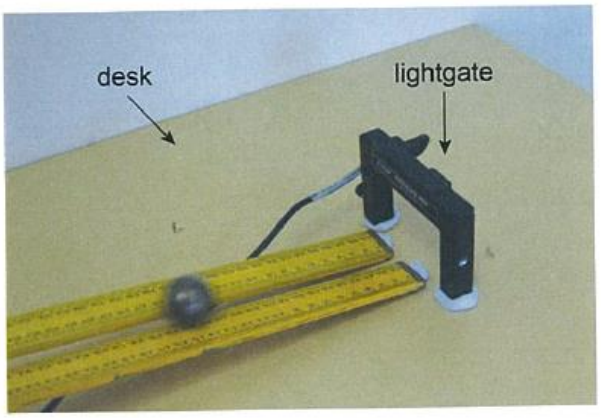
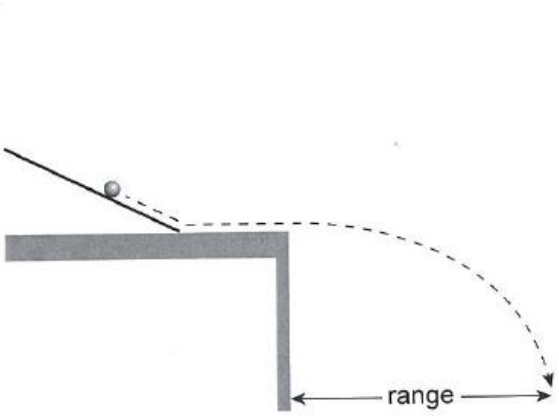
_____ (2 marks)

11. A group of high-school students was asked to determine an appropriate method for investigating the design of a water slide. People slide down a water slide, and at the end of the slide they are projected horizontally and then land in a swimming pool.

Source: © Olena Buyskykh | Dreamstime.com

For their investigation, the students decided to roll a ball bearing down a shallow incline. A lightgate connected to a computer measured the speed of the ball bearing immediately before it travelled along a horizontal section of a desk, as shown in the photograph below. After it left the desk, the ball bearing followed the path of a projectile, as shown in the diagram below.





[*This diagram is not drawn to scale.*]

The students made the following hypothesis:

> *The range of the ball bearing is directly proportional to the speed of the ball bearing measured by the lightgate.*

The students measured the range of the ball bearing for a number of different speeds.

(a) (i) State *one* way in which the speed of the ball bearing could be changed.

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_____ (1 mark)

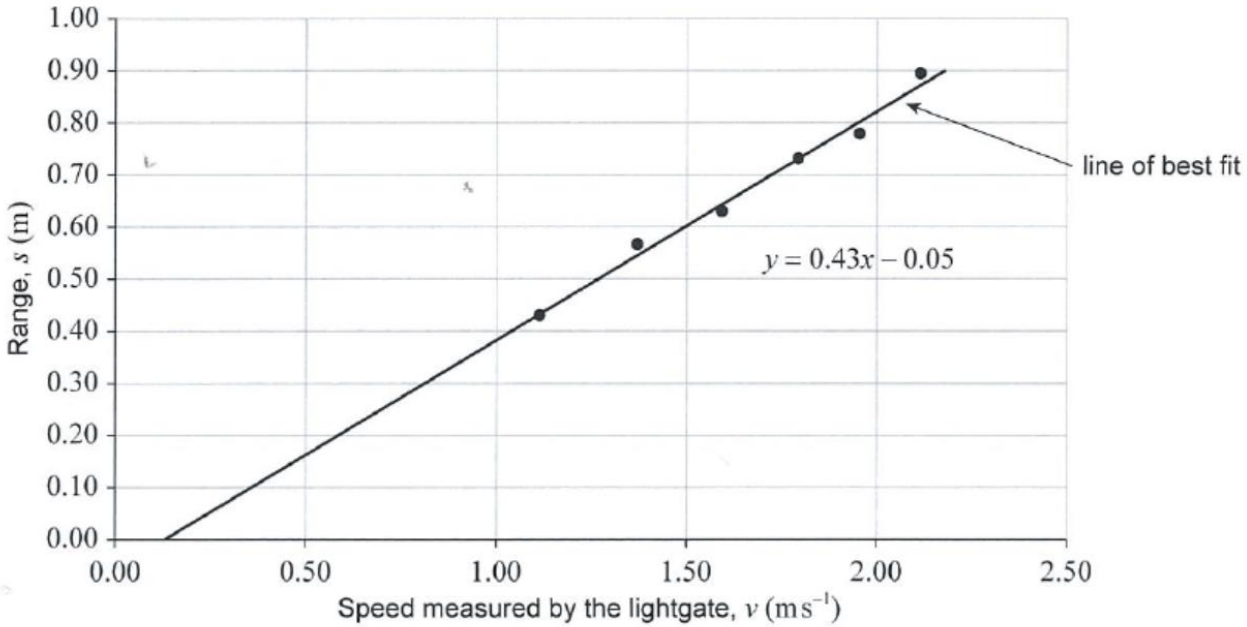
(ii) State why the speed of the ball bearing measured by the lightgate was the *independent* variable in this investigation.

(1 mark)

(iii) Identify *one* factor that the students may ***not*** have been able to control during their investigation, and suggest *one* effect that this may have had on the results.

(2 marks)

(b) The graph below shows the results obtained from the investigation.



Using the information in the graph above, state whether or not the results support the students' hypothesis. Justify your answer.

(2 marks)

(c) Software was used to create the graph shown in part (b). This software calculated that the equation of the line of best fit is

$$y = 0.43x - 0.05.$$

(i) Explain how the gradient of the line of best fit shows that the time of flight of the ball bearing was 0.43 s.

(2 marks)

(ii) Using the gradient of the line of best fit, determine the height of the desk.

(3 marks)

(d) Some people think that it is appropriate to use a ball bearing when investigating the design of water slides. Other people think that this is inappropriate.

Justify *one* of these opinions.

(3 marks)

12. Muons are a type of lepton. A particular muon travels at a constant speed of $0.990\,c$.

(a) Show that the Lorentz factor of this muon is $\gamma = 7.09$.

(2 marks)

(b) The muon has a lifetime of $2.20\ \mu s$ in its own frame of reference before it decays.

(i) Calculate the distance travelled by the muon, in its own frame of reference, before it decays.

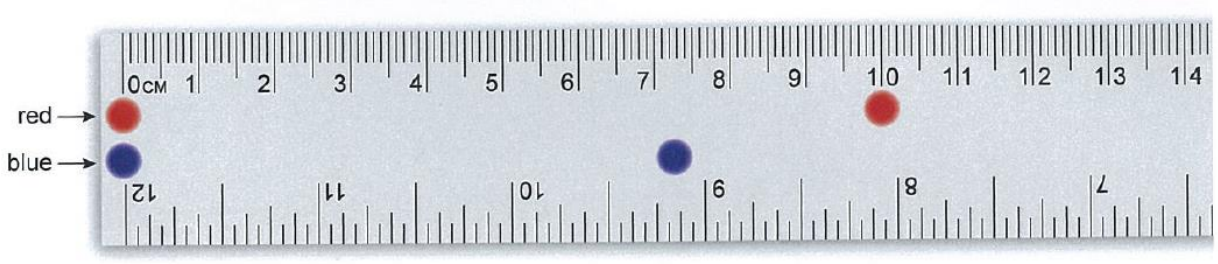
(2 marks)

(ii) Calculate the distance travelled by the muon, in the frame of reference of a stationary observer, before it decays.

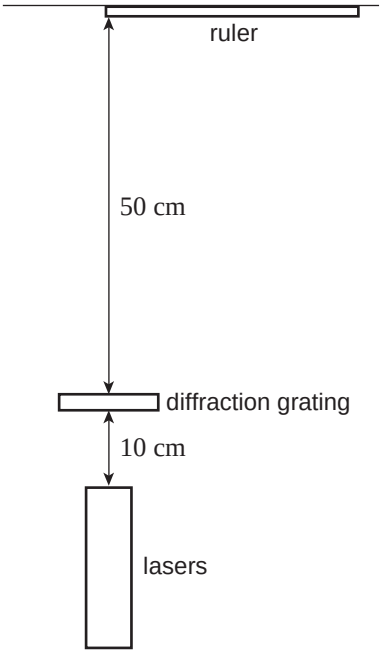
(3 marks)

13. An experiment was conducted using one laser that produced red light and one laser that produced blue light. Each laser projected light through the same diffraction grating at the same time.

The image below shows the central maximum and the first-order maximum for each laser on a ruler.



The ruler was placed 50 cm from the diffraction grating, as shown in the diagram below.



[*This diagram is not drawn to scale.*]

(a) Show that:

- the first-order maximum of the red laser light occurred at an angle of $11°$
- the first-order maximum of the blue laser light occurred at an angle of $8.2°$.

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_____ (2 marks)

(b) The red laser light has a wavelength of $650\ \text{nm}$.

Determine the distance between the slits in the diffraction grating, and hence determine the wavelength of the blue laser light.

(5 marks)

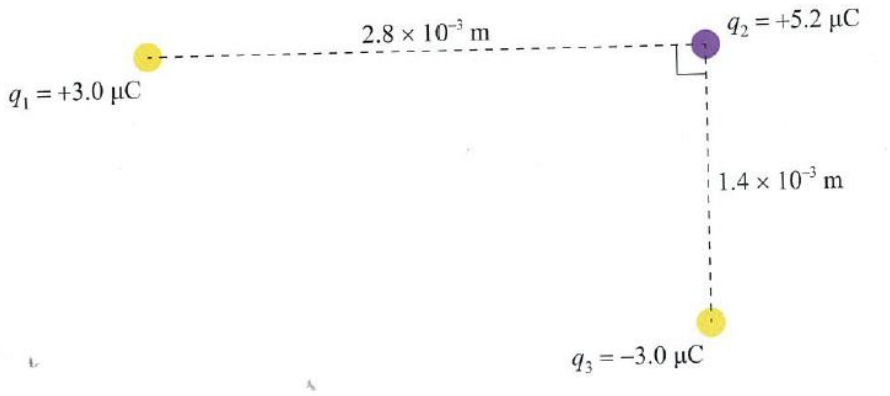
14. The diagram below shows three point charges:

$$q_1 = +3.0\ \mu C$$
$$q_2 = +5.2\ \mu C$$
$$q_3 = -3.0\ \mu C.$$

The point charges are placed in a vacuum, in the arrangement shown below, so that:

q_1 is 2.8×10^{-3} m from q_2

q_3 is 1.4×10^{-3} m from q_2.



(a) Show that the force that q_1 exerts on q_2 has a magnitude of $F_1 = 1.8 \times 10^4$ N.

(2 marks)

(b) Using proportionality, determine the magnitude of the force that q_3 exerts on q_2.

(2 marks)

(c) (i) In the space below, draw a labelled vector diagram that shows the sum of the two forces, $\vec{F}_{\text{Total}}$, exerted on q_2.

(3 marks)

(ii) Hence determine the magnitude of the total force exerted on q_2.

(1 mark)

15. Monochromatic light (Light source 1) was projected onto a metal surface, causing electrons to be emitted. The maximum kinetic energy of the emitted electrons was measured.

Light source 1 was replaced with Light source 2. This resulted in a greater number of electrons being emitted. The maximum kinetic energy of these emitted electrons was the same as those emitted as a result of Light source 1.

Using the law of conservation of energy, compare the intensity and frequency of these two light sources.

(3 marks)

16. A spacecraft is orbiting the Earth.

(a) The mass of the Earth is $5.97 \times 10^{24}\,\text{kg}$.

Calculate the speed of the spacecraft when it is in a circular orbit of radius $7.22 \times 10^{6}\,\text{m}$ around the Earth.

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_____ (2 marks)

The spacecraft can be put into an elliptical 'transfer' orbit (Diagram 1). The spacecraft can then be put into a circular orbit of a larger radius (Diagram 2).

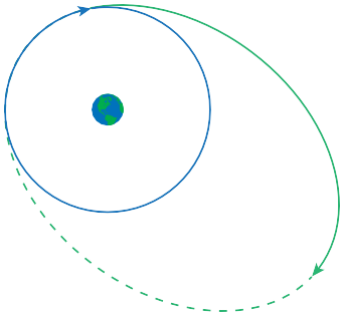


Diagram 1

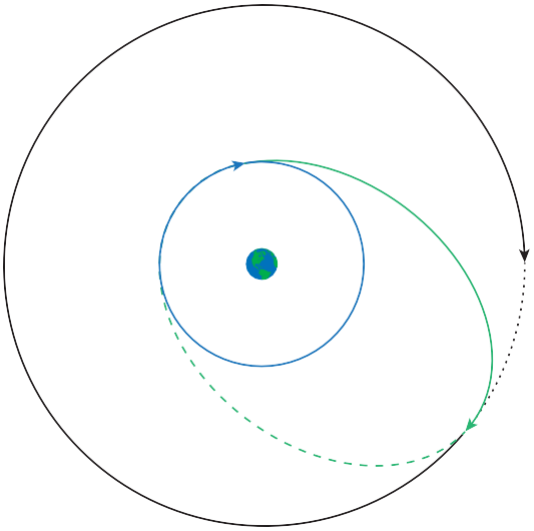


Diagram 2

[*These diagrams are not drawn to scale.*]

(b) • Using the law of conservation of momentum, explain how the speed of a spacecraft can be increased.

• Using Kepler's Second Law of Planetary Motion, explain why a spacecraft travels at different speeds during an elliptical orbit.

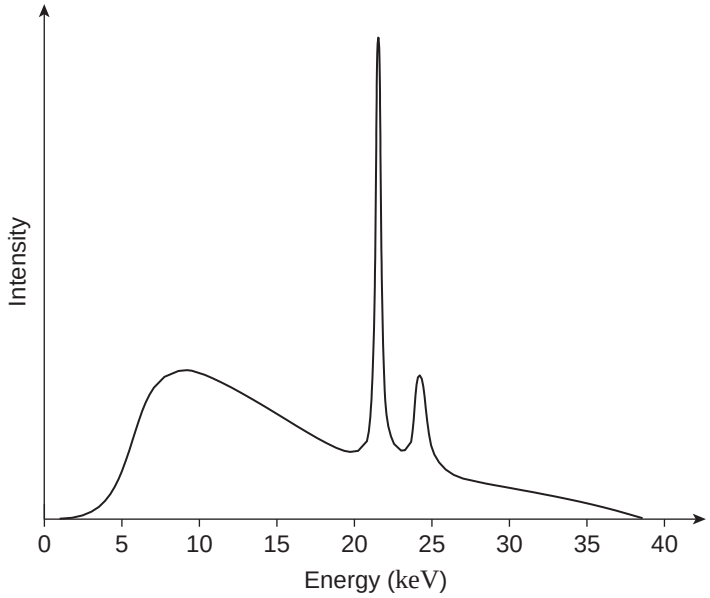
(6 marks)

17. (a) An X-ray tube is operating at a voltage of $38\,\text{kV}$.

Determine the maximum frequency of X-rays emitted by this tube.

(2 marks)

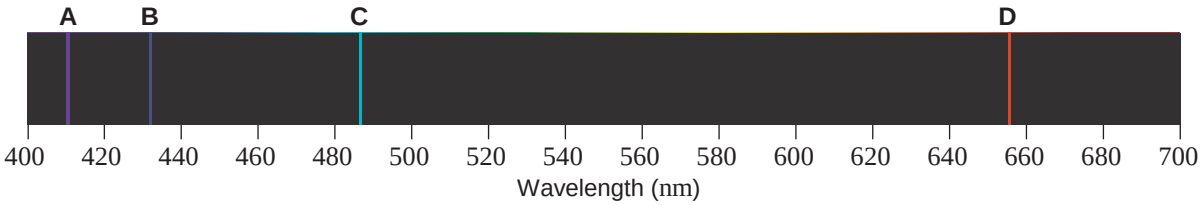
(b) The graph below shows a typical spectrum of X-rays emitted by this tube.



Explain how the characteristic X-rays within a spectrum are produced.

(2 marks)

18. The image below shows a section of the line emission spectrum of hydrogen. The lines have been labelled **A**, **B**, **C**, and **D**.



(a) Using $v = f\lambda$, show that photons that have an energy of 4.6×10^{-19} J can be found in the line emission spectrum of hydrogen.

(3 marks)

(b) Explain how line emission spectra can be used to identify which elements are present in a mixture of gases.

(2 marks)

19. (a) A kaon is a particle that is made up of one quark and one antiquark. Neutral kaons, K^0, can decay into a positive pion, π^+, and another particle, X, as shown below.

$$K^0 \rightarrow \pi^+ + X$$

The table below shows the properties of some subatomic particles. Particle X is one of these particles.

	Charge (e)	Baryon number	Lepton number
mesons			
K^0	0	0	0
π^+	1	0	0
π^-	–1	0	0
baryons and antibaryons			
proton	1	1	0
neutron	0	1	0
antiproton	–1	1	0
antineutron	0	1	0
leptons			
electron	–1	0	1
muon	–1	0	1
tau	–1	0	1

Identify which *one* of the subatomic particles in the table above is particle X. Justify your answer.

(3 marks)

(b)

Scientists believe that equal amounts of matter and antimatter should have been created in the big bang. Within the known universe, virtually everything is made up of matter. In comparison, there is very little antimatter to be found. This 'matter / antimatter asymmetry' is one of the mysteries that scientists seek to solve.

One proposed explanation is that different amounts of matter and antimatter may exist in different areas of the universe. However, astronomers have been unsuccessfully searching the universe for regions of antimatter for many decades, which suggests that this explanation is unlikely to be true.

Scientists are using the Large Hadron Collider (LHC) to discover why some antimatter seems to be 'missing' from the universe. High-energy collisions, which are only possible when using powerful particle accelerators such as the LHC, can be used to explore the ways in which antimatter behaves differently from matter.

The LHC is operated by CERN (the European Organization for Nuclear Research). CERN consists of 22 member countries from Europe, and it has cooperation agreements with non-member countries including Australia, China, and Vietnam.

Using the information above, describe *three* examples of how the search for, and the study of, antimatter demonstrates science as a human endeavour.

(6 marks)

20. A hockey ball was hit from one player to another, as shown in the diagram below.

[*This diagram is not drawn to scale.*]

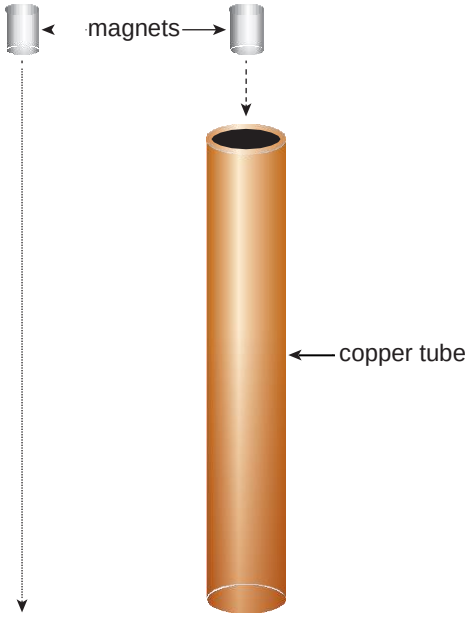
Source: adapted from Shokunin 2018, 'Grass hockey PNG icon', viewed 26 February 2019, www.iconspng.com

The ball left the ground at a speed of $12\ \text{m s}^{-1}$, at an angle of $23°$ above the horizontal.

Determine the horizontal distance travelled by the hockey ball before it landed.
Ignore air resistance in this question.

(5 marks)

21. Two magnets were held at the same height above the ground. Both magnets were dropped, with one magnet falling through a copper tube, as shown in the diagram below.

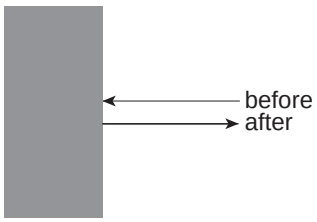


[*This diagram is not drawn to scale.*]

Using Lenz's Law, explain why the magnet that fell through the copper tube hit the ground at a lower speed than the other magnet.

(3 marks)

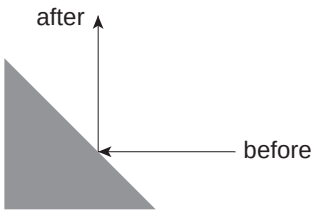
22. An air particle of mass 5.6×10^{-26} kg and speed 522 m s^{-1} collided with a surface. The initial velocity of the air particle was perpendicular to the surface. The air particle rebounded, without losing speed, as shown in the diagram below.



(a) Calculate the magnitude and direction of the change in momentum of the air particle.

(3 marks)

(b) Another air particle, with the same mass and speed, collided with a wedge-shaped surface. The initial velocity of the particle was $45°$ to the surface. The air particle was deflected, without losing speed, as shown in the diagram below.

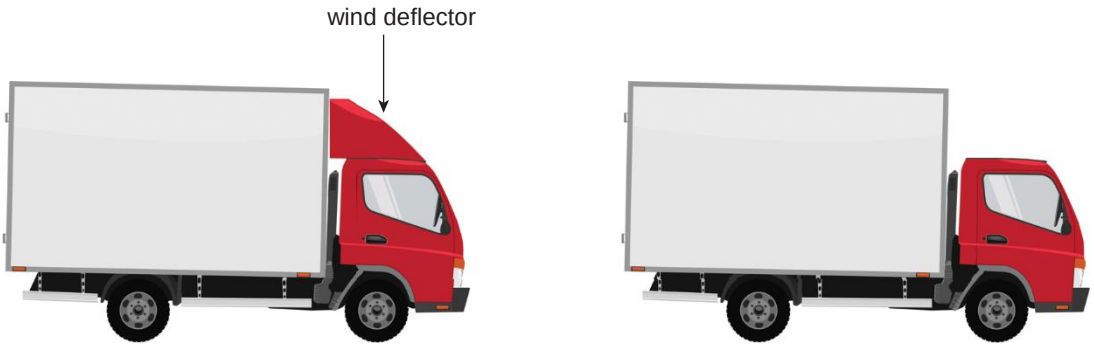


Show that the magnitude of the change in momentum of this air particle is 4.1×10^{-23} kg ms^{-1}.

(2 marks)

(c) The diagrams below show two diesel-fuelled trucks (A and B). Truck A has a wind deflector installed. The trucks are otherwise identical.

Truck A **Truck B**



Source: adapted from © Zeynur Babayev | Dreamstime.com

Using your answers to part (a) and part (b), explain why the wind deflector would allow Truck A to use less diesel than Truck B when travelling at the same speed.

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_____ (2 marks)