South Australian
Certificate of Education

1

Physics
2021

Question booklet 1

- Questions 1 to 10 (60 marks)
- Answer ***all*** questions
- Write your answers in this question booklet
- You may write on page 17 if you need more space
- Allow approximately 65 minutes

Examination information

Materials
- Question booklet 1
- Question booklet 2
- Formula sheet
- SACE registration number label

Instructions
- Use black or blue pen
- You may use a sharp dark pencil for diagrams and other representations
- Approved calculators may be used

Total time: 130 minutes
Total marks: 120

Attach your SACE registration number label here

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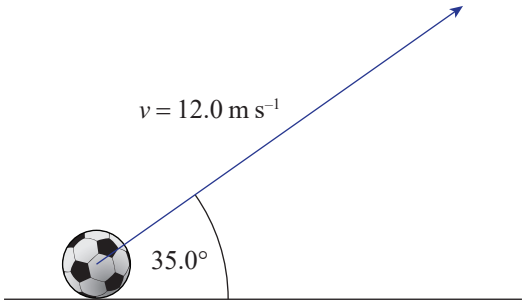
1. A ball on the ground was kicked, giving it a speed of $12.0\ \text{m s}^{-1}$ at an angle of $35.0°$ above the horizontal, as shown in the diagram below.



Ignore air resistance for part (a).

(a) (i) Show that the initial vertical speed was $6.88\ \text{m s}^{-1}$.

_____

_____ (1 mark)

(ii) Show that the ball reached its maximum height after $0.702\ \text{s}$.

_____

_____

_____

_____ (2 marks)

(iii) Determine the maximum height that the ball reached.

_____

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_____

_____ (2 marks)

(b) Explain the effect of air resistance on the maximum height reached by the ball.

_____

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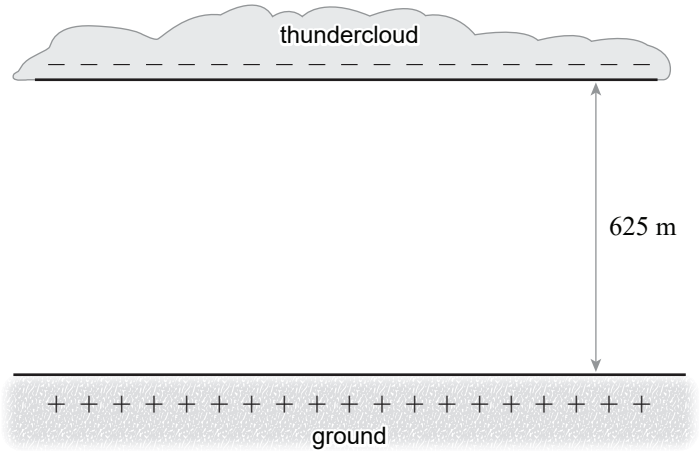
_____

_____ (3 marks)

2. The air currents within a thundercloud can cause an electric field to form between the base of the thundercloud and the ground. This electric field may be considered to be uniform.

The diagram below shows the base of a thundercloud that is $625\ \text{m}$ above the ground.



(a) On the diagram above, sketch the electric field lines between the ground and the base of the thundercloud. (2 marks)

The potential difference between the ground and the base of the thundercloud is $1.00\ \text{GV}$.
The distance between the ground and the base of the thundercloud is $625\ \text{m}$.

(b) Show that the magnitude of the electric field between the ground and the base of the thundercloud is $1.60 \times 10^6\ \text{V m}^{-1}$.

_____

_____

_____

_____ (1 mark)

(c) Calculate the magnitude of the electric force on an electron located within this electric field.

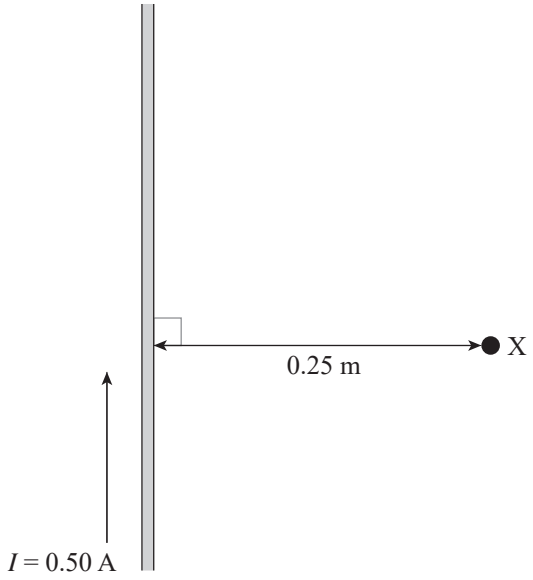
_____

_____

_____

_____ (2 marks)

3. The diagram below shows a straight conductor that is carrying a current of $0.50\ \text{A}$, which is flowing in the direction indicated. Point X is located $0.25\ \text{m}$ from the centre of the conductor.



[This diagram is not drawn to scale.]

The current flowing through the conductor produces a magnetic field.

(a) (i) Show that the magnitude of the magnetic field at X is $4.0 \times 10^{-7}\ \text{T}$.

_____

_____

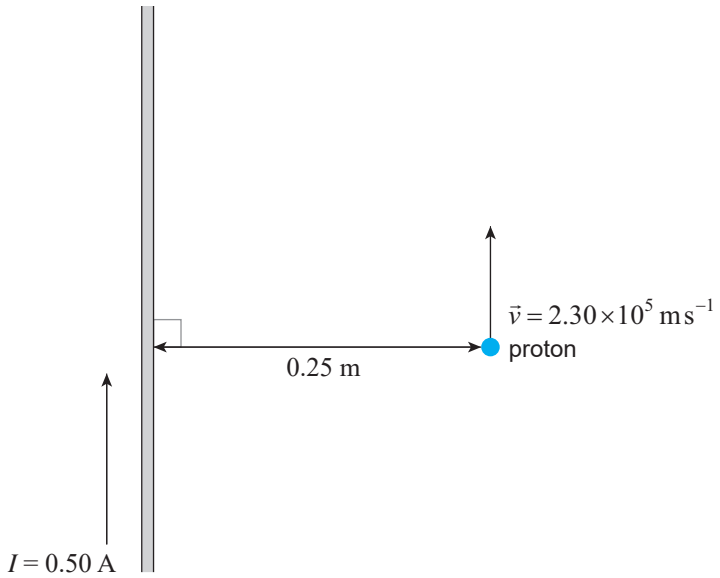
_____ (1 mark)

(ii) State the direction of the magnetic field at X.

_____

_____ (1 mark)

(b) A proton enters the magnetic field. As it passes point X, the velocity of the proton is $2.30 \times 10^5\ \text{m s}^{-1}$, parallel to the conductor, as shown in the diagram below.



[This diagram is not drawn to scale.]

(i) Calculate the magnitude of the force acting on the proton due to the magnetic field at X.

_____

_____

_____

_____ (2 marks)

(ii) State the direction of the force acting on the proton due to the magnetic field at X.

_____

_____ (1 mark)

4. The Sun emits light in a continuous spectrum. Absorption lines (Fraunhofer lines) may be observed when this light is analysed. Fraunhofer lines occur due to the absorption of some photons as the light passes through the outer gas layers of the Sun.

The images below show:

- some of the Fraunhofer lines in the absorption spectrum of the Sun
- the emission spectrum of iron
- the emission spectrum of krypton.

Fraunhofer lines

Iron emission spectrum

Krypton emission spectrum

State which *one* of these two elements — iron or krypton — is more likely to be present in the outer gas layers of the Sun. Give a reason for your answer.

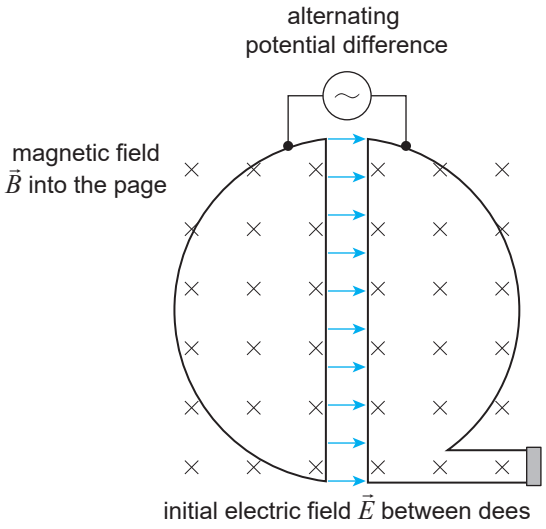
_____

_____

_____

_____ (2 marks)

5. A cyclotron with an alternating potential difference of $50.0\ \text{kV}$ is used to accelerate a particle that has a charge of $1.60 \times 10^{-19}\ \text{C}$. The magnitude of the magnetic field within the dees is $2.20\ \text{T}$.



[This diagram is not drawn to scale.]

(a) Calculate the work done on the particle each time it crosses the gap between the dees.

(2 marks)

(b) The particle exits the cyclotron with a kinetic energy of $2.67 \times 10^{-11}\ \text{J}$. The radius of the cyclotron is $1.20\ \text{m}$.

Determine the mass of the particle.

(3 marks)

6. The satellite *Mangalyaan* is in an elliptical orbit around Mars. The image below depicts the satellite *Mangalyaan* orbiting Mars.

Source: adapted from National Aeronautics Space Administration, European Space Agency & Space Telescope Science Institute 2018, 'Mars opposition', *Hubblesite*, viewed 26 March 2021, https://hubblesite.org/; and Indian Space Research Organisation (ISRO) 2013, 'Mars orbiter mission spacecraft', *ISRO*, viewed 16 April 2021, https://www.isro.gov.in/

The mass of *Mangalyaan* is 511 kg and the mass of Mars is $6.42 \times 10^{23} \text{ kg}$.

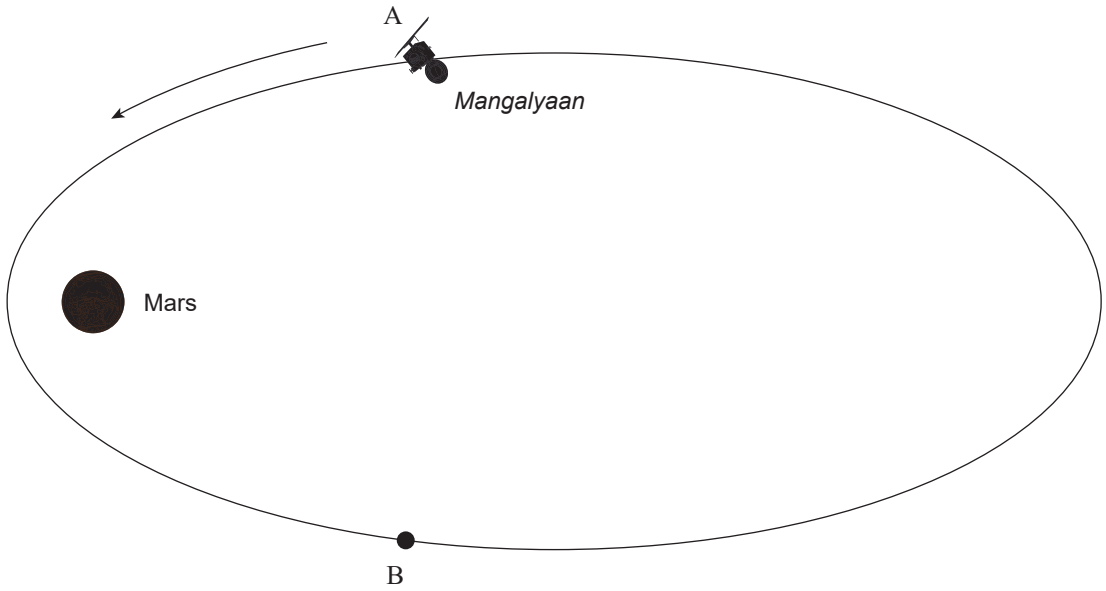
(a) Calculate the magnitude of the gravitational forces between Mars and *Mangalyaan* when *Mangalyaan* is at a distance of 3811 km from the centre of Mars.

(3 marks)

(b) Explain how the gravitational forces between Mars and *Mangalyaan* are consistent with Newton's Third Law of Motion.

(2 marks)

(c) When close enough to Mars, a camera positioned on *Mangalyaan* can take clear images of the surface of Mars. The camera is only close enough to Mars when *Mangalyaan* moves from point A to point B in the direction shown on the diagram below.



[This diagram is not drawn to scale.]

Using *one* of Kepler's Laws, explain why the time taken for *Mangalyaan* to move from point A to point B is much shorter than the time taken for *Mangalyaan* to move from point B to point A.

_____

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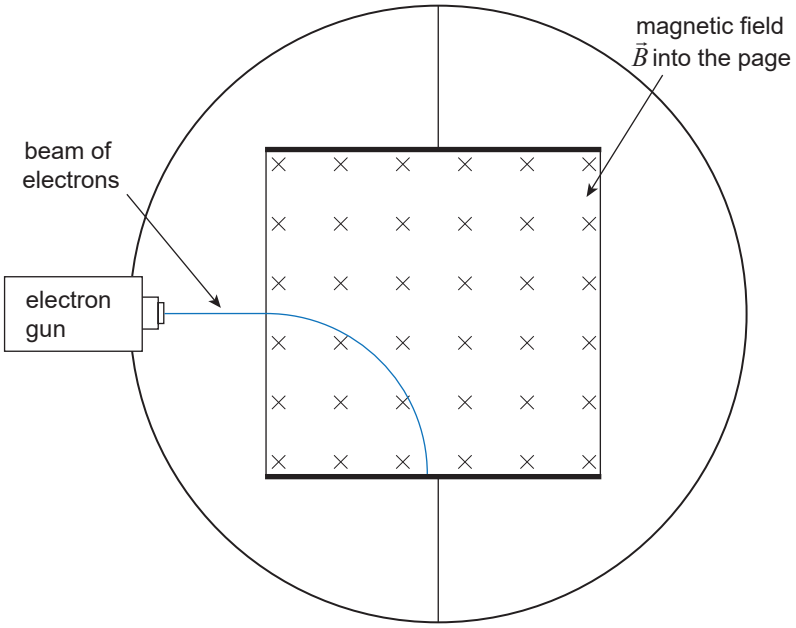
_____ (3 marks)

7. A Teltron® tube uses an electron gun to produce a straight beam of electrons. These electrons are directed into a uniform magnetic field. The velocity of the electrons is perpendicular to the magnetic field. The electrons then undergo uniform circular motion, as shown in the diagram below.



[This diagram is not drawn to scale.]

Ignore the effects of air resistance in this question.

(a) Explain why the electrons undergo uniform circular motion when in the magnetic field.

_____

_____

_____

_____

_____

_____ (3 marks)

(b) The magnitude of the magnetic field is $B = 4.40\ \text{mT}$ and the radius of the circular path of the electrons is $0.050\ \text{m}$.

Calculate the magnitude of the velocity of the electrons when they are in the magnetic field.

_____

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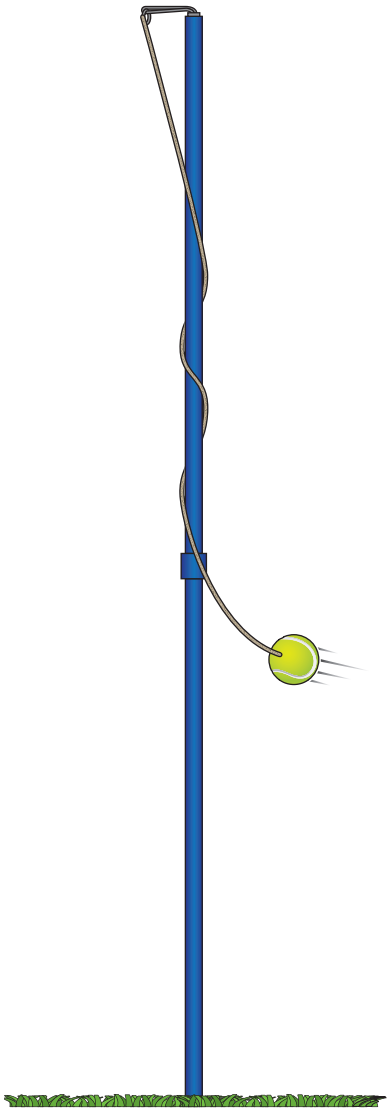
_____

_____

_____ (3 marks)

8. A group of students undertook a deconstruction and design activity. The students observed a ball connected to a rope that was wound around a pole, as shown in the image below. When the ball was struck, the speed of the ball continuously changed as the rope unwound from the pole.



(a) Identify *two* variables that may affect the speed of the ball as the rope unwinds from the pole.

_____

_____

_____

_____ (2 marks)

(b) Design a method to investigate *one* of the variables you identified in part (a).

(5 marks)

9. Capella Space is a company that launches and operates satellites. This company's satellites collect global images that are of significantly higher resolution than images collected by other satellites. The images are collected each hour, and are not significantly affected by smoke, clouds, or air pollution. The images can also be collected at night.

The images are transmitted to the Earth as electromagnetic waves. This allows scientists to constantly monitor the Earth and to respond to environmental challenges such as oil spills, forest fires, and crop production levels.

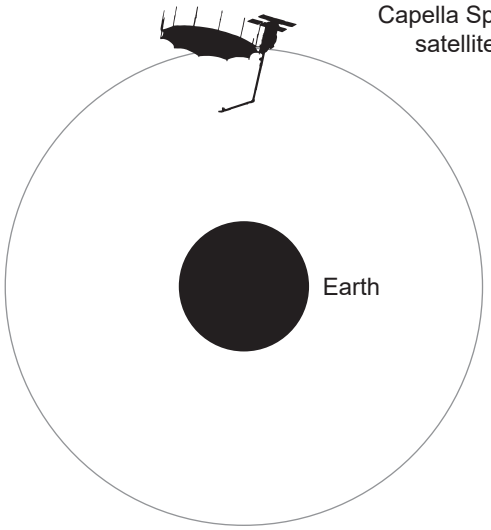
Capella Space is part of the SpaceNet™ partnership that provides satellite imagery for researchers and developers to use in the fields of conservation, security services, and mapping.

Source: Spacewatch.global 2020, 'Capella Space reveals innovative satellite design for its high-res SAR imagery service', 21 January, viewed 14 May 2021, https://spacewatch.global, © Capella Space

(a) Use *two* key concepts of science as a human endeavour to describe how Capella Space and its satellites show the interaction between science and society.

(4 marks)

(b) The image below shows a Capella Space satellite orbiting at an altitude of 4.99×10^5 m above the surface of the Earth.



[This diagram is not drawn to scale.]

Source: adapted from Spacewatch.global 2020, 'Capella Space reveals innovative satellite design for its high-res SAR imagery service', 21 January, viewed 14 May 2021, https://spacewatch.global, © Capella Space

Assume that the satellite moves in a circular orbit.

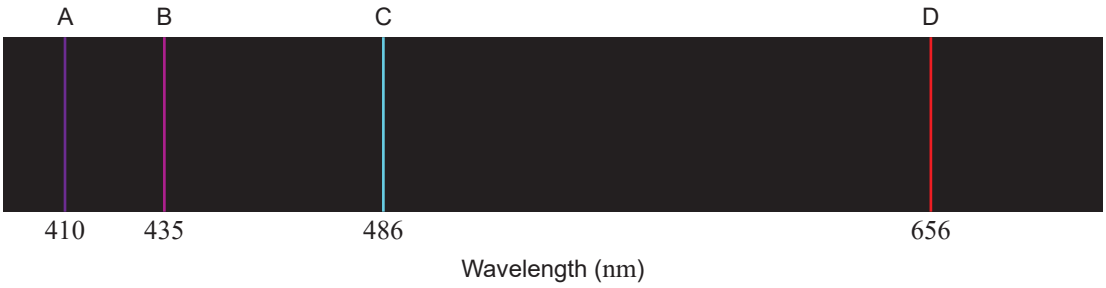
(i) Show that the speed of the satellite is 7.61×10^3 m s^{-1}.

(2 marks)

(ii) Calculate the orbital period of the satellite.

(2 marks)

10. Four of the visible lines in the emission spectrum of hydrogen are shown in the image below. The lines are labelled A, B, C, and D. The wavelength of each line is also shown.



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

Each of these four lines is produced when electrons transition down to the $n = 2$ energy level in hydrogen.

(a) Determine which *one* of the four lines — A, B, C, or D — corresponds to photons that are produced when electrons transition from the $n = 3$ to the $n = 2$ energy level.

(3 marks)

(b) Hence, determine the energy of the photons that are produced when electrons transition from the $n = 3$ to the $n = 2$ energy level.

(3 marks)

You may write on this page if you need more space to finish your answers to any of the questions in this question booklet. Make sure to label each answer carefully (e.g. 9(a) continued).

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Physics
2021

Question booklet 2

- Questions 11 to 19 (60 marks)
- Answer ***all*** questions
- Write your answers in this question booklet
- You may write on page 14 if you need more space
- Allow approximately 65 minutes

2

Copy the information from your SACE label here

SEQ	FIGURES	CHECK LETTER	BIN

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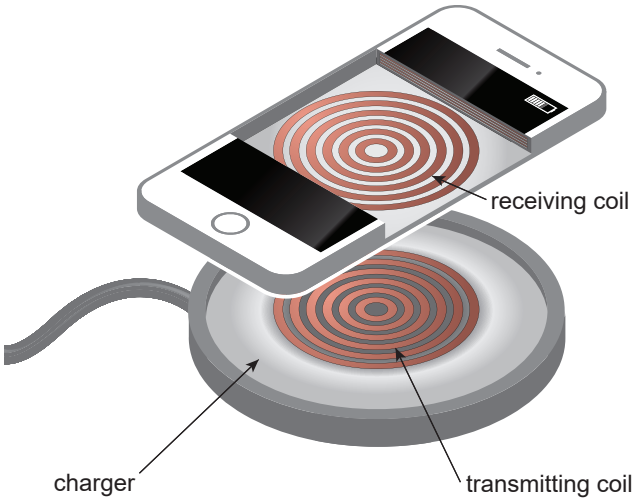
11. The battery in many types of mobile phone can be charged wirelessly using electromagnetic induction. The charger contains a transmitting coil, and the phone contains a receiving coil that is connected to the battery in the phone, as shown in the diagram below.



Source: based on Belkin n.d., 'How inductive wireless charging works', Belkin, viewed 16 April 2021, https://www.belkin.com/au/

An alternating current flows through the transmitting coil of the charger. The battery begins to charge when the receiving coil in the phone is placed near the transmitting coil of the charger.

(a) Explain how the alternating current in the transmitting coil induces an *emf* in the receiving coil.

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_____

_____ (3 marks)

(b) Explain why the induced *emf* in the receiving coil decreases when the phone is placed further away from the transmitting coil.

_____

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_____

_____ (2 marks)

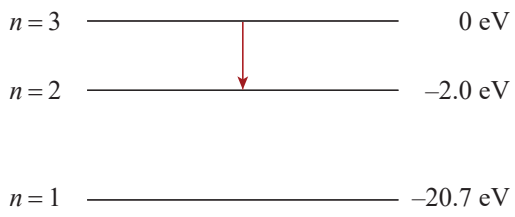
12. Lasers use the process of stimulated emission to produce light.

(a) Compare the process of stimulated emission with that of ordinary (or spontaneous) emission.

(3 marks)

In a helium–neon laser, light is produced when neon undergoes stimulated emission from its metastable state $n = 3$ to the $n = 2$ energy level.

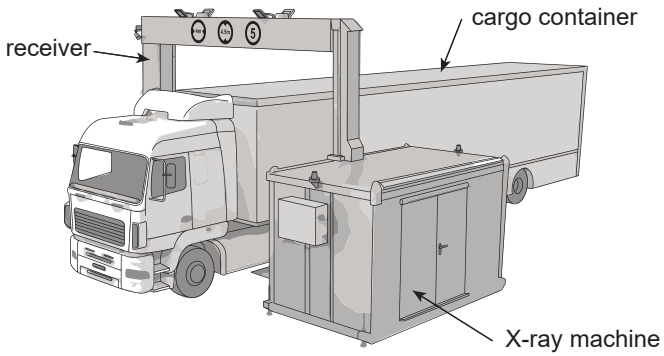
The energy levels of neon are shown in the diagram below.



(b) Using the information on the diagram above, determine the frequency of the light.

(3 marks)

13. X-rays can be used to scan the contents of a cargo container, as shown in the diagram below. The X-rays must have sufficiently high penetrating power to pass through the steel structure of the container so that they can be detected by a receiver on the opposite side of the container. Different contents of the container, such as organic and metallic materials, attenuate the X-rays differently.



Source: based on Westminster Group PLC n.d., 'WG container and cargo X-ray scanning portal', Westminster Group PLC, viewed 26 March 2021, https://www.wi-ltd.com

(a) (i) Explain why an X-ray spectrum from an X-ray tube has a maximum frequency.

_____

_____

_____

_____

_____

_____

_____ (3 marks)

(ii) An X-ray tube in an X-ray scanner has an operating voltage of 7.50×10^6 V.

Calculate the maximum frequency of the X-rays produced by this X-ray tube.

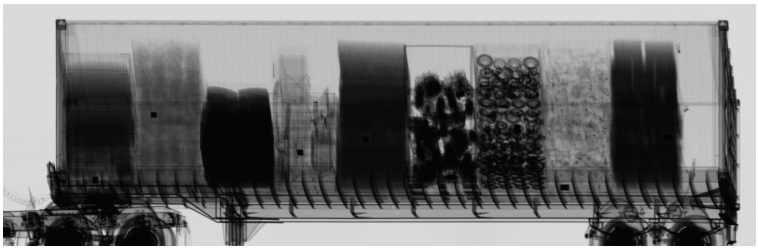
_____

_____

_____

_____ (2 marks)

(b) The image below shows an X-ray scan of the contents of a cargo container.



Source: adapted from Bendahan J 2017, 'Vehicle and cargo scanning for contraband', *Physics procedia,* vol. 90, p 244, Science Direct, viewed 12 August 2021, https://www.sciencedirect.com, published by Elsevier B.V. CC BY-NC-ND 4.0

State *one* adjustment that could be made to the X-ray tube to produce a clearer image of the contents of the container. Justify your answer.

_____

_____

_____

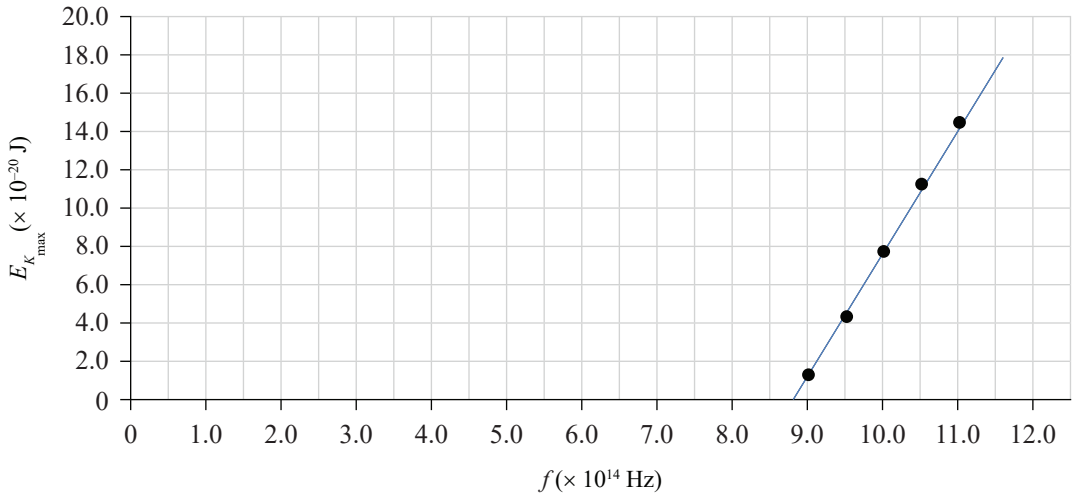
_____

_____

_____ (3 marks)

14. A group of students did an experiment to determine the work function of magnesium, using five monochromatic light sources of different frequencies. The students projected each light source separately onto a magnesium surface and measured the maximum kinetic energy of the electrons emitted for each light source.

The graph below shows the results obtained by the students. A line of best fit has been included.



(a) (i) Use the graph to estimate the threshold frequency for magnesium.

_____

_____ (1 mark)

(ii) Hence determine a value for the work function of magnesium. Give your answer in eV.

_____

_____

_____

_____

_____

_____ (3 marks)

(b) The accepted value for the work function of magnesium is $3.66\ \mathrm{eV}$.

Explain whether or not the work function calculated in part (a)(ii) is accurate.

_____

_____

_____

_____ (2 marks)

(c) The students then shone light of frequency 1.60×10^{15} Hz on the magnesium surface.

Calculate the maximum kinetic energy of an electron that was emitted from the magnesium surface.

_____

_____

_____

_____ (3 marks)

15. The diagram below shows three point charges:

$$q_1 = +2.6 \times 10^{-6} \text{ C}$$

$$q_2 = +4.1 \times 10^{-6} \text{ C}$$

$$q_3 = +5.2 \times 10^{-6} \text{ C}.$$

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

q_1 is 1.20 m from q_2
q_3 is 0.30 m from q_2.

(a) Show that the magnitude of the electric force that q_1 exerts on q_2 is $F_1 = 0.067$ N.

(2 marks)

(b) Using proportionality, show that the magnitude of the electric force that q_3 exerts on q_2 is $F_2 = 2.1$ N.

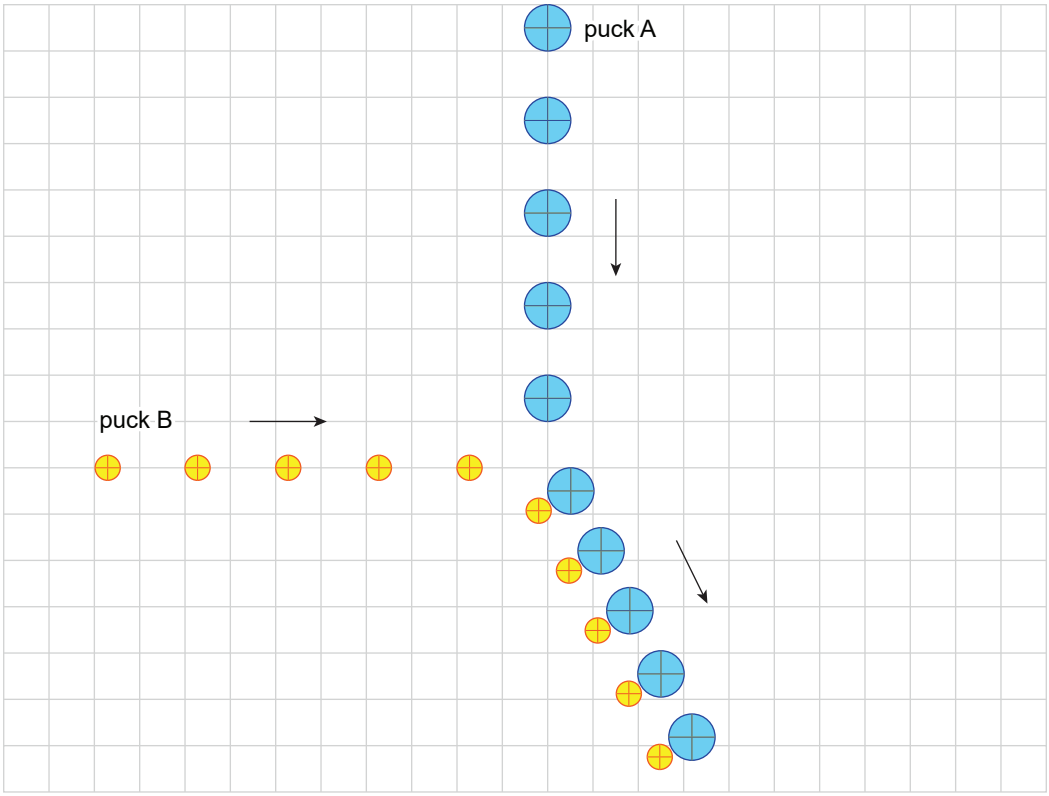
(3 marks)

(c) Hence determine the magnitude and direction of the total electric force that q_1 and q_3 exert on q_2.

(2 marks)

16. The motion of two pucks on an air table is shown in the multi-image diagram below. The mass of puck A is $2m$, and the mass of puck B is m.

Puck A was initially moving south before it collided with puck B, which was initially moving east. During the collision, the pucks joined and moved together in the direction shown. The time between each image is constant.



(a) On the diagram above, draw and label vectors that represent the momentum of:

- puck A before the collision
- puck B before the collision
- the joined pucks A and B after the collision.

(3 marks)

(b) Hence determine whether or not momentum was conserved during the collision.

_____

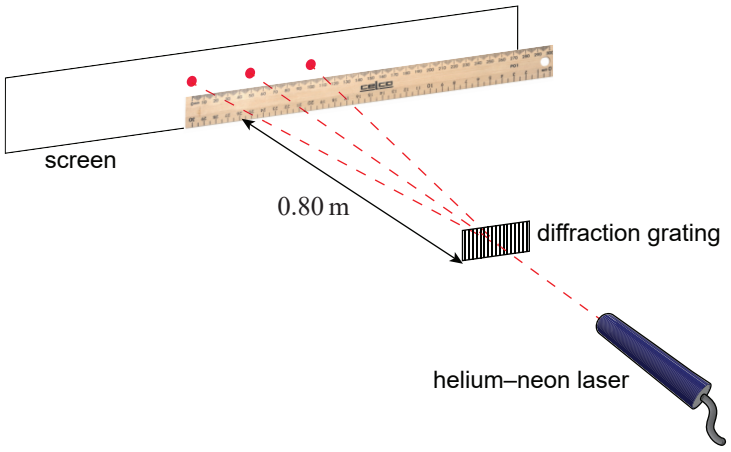
_____

_____

_____ (2 marks)

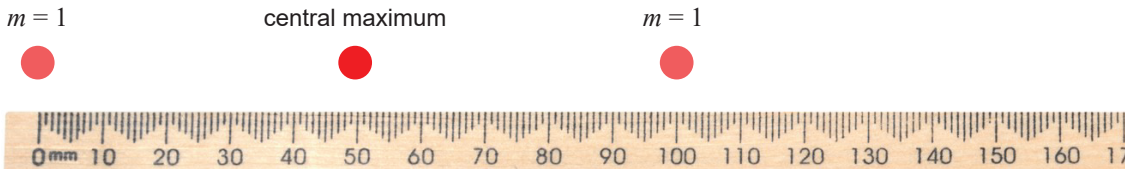
17. A student undertook an experiment to determine the wavelength of the light from a helium–neon laser. The student used a diffraction grating containing 100 slits per mm, and the grating was positioned $0.80\ \text{m}$ from the screen.

The diagram below shows the experimental arrangement used by the student.



[This diagram is not drawn to scale.]

The image below shows the distances between the central maximum and the first orders of the diffraction pattern that was observed on the screen.

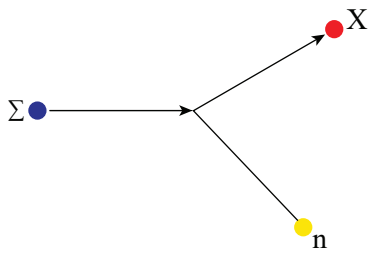


[This diagram is drawn to scale.]

Using this information, determine the wavelength of the helium–neon laser light.

(5 marks)

18. One type of sigma particle, Σ, decays into a neutron, n, and one other particle, X, as shown in the diagram below.



The quark composition of this sigma particle is dds.

(a) Determine whether particle X is a baryon, lepton, or meson.

_____

_____

_____

_____

_____

_____ (3 marks)

(b) Determine whether particle X is positively charged, negatively charged, or neutral.

_____

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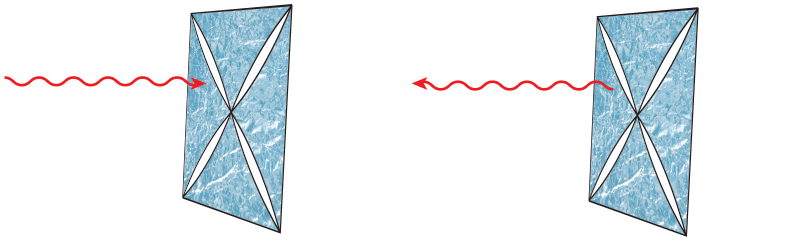
_____

_____ (2 marks)

19. 'Breakthrough Starshot' is a proposed mission in which a nano-spacecraft carrying a very small camera would be sent to the Alpha Centauri star system. The nano-spacecraft would be accelerated when light from a high-powered laser on Earth is incident on a solar sail on the nano-spacecraft.

The diagram below shows light being reflected perpendicularly from a solar sail with no loss of energy.



light incident on solar sail light reflected from solar sail

(a) Show that the magnitude of the change in momentum of a photon reflected from the solar sail is given by the formula below.

$$\Delta p = \frac{2hf}{c}$$

(3 marks)

(b) Using the formula given in part (a), determine the magnitude of the net force exerted on the solar sail if 9.30×10^{12} photons with a frequency of 5.17×10^{14} Hz are reflected from the solar sail in 1.70×10^{-10} s.

(4 marks)

(c) The laser would only be used until the nano-spacecraft reaches a speed of $6.00 \times 10^7\ \mathrm{m\,s^{-1}}$.

Show that a nano-spacecraft travelling at $v = 6.00 \times 10^7\ \mathrm{m\,s^{-1}}$ has a Lorentz factor of $\gamma = 1.02$.

(1 mark)

(d) After the nano-spacecraft reaches $v = 6.00 \times 10^7\ \mathrm{m\,s^{-1}}$, its speed will remain constant. Travelling at this speed, it would take 19.0 years to reach Alpha Centauri, as measured in the frame of reference of the Earth.

Determine the time taken to reach Alpha Centauri, as measured in the frame of reference of the nano-spacecraft.

(2 marks)

You may write on this page if you need more space to finish your answers to any of the questions in this question booklet. Make sure to label each answer carefully (e.g. 13(a)(ii) continued).