South Australian
Certificate of Education

1

Physics
2019

Question booklet 1

- Questions 1 to 9 (59 marks)
- Answer ***all*** questions
- Write your answers in this question booklet
- You may write on page 13 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: 119

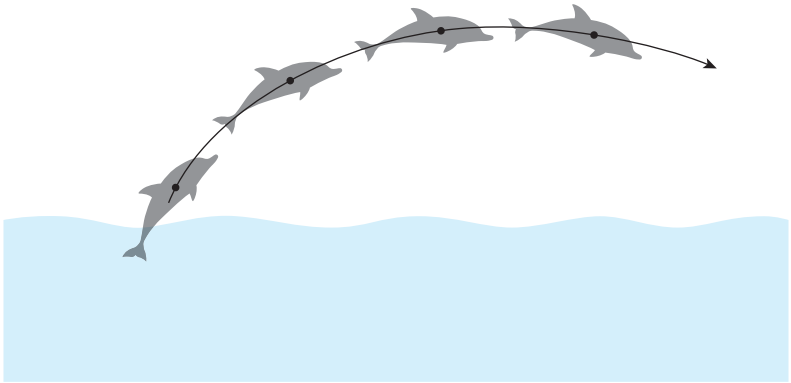
Attach your SACE registration number label here

Government
of South Australia

1. The photograph below shows a dolphin that has jumped out of the water.

Source: © Mariamichelle | Pixabay.com

The multi-image diagram below shows a dolphin jumping out of the water and following the path of a projectile.



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

The dolphin jumped out of the water with an initial velocity of $9.5\ \text{m s}^{-1}$ at an angle of $72°$ above the horizontal.

Ignore air resistance in all parts of this question.

(a) Show that the magnitude of the initial vertical component of the velocity was $9.0\ \text{m s}^{-1}$.

_____

_____

_____ (1 mark)

(b) Show that the time taken for the dolphin to reach its maximum height was 0.92 s.

(2 marks)

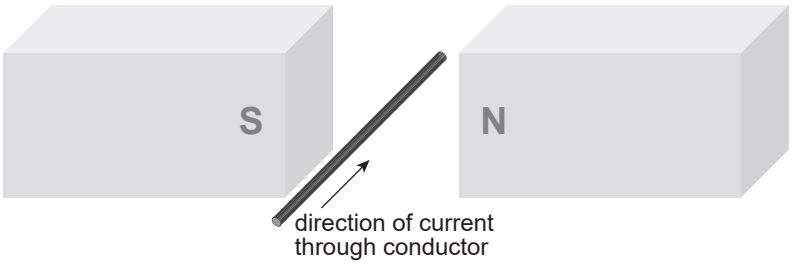
(c) Determine the maximum height reached by the dolphin.

(3 marks)

(d) Determine the horizontal distance travelled by the dolphin while it was out of the water.

(3 marks)

2. A straight conductor is positioned between the poles of two magnets, as shown in the diagram below. The conductor is perpendicular to the magnetic field between the two poles.



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

A current of $1.2\ \text{A}$ flows through the conductor, in the direction shown on the diagram.

The length of conductor within the magnetic field is $2.5 \times 10^{-2}\ \text{m}$.

The magnitude of the magnetic field between the poles of the magnets is $7.5 \times 10^{-3}\ \text{T}$.

(a) *On the diagram above*, show the direction of the magnetic force on the conductor. (1 mark)

(b) Determine the magnitude of the magnetic force on the conductor.

_____

_____

_____

_____ (2 marks)

3. A proton entered a uniform magnetic field that had a magnitude of $0.76\ \mathrm{T}$. The initial velocity of the proton was $2.3 \times 10^{6}\ \mathrm{m\,s^{-1}}$ perpendicular to the magnetic field.

(a) (i) Explain why the proton travelled in a circular path at a constant speed.

_____

_____

_____

_____

_____

_____ (3 marks)

(ii) Determine the radius of the circular path taken by the proton.

_____

_____

_____

_____

_____

_____ (2 marks)

(b) Calculate the de Broglie wavelength of the proton.

_____

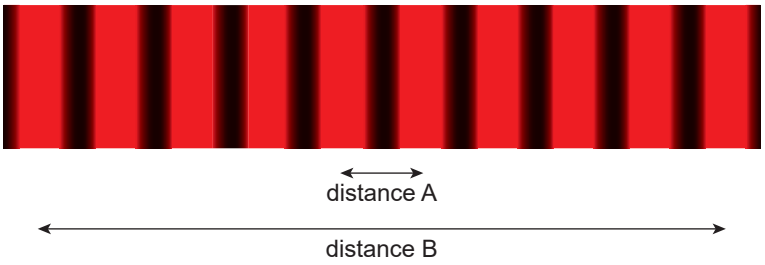
_____

_____

_____

_____ (3 marks)

4. Two students conducted a two-slit experiment to determine the wavelength of the red light produced by a laser. The distance between the slits was 1.2×10^{-4} m. The diagram below shows the pattern that was produced on a screen that was positioned 1.9 m from the slits.



When determining the distance between adjacent maxima, one student measured distance A and found that it was 11 mm. The other student measured distance B and found that it was 91 mm.

(a) Explain why measuring distance B demonstrates better experimental skills than measuring distance A.

_____

_____

_____

_____

_____ (2 marks)

(b) (i) Distance B was used in a calculation of the distance between adjacent maxima.

Show that the result was $\Delta y = 1.0 \times 10^{-2}$ m.

_____

_____

_____ (1 mark)

(ii) Determine the wavelength of the light used in the experiment.

_____

_____

_____

_____

_____

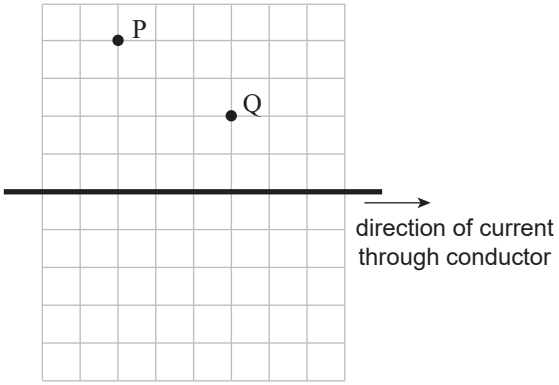
_____

_____ (3 marks)

(c) Explain how the bright fringes in the pattern on page 6 were produced.

(2 marks)

5. The diagram below shows a straight conductor. A current flows through the conductor, in the direction shown below.



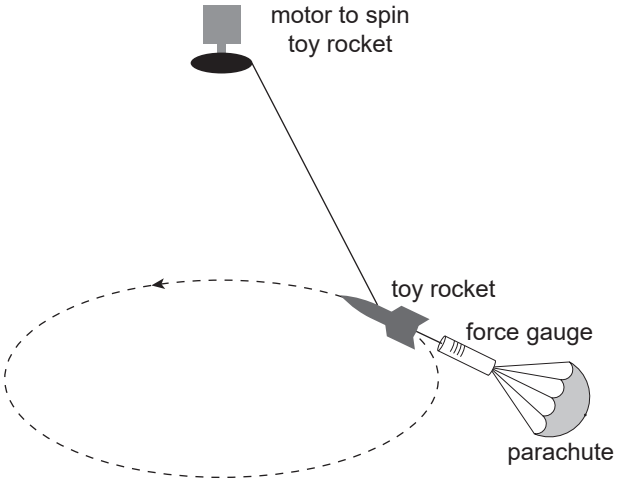
At point P, the magnitude of the magnetic field due to the current is $3.4\ \mu T$.

Using proportionality, determine the magnitude of the magnetic field at point Q.

(3 marks)

6. A group of students investigated the relationship between the radius, r, of a circular parachute and the drag force due to the air resistance that the parachute creates.

The students attached a parachute and a force gauge to a toy rocket, as shown in the diagram below. An adjustable electric motor was used to spin the toy rocket in a horizontal circular path.

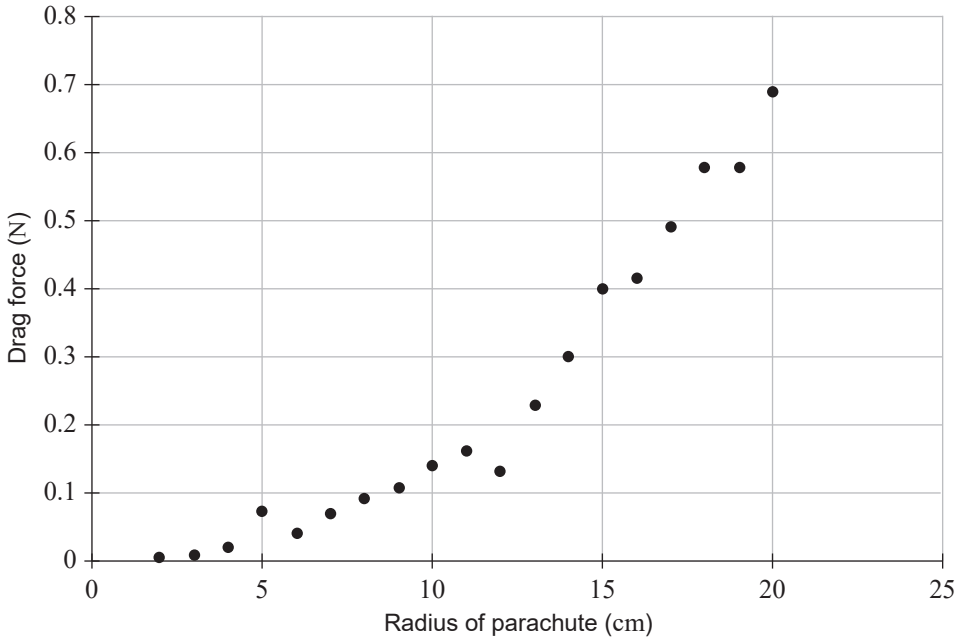


[*This diagram is not drawn to scale.*]

The force gauge was used to measure the drag force.

The students used other parachutes of different radii and repeated the measurement of the drag force. The motor was adjusted to try to keep the toy rocket travelling at the same speed in each test.

The data collected in the investigation are shown in the graph below.



(a) State how the graph on page 8 shows that the drag force was ***not*** directly proportional to the radius of the parachute.

_____

_____

_____ (1 mark)

(b) (i) State the type of error evident in the graph.

_____ (1 mark)

(ii) Identify *one* possible source of this type of error in this investigation.

_____

_____

_____ (1 mark)

(c) Describe how the students could use the data collected in the investigation to show a linear relationship.

_____

_____

_____

_____ (2 marks)

7. In 2013, three Swarm satellites were launched to study the Earth's magnetic field. The satellites orbit the Earth in circular, polar orbits.

Two of the satellites, Swarm A and Swarm C, orbit $462\ \text{km}$ above the Earth's surface.

The third satellite, Swarm B, orbits at a larger radius than the other two satellites.

(a) (i) Calculate the speed of Swarm A.

(3 marks)

(ii) Swarm B completes 15.1 orbits in 1 day (86 400 seconds).

Determine the radius of the orbit of Swarm B.

(4 marks)

(iii) Suggest *one* reason why polar orbits were selected for the Swarm satellites.

(1 mark)

(iv) Explain why the centre of these circular orbits must coincide with the centre of the Earth.

(3 marks)

(b)

The European Space Agency (ESA) used a Russian rocket to launch the three Swarm satellites. The Swarm satellites monitor and measure the Earth's magnetic field, helping scientists to understand how it is changing.

ESA's Swarm mission manager, Rune Floberghagen, has said that 'What we see here is a striking example of a technical challenge being turned into exciting science'.†

Using recently engineered technologies, the Swarm satellites carry a range of instruments to collect highly accurate data about the Earth's magnetic field. Using these data, historical data, and new modelling techniques, scientists are able to measure the Earth's magnetic field to significant depths below the Earth's crust and also within the ionised part of the upper atmosphere. These data have led to a better understanding of the movement of tectonic plates. Scientists can also use the data to predict changes in the Earth's magnetic field and to analyse 'space weather' events such as the auroras.

† European Space Agency 2016, 'Swarm reveals why GPS satellites lose track over the equator between Africa and South America', *Phys.org*, viewed 11 July 2019, https://phys.org/news/2016-10-swarm-reveals-gps-satellites-track.html

(i) Identify *one* key concept of science as a human endeavour that is evident in the quote from Rune Floberghagen. Justify your answer.

(2 marks)

(ii) Describe *two* other examples of how the Swarm satellite project demonstrates science as a human endeavour.

(4 marks)

8. The work function of a selenium surface is $5.9\ \text{eV}$.

Determine if ultraviolet light that has a frequency of $7.9 \times 10^{14}\ \text{Hz}$ can cause electrons to be emitted from the selenium surface via the photoelectric effect.

(3 marks)

9. One possible decay of a negatively charged tau particle, τ^-, produces two mesons (a charged pion, π^-, and a neutral pion, π^0) and a tau neutrino, ν_τ.

The reaction below shows this decay.

$$\tau^- \longrightarrow \pi^- + \pi^0 + \nu_\tau$$

Show that this decay obeys the laws of:

- conservation of charge
- conservation of lepton number
- conservation of baryon number.

(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. 4(c) continued).

South Australian
Certificate of Education

Physics
2019

Question booklet 2

- Questions 10 to 21 (60 marks)
- Answer ***all*** questions
- Write your answers in this question booklet
- You may write on page 13 if you need more space
- Allow approximately 65 minutes

2

Copy the information from your SACE label here

SEQ	FIGURES	CHECK LETTER	BIN

Government
of South Australia

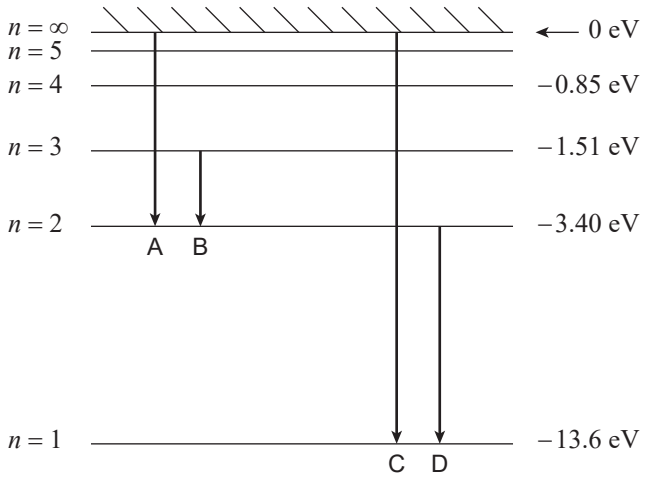
10. The diagram below shows some of the energy levels of hydrogen.

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

(a) Determine whether or not hydrogen at room temperature would absorb photons that have an energy of $1.89\ \text{eV}$.

(3 marks)

The diagram below shows four transitions (A, B, C, and D) in a hydrogen atom.



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

(b) (i) Identify which *two* transitions shown on the diagram above would produce ultraviolet photons.

_____ (1 mark)

(ii) Identify which of the two transitions that you identified in part (i) would produce the ultraviolet photon that has the *longer* wavelength.

_____ (1 mark)

(c) Determine the wavelength of the photons that would be emitted when hydrogen atoms undergo transition D.

_____

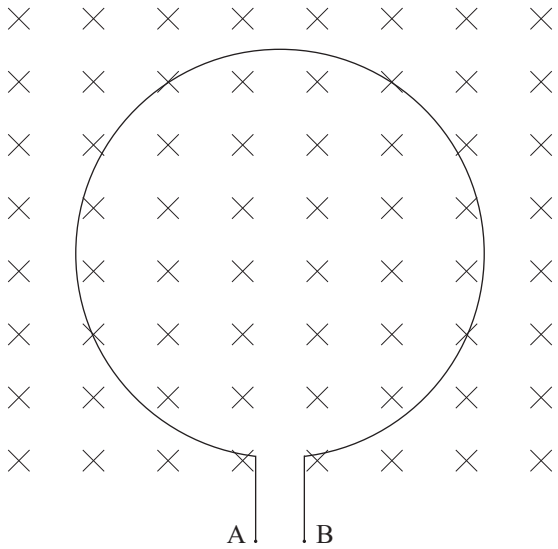
_____

_____

_____

_____ (3 marks)

11. A circular conducting loop of area 5.0×10^{-3} m^2 was located within a uniform magnetic field. Two points on the loop are labelled A and B. The loop was perpendicular to the magnetic field, as shown in the diagram below.



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

The magnitude of the magnetic field was increased uniformly from 0.040 T to 0.12 T in a time of 3.0 s.

(a) Determine the magnitude of the electromotive force (*emf*) induced between points A and B.

_____

_____

_____

_____

_____

_____ (3 marks)

(b) In order to measure the current induced in the loop, an ammeter was placed between points A and B.

Using Lenz's Law, determine whether this current flowed clockwise or anticlockwise.

_____

_____

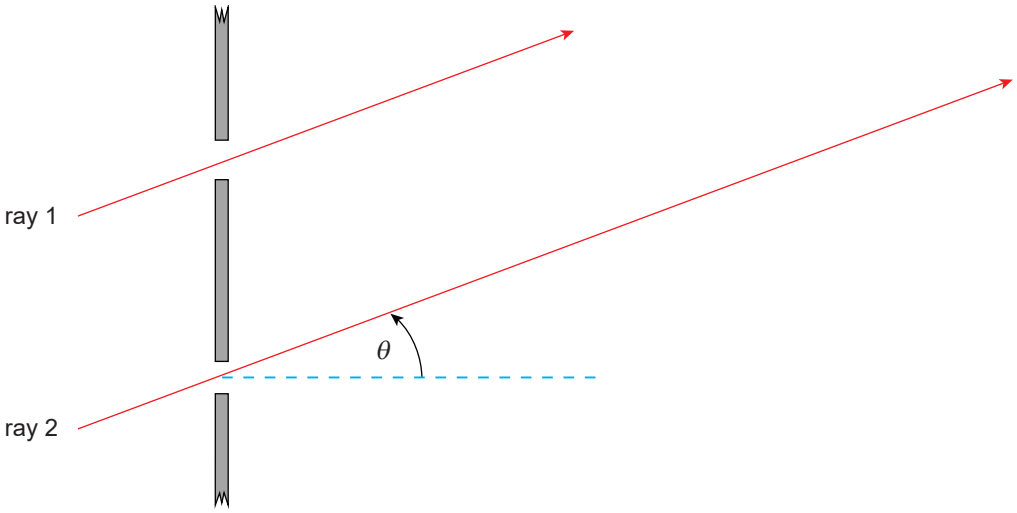
_____

_____

_____

_____ (3 marks)

12. The diagram below shows two rays of monochromatic light incident on a diffraction grating. Each ray passed through a different slit in the diffraction grating.



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

The m^{th} maximum in the interference pattern occurs when rays 1 and 2 constructively interfere. This maximum occurs at angle θ.

(a) Show that $d \sin\theta = m\lambda$, where d is the distance between the slits in the diffraction grating.

(3 marks)

(b) The light has a wavelength of 5.89×10^{-7} m and the diffraction grating contains 300 slits per mm.

Determine the angular position of the third-order maxima.

(3 marks)

13. The potential difference across a simple X-ray tube was set to $12\ \mathrm{kV}$ in order to produce an X-ray image.

(a) Calculate the maximum frequency in the spectrum of the X-rays produced by this X-ray tube.

(2 marks)

(b) A veterinarian used this X-ray tube to examine a dog's paw.

The images below show two X-rays of the paw.

X-ray image 1

X-ray image 2

Source: adapted from © Northernprairie | Dreamstime.com

The veterinarian was unable to use X-ray image 1 to diagnose any problems with the dog's paw. She made an adjustment to the X-ray tube, which then produced X-ray image 2.

State *one* adjustment that may have been made to the X-ray tube, and explain how this produced the clearer image.

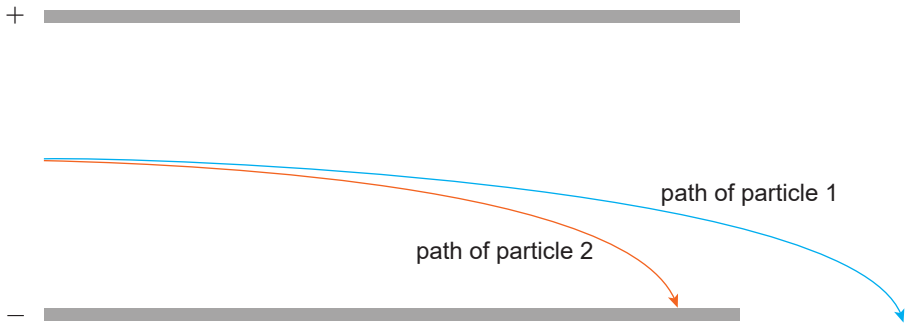
Adjustment:

Explanation:

(3 marks)

14. The diagram below shows the paths of two positively charged particles that moved through the electric field between two parallel plates.

Ignore the effect of gravity in this question.



The two particles entered the electric field with the same velocity, which was initially perpendicular to the electric field. The positive charge on each particle was the same magnitude.

Determine which particle (particle 1 or particle 2) had the greater mass. Justify your answer.

_____

_____

_____

_____

_____ (3 marks)

15. Many modern cars have rain sensors that automatically turn on the windscreen wipers when there is water on the windscreen. Within the sensors, light from an LED source is reflected onto a photoelectric cell. When there is water on the windscreen, less light reflects onto the photoelectric cell.

Describe any effects on the number, and the maximum kinetic energy, of electrons emitted in a photoelectric cell when the intensity of the incident light is reduced.

_____

_____

_____

_____

_____

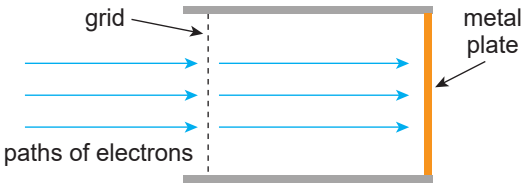
_____

_____ (3 marks)

16. The Parker Solar Probe has been launched to study the Sun. The probe will orbit the Sun several times. During some of these orbits it will travel through the Sun's atmosphere.

(a) The probe contains a Faraday cup that collects moving charged particles emitted by the Sun. Once in the cup, the charged particles pass through a grid and move towards a metal plate, as shown in the diagram below. When the charged particles strike the metal plate, a current is detected.

When the Faraday cup collects electrons, a potential difference of $3200\ \text{V}$ is set up between the grid and the metal plate, which *slows* the electrons before they strike the metal plate.



(i) State whether the metal plate must be positive or negative relative to the grid in order to *slow* the electrons.

_____ (1 mark)

(ii) Determine the minimum speed that an electron must be travelling at in order to move through the potential difference of $3200\ \text{V}$ and strike the metal plate.

_____

_____

_____

_____

_____

_____

_____

_____ (4 marks)

(b) Due to the gravitational pull of the Sun, the Parker Space Probe will become the fastest-ever engineered object. It is predicted to travel at speeds of approximately $192\,000\ \text{m s}^{-1}$.

Determine whether or not travelling at a speed of $192\,000\ \text{m s}^{-1}$ would produce any significant relativistic effects.

_____

_____

_____

_____

_____

_____ (3 marks)

17. When playing the game of pool, players may want the white cue ball to collide with a coloured ball and then have these two balls move in different directions.

The photograph shows a white cue ball about to collide slightly off-centre with an orange ball.

Source: adapted from © Hxdylzj | Dreamstime.com

The mass of each of these two balls is $0.17\ \text{kg}$.

Before the collision, the white cue ball moved at a speed of v and the orange ball was stationary.

After the collision, the white cue ball moved with a speed of $0.28\ \text{m s}^{-1}$ and the orange ball moved with a speed of $0.53\ \text{m s}^{-1}$. When viewed from above, the directions of the two balls before and after the collision are shown in the diagrams below.

before collision **after collision**

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

Using the law of conservation of momentum, determine the speed of the white cue ball before the collision.

Assume that no outside forces act during the collision.

(5 marks)

18. (a) Describe the effects on the momentum of a subatomic particle when it is accelerated to speeds that are close to the speed of light.

(2 marks)

(b) Hence state why subatomic particles cannot be accelerated to the speed of light.

(1 mark)

19. A cyclotron was used to accelerate positive ions that have a charge of 1.6×10^{-19} C and a mass of 1.7×10^{-27} kg. There was a potential difference of 2.5 kV between the dees of the cyclotron, and a magnetic field of magnitude 1.7 T within the dees of the cyclotron.

The ions completed 4200 full revolutions before they emerged from the cyclotron.

Determine the radius at which the ions emerged from the cyclotron.

(4 marks)

20. The photograph below shows a skydiver.

Source: © The Skydiver | Dreamstime.com

The skydiver jumped out of an aircraft, and eventually reached terminal velocity.

Explain how the net force on the skydiver changed during this time.

_____

_____

_____

_____

_____

_____ (3 marks)

21. A helium nucleus contains two protons. The distance between the centres of the protons is 3.8×10^{-15} m.

Treat the protons as stationary point charges in all parts of this question.

(a) (i) Calculate the magnitude of the repulsive electric forces between the two protons.

(2 marks)

(ii) State how protons are held within a nucleus despite these repulsive forces.

(1 mark)

(b) Using the concepts of **fields** and **gauge bosons**, provide *two* explanations for how two protons exert electric forces on each other, despite not being in contact.

(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. 17 continued).

PHYSICS FORMULA SHEET

Vectors are indicated by arrows. If only the magnitude of a vector quantity is used, the arrow is not used.

Symbols of common quantities

acceleration	$\vec{a}$	force	$\vec{F}$	magnetic flux	Φ	time	t
charge	q	frequency	f	mass	m	velocity	$\vec{v}$
displacement	$\vec{s}$	kinetic energy	E_K	momentum	$\vec{p}$	wavelength	λ
electric current	I	length	l	period	T		
electromotive force	emf	magnetic field	$\vec{B}$	potential difference	ΔV		

Magnitude of physical constants

acceleration due to gravity at the Earth's surface	$g = 9.80\ \text{m s}^{-2}$	Planck's constant	$h = 6.63 \times 10^{-34}\ \text{J s}$
constant of universal gravitation	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$	charge of the electron	$e = 1.60 \times 10^{-19}\ \text{C}$
speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$	mass of the electron	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
Coulomb's Law constant	$\frac{1}{4\pi\varepsilon_0} = 9.00 \times 10^{9}\ \text{N m}^2\ \text{C}^{-2}$	mass of the proton	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
constant for the magnetic field around a conductor	$\frac{\mu_0}{2\pi} = 2.00 \times 10^{-7}\ \text{T m A}^{-1}$	mass of Earth	$5.97 \times 10^{24}\ \text{kg}$
		mean radius of Earth	$6.37 \times 10^{6}\ \text{m}$

Topic 1: Motion and relativity

$\vec{v} = \vec{v}_0 + \vec{a}t$	$\vec{v}$ = velocity at time t $\vec{v}_0$ = velocity at time 0	$v = \frac{2\pi r}{T}$	
$\vec{s} = \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$		$\vec{g} = \frac{\vec{F}}{m}$	$\vec{g}$ = gravitational field strength
$v^2 = v_0^2 + 2as$		$F = G\frac{m_1 m_2}{r^2}$	r = distance between masses m_1 and m_2
$v_H = v\cos\theta$ $v_V = v\sin\theta$	θ = angle to horizontal	$v = \sqrt{\frac{GM}{r}}$	M = mass of object orbited by satellite r = radius of orbit
$E_K = \frac{1}{2}mv^2$		$T^2 = \frac{4\pi^2}{GM}r^3$	
$\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$		$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$	γ = Lorentz factor
$\vec{F} = m\vec{a}$		$t = \gamma t_0$	t_0 = time interval in the moving frame of reference
$\vec{F} = \frac{\Delta\vec{p}}{\Delta t}$		$l = \frac{l_0}{\gamma}$	l_0 = length in the moving object's frame of reference
$\vec{p} = m\vec{v}$		$p = \gamma m_0 v$	m_0 = mass in the frame of reference where the object is stationary
$a = \frac{v^2}{r}$	r = radius of circle		

Topic 2: Electricity and magnetism

$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$	r = distance between charges q_1 and q_2	$F = qvB\sin\theta$	θ = angle between field $\vec{B}$ and velocity $\vec{v}$
$\vec{E} = \frac{\vec{F}}{q}$	$\vec{E}$ = electric field	$r = \frac{mv}{qB}$	r = radius of circle
$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$	r = distance from charge	$T = \frac{2\pi m}{qB}$	
$W = q\Delta V$	W = work done	$E_K = \frac{q^2 B^2 r^2}{2m}$	r = radius at which ions emerge from cyclotron
$E = \frac{\Delta V}{d}$	d = distance between parallel plates	$\Phi = BA_\perp$	$A_\perp$ = area perpendicular to the magnetic field
$\vec{a} = \frac{q\vec{E}}{m}$		$emf = \frac{\Delta\Phi}{\Delta t}$	
$B = \frac{\mu_0}{2\pi}\frac{I}{r}$	r = distance from conductor	$emf = \frac{N\Delta\Phi}{\Delta t}$	N = number of conducting loops
$F = IlB\sin\theta$	θ = angle between field $\vec{B}$ and current element $I\vec{l}$	$\frac{V_p}{V_s} = \frac{N_p}{N_s}$	V = potential difference in transformer coils

Topic 3: Light and atoms

$v = f\lambda$		$W = hf_0$	W = work function of the metal f_0 = threshold frequency
$d\sin\theta = m\lambda$	d = distance between slits θ = angular position of mth maximum m = integer (0, 1, 2, …)	$E_{K\max} = eV_s$	$E_{K\max}$ = maximum kinetic energy of electrons V_s = stopping voltage
$\Delta y = \frac{\lambda L}{d}$	Δy = distance between adjacent minima or maxima L = slit-to-screen distance	$E_{K\max} = hf - W$	
$E = hf$	E = energy of photon	$f_{\max} = \frac{e\Delta V}{h}$	ΔV = potential difference across the X-ray tube
$p = \frac{h}{\lambda}$		$E = \Delta mc^2$	E = energy

Table of prefixes

Prefix	Symbol	Value
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

Quarks

Quark	Symbol	Charge (e)
Up	u	$+\frac{2}{3}$
Down	d	$-\frac{1}{3}$
Strange	s	$-\frac{1}{3}$
Charm	c	$+\frac{2}{3}$
Top	t	$+\frac{2}{3}$
Bottom	b	$-\frac{1}{3}$