South Australian
Certificate of Education

1

Physics
2025

Question booklet 1

- Questions 1 to 11 (60 marks)
- Answer ***all*** questions
- Write your answers in this question booklet
- You may write on page 19 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

The SACE Board of South Australia acknowledges that this examination was created on Kaurna Land. We acknowledge First Nations Elders, parents, families, and communities as the first educators of their children, and we recognise and value the cultures and strengths that First Nations students bring to the classroom. We respect the unique connection and relationship that First Nations peoples have to Country, and their ever-enduring cultural heritage.

Attach your SACE registration number label here

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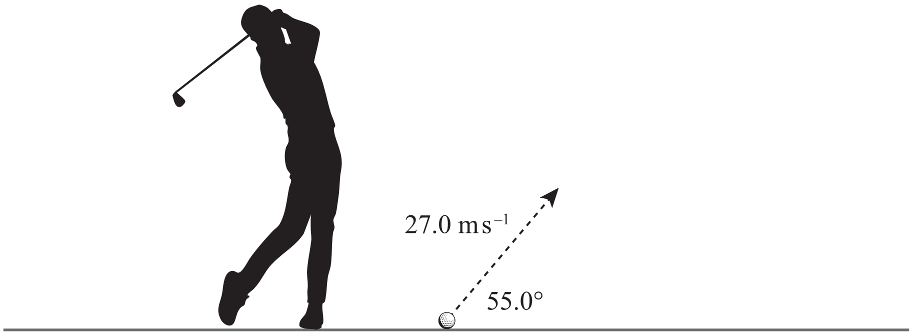
of South Australia

1. A golf ball was struck from ground height giving the ball an initial speed of $27.0\ \text{m s}^{-1}$ at an angle of $55.0°$ above horizontal, as shown in the diagram below.



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

Assume that air resistance is negligible for parts (a) to (d) of this question.

(a) Show that the initial vertical speed of the golf ball after it was struck was $22.1\ \text{m s}^{-1}$.

____ (1 mark)

(b) Show that the initial horizontal speed of the golf ball after it was struck was $15.5\ \text{m s}^{-1}$.

____ (1 mark)

(c) Show that the golf ball reached its maximum height after 2.26 seconds.

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____ (2 marks)

(d) Determine the horizontal distance travelled by the golf ball while it is in the air.

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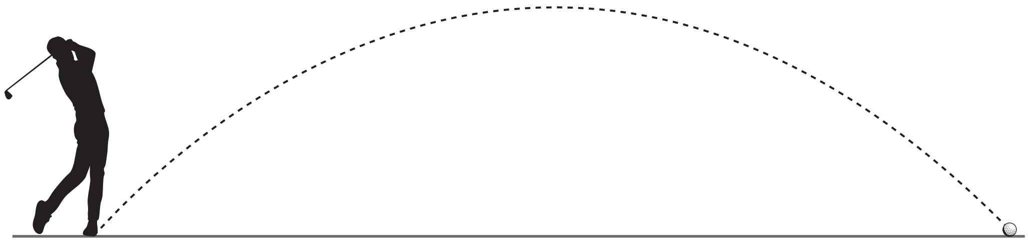
____ (2 marks)

(e) The diagram below shows the path taken by the golf ball if air resistance is negligible.

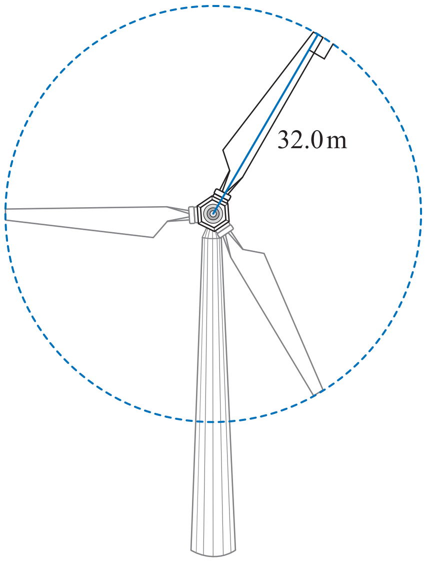


On the diagram above, sketch the path taken by the golf ball if air resistance is *not* negligible.

(2 marks)

2. A wind turbine has three blades that move in a circular path to generate electricity.

Each blade is $32.0\ \mathrm{m}$ long. The tips of the blades move at a constant speed of $49.3\ \mathrm{m\,s^{-1}}$.



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

(a) Show that the period of rotation of the blades is $4.08\ \mathrm{s}$.

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____ (2 marks)

(b) Calculate the magnitude of the acceleration of the tip of the blades.

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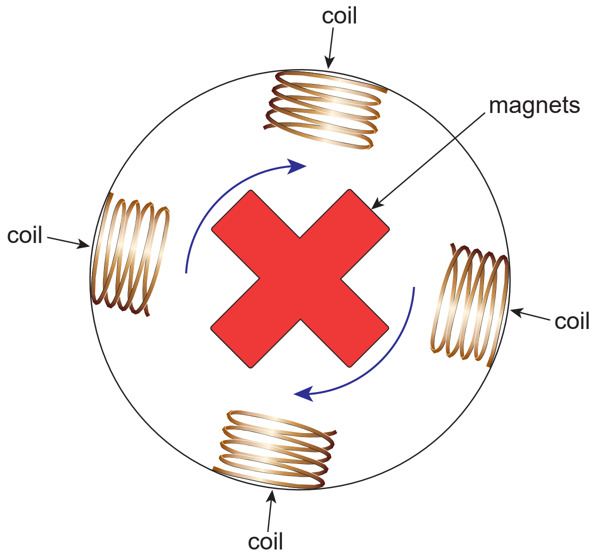
____ (2 marks)

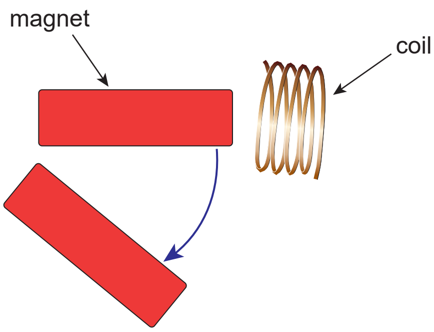
The generator in the wind turbine contains rotating magnets which pass by stationary coils of wire to generate electricity. A simplified diagram is shown below.



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

As one magnet passes by one coil, the magnetic field passing through the coil decreases by 0.35 T in 0.048 s.

The coil has 58 conducting loops and a cross-sectional area of 0.45 m^2.



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

(c) Calculate the magnitude of the *emf* induced in the coil.

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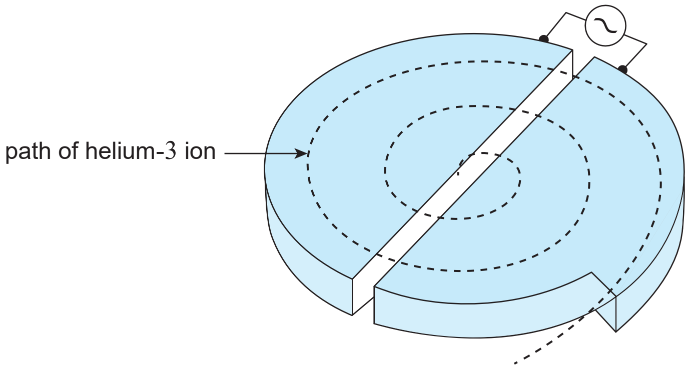
____ (3 marks)

3. A cyclotron accelerates a helium-3 ion. The path of the helium-3 ion is shown in the diagram below.



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

Helium-3 ions have a mass of 5.02×10^{-27} kg and a charge of 3.20×10^{-19} C.

The cyclotron has a radius of 0.45 m and a magnetic field of magnitude 1.08 T.

(a) (i) Show that the period of the circular motion of the helium-3 ion is 9.13×10^{-8} s.

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____ (1 mark)

(ii) Calculate the frequency of the alternating potential difference.

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____ (1 mark)

(b) (i) Explain how the helium-3 ion gains energy each time it passes between the dees of the cyclotron.

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____ (2 marks)

(ii) Calculate the kinetic energy of the helium-3 ion as it exits the cyclotron.

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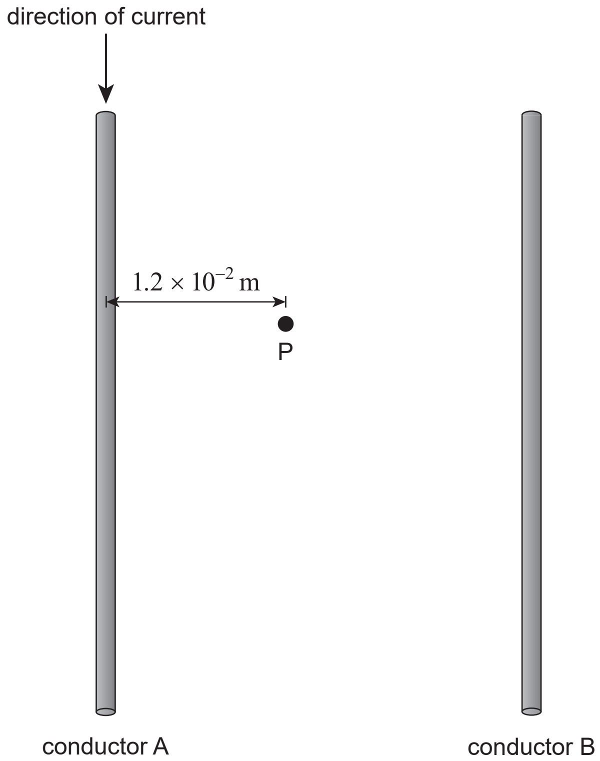
____ (2 marks)

4. Two current-carrying conductors, A and B, are placed parallel to each other. The current in conductor A is in the direction shown in the diagram below.

Point P is 1.2×10^{-2} m from the centre of conductor A.



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

(a) A current of 450 mA flows through conductor A.

Calculate the magnitude of the magnetic field at point P due to the current flowing through conductor A.

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____ (2 marks)

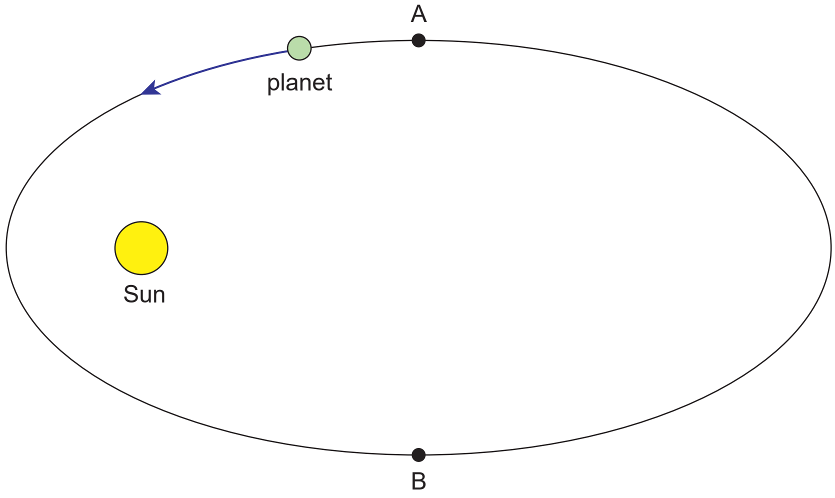
The net magnetic field at point P is zero.

(b) *On the diagram above*, draw an arrow showing the direction of the current flowing through conductor B.

(1 mark)

5. A planet moves in an elliptical orbit around the Sun as shown in the diagram below.

Points A and B are shown along the orbit.



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

Use one of Kepler's Laws to explain whether it takes longer for the planet to move from A to B along the orbit, or from B to A along the orbit.

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____ (3 marks)

6. A uniform electric field is produced by applying a potential difference of 3.00×10^3 V between two parallel plates that are separated by a distance of 5.80×10^{-2} m.

(a) Show that the magnitude of the uniform electric field between the plates is 5.17×10^4 Vm^{-1}.

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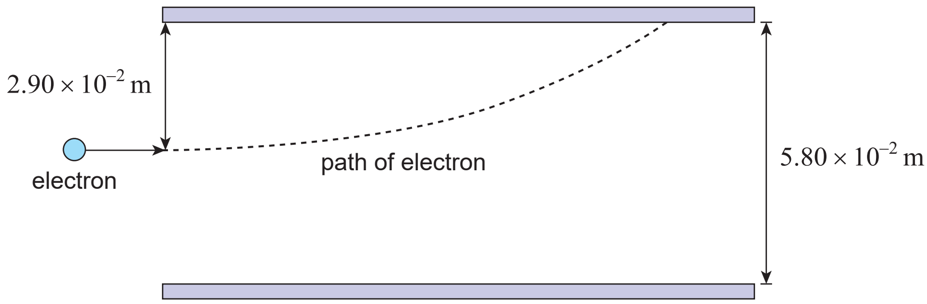
____ (1 mark)

An electron enters the region between the plates, perpendicular to the electric field, at a point midway between the plates, as shown in the diagram below.



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

(b) Show that the magnitude of the acceleration of the electron is 9.08×10^{15} ms^{-2}.

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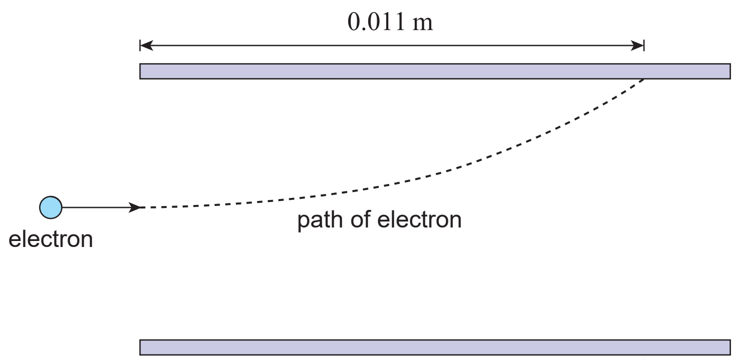
____ (1 mark)

(c) Show that it took 2.53×10^{-9} s for the electron to strike the upper plate.

(2 marks)

The electron travels a horizontal distance of 0.011 m before striking the upper plate, as shown in the diagram below.



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

(d) Determine the speed of the electron as it enters the uniform electric field.

(2 marks)

7. Some spacecraft use ion thrusters for propulsion. An ion thruster emits xenon ions to cause the spacecraft to accelerate.

This image cannot be reproduced here for copyright reasons.

Source: © Science Photo Library 'Dawn Probe Xenon Ion Thruster,' viewed 19 May 2025, alamy.com

Use the law of conservation of momentum to explain how the emission of xenon ions from an ion thruster can cause a spacecraft to accelerate.

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____ (4 marks)

8. Positron emission tomography (PET) scans are used to diagnose medical conditions. Positrons are the antiparticles of electrons.

The scans involve introducing a radioactive element into the bloodstream. The radioactive element emits positrons which annihilate with electrons to produce photons.

Source: © Portra | iStockphoto.com

A positron and an electron annihilate to produce two photons.

Calculate the frequency of *one* of the photons that is produced in the annihilation.

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____ (4 marks)

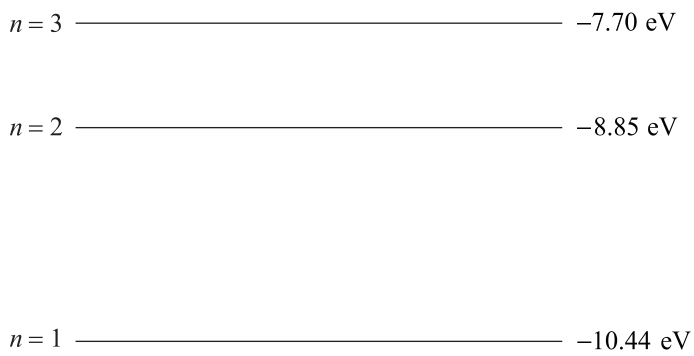
9. Some fluorescent lights require a step-down transformer to operate effectively.

A transformer is required to convert 220 V to 5.50 V. The output coil of the transformer has 4 turns.

(a) Determine the number of turns in the input coil of the transformer.

(2 marks)

One fluorescent light contains mercury gas. Some of the energy levels of mercury are shown in the energy level diagram below.



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

A photon is incident on an electron which causes the electron to transition from the $n = 1$ electron energy level to the $n = 3$ electron energy level.

(b) (i) Show that the incident photon has an energy of 4.38×10^{-19} J.

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___ (2 marks)

(ii) Determine the frequency of the photon in part (b)(i).

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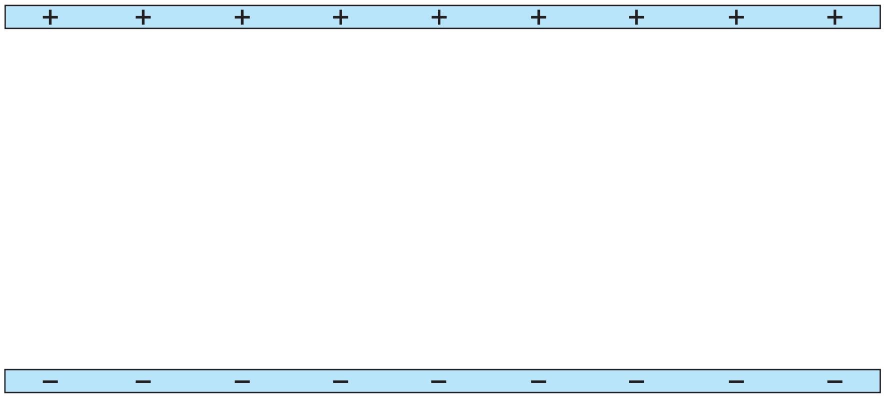
___ (2 marks)

The mercury gas undergoes fluorescence, and the electron reverts to the $n = 1$ electron energy level.

(c) *On the diagram on page 14*, draw an arrow showing the transition that results in the emission of a photon with the lowest frequency as the mercury gas undergoes fluorescence.

(1 mark)

10. An electrostatic precipitator contains two oppositely charged parallel plates, as shown in the diagram below.



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

(a) *On the diagram above*, sketch the electric field between the plates. (2 marks)

Advances in nanotechnology have increased the production of nanoparticles with specific optical, magnetic and electrical properties. These particles are used in various scientific fields, such as medicine, electronics, and energy production. However, the increase in the number of nanoparticles has been linked to an increase in neurodegenerative diseases.

Electrostatic precipitators (ESPs) are used to remove nanoparticles from the air before they enter the human body. The nanoparticles are removed from the air using a corona discharge and charged plates. ESPs are a preferred method of removing nanoparticles due to their efficiency, low maintenance, and ability to operate at high temperatures. However, if an ESP is not operating effectively, it may produce harmful by-products and pose risks to respiratory health.

(b) Explain how this context demonstrates *one* key concept of science as a human endeavour.

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____ (3 marks)

11. A group of students undertook a deconstruct and design activity using parachute toys.

The students observed that the time taken for a parachute toy to fall to the ground depended on different variables.

This image cannot be reproduced here for copyright reasons.

Source: © Tiny Science Lab 'Parachute Man Toy,'
viewed 19 May 2025, tinysciencelab.com.au

(a) Identify *two* variables that may affect the time taken for a parachute toy to reach the ground.

(2 marks)

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

(5 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(b)(ii) continued).

South Australian Certificate of Education

Physics
2025

Question booklet 2

- Questions 12 to 21 (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

2

Copy the information from your SACE label here

SEQ	FIGURES	CHECK LETTER	BIN

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12. *BlackSky Global-4* is a satellite that passes above South Australia as part of its orbit.

BlackSky Global-4 has an orbital radius of 6.87×10^6 m.

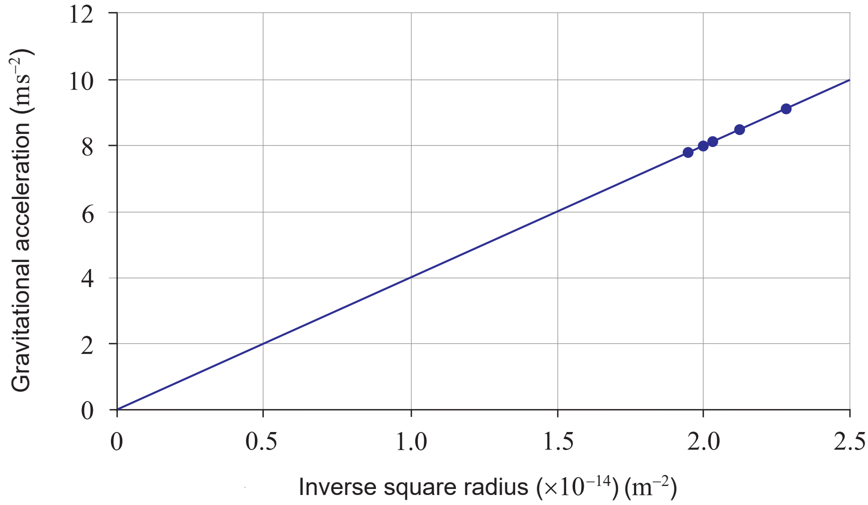
(a) Calculate the orbital period of *BlackSky Global-4*.

(2 marks)

(b) Calculate the orbital speed of *BlackSky Global-4*.

(2 marks)

The data in the graph below shows how the gravitational acceleration of different satellites orbiting the Earth varies with the inverse square of their orbital radius.



The equation of the line of best fit has a gradient of $3.50 \times 10^{14}\ \mathrm{m^3s^{-2}}$.

The relationship between the gravitational acceleration, g, and orbital radius, r, is given by

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

where M is the mass of the Earth.

(c) Use the gradient of the line of best fit to determine an experimental value for the mass of the Earth.

____ (3 marks)

13. A group of students conducted a two-slit experiment to determine the wavelength of the light produced by a laser. The students directed laser light between two slits and observed bright fringes on a screen.

(a) Explain the presence of bright fringes in the two-slit interference pattern.

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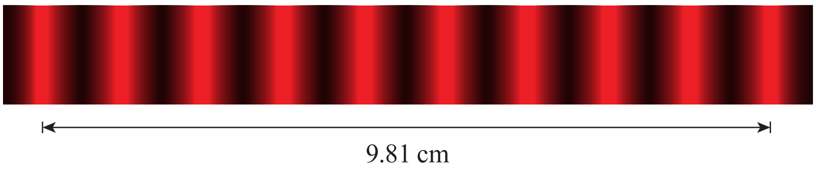
____ (3 marks)

The diagram below shows the interference pattern observed on the screen and a measurement taken by the students.



[*This diagram is drawn to scale.*]

(b) Show that the average distance between the bright fringes was 1.09 cm.

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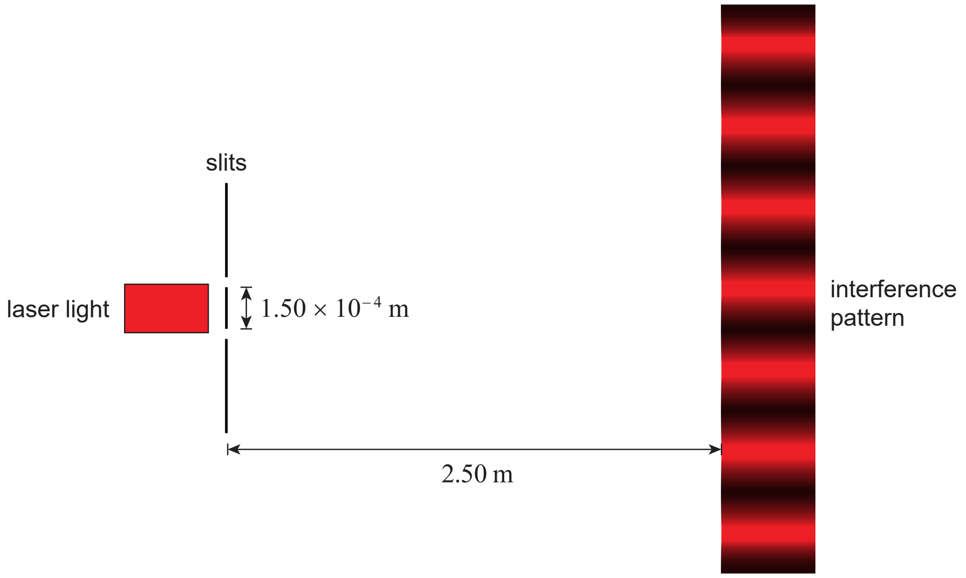
____ (1 mark)

The two slits were separated by 1.50×10^{-4} m and the screen was positioned 2.50 m from the slits, as shown in the diagram below.



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

(c) Calculate the experimental value for the wavelength of the light produced by the laser.

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____ (3 marks)

The laser is replaced with a different laser that produces light with a longer wavelength.

(d) State whether the separation of adjacent fringes in the interference pattern produced would increase or decrease.

Justify your answer.

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____ (2 marks)

 PLEASE TURN OVER

14. The line absorption spectrum and the line emission spectrum of an atom are shown in the images below.

(a) Explain how the presence of discrete frequencies in line emission spectra provides evidence for the existence of states with discrete electron energy levels in atoms.

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____ (2 marks)

(b) Explain the presence of dark lines in the line absorption spectrum.

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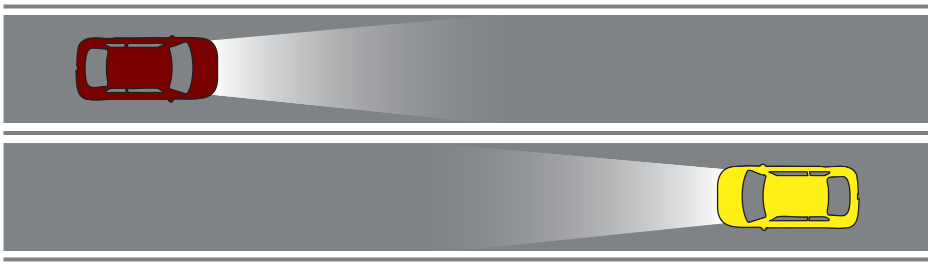
____ (3 marks)

15. Some headlights are designed so that the intensity of the light emitted reduces automatically when another car approaches when driving at night.



The headlights contain a photoelectric material that produces a current when the frequency of the light from an oncoming car is greater than the threshold frequency of a metal target in the headlights.

(a) The work function of the metal target is 1.78 eV.

Monochromatic light with a frequency of $5.45 \times 10^{14} \text{ Hz}$ was incident on the target.

Calculate the maximum kinetic energy of the electrons emitted from the surface of the target.

(3 marks)

(b) Explain why the maximum kinetic energy of the electrons does *not* increase when the intensity of the incident light increases.

(2 marks)

PLEASE TURN OVER

16. A diffractometer uses X-rays to determine the spacing between atoms in a crystal structure.

Some diffractometers use X-rays that are produced by an X-ray tube.

(a) An X-ray tube produces X-rays with a maximum frequency of 1.96×10^{18} Hz.

Determine the potential difference across the X-ray tube.

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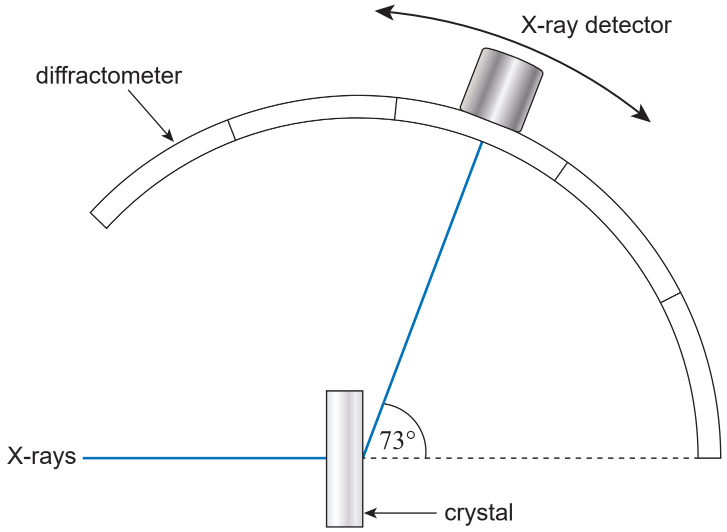
______________________________________ (3 marks)

The X-rays produced by a diffractometer are directed at a crystal surface. The X-rays diffract from the crystal surface and form an interference pattern identical to the pattern formed from a diffraction grating.



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

X-rays with a wavelength of 1.53×10^{-10} m are directed towards a crystal structure.

The first-order X-rays were detected at an angle of $73°$.

(b) Determine the spacing between the ions in the crystal.

(2 marks)

(c) The experiment was repeated but the X-ray tube was replaced with an electron gun.

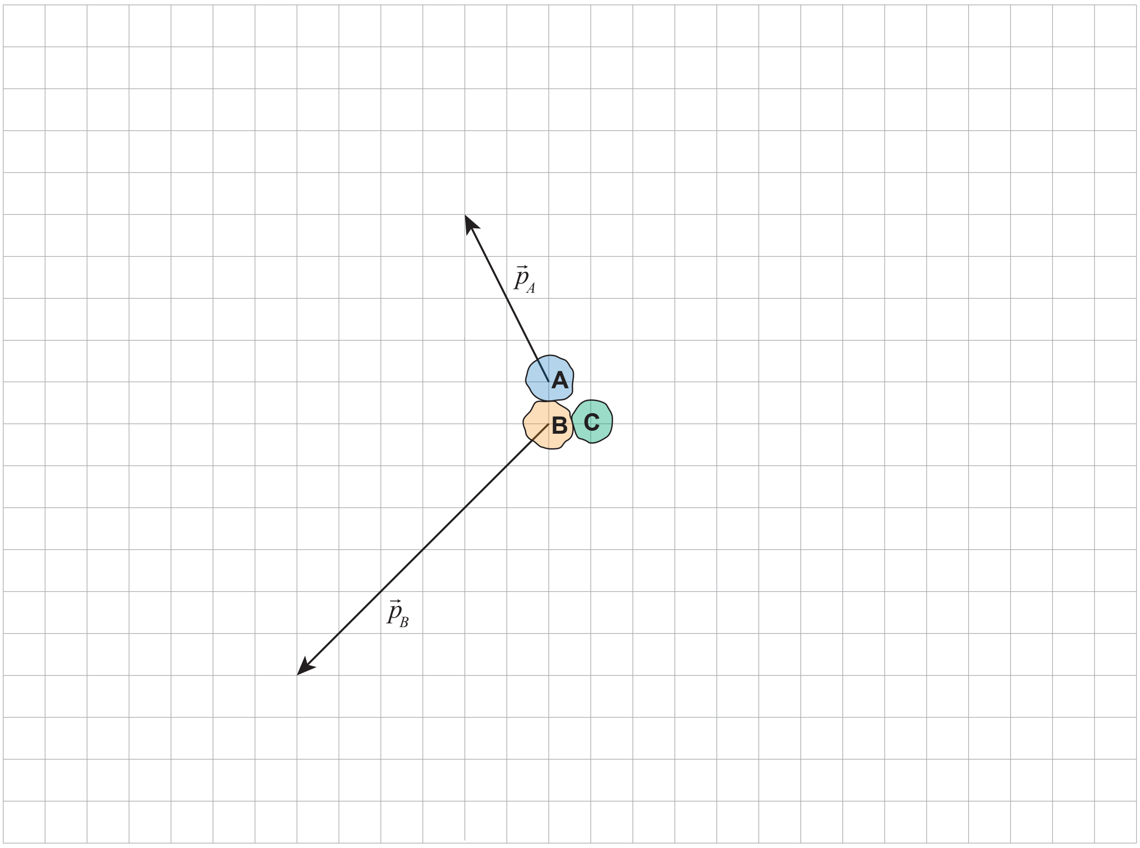
The electrons emitted from the electron gun had a de Broglie wavelength of 1.53×10^{-10} m.

Determine the speed of the electrons.

(3 marks)

17. A stationary object explodes into three pieces: A, B, and C. The momentum vectors of pieces A and B immediately after the explosion are shown on the diagram below.

Assume that air resistance is negligible.



Use the law of conservation of momentum to determine the momentum vector of piece C immediately after the explosion.

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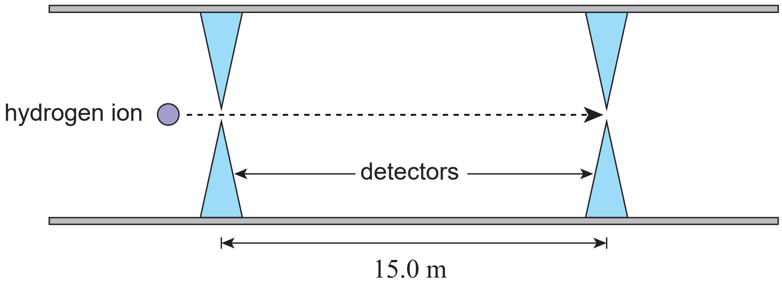
____ (3 marks)

18. A hydrogen ion is accelerated in a linear particle accelerator until it reaches a constant speed.

Scientists measured that it took 85.8 ns for the ion to travel 15.0 m in one section of the linear particle accelerator, as shown in the diagram below.



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

(a) Show that the Lorentz factor of the hydrogen ion is $\gamma = 1.23$.

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____ (3 marks)

(b) Determine the time taken for the hydrogen ion to travel 15.0 m, as measured in the frame of reference of the moving hydrogen ion.

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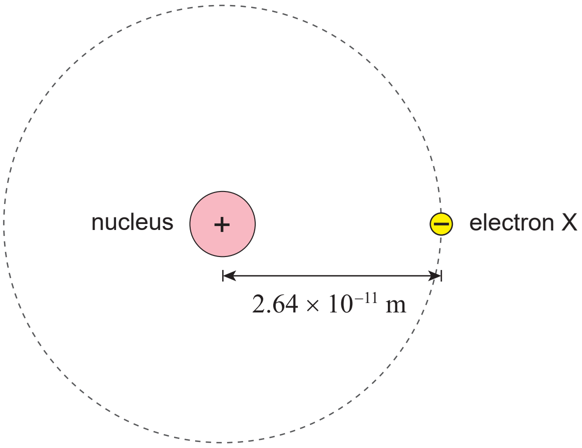
____ (2 marks)

19. Electron X is located at a distance of 2.64×10^{-11} m from the positively charged nucleus of an atom, as shown in the diagram below.

The nucleus has a charge of magnitude 9.60×10^{-19} C.



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

(a) Show that the magnitude of the electric forces between the electron and the nucleus is 1.98×10^{-6} N.

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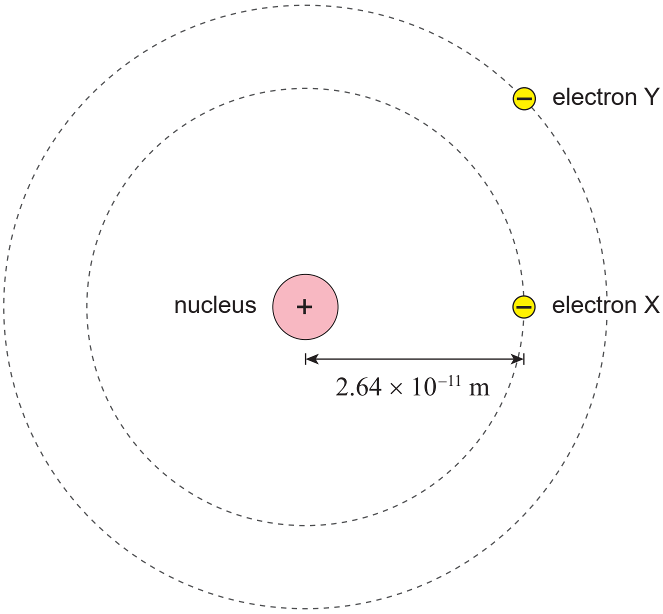
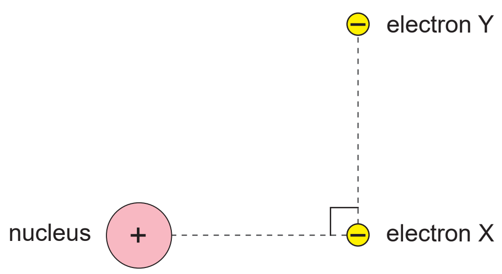
____ (1 mark)

Electron Y is located near the nucleus as shown in the diagram below.



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

The electrons and nucleus form a right-angled triangle, as shown in the diagram below.



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

(b) (i) *On the diagram above*, draw an arrow showing the direction of the net electric force acting on electron X.

(1 mark)

(ii) The electric forces between the two electrons have a magnitude of 2.09×10^{-6} N.

Calculate the magnitude of the net force acting on electron X due to the electric forces from the nucleus and electron Y.

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____ (2 marks)

20. The mass of a charged particle may be determined by measuring the radius of the circular path it makes when it enters in a uniform magnetic field perpendicularly at a known velocity.

(a) Show that the radius, r, of the circular path of a particle with mass m, charge q, and speed v, that is perpendicular to a uniform magnetic field, B, is given by $r = \frac{mv}{qB}$.

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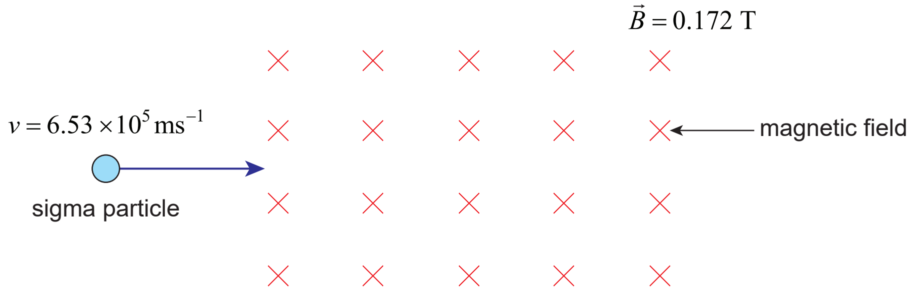
____ (3 marks)

A sigma particle, with a charge of 1.60×10^{-19} C and a speed of 6.53×10^{5} ms^{-1} enters a uniform magnetic field perpendicularly. The magnitude of the magnetic field is 0.172 T, and is directed into the plane of the page as shown in the diagram below.



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

(b) Calculate the magnitude of the force acting on the sigma particle as it enters the uniform magnetic field.

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____ (2 marks)

(c) The sigma particle moves in a circular path of radius 4.75 cm when in the region of the magnetic field.

Determine the mass of the sigma particle.

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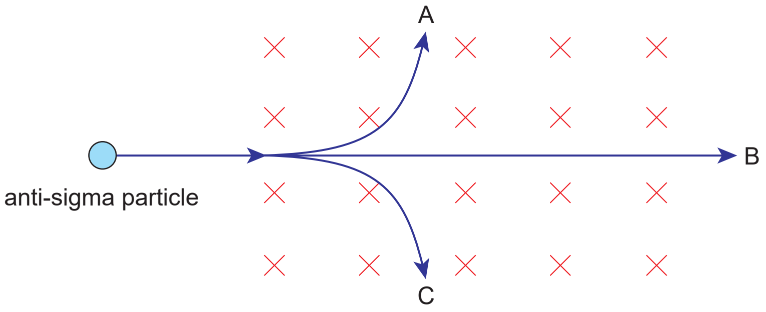
____ (3 marks)

A sigma particle has a quark composition of dds.

An *anti-sigma particle* enters the same uniform magnetic field perpendicularly at the same speed as the sigma particle.

Three different paths, A, B, and C, are shown on the diagram below.



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

(d) State which *one* of the paths on the diagram above corresponds to the motion of the *anti-sigma particle*.

Justify your answer.

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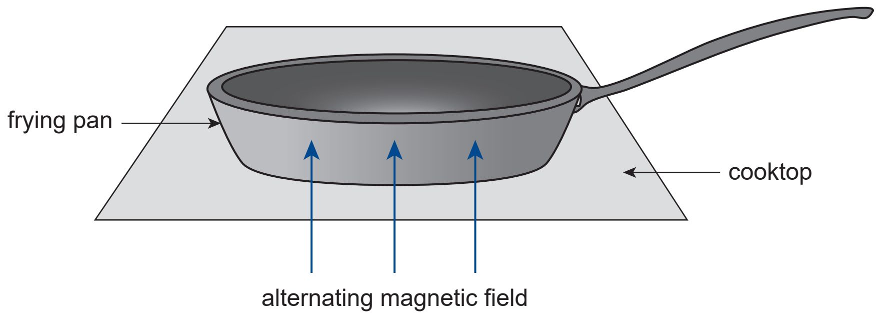
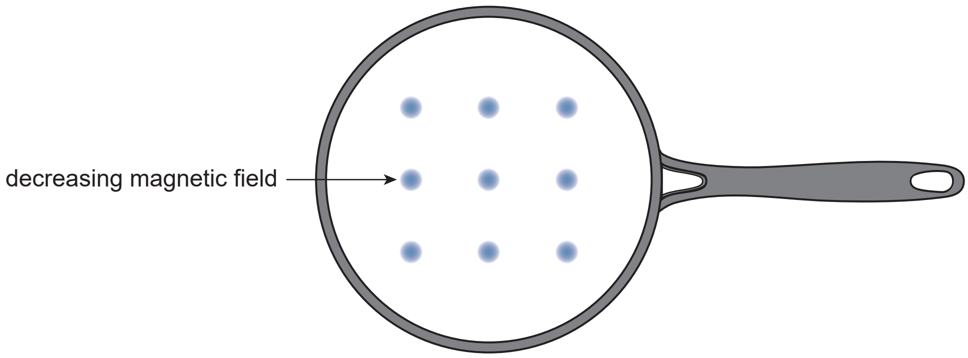
____ (3 marks)

21. An induction cooktop uses eddy currents to generate heat in a frying pan.

A frying pan is placed over an alternating magnetic field, as shown in the diagram below. This alternating magnetic field produces eddy currents in the frying pan which increases its temperature.



The magnetic field passing through the frying pan is decreasing. The diagram below shows the direction of the magnetic field passing through the frying pan when viewed from above.



(a) Sketch *one* of the eddy currents produced in the frying pan on the diagram above.

(1 mark)

(b) Use Lenz's Law to explain your answer to part (a).

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____ (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. 20(a) 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	ε	magnetic field	$\vec{B}$	potential difference	ΔV		

Magnitude of physical constants

acceleration due to gravity at the Earth's surface	$g = 9.80\ \mathrm{m\,s^{-2}}$	Planck's constant	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
constant of universal gravitation	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^2\,kg^{-2}}$	charge of an electron	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$	mass of an electron	$9.11 \times 10^{-31}\ \mathrm{kg}$
		mass of a proton	$1.67 \times 10^{-27}\ \mathrm{kg}$
Coulomb's Law constant	$\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{N\,m^2\,C^{-2}}$	mass of Earth	$5.97 \times 10^{24}\ \mathrm{kg}$
constant for the magnetic field around a conductor	$\frac{\mu_0}{2\pi} = 2.00 \times 10^{-7}\ \mathrm{T\,m\,A^{-1}}$	mean radius of Earth	$6.37 \times 10^{6}\ \mathrm{m}$

Topic 1: Motion and relativity

$\vec{v} = \vec{v}_0 + \vec{a}t$	$\vec{v}$ = velocity at time t $\vec{v}_0$ = initial velocity	$v = \frac{2\pi r}{T}$	
$\vec{s} = \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$		$\vec{g} = \frac{\vec{F}}{m}$	$\vec{g}$ = 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 magnetic 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	$E_K = \frac{q^2B^2r^2}{2m}$	r = radius at which ions emerge from cyclotron
$E = \frac{\Delta V}{d}$	d = distance between parallel plates	$f = \frac{1}{T}$	f = frequency of the alternating potential difference
$\vec{a} = \frac{q\vec{E}}{m}$		$\Phi = BA_\perp$	$A_\perp$ = area perpendicular to the magnetic field
$B = \frac{\mu_0}{2\pi}\frac{I}{r}$	r = distance from conductor	$\varepsilon = \frac{N\Delta\Phi}{\Delta t}$	N = number of conducting loops
$F = IlB\sin\theta$	θ = angle between magnetic field and direction of current	$\frac{V_{\text{input}}}{V_{\text{output}}} = \frac{N_{\text{input}}}{N_{\text{output}}}$	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 m^{th} maximum m = integer $(0, 1, 2, \ldots)$	$E_{K\,\max} = eV_s$	$E_{K\,\max}$ = 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	$-\frac{1}{3}$