Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A420U30-1

Z22-A420U30-1

THURSDAY, 16 JUNE 2022 – MORNING

PHYSICS – A level component 3

Light, Nuclei and Options

2 hours 15 minutes

	For Examiner's use only		
	Question	Maximum Mark	Mark Awarded
Section A	1.	13	
	2.	9	
	3.	8	
	4.	14	
	5.	13	
	6.	8	
	7.	17	
	8.	13	
	9.	5	
Section B	Option	20	
	Total	120	

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ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.
Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 2 sections, **A** and **B**.

Section **A**: 100 marks. Answer **all** questions. You are advised to spend about 1 hour 50 minutes on this section.

Section **B**: 20 marks; Options. Answer **one option only**. You are advised to spend about 25 minutes on this section.

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in question **7(b)**.

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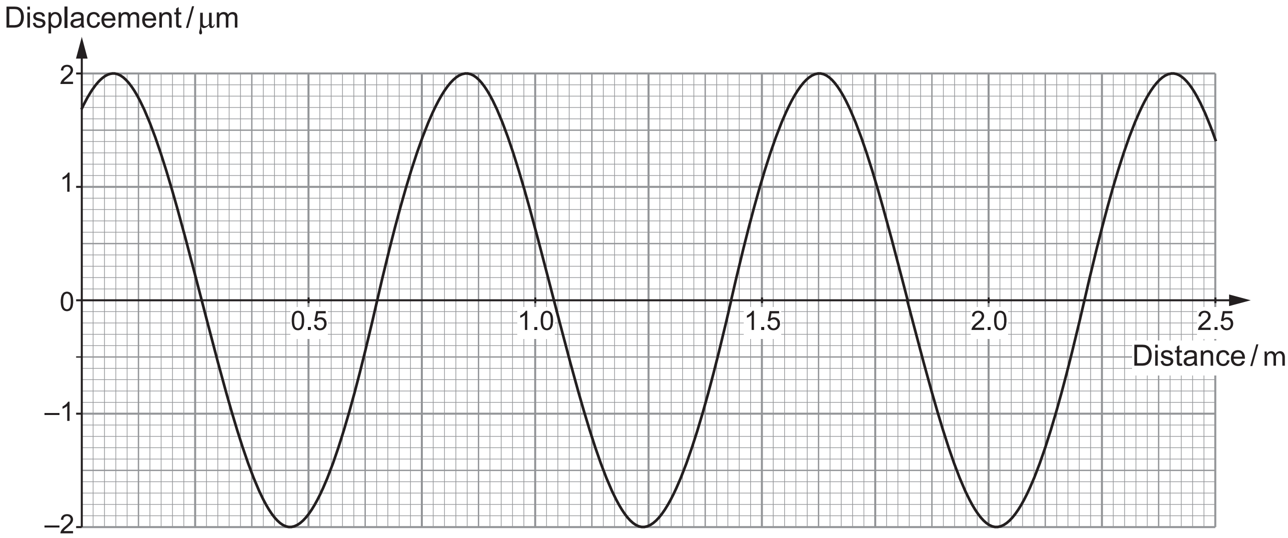
SECTION A

Answer **all** questions.

1. (a) The instantaneous displacement-distance graph of a progressive wave is shown.



(i) State the amplitude of the wave. .... [1]

(ii) Calculate the wavelength of the wave as precisely as you can from the graph. [2]

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(iii) Use the graph to explain how the phase of the wave varies with distance. In your explanation you should include the terms "in phase" and "in anti-phase". [4]

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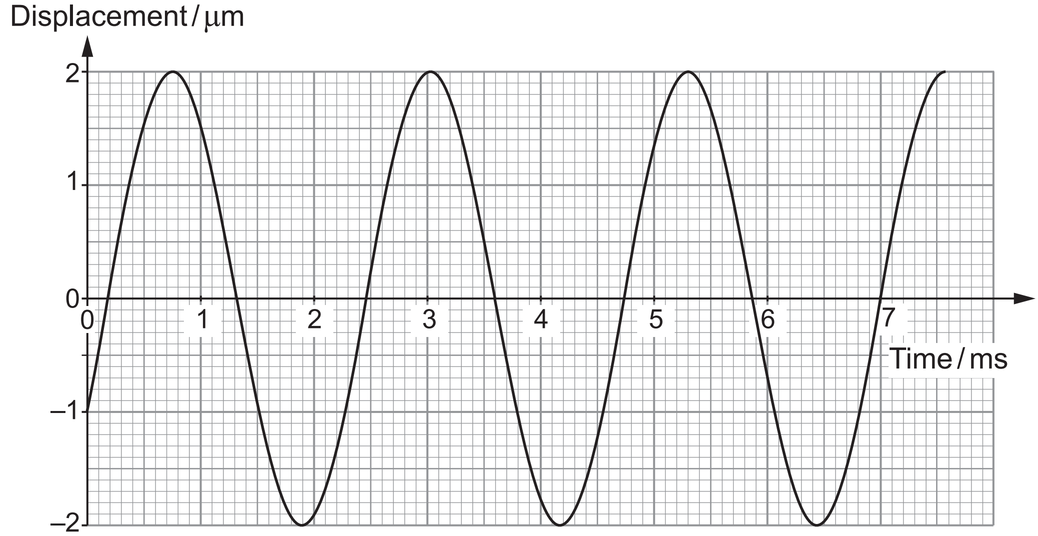
(b) The displacement-time graph is shown below for a point on the wave in part (a).



(i) Calculate the speed of the wave as precisely as you can. [4]

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(ii) Explain the value of the displacement when the time is 8.7 ms. [2]

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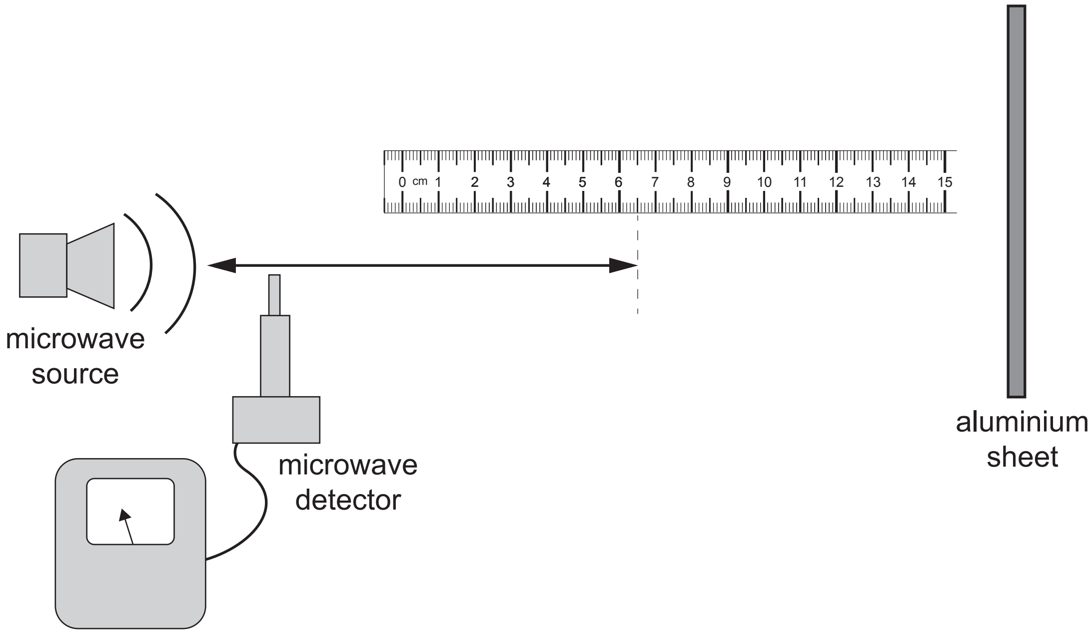
2. Anushka sets up an experiment to demonstrate stationary waves using a microwave source, detector and reflector.



The microwave detector is moved from left to right and the positions of nodes and anti-nodes are recorded.

(a) Explain how a stationary wave is produced between the microwave source and the aluminium sheet. [2]

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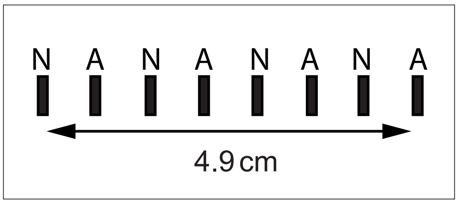
(b) The positions of nodes (N) and anti-nodes (A) are recorded on a piece of paper using a pencil and can be seen below.



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(i) Calculate the **wavelength and frequency** of the microwaves. [3]

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(ii) The data in part (b)(i) should lead to a value of wavelength with an uncertainty of approximately 2%. Explain a very simple modification to the method that would halve the percentage uncertainty. [2]

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(c) Anushka suggests that replacing the microwave source with a loudspeaker oscillating at 12.25 kHz and using a microphone as a detector will produce nodes with the same separation. Determine whether, or not, Anushka is correct.
(Speed of sound in air = 343 m s^{-1}.) [2]

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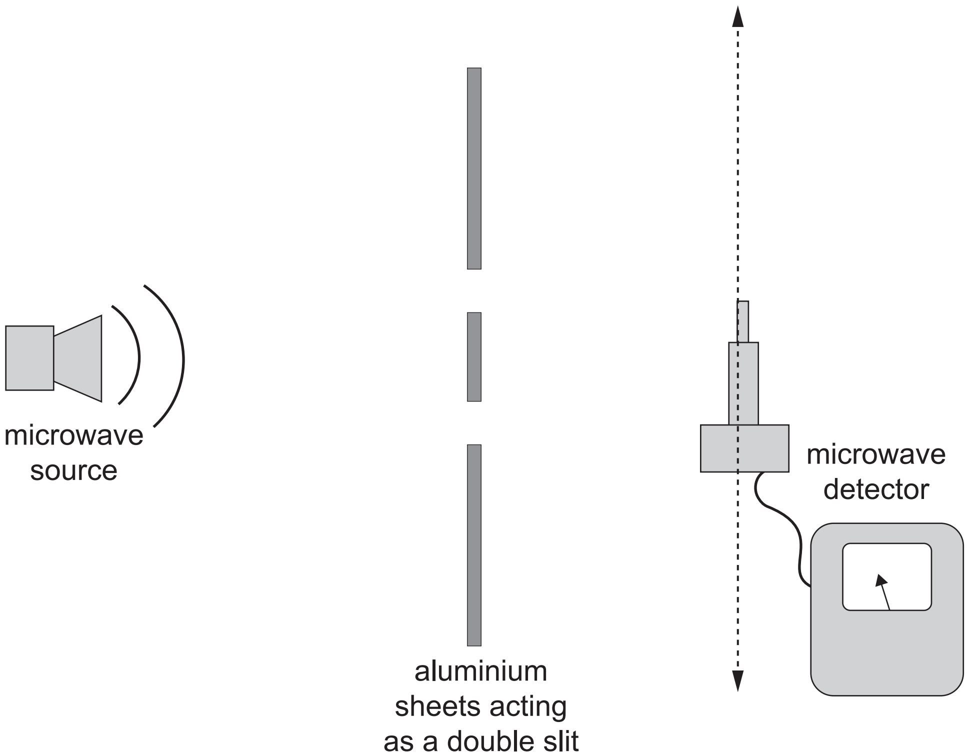
3. Charlie investigates two-source interference of microwaves using the following set-up.



(a) Describe how the detected microwave intensity varies as she moves the detector along the dotted path and explain what causes this variation in intensity. [5]

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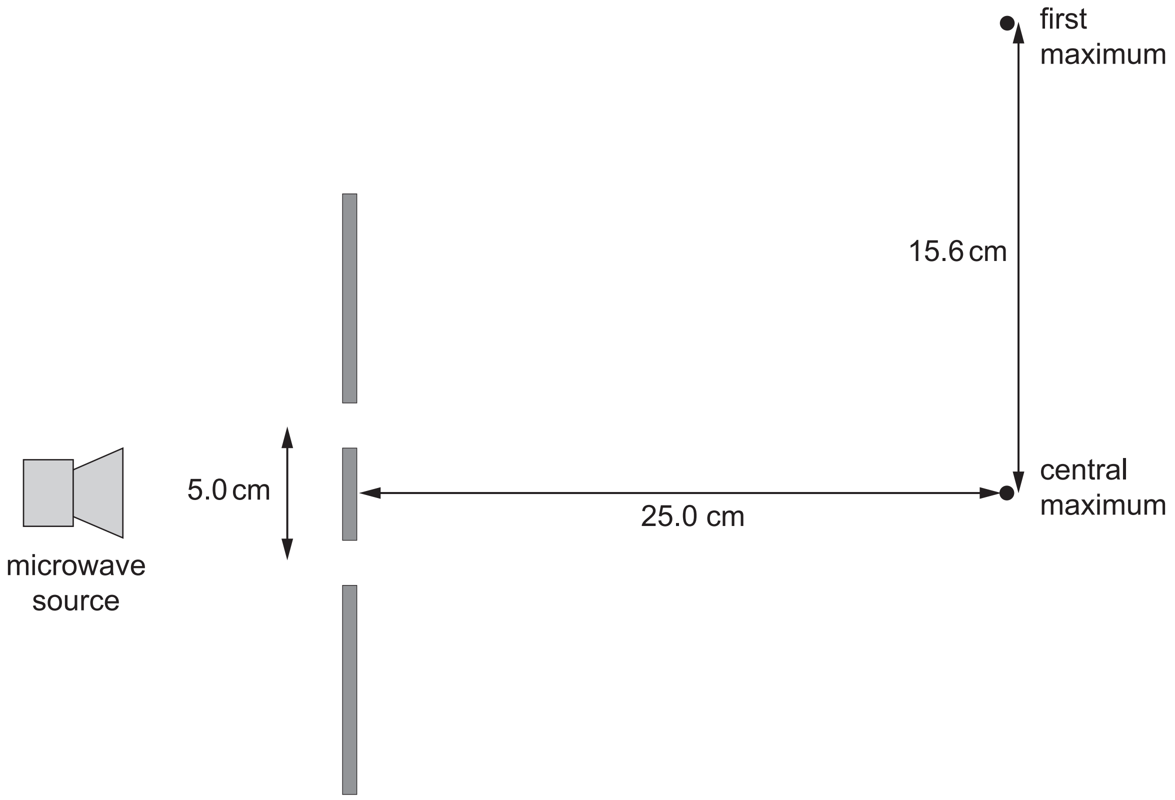
(b) Calculate the wavelength of the microwaves from Charlie's data. [2]



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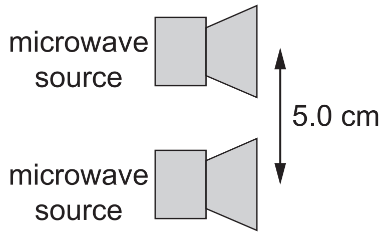
(c) Reggie has two microwave sources and believes he can reproduce Charlie's results with the following set-up:



Each microwave source has its own internal signal generator that will be different from the other. Charlie tells Reggie that his set-up won't work because of this. Discuss briefly whether Charlie is correct. [1]

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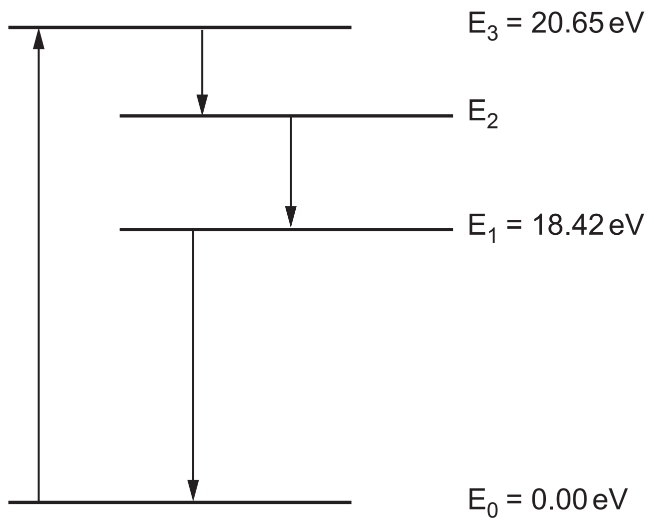
4. A 4-level laser system has the following energy levels.



(a) (i) Explain briefly why energy level E_2 should have a long lifetime. [2]

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(ii) The output wavelength of the laser is 632.8 nm. Calculate the energy of level E_2. [3]

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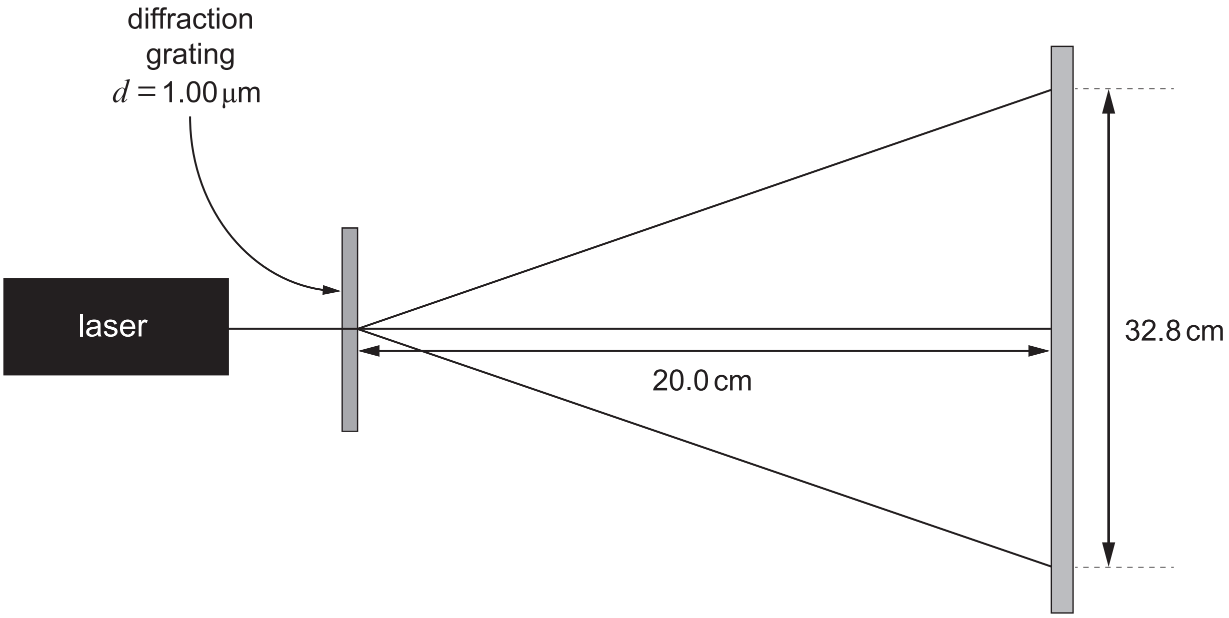
(b) Sean uses a diffraction grating to check the wavelength of the laser. His results are shown in the diagram for the n = 1 lines.



(i) Evaluate whether Sean's data agree with the given wavelength of 632.8 nm. [4]

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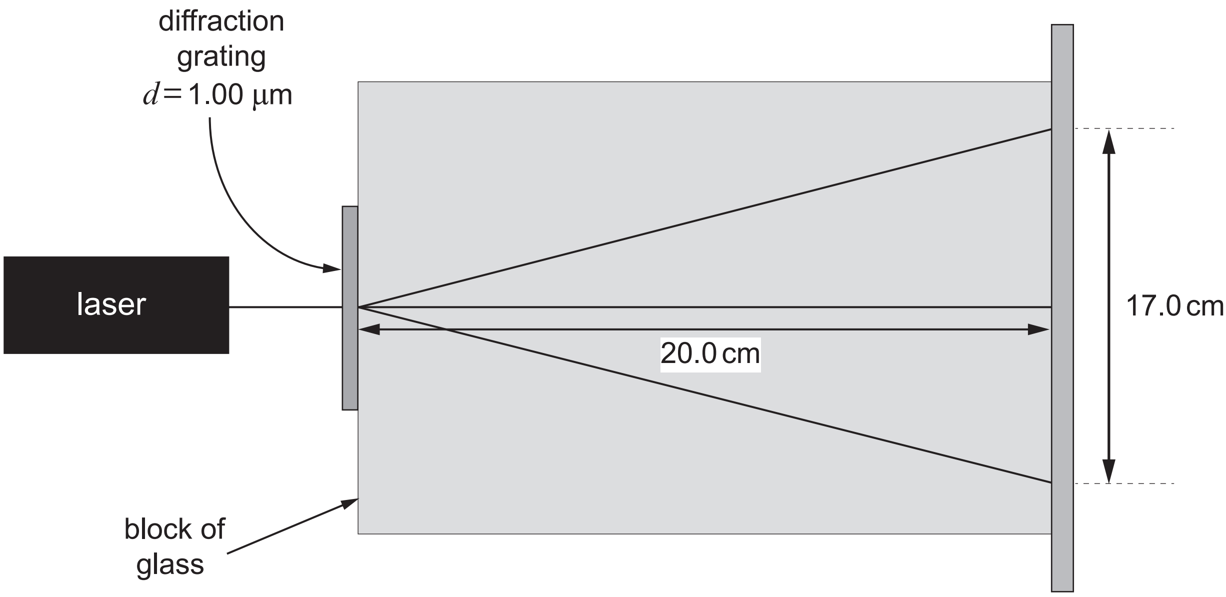
(ii) Sean then extends his experiment to measure the refractive index of a rectangular block of glass of width 20.0 cm using the same apparatus (see the diagram).



I. Explain why the distance between the $n = 1$ lines has decreased. [2]

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II. Calculate the refractive index of the block of glass. [3]

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Turn over.

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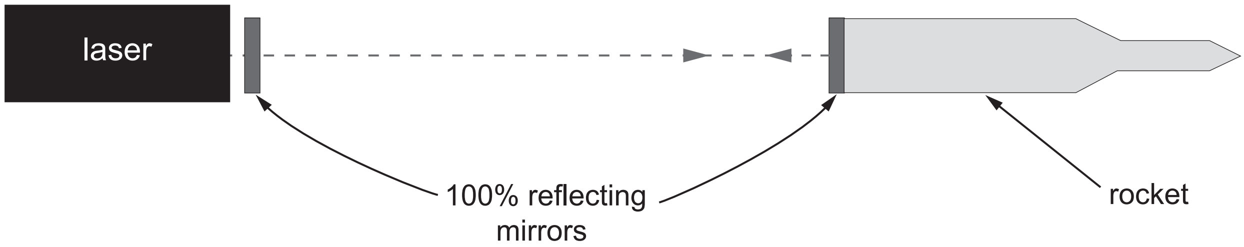
5. A small rocket is placed in space and is propelled using a single pulse of laser light.



When the pulse of light reaches the rocket, it is reflected back by the mirror on the rocket. Before the pulse returns to the laser, a mirror is placed in front of the laser and the pulse of light is reflected back to the rocket. This process repeats over and over for the rocket to accelerate.

(a) Explain briefly how the laser light can provide a forward momentum for the rocket. [2]

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(b) (i) The wavelength of the laser is 403 nm and the total energy of the laser pulse is 1.27 kJ. Show that the number of photons in the pulse is approximately 2.6×10^{21}. [2]

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(ii) Hence, show that the momentum transferred to the rocket each time the pulse is reflected is approximately 8×10^{-6} kg m s^{-1}. [2]

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Examiner only

(iii) The rocket has a mass of 0.029 kg. Assuming that the same momentum is transferred to the rocket each time it reflects the pulse, calculate the number of reflections required for the kinetic energy of the rocket to exceed the energy of the pulse. [4]

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(iv) By discussing kinetic energy and light energy, determine whether this rocket disobeys a fundamental law of physics. [3]

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6. (a) Calculate the energy released in the following hydrogen fusion reaction. [3]

$$^{3}_{1}\mathrm{H} + ^{2}_{1}\mathrm{H} \longrightarrow ^{4}_{2}\mathrm{He} + ^{1}_{0}\mathrm{n}$$

Mass of $^{3}_{1}\mathrm{H}$ = 3.01605 u, Mass of $^{2}_{1}\mathrm{H}$ = 2.01410 u,

Mass of $^{4}_{2}\mathrm{He}$ = 4.00260 u, Mass of $^{1}_{0}\mathrm{n}$ = 1.00866 u, 1 u = 931 MeV

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(b) Use the binding energy per nucleon graph to explain why this reaction releases a large amount of energy. [2]

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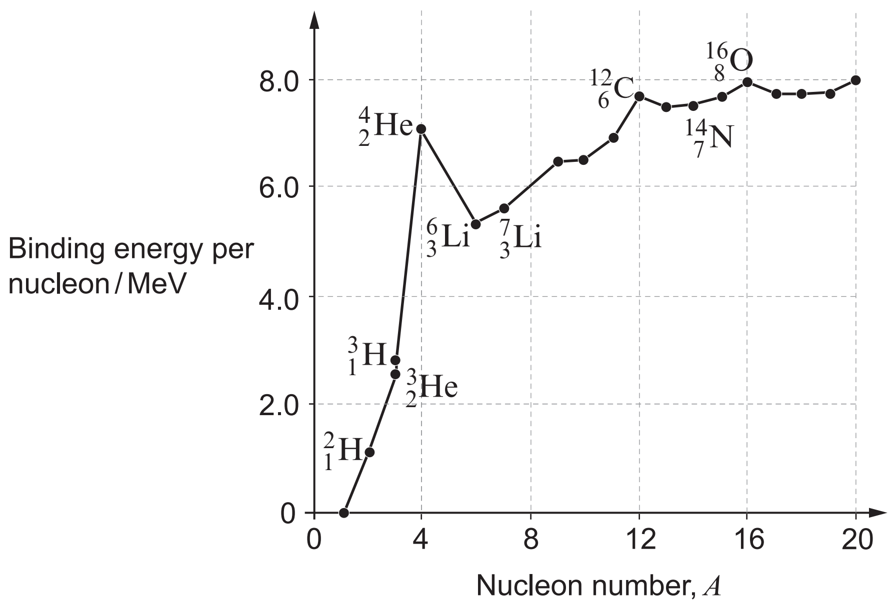

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(c) For many years, research has been carried out on this hydrogen fusion reaction. A fusion reactor project called ITER (International Thermonuclear Experimental Reactor) has cost around £20 billion and has produced no electricity.

If the ITER project is successful, the next fusion project will cost another £20 billion and might produce a demonstration fusion reactor by the year 2050. Many people believe this to be a complete waste of money and that this money would be better spent harnessing existing cheap solar power.

Discuss whether spending money on fusion power or solar power is the better solution. [3]

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7. (a) (i) A ${}^{3}_{1}\mathrm{H}$ nucleus is unstable and decays by emission of a β^- particle to helium. Complete the decay equation. [3]

$${}^{3}_{1}\mathrm{H} \longrightarrow \ldots\ldots + \ldots\ldots + \ldots\ldots$$

(ii) The molecules of a gas each consist of two ${}^{3}_{1}\mathrm{H}$ atoms. The gas has a volume of $17.2 \times 10^{-3}\,\mathrm{m}^3$, a temperature of 293 K and a pressure of 227 kPa. Show that the number of ${}^{3}_{1}\mathrm{H}$ nuclei is approximately 2×10^{24}. [3]

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(iii) The ${}^{3}_{1}\mathrm{H}$ nucleus has a half-life of 12.32 years. Calculate the initial activity of the ${}^{3}_{1}\mathrm{H}$ gas. [2]

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(iv) Calculate the time taken for the activity to drop to 10% of its initial activity. [3]

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Examiner only

(b) Pions are also unstable particles and can decay according to the following equations.

$$\pi^+ \longrightarrow e^+ + \nu_e$$

$$\pi^0 \longrightarrow \gamma + \gamma$$

Discuss both these decays in terms of conservation laws and forces. [6 QER]

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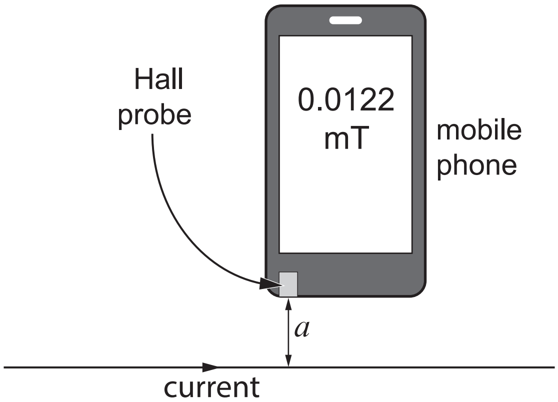
8. Dafydd carries out an experiment to investigate the variation of magnetic field with distance for a long, current-carrying wire. He uses the Hall probe in his mobile phone to measure the magnetic flux density.



He varies the distance, a, from the wire to the edge of the phone and measures the magnetic flux density each time. The current is kept constant.
His results are shown in the table.

Distance, a/cm	Magnetic flux density, B/mT	$\frac{1}{B}$ / 10^3 T^{-1}
2.0	0.0907	11.0
4.0	0.0470	21.3
6.0	0.0325	30.8
8.0	0.0246	40.7
10.0	0.0195	51.3
12.0	0.0167	59.9

The equation for the magnetic flux density is:

$$B = \frac{\mu_0 I}{2\pi a}$$

Which, rearranged for the current is:

$$I = \frac{2\pi a B}{\mu_0}$$

(a) Use the a = 10.0 cm data to calculate a value for the current. [2]

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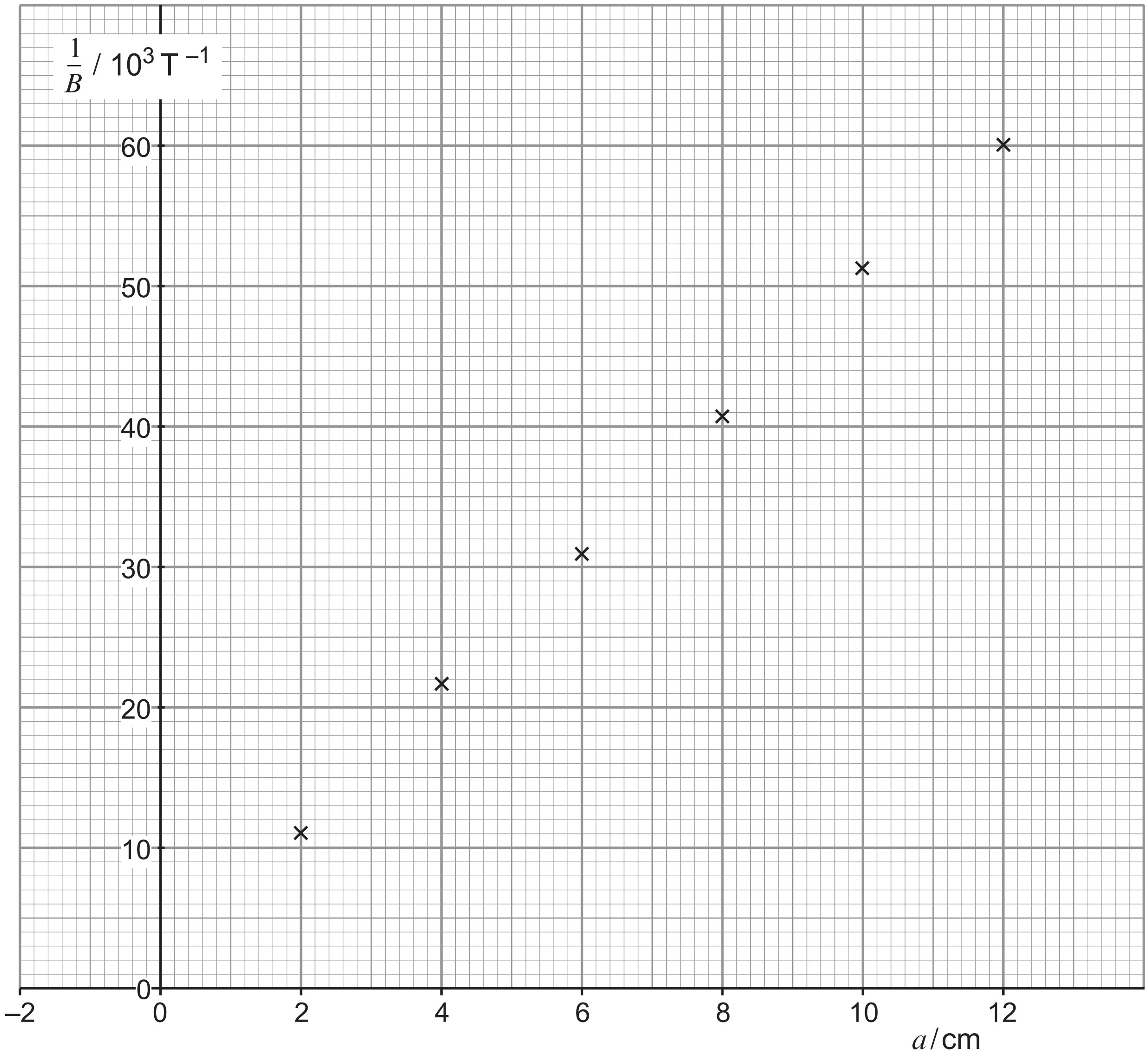
The data are plotted in the following graph.



(b) (i) **Draw a single line of best fit.** [1]

(ii) Use the graph to determine the distance from the edge of the phone to the centre of the Hall probe (see diagram of the set-up). [2]

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(c) Determine the current in the wire. [4]

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(d) Dafydd measured the current in the wire as (10.5 ± 0.5) A. Evaluate the quality of the data obtained in this experiment. [4]

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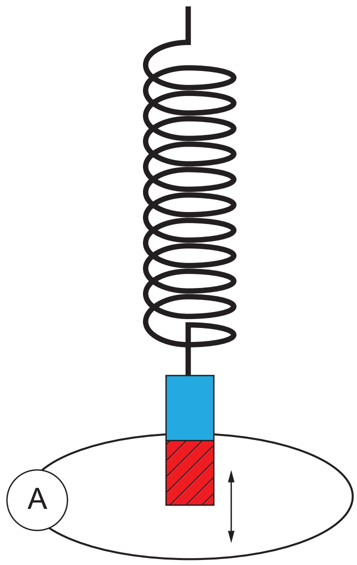
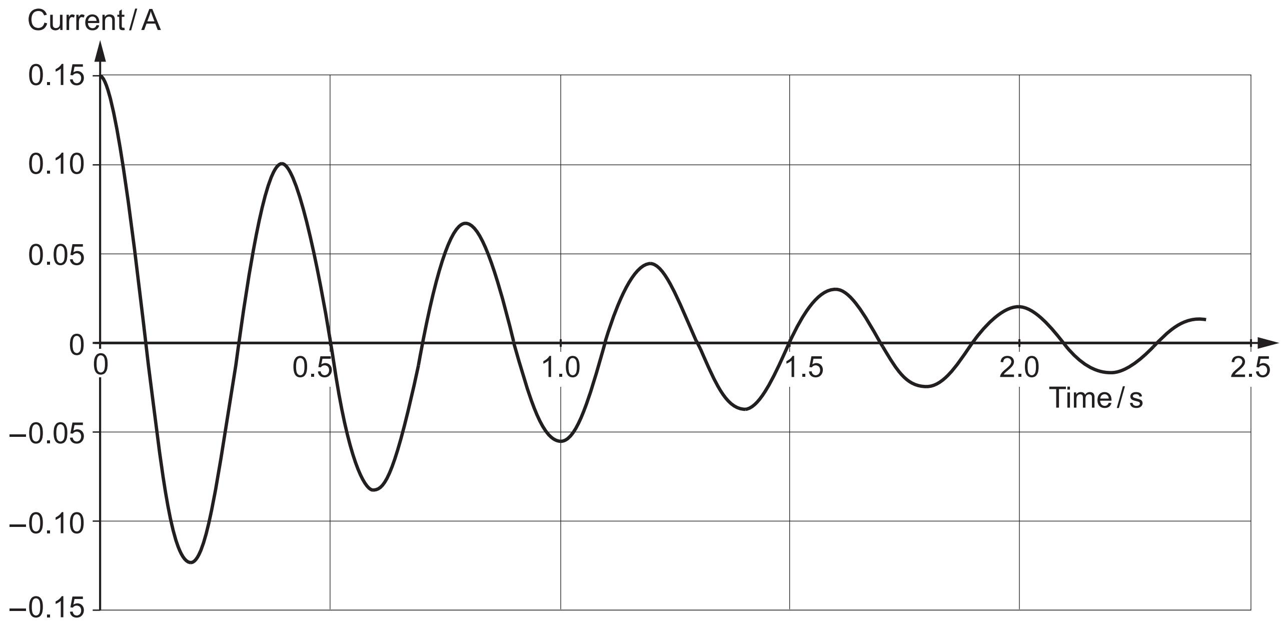
9. A strong magnet is attached to a spring and oscillates vertically through a metal hoop.



A graph of current in the metal hoop against time is given below.



(a) A periodic induced emf is expected because of the periodic change of flux in the metal hoop. Explain briefly why the oscillations are damped. [3]

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(b) The resistance of the metal hoop is $0.18\,\Omega$. Explain what the value of the rate of change of flux in the metal hoop is at time $t = 0$. [2]

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SECTION B: OPTIONAL TOPICS

Option A – **Alternating Currents** ☐

Option B – **Medical Physics** ☐

Option C – **The Physics of Sports** ☐

Option D – **Energy and the Environment** ☐

Answer the question on **one topic only**.

Place a tick (✓) in **one** of the boxes above, to show which topic you are answering.

You are advised to spend about 25 minutes on this section.

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Option A – **Alternating Currents**

10. (a) (i) Describe how, if at all, the reactance of an inductor and the resistance of a resistor vary with frequency. [2]

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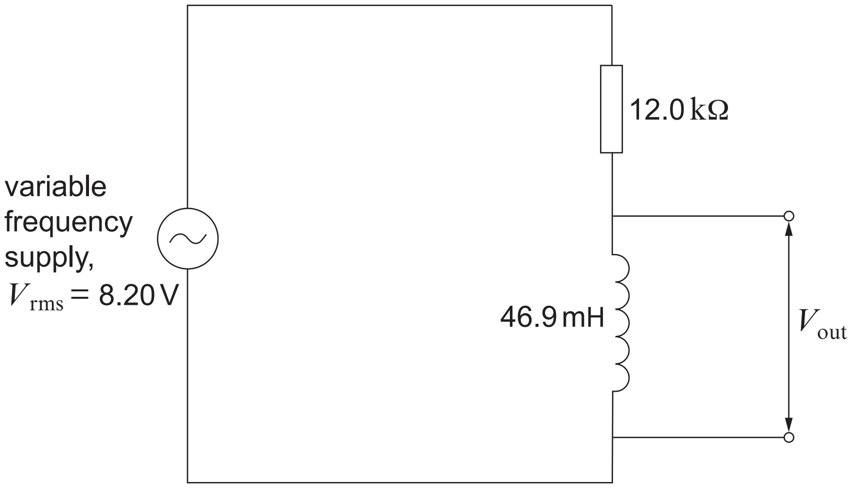
(ii) In the following potential divider circuit, the output pd (V_{out}) is taken across the inductor.



I. Calculate the output pd when the frequency is 5.0×10^4 Hz. [3]

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II. State what happens to the output pd when the frequency is increased above 5.0×10^4 Hz. [1]

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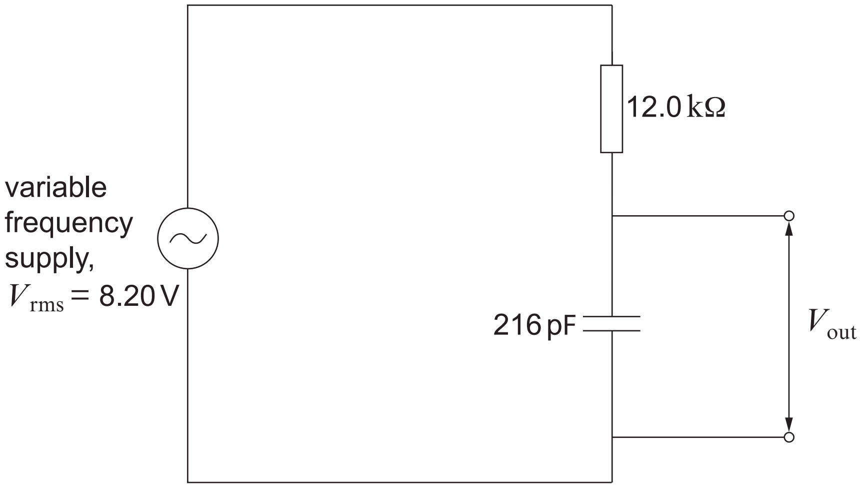
(iii) In the following potential divider circuit, the output pd (V_{out}) is taken across the capacitor.



I. Calculate the reactance of the capacitor at 5.0×10^4 Hz. [1]

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II. Explain why the output pd decreases with frequency. [2]

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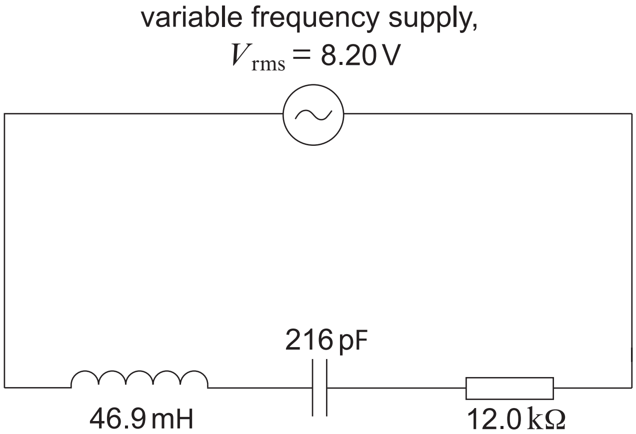
(iv) Hence, explain briefly why the following circuit has a Q factor slightly greater than 1 and why 5.0×10^4 Hz is its resonant frequency. [2]



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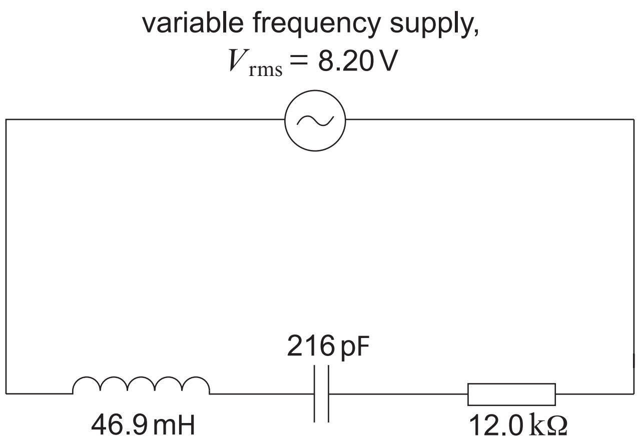
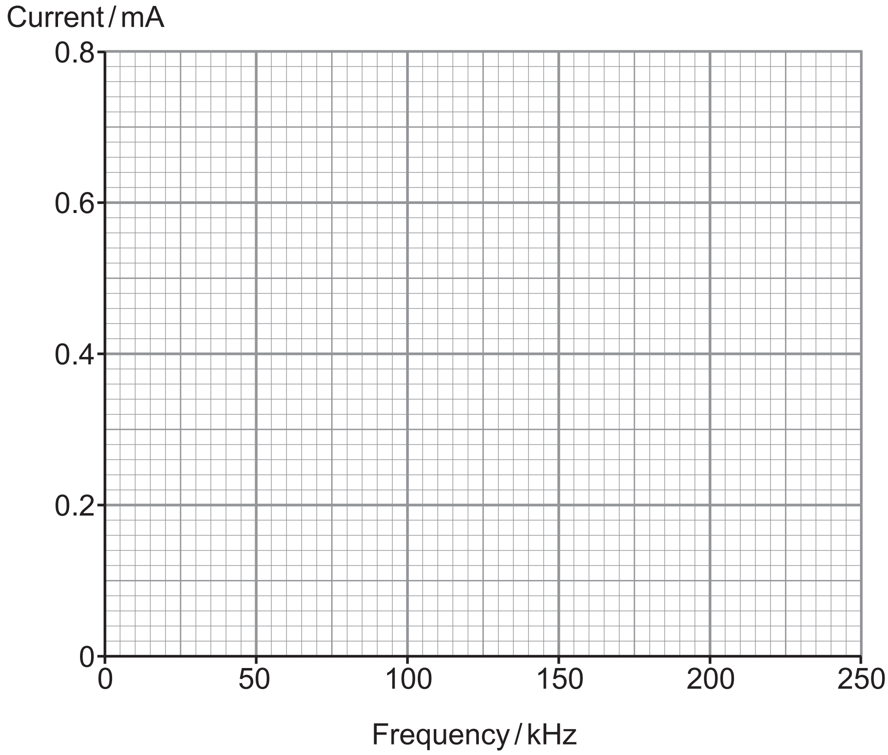
(v) Sketch a graph of current against frequency for the circuit shown (only one point needs to be calculated). [4]

Space for calculation:





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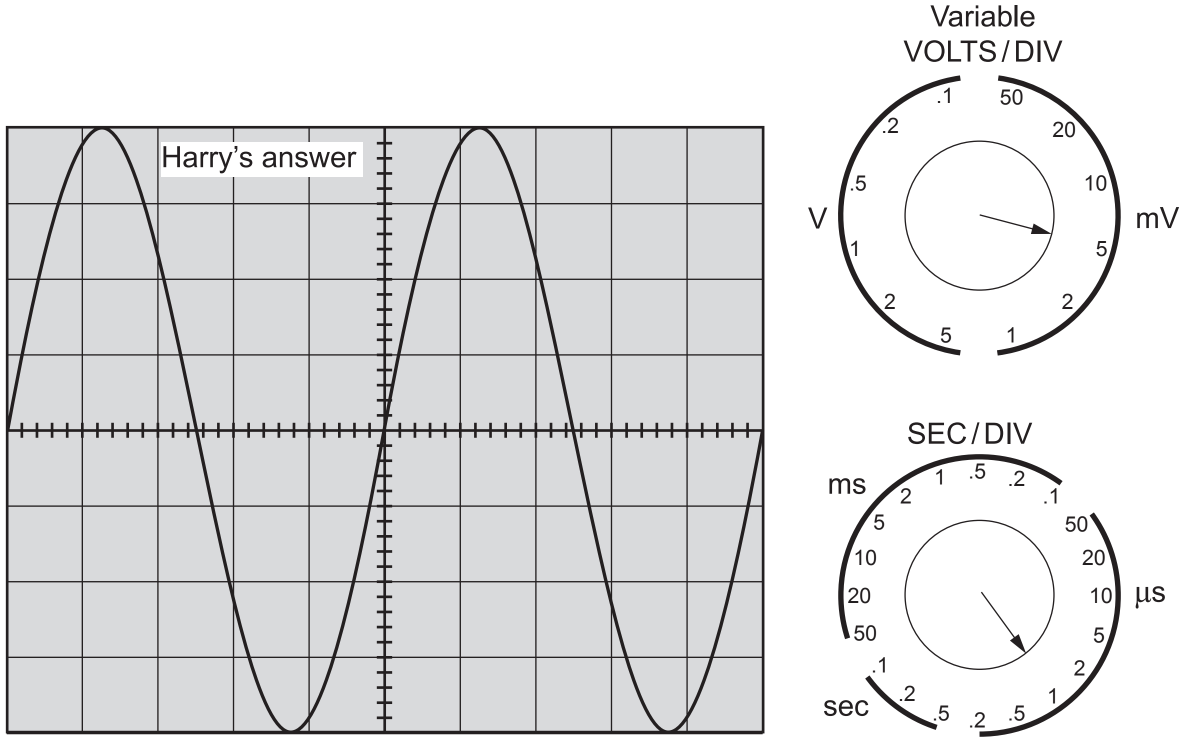
(b) Harry is asked by his teacher to sketch an expected oscilloscope trace for a sinusoidal power supply of rms pd 20.0 mV and frequency 0.200 MHz. He is also expected to suggest sensible values of the y-sensitivity (Variable VOLTS / DIV) and the time base (SEC / DIV). **His answer is shown below.** Determine to what extent he has answered correctly. [5]



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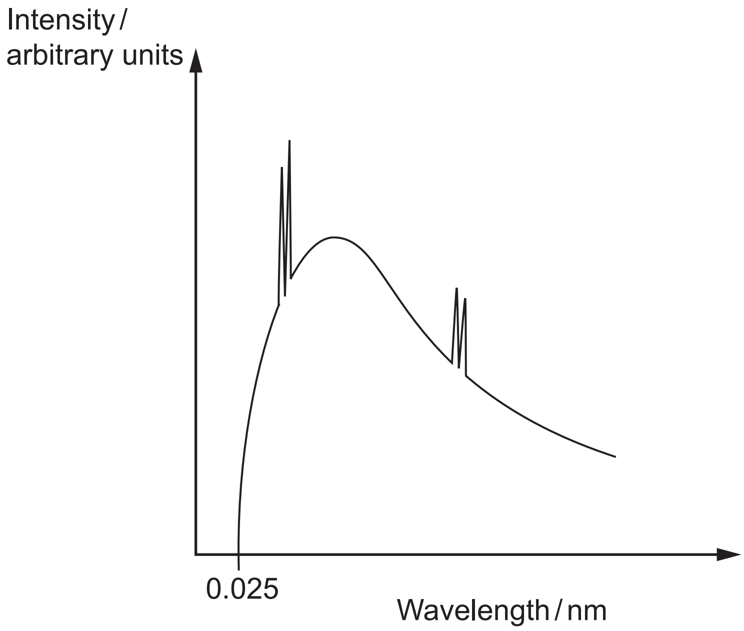
Option B – **Medical Physics**

11. (a) The diagram below is a typical X-ray emission spectrum for an X-ray tube with a tungsten target.



(i) Determine the operating voltage of the X-ray tube. [2]

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(ii) **Draw**, **on the diagram above**, the emission spectrum for an X-ray tube operating at a lower operating voltage **and** using a different metal target. [2]

(iii) When a beam of X-rays passes through bone, the X-rays are absorbed and the beam becomes attenuated. The thickness of bone needed to reduce the original intensity by 50% is known as the half-value thickness, $x_{\frac{1}{2}}$. Show that:

$$x_{\frac{1}{2}} = \frac{\ln 2}{\mu}$$

where μ is the attenuation coefficient. [2]

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(iv) A beam of X-rays is used to detect a fracture in a bone. If the half-value thickness for these X-rays is 1.4 cm, calculate the thickness of bone that reduces the intensity to 65% of its original value. [3]

(b) (i) Explain briefly the role played by radio waves in the process of MRI scans. [2]

(ii) An MRI scanner uses radio waves of wavelength 5.9 m. Calculate the magnetic field needed for the MRI to work effectively. [2]

(c) A radionuclide such as iodine-131 or iodine-123 can be used to investigate kidney function. Give **two** important properties of any radionuclide that is used as a tracer. [2]

Examiner only

(d) Doctors are concerned about a head injury sustained by a rugby player and, in particular, if there is a bleed in the brain. They have the choice of the following forms of imaging techniques.

X-ray **MRI** **ultrasound B-scan** **radioactive tracers** **CT scan**

Evaluate the suitability of **all five** types of imaging techniques for diagnosing the player. [5]

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Option C – **The Physics of Sports**

12. (a) Explain why the hockey player is in a stable position. [2]

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(b) The following table gives values of the coefficient of restitution between a hockey ball and three different types of hockey sticks.

Stick	Coefficient of restitution
A	0.68
B	0.72
C	0.74

Andrea decides to use stick C as it will enable the ball to gain higher speeds. Evaluate whether Andrea is correct in her choice of a hockey stick. [2]

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Examiner only

(c) The remaining questions are about a hockey ball.

Mass of hockey ball = 163 g

Diameter of hockey ball = 71.3 mm

(i) Determine the torque that a player must apply to a hockey ball for the ball to reach a spin rate of 752 revolutions per minute from rest in a time of 0.212 ms. The moment of inertia of a hockey ball = $\frac{2}{5}mr^2$. [4]

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(ii) Determine the **linear and rotational** kinetic energies acquired by the ball if it also moves with a linear speed of 42 m s^{-1}. [3]

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(iii) A goalkeeper saves a shot with their leg pads. The initial speed of the ball is 42 m s^{-1} just before the goalkeeper saves the shot. The ball is in contact with the leg pads for 5.2 ms and **rebounds in the opposite direction** with a speed of 27 m s^{-1}. Evaluate whether the goalkeeper's leg pads are advisable for protection. [3]

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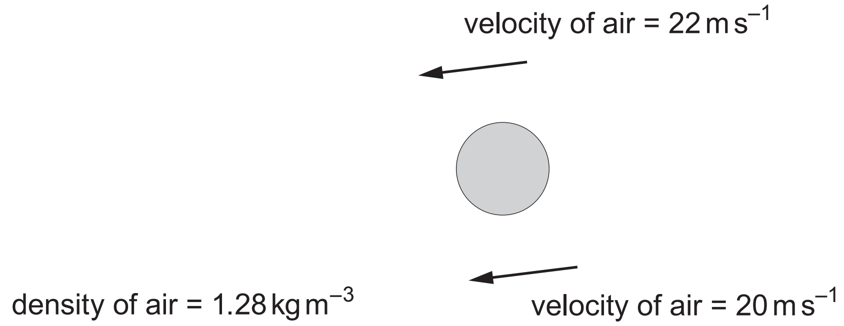
(iv) During a hockey match, Sandeep takes a shot and the ball is moving to the right. The diagram below shows the velocity of the air relative to the ball. During its flight, the velocity of the air above the ball is greater than below it, creating lift.



I. Calculate the lift force acting on the ball and show that this is considerably smaller than the weight of the ball. [4]

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II. As the ball travels through the air, the speed of the ball decreases from 32 m s^{-1} to 16 m s^{-1}. Determine by what factor the magnitude of the drag force acting on the ball changes. [2]

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Option D – **Energy and the Environment**

13. (a) (i) The solar constant can be defined as the intensity of the electromagnetic radiation from the Sun, just outside the Earth's atmosphere. State what is meant by intensity and give a suitable unit. [1]

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(ii) Assuming the Sun behaves as a black body, show that a value for this intensity, I, can be calculated using:

$$I = \frac{r^2 \sigma W^4}{R^2 \lambda^4}$$

Where r is the radius of the Sun, R is the mean Earth-Sun separation and λ is the wavelength of maximum intensity emitted by the Sun. [2]

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(iii) Calculate the value of the solar constant given that $r = 6.96 \times 10^5$ km, $R = 150 \times 10^6$ km and $\lambda = 500$ nm. [2]

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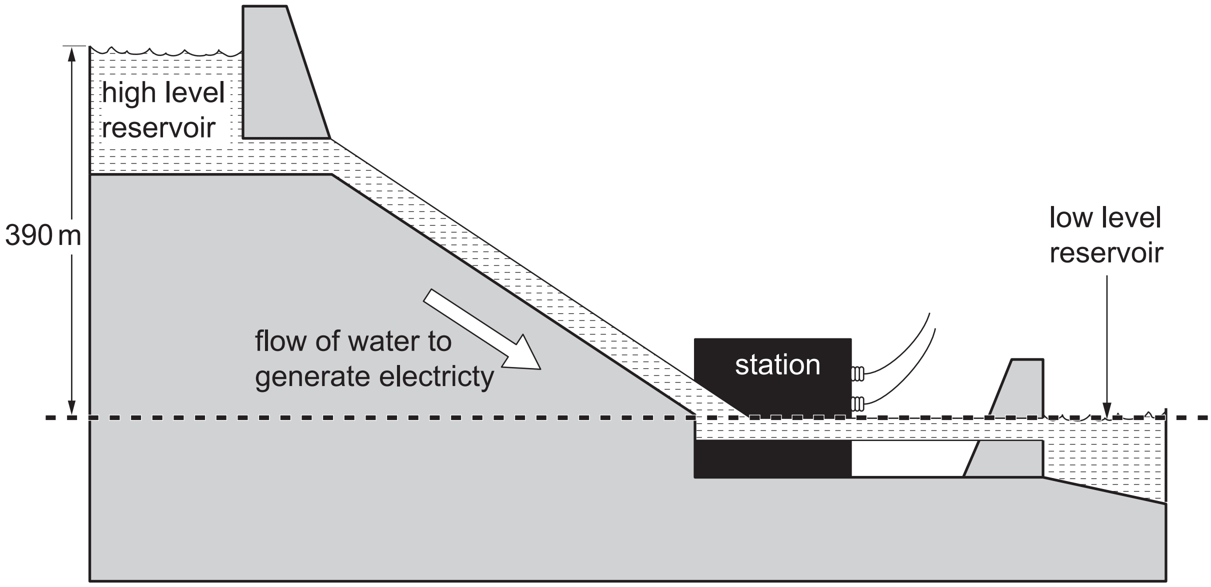
(b) A pumped storage hydroelectric power station can provide electrical power in times of high demand.



(i) The station consists of a generator that can also act as a pump. During times of low electrical power demand, 40 m^3 of water per second is pumped up to the high level reservoir. The height difference between the high level reservoir and station is 390 m. Calculate the mean power required for this process. (Density of water = $1.0 \times 10^3\ kg\,m^{-3}$.) [2]

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(ii) Discuss the impact that pumped storage hydroelectric power stations have on greenhouse gas emissions. [3]

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Examiner only

(c) In fusion reactions, the triple product, $nT\tau_E$ is a combination of the temperature, T, particle density, n, and confinement time, τ_E of the fuel.

(i) Explain what is meant by the confinement time of the fuel. [1]

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(ii) A nuclear fusion power plant aims to produce a fusion triple product of $8.0 \times 10^{22}\,\mathrm{m^{-3}\,s\,keV}$ at a temperature of $1.1 \times 10^{8}\,\mathrm{K}$.

I. Show that this temperature is equivalent to a particle energy of approximately 10 keV. [2]

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II. Hence, determine the value of τ_E required if the particle density, n, is $2.0 \times 10^{21}\,\mathrm{m^{-3}}$. [2]

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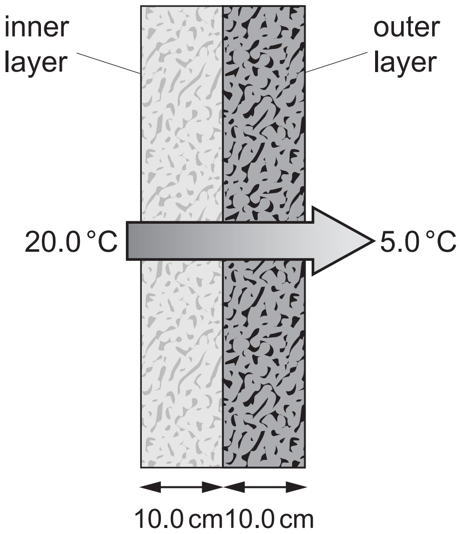
Examiner only

(d) Two layers of equal thickness form the external wall of a building as shown.



The thermal conductivity of the inner layer is $0.10\,W\,m^{-1}\,K^{-1}$ and that of the outer layer is $0.50\,W\,m^{-1}\,K^{-1}$. Tom states that the temperature at the boundary between the two layers is 7.5 °C and that the rate of heat flow per unit area through the wall is $90\,W\,m^{-2}$. Determine whether Tom's statement is correct. [5]

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END OF PAPER

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

Examiner only

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GCE A LEVEL

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THURSDAY, 16 JUNE 2022 – MORNING

PHYSICS – A level component 3
Data Booklet

A clean copy of this booklet should be issued to candidates for their use during each A level component 3 Physics examination.

Centres are asked to issue this booklet to candidates at the start of the course to enable them to become familiar with its contents and layout.

A420U301A
01

Values and Conversions

Avogadro constant	N_A	=	$6{\cdot}02 \times 10^{23}$ mol^{-1}
Fundamental electronic charge	e	=	$1{\cdot}60 \times 10^{-19}$ C
Mass of an electron	m_e	=	$9{\cdot}11 \times 10^{-31}$ kg
Molar gas constant	R	=	$8{\cdot}31$ J mol^{-1} K^{-1}
Acceleration due to gravity at sea level	g	=	$9{\cdot}81$ m s^{-2}
Gravitational field strength at sea level	g	=	$9{\cdot}81$ N kg^{-1}
Universal constant of gravitation	G	=	$6{\cdot}67 \times 10^{-11}$ N m^2 kg^{-2}
Planck constant	h	=	$6{\cdot}63 \times 10^{-34}$ J s
Boltzmann constant	k	=	$1{\cdot}38 \times 10^{-23}$ J K^{-1}
Speed of light in vacuo	c	=	$3{\cdot}00 \times 10^{8}$ m s^{-1}
Permittivity of free space	ε_0	=	$8{\cdot}85 \times 10^{-12}$ F m^{-1}
Permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
Stefan constant	σ	=	$5{\cdot}67 \times 10^{-8}$ W m^{-2} K^{-4}
Wien constant	W	=	$2{\cdot}90 \times 10^{-3}$ m K
Hubble constant	H_0	=	$2{\cdot}20 \times 10^{-18}$ s^{-1}

T/K = θ/°C + 273·15

1 parsec = $3{\cdot}09 \times 10^{16}$ m

1 u = $1{\cdot}66 \times 10^{-27}$ kg

1 eV = $1{\cdot}60 \times 10^{-19}$ J

$$\frac{1}{4\pi\varepsilon_0} \approx 9{\cdot}0 \times 10^{9}\ \mathrm{F^{-1}\,m}$$

$\rho = \frac{m}{V}$	$T = 2\pi\sqrt{\frac{l}{g}}$
$v = u + at$	$pV = nRT$ and $pV = NkT$
$x = \frac{1}{2}(u + v)t$	$p = \frac{1}{3}\rho\overline{c^2} = \frac{1}{3}\frac{N}{V}m\overline{c^2}$
$x = ut + \frac{1}{2}at^2$	M / kg $= \frac{M_r}{1000}$
$v^2 = u^2 + 2ax$	$n = \frac{\text{total mass}}{\text{molar mass}}$
$\sum F = ma$	$k = \frac{R}{N_A}$
$p = mv$	$U = \frac{3}{2}nRT = \frac{3}{2}NkT$
$W = Fx\cos\theta$	$W = p\Delta V$
$\Delta E = mg\Delta h$	$\Delta U = Q - W$
$E = \frac{1}{2}kx^2$	$Q = mc\Delta\theta$
$E = \frac{1}{2}mv^2$	$I = \frac{\Delta Q}{\Delta t}$
$Fx = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$	$I = nAve$
$P = \frac{W}{t} = \frac{\Delta E}{t}$	$R = \frac{V}{I}$
efficiency $= \frac{\text{useful energy transfer}}{\text{total energy input}} \times 100\%$	$P = IV = I^2R = \frac{V^2}{R}$
$\omega = \frac{\theta}{t}$	$R = \frac{\rho l}{A}$
$v = \omega r$	$V = E - Ir$
$a = \omega^2 r$	$\frac{V}{V_{\text{total}}}\left[\text{or } \frac{V_{\text{OUT}}}{V_{\text{IN}}}\right] = \frac{R}{R_{\text{total}}}$
$a = \frac{v^2}{r}$	$C = \frac{Q}{V}$
$F = \frac{mv^2}{r}$	$C = \frac{\varepsilon_0 A}{d}$
$F = m\omega^2 r$	$E = \frac{V}{d}$
$a = -\omega^2 x$	$U = \frac{1}{2}QV$
$x = A\cos(\omega t + \varepsilon)$	$Q = Q_0\left(1 - e^{-\frac{t}{RC}}\right)$
$T = \frac{2\pi}{\omega}$	$Q = Q_0 e^{-\frac{t}{RC}}$
$v = -A\omega\sin(\omega t + \varepsilon)$	$F = kx$
$T = 2\pi\sqrt{\frac{m}{k}}$	$\sigma = \frac{F}{A}$

$\varepsilon = \frac{\Delta l}{l}$	$n = \frac{c}{v}$
$E = \frac{\sigma}{\varepsilon}$	$n_1 v_1 = n_2 v_2$
$W = \frac{1}{2} Fx$	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$	$n_1 \sin\theta_C = n_2$
$F = G\frac{M_1 M_2}{r^2}$	$E_{k\,max} = hf - \phi$
$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$	$p = \frac{h}{\lambda}$
$g = \frac{GM}{r^2}$	$A = \lambda N$
$V_E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$	$N = N_0 e^{-\lambda t}$
$\text{PE} = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r}$	$A = A_0 e^{-\lambda t}$
$V_g = -\frac{GM}{r}$	$N = \frac{N_0}{2^x}$
$\text{PE} = -\frac{GM_1 M_2}{r}$	$A = \frac{A_0}{2^x}$
$W = q\Delta V_E$	$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$
$W = m\Delta V_g$	
$\lambda_{max} = \frac{W}{T}$	
$P = A\sigma T^4$	
$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$	
$v = H_0 D$	
$\rho_c = \frac{3{H_0}^2}{8\pi G}$	$E = mc^2$
$r_1 = \frac{M_2}{M_1 + M_2} d$	$F = BIl\sin\theta$
$T = 2\pi\sqrt{\frac{d^3}{G(M_1 + M_2)}}$	$F = Bqv\sin\theta$
$T = \frac{1}{f}$	$B = \frac{\mu_0 I}{2\pi a}$
$c = f\lambda$	$B = \mu_0 nI$
$\lambda = \frac{a\Delta y}{D}$	$\Phi = AB\cos\theta$
$d\sin\theta = n\lambda$	flux linkage = $N\Phi$

	leptons		quarks	
particle (symbol)	electron (e^-)	electron neutrino (ν_e)	up (u)	down (d)
charge (e)	– 1	0	$+\frac{2}{3}$	$-\frac{1}{3}$
lepton number	1	1	0	0

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03

OPTION A

flux linkage $= BAN\cos\omega t$	$X_L = \omega L$
$V = \omega BAN\sin\omega t$	$X_C = \dfrac{1}{\omega C}$
$I_{\mathrm{rms}} = \dfrac{I_0}{\sqrt{2}}$	$Z = \sqrt{X^2 + R^2}$
$V_{\mathrm{rms}} = \dfrac{V_0}{\sqrt{2}}$	$Q = \dfrac{V_L}{V_R}\left(= \dfrac{V_c}{V_R}\right)$
$V_{\mathrm{rms}} = \dfrac{\omega BAN}{\sqrt{2}}$	$Q = \dfrac{\omega_0 L}{R}$

OPTION B

$I = I_0\ e^{-\mu x}$	$f = 42.6 \times 10^6 B$
$Z = c\rho$	$H = DW_R$
$\dfrac{\Delta f}{f_0} = \dfrac{2v}{c}\cos\theta$	$E = HW_T$

OPTION C

$Ft = mv - mu$	$\tau = I\alpha$
$e = \dfrac{\text{Relative speed after collision}}{\text{Relative speed before collision}}$	$L = I\omega$
$e = \sqrt{\dfrac{h}{H}}$	$KE = \frac{1}{2}I\omega^2$
$I = \frac{2}{5}mr^2$	$p = p_0 - \frac{1}{2}\rho v^2$
$I = \frac{2}{3}mr^2$	$F_D = \frac{1}{2}\rho v^2 A C_D$
$\alpha = \dfrac{\omega_2 - \omega_1}{t}$	

OPTION D

$I = \dfrac{P}{A}$	$\dfrac{\Delta Q}{\Delta t} = -AK\dfrac{\Delta\theta}{\Delta x}$
$P = \frac{1}{2}A\rho v^3$	$P = UA\Delta\theta$

Mathematical Information

SI multipliers

Multiple	Prefix	Symbol
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c

Multiple	Prefix	Symbol
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E
10^{21}	zetta	Z

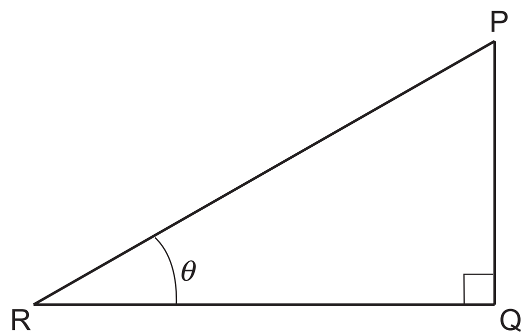
Areas and Volumes

Area of a circle = $\pi r^2 = \frac{\pi d^2}{4}$

Area of a triangle = $\frac{1}{2}$ base × height

Solid	Surface area	Volume
rectangular block	$2\,(lh + hb + lb)$	lbh
cylinder	$2\pi r\,(r + h)$	$\pi r^2 h$
sphere	$4\pi r^2$	$\frac{4}{3}\pi r^3$

Trigonometry



$$\sin\theta = \frac{\text{PQ}}{\text{PR}}, \quad \cos\theta = \frac{\text{QR}}{\text{PR}}, \quad \tan\theta = \frac{\text{PQ}}{\text{QR}}, \quad \frac{\sin\theta}{\cos\theta} = \tan\theta$$

$$\text{PR}^2 = \text{PQ}^2 + \text{QR}^2$$

Logarithms

[Unless otherwise specified ‘log’ can be $\log_e$ (i.e. ln) or $\log_{10}$.]

$\log(ab) = \log a + \log b$

$\log\left(\frac{a}{b}\right) = \log a - \log b$

$\log x^n = n \log x$

$\log_e e^{kx} = \ln e^{kx} = kx$

$\log_e 2 = \ln 2 = 0{\cdot}693$

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