VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2006

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

									Letter
Figures									
Words									

PHYSICS

Written examination 2

Wednesday 8 November 2006

Reading time: 11.45 am to 12.00 noon (15 minutes)
Writing time: 12.00 noon to 1.30 pm (1 hour 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A – Core – Areas of study			
1. Electric power	17	17	40
2. Interactions of light and matter	11	11	25
B – Detailed studies			
1. Synchrotron and its applications	10	10	25
OR			
2. Photonics	11	11	25
OR			
3. Sound	11	11	25
			Total 90

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, up to two pages (one A4 sheet) of pre-written notes (typed or handwritten) and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape.

Materials supplied
- Question and answer book of 33 pages, with a detachable data sheet in the centrefold.

Instructions
- Detach the data sheet from the centre of this book during reading time.
- Write your **student number** in the space provided above on this page.
- Answer all questions in the spaces provided.
- **Always** show your working where space is provided because marks may be awarded for this working.
- All written responses must be in English.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

SECTION A – Core

Instructions for Section A

Answer **all** questions **for both** Areas of study in this section of the paper.

Area of study 1 – Electric power

Figure 1 below shows a solenoid powered by a battery.

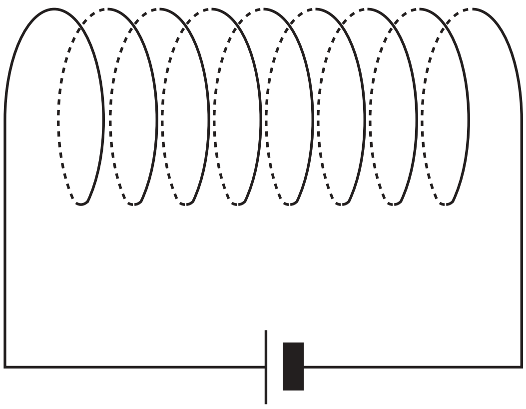


Figure 1

Question 1

Complete the diagram above by sketching **five** magnetic field lines created by the solenoid.

Make sure that you clearly show the direction of the field, including both inside and outside the solenoid.

3 marks

The magnetic field strength in the solenoid is 2.0×10^{-2} T (Wb m^{-2}). A U-shaped conducting wire (a, b, c, d), carrying a current of 5.0 A in the direction a → d, is placed inside the solenoid as shown in Figure 2a below.

The highlighted segment, **abcd**, of size 6.0 cm × 2.0 cm is completely immersed in the magnetic field as shown in Figure 2a also.

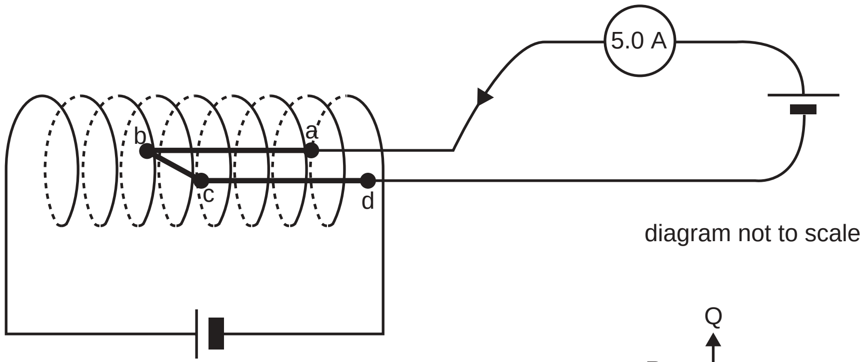


Figure 2a

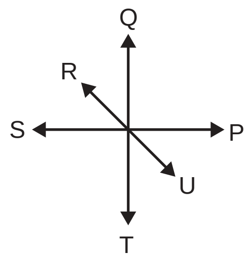


Figure 2b

In Questions 2 and 3 use the key, PQRSTU, in Figure 2b to indicate direction. If there is no direction, write **none**.

Question 2

What is the force (magnitude and direction) on the 6.0 cm section of wire, **cd**, in Figure 2a?

magnitude	direction
N	

2 marks

Question 3

What is the force (magnitude and direction) on the 2.0 cm section of wire, **bc**, in Figure 2a?

magnitude	direction
N	

2 marks

Jo and Effie have found a design for a small electric motor, shown in Figure 3a below. It consists of two large permanent magnets, a coil of wire and a commutator. They plan to build the motor as part of their Physics experiment. The area of the coil is 5.0 cm^2 and the magnetic field strength (which can be assumed to be uniform) between the poles is 2.0×10^{-4} T (Wb m^{-2}).

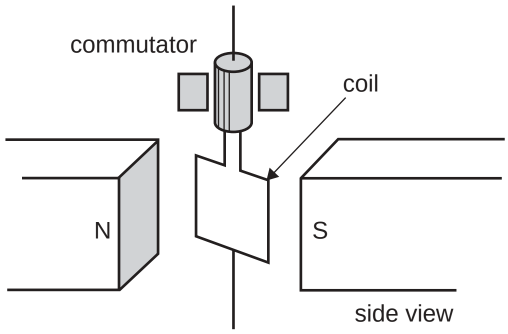


Figure 3a

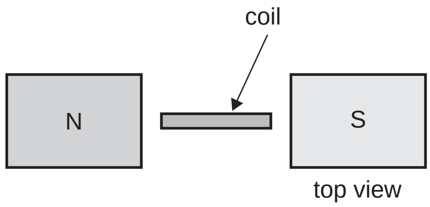


Figure 3b

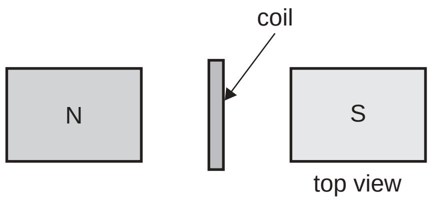


Figure 3c

Question 4

What is the magnetic flux, ϕ_B, threading the loop when the face of the coil is aligned as shown in Figure 3b? Include the unit.

2 marks

Question 5

What is the magnetic flux, ϕ_B, threading the loop when the face of the coil is aligned as shown in Figure 3c? Include the unit.

2 marks

Jo tests the motor using a 6.0 V battery as a power source and it turns very slowly. Effie suggests that they should replace the commutator with slip rings to make it turn faster.

Question 6

What is the role of the commutator? Can Effie's idea work? Explain your answer.

3 marks

A loop of wire in the form of a 2.0 cm square is moved through a uniform magnetic field at a constant speed of 4.0 cm s^{-1}. This is shown in Figure 4a.

Figure 4b shows an end-on view of the loop as it passes across the face of the north pole of the magnet. Current flowing through the loop is measured by a micro-ammeter (μA).

You may assume the magnetic field exists **only** in the region between the north and south poles.

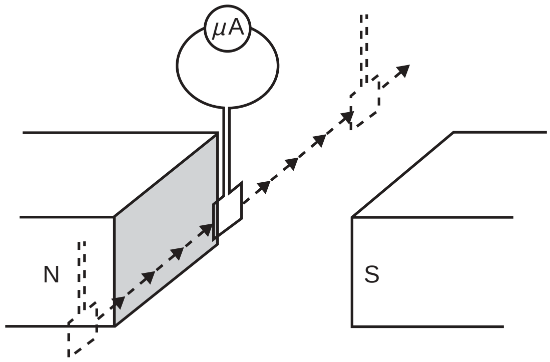


Figure 4a

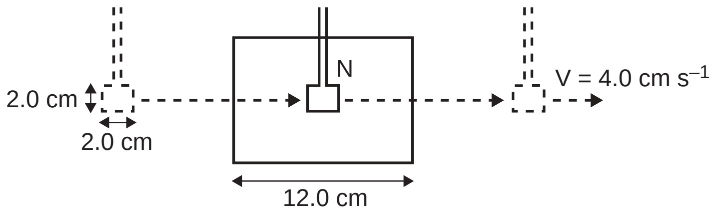


Figure 4b

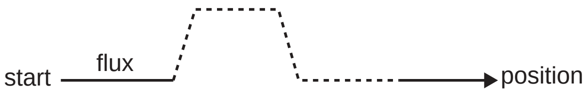


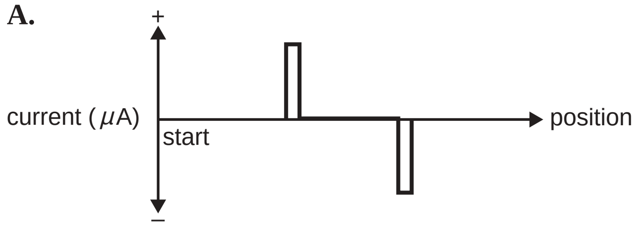
Figure 4c

Initially, the loop is placed well outside of the magnetic field and the micro-ammeter confirms that no current is flowing through the loop. The loop is now moved at a constant rate through the magnetic field, as shown in Figure 4b. Figure 4c shows the flux through the loop as a function of position of the leading edge of the loop.

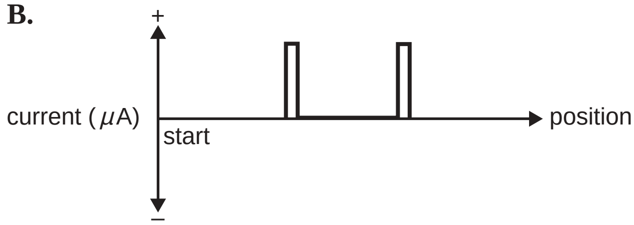
Question 7

Which one of the following (A–D below) best describes the current in the loop as it passes through the magnetic field?

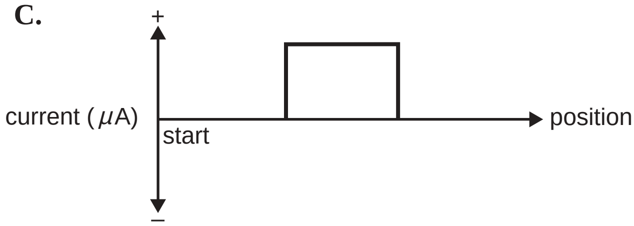
A.



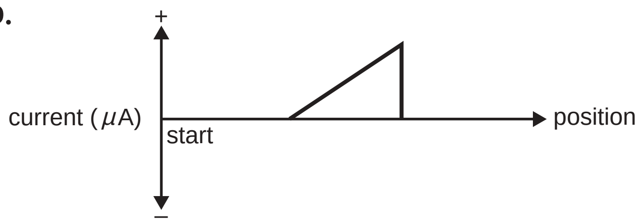
B.



C.



D.



2 marks

The field strength between the poles is 3.7×10^{-3} T (Wb m^{-2}).

Question 8

Calculate the maximum induced voltage in the loop.

V

4 marks

A village has a maximum electrical power requirement of 100 kW. The power is supplied by an alternator, approximately 20.0 km from the village, which generates electricity at 250 V_{RMS} at a frequency of 50 Hz. This is converted by a step-up transformer (T_1) to 22 000 V_{RMS}, transmitted to the edge of the village by power lines with a total resistance of 2.0 Ω, and converted back to 250 V_{RMS} by a step-down transformer (T_2) near the village. A diagram of the system is shown in Figure 5 below.

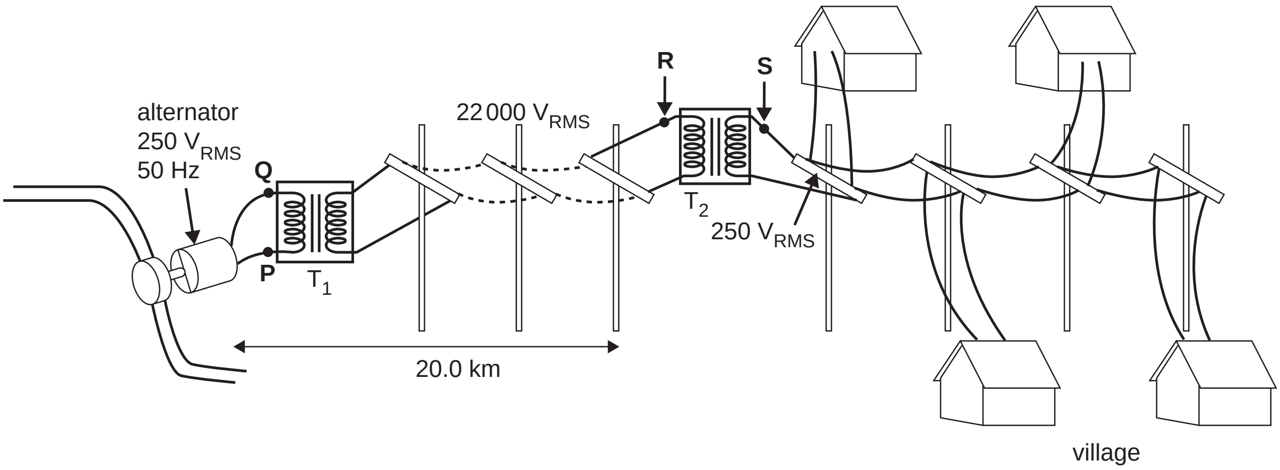


Figure 5

Question 9

What would be the current in the wires at the point marked S when 100 kW of power is being used?

A

2 marks

Question 10

Show that the current at point R is approximately 4.55 A when 100 kW of power is being used.

2 marks

Question 11

Estimate the power loss in the high voltage transmission lines supplying transformer T_2 when 100 kW of power is being used in the village. Show your working. Include the unit.

3 marks

Question 12

Briefly explain how high-voltage transmission leads to lower power losses in the system.

2 marks

A number of different transformers, A–D, are available for use as transformer T_1 in the system. Their characteristics are shown below.

Transformer	Number of turns in primary (input)	Number of turns in secondary (output)
A	62 200	500
B	44 000	500
C	500	44 000
D	500	62 200

Question 13

Which one of the transformers, A–D, would be suitable for use as transformer T_1?

2 marks

Question 14

Explain the operation of a transformer in terms of electromagnetic induction.

3 marks

The alternator fails and the village is without power. One possibility is to replace the alternator with a DC generator but an electrician says this should not be used.

Question 15

Explain why an alternator rather than a DC generator should be used in this system.

2 marks

Normally, the power being used in the village is 40 kW. However, as people come home, the power use increases to 80 kW. The alternator continues to provide 250 V_{RMS} at point P.

Question 16

Which one of the following (A–D below) is the most likely effect on the voltage at point S in Figure 5?

A. The voltage would increase slightly.

B. The voltage would decrease slightly.

C. The voltage would remain the same.

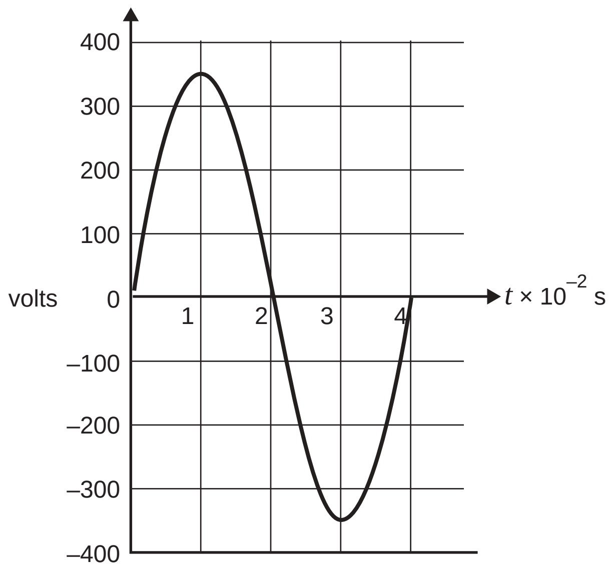
D. The voltage would halve.

2 marks

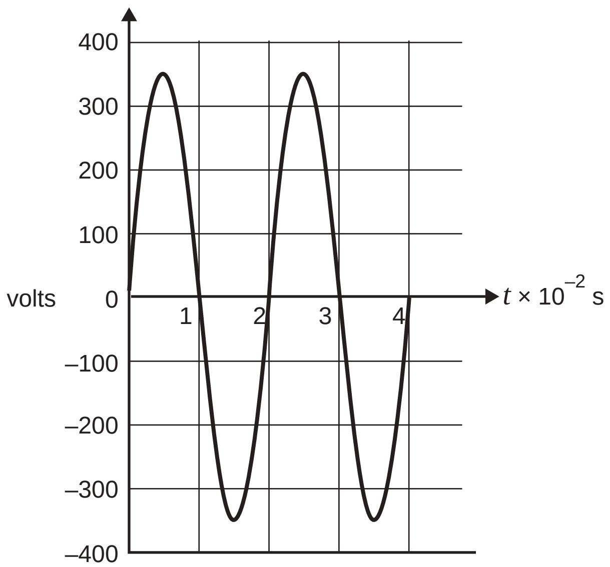
Question 17

Which one of the following graphs, A–D, best represents the output (voltage against time) at the alternator output terminals (P and Q).

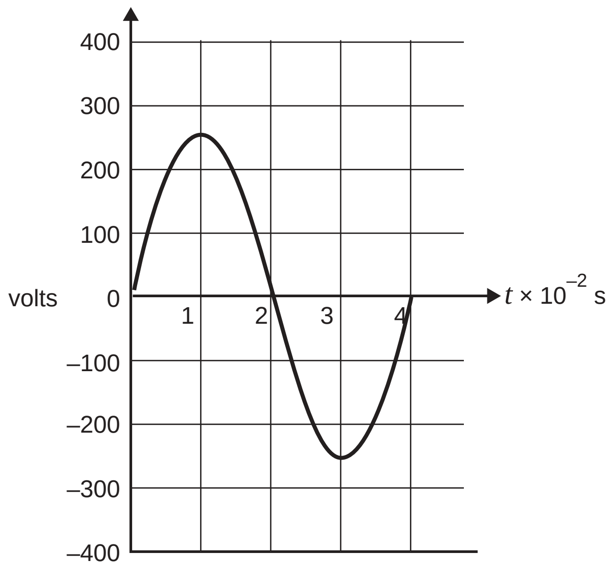
A.



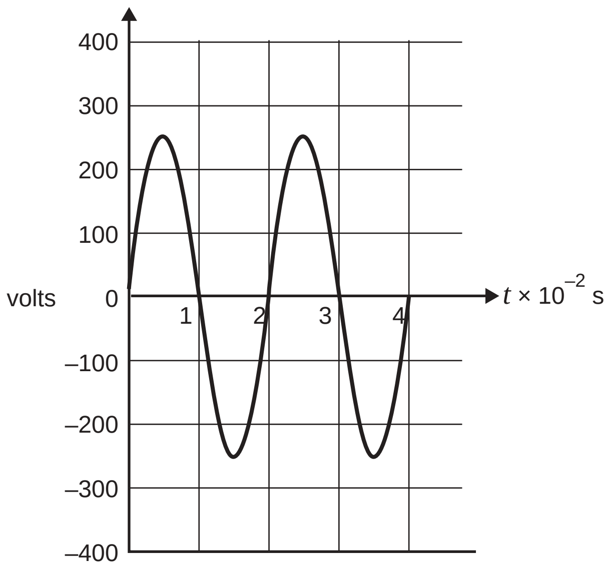
B.



C.



D.



2 marks

Area of study 2 – Interactions of light and matter

Question 1

The light from a candle can best be described as

A. coherent, arising from the vibrations of electrons.

B. incoherent, arising only from the transition of electrons in excited energy levels falling to lower energy levels.

C. coherent, arising only from the transition of electrons in excited energy levels falling to lower energy levels.

D. incoherent, arising from the vibrations of electrons.

2 marks

Question 2

The table below contains some predictions for the behaviour of light incident on a shiny metal sheet. Complete the table by placing a 'Y' (Yes) or 'N' (No) in the appropriate boxes if the prediction is supported by the wave **and/or** particle model of light. Some answers have already been provided. It is possible for predictions to be supported by both models.

Prediction	Wave model	Particle model
The number of photoelectrons produced is proportional to the intensity of the incident beam.	Y	
Light of low intensity will give rise to the emission of photoelectrons later than light of high intensity.		N
Light of high intensity will produce photoelectrons with a greater maximum kinetic energy than light of low intensity.	Y	
Light of sufficient intensity of any frequency should produce the photoelectric effect.	Y	

4 marks

Measurements of the kinetic energy of electrons emitted from potassium metal were made at a number of frequencies. The results are shown in Figure 1.

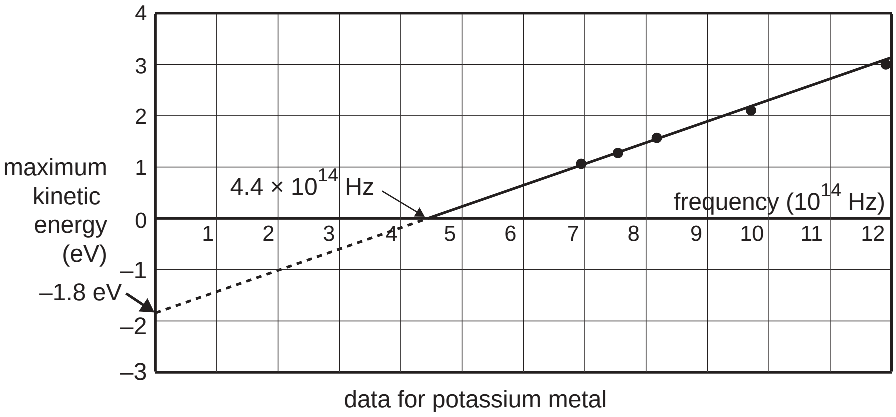


Figure 1

Question 3

What is the minimum energy of a light photon that can eject an electron from potassium metal?

eV

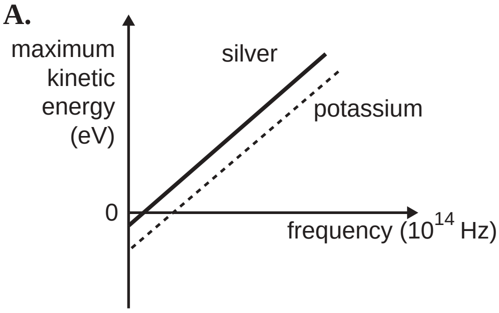
2 marks

The work function for silver metal is higher than the work function for potassium metal.

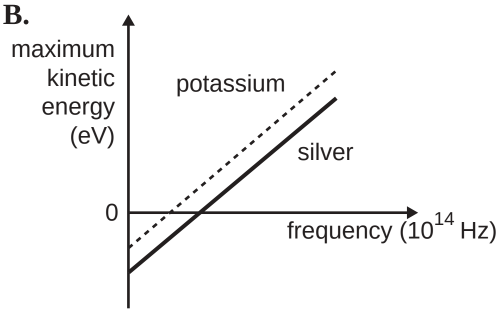
Question 4

Which one of the graphs (A–D below) would best describe the result if the experiment was repeated with silver metal instead of potassium metal?

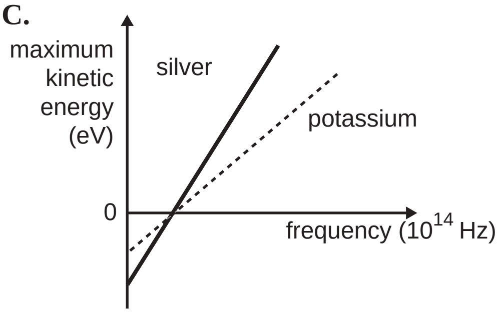
A.



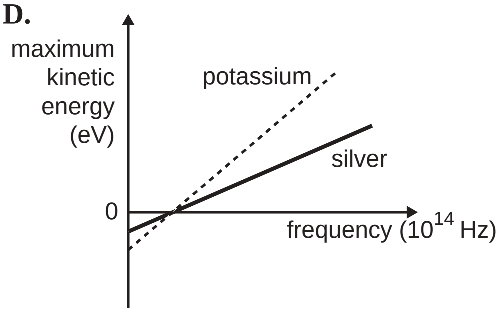
B.



C.



D.



2 marks

Figure 2 shows the energy levels of a sodium atom.

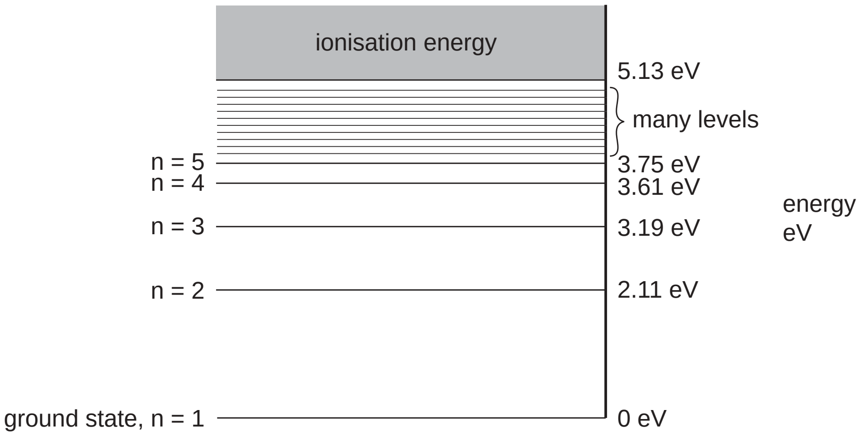


Figure 2

A sodium atom is initially in an n = 4 excited state.

Question 5

Calculate the highest frequency of light that this sodium atom could emit.

Hz

2 marks

Figure 2 shows that electrons in a sodium atom can only occupy specific energy levels.

Question 6

Describe how the wave nature of electrons can explain this.

2 marks

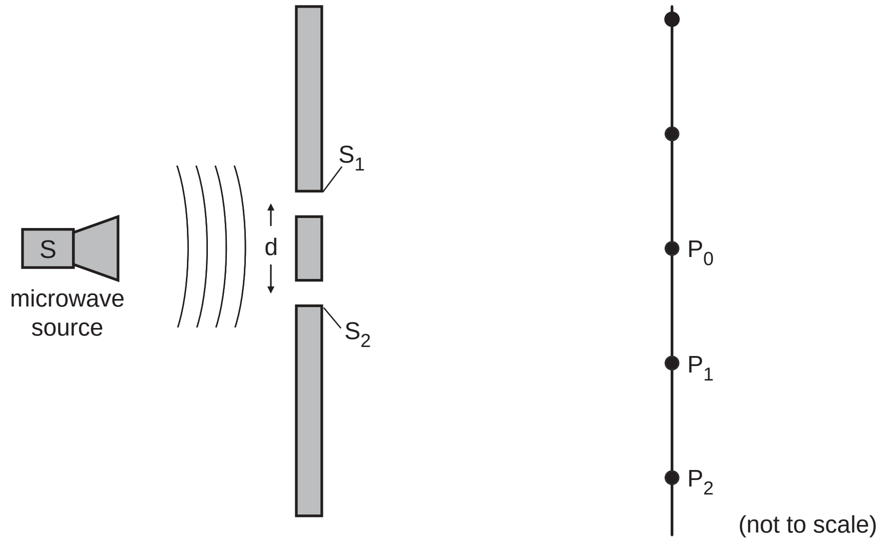


Figure 3

Students have set up an experiment similar to that of English physicist Thomas Young. The students' experiment uses microwaves of wavelength $\lambda = 2.8$ cm instead of light.

The beam of microwaves passes through two narrow slits shown as S_1 and S_2 in Figure 3.

The students measure the intensity of the resulting beam at points along the line shown and determine the positions of maximum intensity. These are shown as filled circles and marked P_0, P_1 . . .

Question 7

What is the difference in length ($S_2P_2 - S_1P_2$) where P_2 is the second maximum away from the central axis.

cm

2 marks

Question 8

Explain what Young's observation of bright and dark regions tells us about the nature of light.

2 marks

A beam of X-rays, wavelength $\lambda = 250$ pm (250×10^{-12} m), is directed onto a thin aluminium foil as shown in Figure 4a. The X-rays scatter from the foil onto the photographic film.

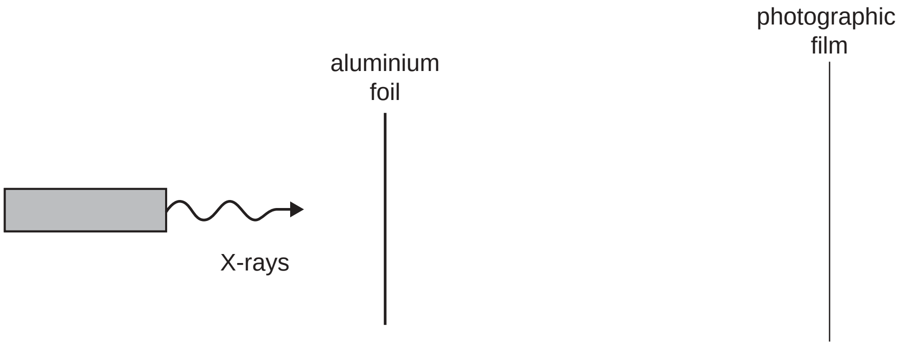


Figure 4a

Question 9

Calculate the energy, in keV, of these X-rays.

keV

2 marks

After the X-rays pass through the foil, a diffraction pattern is formed as shown in Figure 4b.

In a later experiment, the X-rays are replaced with a beam of energetic electrons. Again, a diffraction pattern is observed which is very similar to the X-ray diffraction pattern. This is shown in Figure 4c.

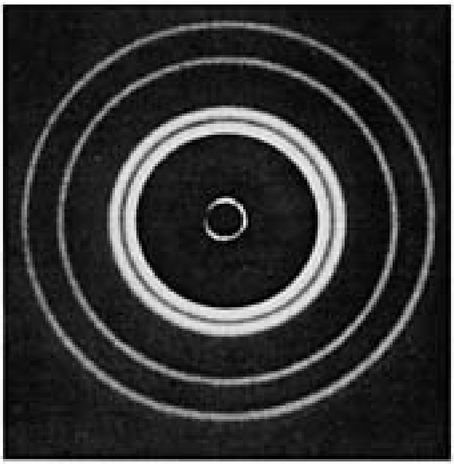


Figure 4b

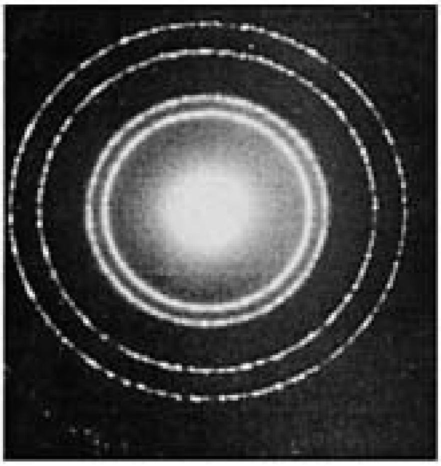


Figure 4c

Question 10

Explain why the electrons produce a diffraction pattern similar to that of the X-rays.

2 marks

Question 11

Assuming the two diffraction patterns are identical, estimate the momentum of the electrons. Include the unit.

3 marks

END OF SECTION A

TURN OVER

SECTION B – Detailed studies

Instructions for Section B

Choose **one** of the following **Detailed studies**. Answer **all** the questions on the Detailed study you have chosen.

Detailed study 1 – Synchrotron and its applications

Question 1

A student is preparing a brief talk on the operation of the Australian Synchrotron Facility. In the speech below, options to complete each sentence are given within the brackets. Circle the correct option in each case.

> In the Australian synchrotron, a beam of electrons is accelerated to almost the speed of light by the **[storage ring / linear accelerator / beam line]**. The beam is then confined to a circular orbit by a series of **[RF cavities / bending magnets / beam lines]** separated by straight sections. As the beam is deflected, **[monochromatic / longitudinal / electromagnetic]** radiation, which is commonly called synchrotron light, is produced.

3 marks

It is claimed that synchrotrons provide a superior source of X-rays compared to those produced by an X-ray tube.

Question 2

Explain **two** advantages of using a synchrotron as a source of X-rays rather than an X-ray tube.

Advantage 1

Advantage 2

4 marks

Question 3

In the Synchrotron Facility electrons are accelerated by several devices.

Which one of the following statements (A–D below) **best** describes the order in which this acceleration occurs?

A. linac → electron gun → booster ring

B. electron gun → linac → booster ring

C. linac → booster ring → electron gun

D. electron gun → booster ring → linac

2 marks

Electrons are circulated in the synchrotron ring when they have reached their maximum energy. To overcome energy loss in the circulating beam, additional energy is provided by RF acceleration in one of the straight sections of the ring.

Question 4

Which one of the following statements (A–D below) **best** describes the largest contribution to this energy loss?

A. The vacuum is not completely zero and so electrons lose energy as they circulate through the ring.

B. The bending and focusing magnets consume energy.

C. Electrons collide with each other and lose energy.

D. Electrons lose energy because of synchrotron radiation.

2 marks

X-rays of wavelength 71 pm are incident on a carbon block. The spectrum of X-rays has been measured at several scattering angles, and the results are shown below. The measurement directly in line with the beam at 0° (Figure 1a) shows a clear peak at 71 pm, as expected. However, at right angles (Figure 1b) and another unknown angle (Figure 1c), two distinct peaks are evident.

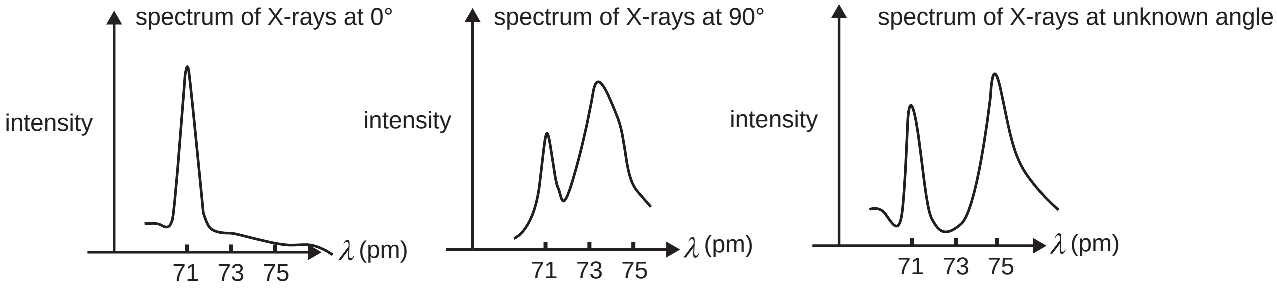


Figure 1a **Figure 1b** **Figure 1c**

Question 5

Identify and describe the process that could lead to the formation of peaks in the data at wavelengths greater than 71 pm.

2 marks

Question 6

Which one of the following (A–D below) is most likely to be the angle at which the measurement in Figure 1c was made?

A. 15°

B. 45°

C. 80°

D. 135°

2 marks

A simplified set-up for an electron gun is shown in Figure 2 below. It contains a high-voltage source (HV). In normal operation, electrons emerge from the gun with energies of 5 keV.

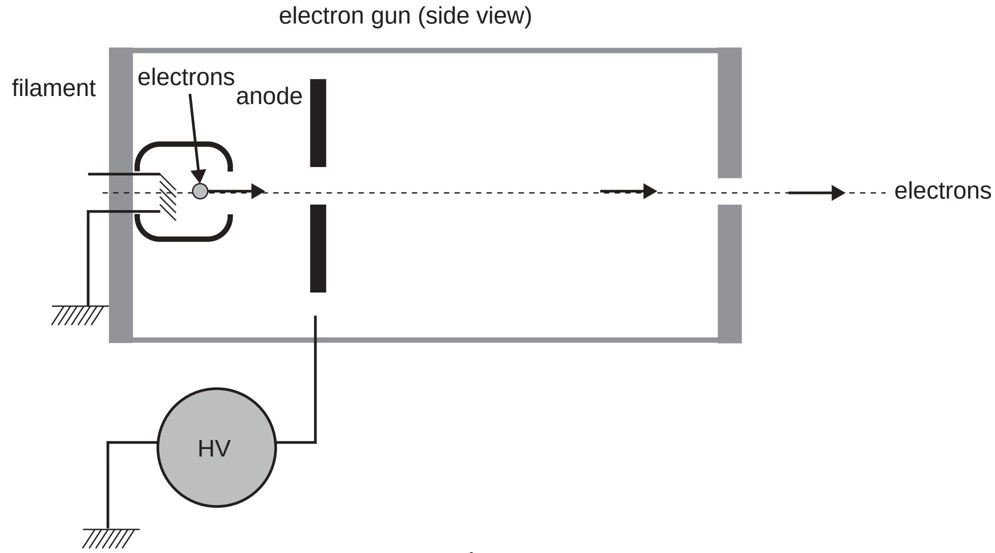


Figure 2

Question 7

Calculate the velocity for electrons of energy 5 keV.

($m_e = 9.11 \times 10^{-31}$ kg)

3 marks

As high-energy electrons pass through one of the bending magnets in the Australian Synchrotron Facility, they are bent through an arc of radius 7 m. The magnetic field strength is 1.7 T (Wb m^{-2}).

Question 8

Use the information above to determine the momentum of the electrons. Include a unit in your answer. (Ignore any relativistic effects in your calculation.)

3 marks

A beam of X-rays with a range of wavelengths is incident on the face of a perfect crystal as shown in Figure 3 below. As a result of Bragg diffraction, one of the scattered beams will be monochromatic.

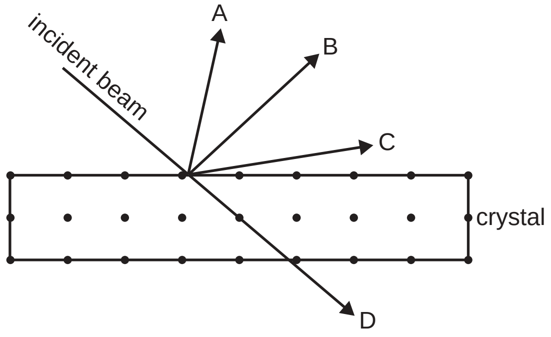


Figure 3

Question 9

Which one of the beams (A–D) in Figure 3 contributes to Bragg diffraction?

2 marks

Question 10

When the sample shown in Figure 3 was rotated, Bragg diffracted X-rays of wavelength 35 pm were observed to exit the sample at a minimum angle of 5° to the surface.

What is the spacing between the layers in the crystal?

m

2 marks

END OF DETAILED STUDY 1
TURN OVER

Detailed study 2 – Photonics

Question 1

In the paragraph below, options to complete each sentence are given within the brackets. Circle the correct option in each case.

> A fibre-optic cable is composed of two concentric layers called the core and the cladding. The refractive index of the core is always **[less than / equal to / greater than]** the index of the cladding. In a single-mode fibre, light enters the cable and propagates along a path which is the **[highest / lowest]** order mode. In this mode, chromatic dispersion and attenuation are **[reduced / increased]**.

3 marks

An LED emits light of wavelength 5.8×10^{-7} m.

Question 2

Which one of the following (A–D below) is the best estimate of the band gap of the semi-conductor material in this LED?

A. 2.14 eV
B. 21.4 eV
C. 214 eV
D. 2.14 keV

2 marks

Question 3

Which one of the following (A–D below) indicates the correct sequence of LED colours in **decreasing** value of band gap?

A. blue, green, red
B. red, blue, green
C. green, red, blue
D. blue, red, green

2 marks

The light produced by a red LED and a red HeNe laser is being compared.

Question 4

Identify **three** features of the red HeNe laser light that are superior to the light produced by the red LED.

3 marks

Graded-index multimodal fibres are constructed so that the refractive index is high at the core of the fibre and gradually decreases outwards to the boundary between the core and the cladding.

Question 5

Explain why these fibres have less modal dispersion than stepped-index fibres.

2 marks

A stepped-index optical fibre is shown in Figure 1. A ray of light is shown entering the optical fibre, with an angle of incidence, theta (θ). The ray meets the boundary between the core and the cladding at an angle of 10° to the interface.

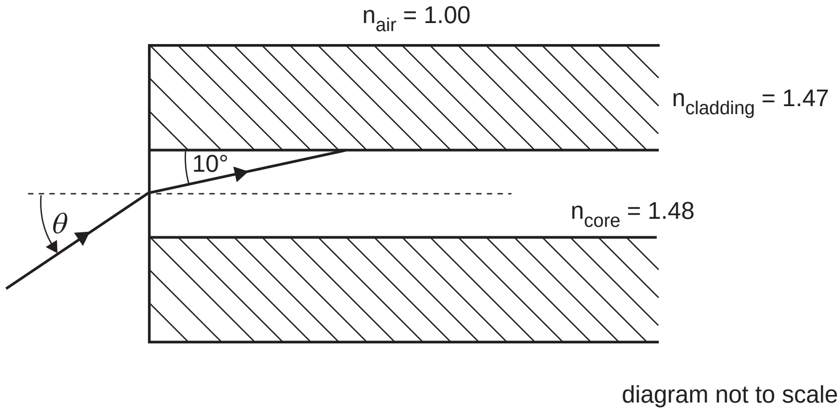


Figure 1

Question 6

What is the value of angle θ?

2 marks

Question 7

Calculate the critical angle for total internal reflection at the interface between the core and the cladding of this optical fibre.

°

3 marks

The stepped-index fibre is placed into water (n_{water} = 1.33).

Question 8

Which of the following changes for the acceptance angle and the critical angle will occur? Circle the appropriate option for each angle.

The acceptance angle will **change/remain the same**

The critical angle will **change/remain the same**

2 marks

Technicians are testing the transmission of light signals down a single-mode optical fibre that is many kilometres long (as shown in Figure 2 below). In one of the tests, the technicians simultaneously transmit an infrared (IR) pulse (λ = 1 200 nm) and a red (RD) pulse (λ = 650 nm). Both pulses reach the other end of the optical fibre.

Figure 2

Question 9

Which one of the following statements (A–C below) is correct?

A. The IR pulse arrives at the other end of the optical fibre **at the same time** as the RD pulse.

B. The IR pulse arrives at the other end of the optical fibre **before** the RD pulse.

C. The IR pulse arrives at the other end of the optical fibre **after** the RD pulse.

2 marks

The technicians find that the RD pulse suffers greater attenuation than the IR pulse.

Question 10

In terms of light scattering and absorption, provide an explanation for this finding.

2 marks

A bottle filled with water has a small hole drilled in one side. When the cork is removed from the hole, water will begin to stream out. A beam of laser light is directed into the bottle from the opposite side of the hole, through the water (as shown in Figure 3). The laser light exits the jug through the hole but remains contained in the water.

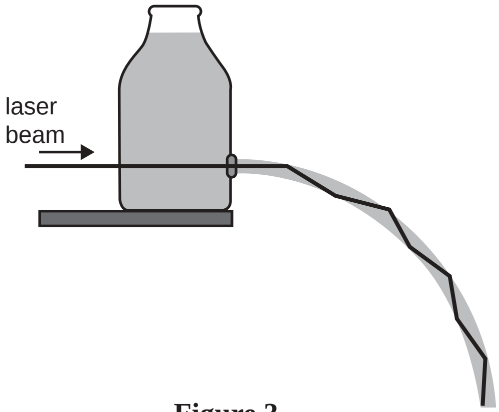


Figure 3

Question 11

Explain why the laser beam remains contained within the stream of water.

2 marks

END OF DETAILED STUDY 2

Detailed study 3 – Sound

Question 1

In the paragraph below, options to complete each sentence are given within the brackets. Circle the correct option in each case.

> Jamie is listening to the sound of an orchestra through a small gap in a partly open sliding door.
>
> When the sound wave travels through the gap,
>
> **[constructive interference / destructive interference / diffraction]** occurs and spreading of the wave results. High pitched (frequency) instruments such as flutes experience **[more / the same / less]** spreading than lower pitched instruments. As the size of the gap decreases, the angle of spreading will **[increase / not change / decrease]**.

3 marks

Consider a dust particle one metre in front of a loudspeaker that is producing a constant tone sound wave.

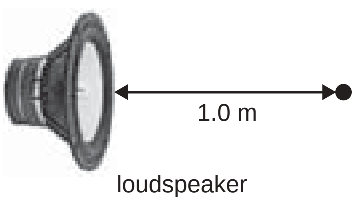


Figure 1

Question 2

Which one of the following statements and diagrams (A–D below) best describes the motion of the dust particle?

A.  The dust particle oscillates in a vertical direction.

B.  The dust particle travels away from the speaker with the wave.

C.  The dust particle remains stationary as the wave passes.

D.  The dust particle oscillates in a horizontal direction.

2 marks

Rachel and Bruce have assembled some laboratory equipment and are planning a series of sound-related experiments.

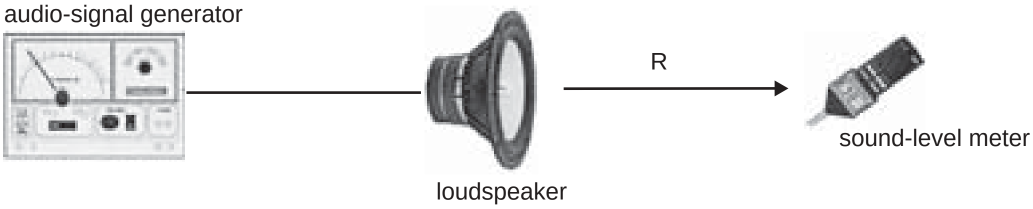


Figure 2

An audio-signal generator is used to drive a small loudspeaker, which emits sound uniformally in all directions. The audio power from the loudspeaker is kept constant at all frequencies used in the experiments. A sound-level meter is used to measure sound intensity. This is shown in Figure 2 above. Initially, the frequency of the signal generator is set to 476 Hz.

The speed of sound at the time of the experiment was 340 m s^{-1}.

Question 3

Calculate the wavelength of the 476 Hz sound wave. Include a unit in your answer.

2 marks

Rachel measures the **sound intensity level** 2.0 m directly in front of the loudspeaker to be 64 dB.

Question 4

What is the **sound intensity** (W m^{-2}) at this location?

W m^{-2}

2 marks

Rachel repeats the previous measurement, this time a distance 8.0 m directly in front of the loudspeaker.

Question 5

Which one of the following (A–D below) is the best estimate for the sound intensity level at this distance?

A. 4 dB
B. 16 dB
C. 32 dB
D. 58 dB

2 marks

Bruce places the loudspeaker in a box as shown in Figure 3 below. Rachel observes that the sound intensity level at 8.0 m directly in front of the loudspeaker has increased.

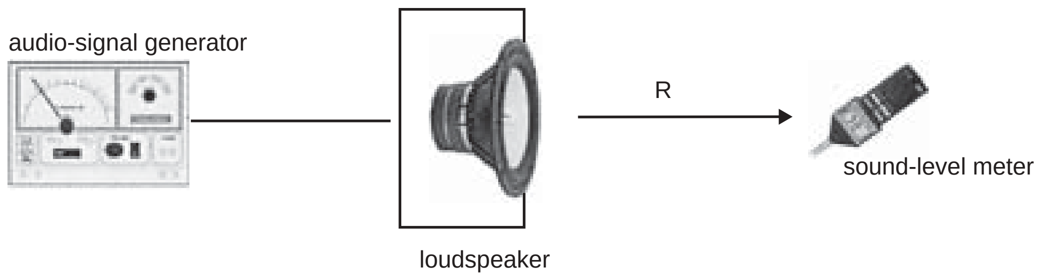


Figure 3

Question 6

In terms of wave theory, explain how the box increases the sound intensity level. Make sure that your answer includes references to both **interference** and **phase**.

2 marks

Sarah is planning to buy some plastic pipe from a hardware store. To measure the length of the pipe, she intends to blow across one end of the pipe and measure the frequency of the resonance produced.

The shop owner questions this method, but in the end agrees to let her perform the measurements. Sarah takes a section of pipe **open at both ends**, and performs the measurements. A clear resonance of 200 Hz can be heard.

Question 7

Use this information to determine the length of the pipe. Show your working/reasoning.

(speed of sound 340 m s^{-1})

m

3 marks

Question 8

At which **one or more** of the following frequencies could the pipe also resonate?

A. 300 Hz

B. 400 Hz

C. 500 Hz

D. 600 Hz

2 marks

Question 9

Briefly explain resonance in terms of the behaviour of the sound waves in a tube open at both ends.

3 marks

Question 10

Which one of the following (A–D below) best describes the physical operating principle of the electret-condensor microphone?

A. electromagnetic induction

B. piezo-electric effect

C. capacitance

D. electrical resistance

2 marks

Question 11

Briefly explain the operation of a dynamic microphone.

2 marks

END OF QUESTION AND ANSWER BOOK

PHYSICS

Written examination 2

DATA SHEET

Directions to students

Detach this data sheet before commencing the examination. This data sheet is provided for your reference.

1	photoelectric effect	$E_{k\max} = hf - W$
2	photon energy	$E = hf$
3	photon momentum	$p = \frac{h}{\lambda}$
4	de Broglie wavelength	$\lambda = \frac{h}{p}$
5	resistors in series	$R_T = R_1 + R_2$
6	resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$
7	magnetic force	$F = I\,l\,B$
8	electromagnetic induction	emf : $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$ flux: $\Phi = BA$
9	transformer action	$\frac{V_1}{V_2} = \frac{N_1}{N_2}$
10	AC voltage and current	$V_{\text{RMS}} = \frac{1}{\sqrt{2}}V_{\text{peak}}$ $I_{\text{RMS}} = \frac{1}{\sqrt{2}}I_{\text{peak}}$
11	voltage; power	$V = RI$ $P = VI$
12	transmission losses	$V_{\text{drop}} = I_{\text{line}} R_{\text{line}}$ $P_{\text{loss}} = I^2_{\text{line}} R_{\text{line}}$
13	mass of the electron	$m_e = 9.11 \times 10^{-31}$ kg
14	charge on the electron	$e = -1.60 \times 10^{-19}$ C
15	Planck's constant	$h = 6.63 \times 10^{-34}$ J s $h = 4.14 \times 10^{-15}$ eV s
16	speed of light	$c = 3.0 \times 10^8$ m s^{-1}

Detailed study 3.1 – Synchrotron and applications

17	energy transformations for electrons in an electron gun (<100 keV)	$\frac{1}{2}\text{m v}^2 = \text{eV}$
18	radius of electron beam	$\text{r} = \text{p}/e\text{B}$
19	force applied to an electron beam	$\text{F} = e\text{vB}$
20	Bragg's law	$n\lambda = 2d\sin\theta$
21	electric field between charged plates	$E = \frac{\text{V}}{d}$

Detailed study 3.2 – Photonics

22	band gap energy	$E = \frac{hc}{\lambda}$
23	Snell's law	$n_1 \sin i = n_2 \sin r$

Detailed study 3.3 – Sound

24	speed, frequency and wavelength	$v = f\lambda$
25	intensity and levels	sound intensity level (in dB) $= 10\log_{10}\left(\frac{I}{I_0}\right)$ where $I_0 = 1.0 \times 10^{-12}$ W m^{-2}

Prefixes/Units

p = pico = 10^{-12}

n = nano = 10^{-9}

μ = micro = 10^{-6}

m = milli = 10^{-3}

k = kilo = 10^{3}

M = mega = 10^{6}

G = giga = 10^{9}

t = tonne = 10^{3} kg

END OF DATA SHEET