VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2016

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

Letter

STUDENT NUMBER

PHYSICS
Written examination

Wednesday 9 November 2016

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section		*Number of questions*	*Number of questions to be answered*	*Number of marks*
A – Motion in one and two dimensions		6	6	40
Electronics and photonics		5	5	20
Electric power		6	6	38
Interactions of light and matter		4	4	30
	Number of detailed studies	*Number of detailed studies to be answered*	*Number of questions to be answered*	*Number of marks*
B – Detailed studies	6	1	11	22
				Total 150

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape) and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

Materials supplied
- Question and answer book of 72 pages.
- Formula sheet.
- Answer sheet for multiple-choice questions.

Instructions
- Write your **student number** in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.
- You may keep the formula sheet.

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

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Table of contents

SECTION A

SECTION B

SECTION A – Core studies

Instructions for Section A

Answer **all** questions in this section in the spaces provided. Write using blue or black pen.
Where an answer box has a unit printed in it, give your answer in that unit.
You should take the value of g to be 10 m s^{-2}.
Where answer boxes are provided, write your final answer in the box.
In questions worth more than 1 mark, appropriate working should be shown.
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Area of study – Motion in one and two dimensions

Question 1 (11 marks)

a. A train consists of an engine of mass 20 tonnes (20 000 kg) towing one wagon of mass 10 tonnes (10 000 kg), as shown in Figure 1.

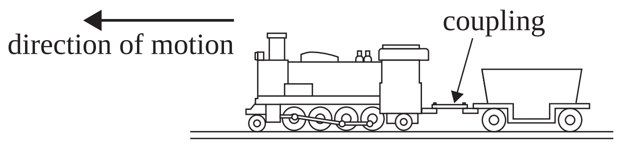


Figure 1

The train accelerates from rest with a constant acceleration of 0.10 m s^{-2}.

Calculate the speed of the train after it has moved 20 m. Show your working. 2 marks

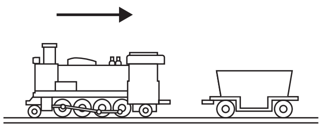
m s^{-1}

b. The wagon has a frictional resistance of 2000 N.

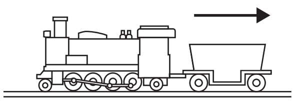
Calculate the tension in the coupling between the engine and the wagon. 2 marks

N

c. In another situation, the engine, of mass 20 tonnes and moving at 3.0 m s^{-1}, collides with a stationary wagon of mass 10 tonnes and couples with it, as shown in Figure 2.



before the collision



after the collision

Figure 2

Calculate the speed of the train (engine and wagon) after the collision. 2 marks

m s^{-1}

d. Determine whether the collision shown in Figure 2 was elastic or inelastic. Show your working. 2 marks

e. In another situation, the engine, moving to the right at 2.0 m s^{-1}, collides with but does not couple with the stationary wagon of mass 10 tonnes. After the collision, the wagon moves off to the right at 2.0 m s^{-1}.

Calculate the velocity (magnitude and direction) of the engine after the collision. Show your working. 3 marks

Magnitude m s^{-1}	Direction (left or right)

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Question 2 (5 marks)

A steel ball of mass 2.0 kg is swinging in a circle of radius 0.50 m at a constant speed of 1.7 m s^{-1} at the end of a string of length 1.0 m, as shown in Figure 3a.

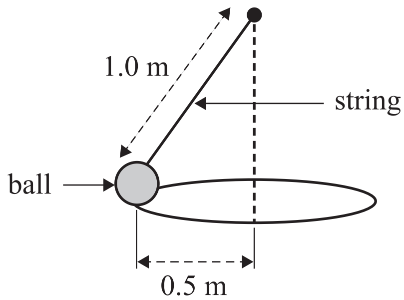

Figure 3a

Figure 3b

a. On Figure 3b above, draw all the forces **on the ball**. Label all forces. Draw the resultant force as a dotted line labelled F_R. 2 marks

b. Calculate the tension in the string shown in Figure 3a. Show your working. 3 marks

N

Question 3 (4 marks)

To determine the spring constant, k, of a spring, students attach 50 g masses to it consecutively and measure the extension, Δx. This is shown in Figure 4a.

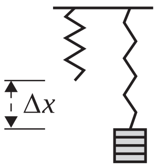

Figure 4a

The students' results are shown in the table below.

Number of masses	**Extension from unstretched length, Δx**
0	0 cm
1	25 cm
2	50 cm
3	75 cm

a. Calculate the value of the spring constant, k. 2 marks

N m^{-1}

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b. With four masses on the spring, the students release it from its unstretched length, as shown in Figure 4b.

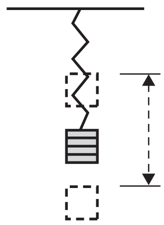
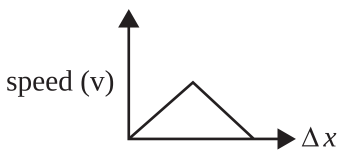


Figure 4b

Which one of the following graphs (**A.–E.**) best shows the speed as a function of extension Δx as the mass moves from top to bottom? Explain your answer. 2 marks

A.



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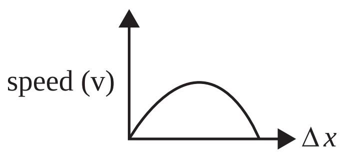

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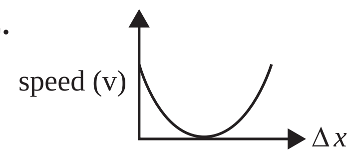
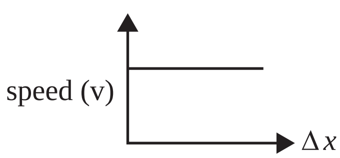
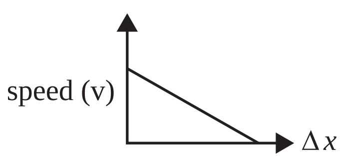


D.



E.



Question 4 (9 marks)

In a test, an unpowered toy car of mass 4.0 kg is held against a spring, compressing the spring by 0.50 m, and then released, as shown in Figure 5.

There is negligible friction while the car is in contact with the spring.

Figure 5 also shows the force–extension graph for the spring.

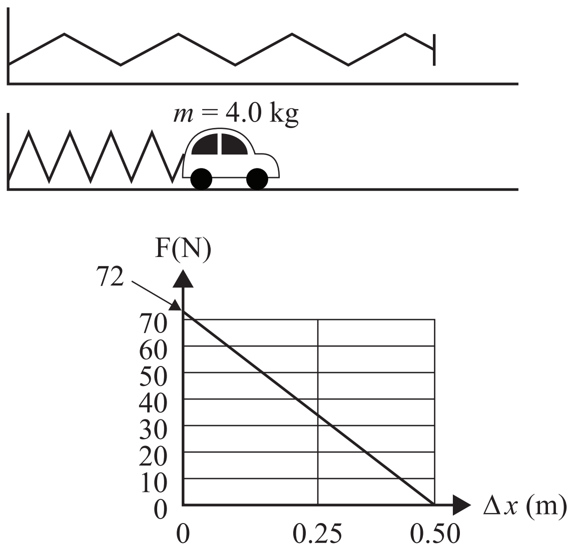


Figure 5

a. Determine the energy stored in the spring before release. 2 marks

J

b. Calculate the speed of the car as it leaves the spring. Ignore any frictional forces. 2 marks

m s^{-1}

A second test is done, where the spring is not compressed as far, and the car moves off at a speed of 2.0 m s^{-1}.

c. Calculate the impulse given to the car by the spring. Include an appropriate unit. 2 marks

d. After the car leaves the spring at 2.0 m s^{-1}, the car has a constant frictional resistance of 2.0 N.

Calculate how far the car travels before it stops. Show your working. 3 marks

m

Question 5 (5 marks)

A ball is projected from the ground at an angle of 30° to the horizontal and at a speed of 40 m s^{-1}, as shown in Figure 6. Ignore any air resistance.

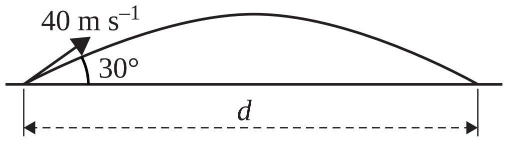


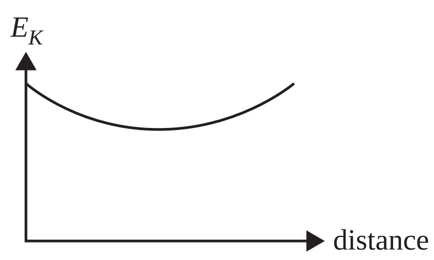
Figure 6

a. Calculate the distance, d, to the point where the ball hits the ground. Show your working. 3 marks

m

b. Which one of the following graphs (**A.–D.**) best shows the kinetic energy of the ball as a function of horizontal distance, d, from the launching point? Explain your answer. 2 marks

A.



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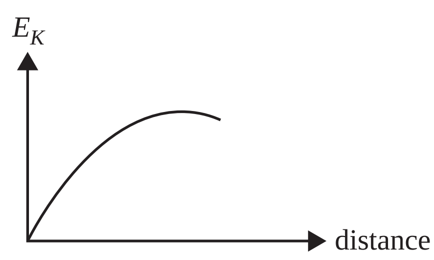

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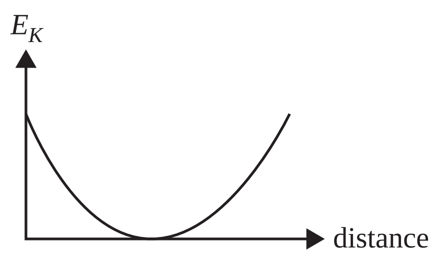
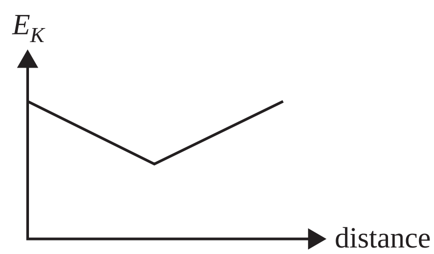


D.



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Question 6 (6 marks)

a. Explain the conditions for a satellite to be in a geostationary orbit (that is, stationary over a fixed point on Earth's surface). There is no need to calculate the actual radius of the orbit. 3 marks

b. Roger states that there are a number of situations on or near Earth's surface where a person may 'feel weightless'.

Emily states that this is impossible. It is only possible to feel weightless in deep space where there is no, or very little, gravitational force on a person.

Is Emily correct or incorrect? Explain your answer. 3 marks

Area of study – Electronics and photonics

Question 7 (6 marks)

Students set up the circuit shown in Figure 7.

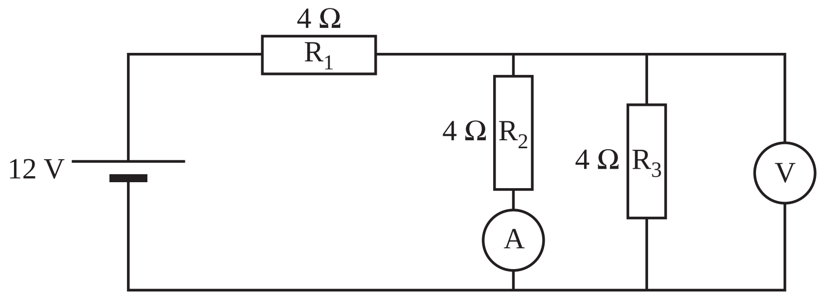


Figure 7

a. What is the reading on voltmeter V in Figure 7? 2 marks

V

b. What is the reading on ammeter A in Figure 7? 2 marks

A

R_3 is replaced by a light-emitting diode (LED). The characteristics of the LED are shown in Figure 8.

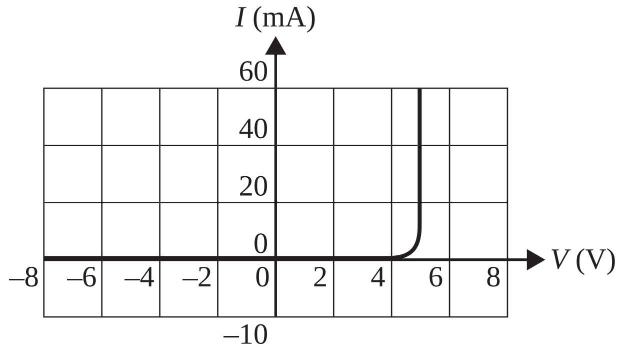


Figure 8

The circuit is shown in Figure 9.

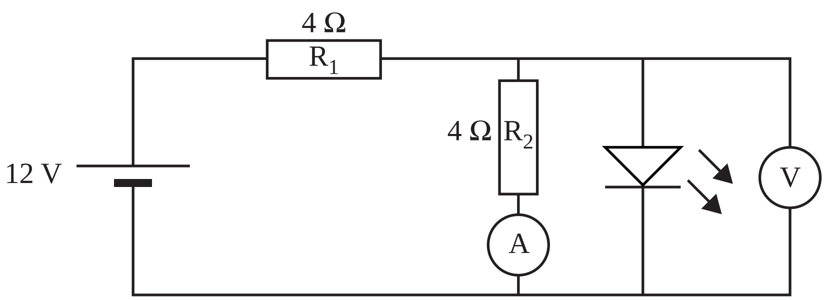


Figure 9

c. What is the reading on ammeter A in Figure 9? 2 marks

A

Question 8 (5 marks)

In many cases, LEDs are replacing other types of lights because they use less power.

The tail-light of a train is made up of six red LEDs arranged as shown in Figure 10a. The characteristics of each LED are shown in Figure 10b.

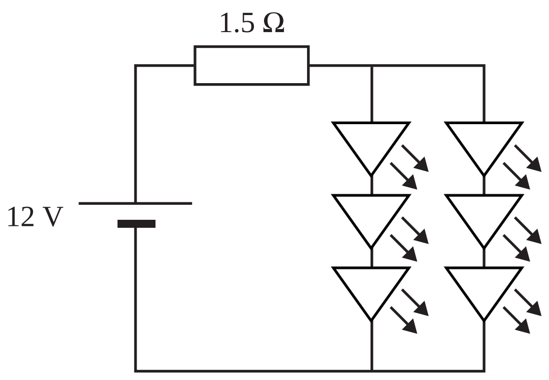


Figure 10a

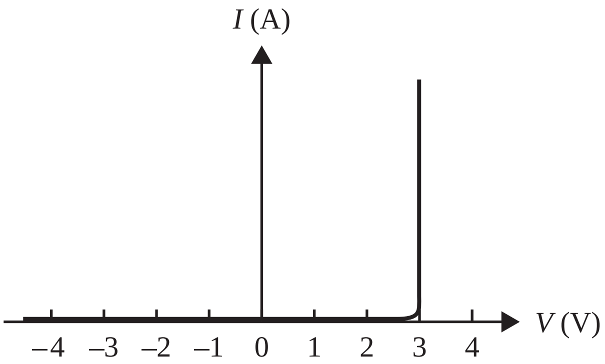


Figure 10b

a. Calculate the total power dissipated in the six LEDs (not the resistor). Show each step of your working clearly. 3 marks

W

b. Discuss the effect on the currents in the circuit shown in Figure 10a if one LED fails (open circuit). 2 marks

Question 9 (2 marks)

A fibre-optic cable is used to carry the signal from a singer's microphone to a theatre's amplifier system, as shown in Figure 11.

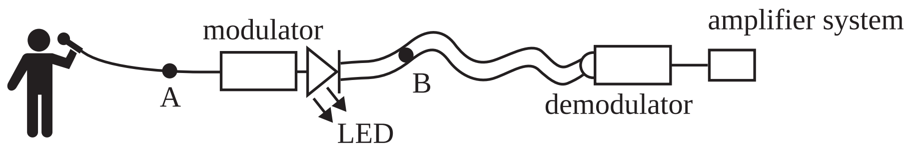


Figure 11

The electrical input signal from the microphone at point A is shown in Figure 12.

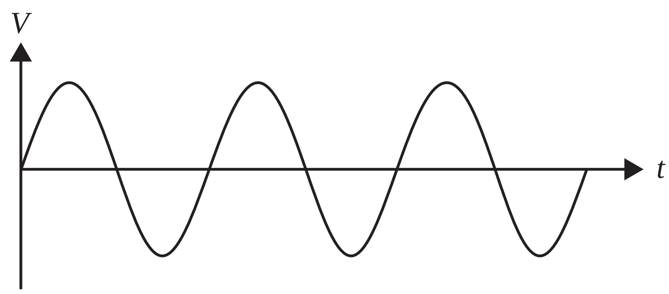
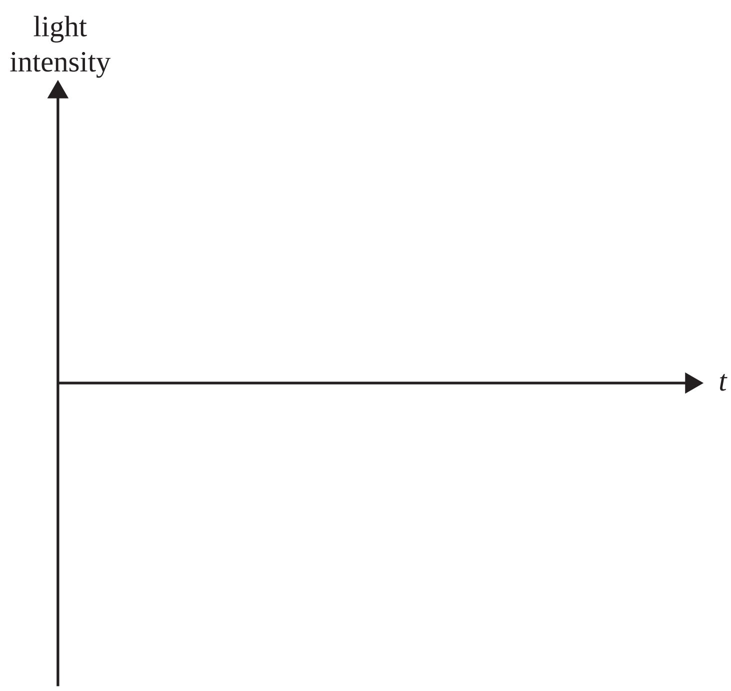


Figure 12

On the axes below, sketch the light intensity in the fibre-optic cable at point B, shown in Figure 11.



Question 10 (3 marks)

A thermistor is a device in which resistance is a function of temperature. The characteristics of a particular thermistor are shown in Figure 13.

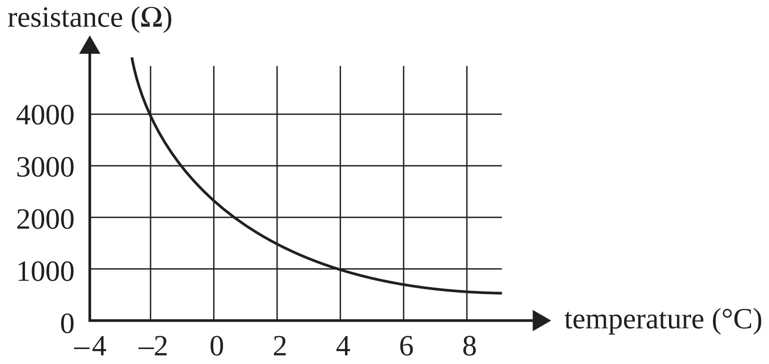


Figure 13

a. What is the resistance of the thermistor at 4 °C? 1 mark

Ω

b. This thermistor is used to control the temperature of a freezer unit. The circuit is shown in Figure 14 below.

The switch controlling the freezer switches it on when the voltage across the variable resistor R is equal to or greater than 2 V.

The freezer unit must turn on when the temperature is –2 °C or higher.

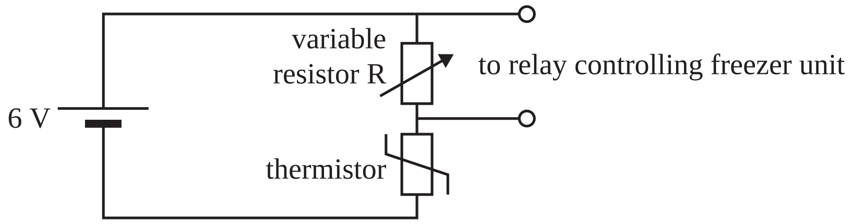


Figure 14

What value should resistor R have in order to achieve this? 2 marks

Ω

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Question 11 (4 marks)

The characteristics of a voltage amplifier are shown in Figure 15.

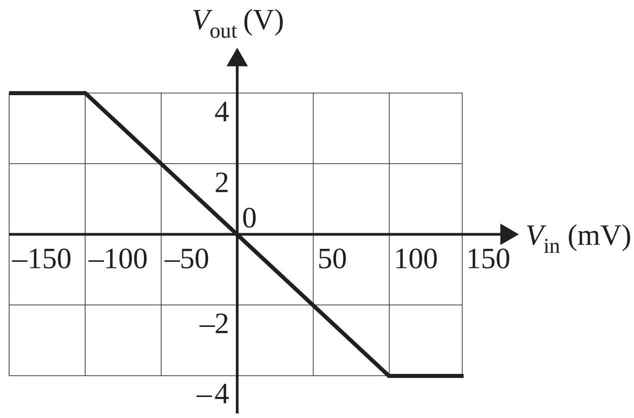

Figure 15

The input signal to the amplifier is shown in Figure 16.

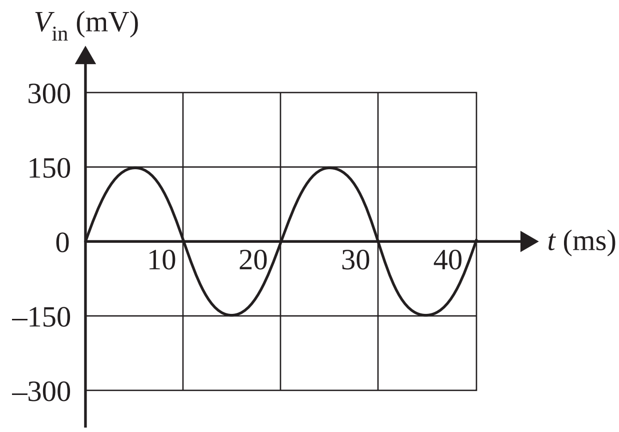

Figure 16

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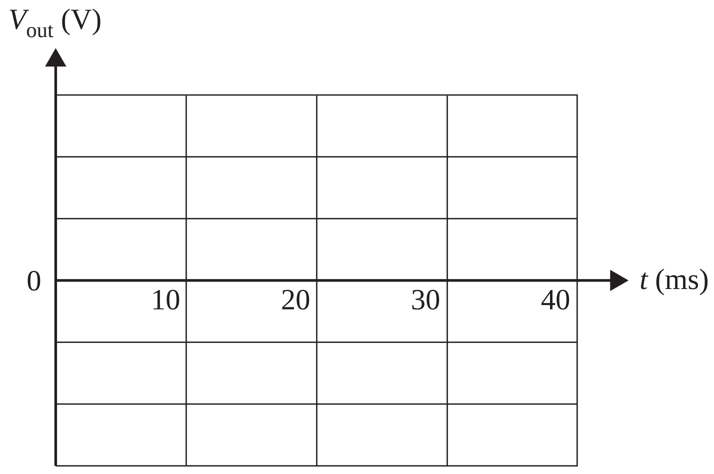
a. On the axes below, draw a graph of the output voltage, V_{out}, against time. Include a scale on the V_{out} y-axis. 2 marks



b. Explain the meaning of the term 'clipping', including its cause. 2 marks

Area of study – Electric power

Question 12 (3 marks)

Two bar magnets are arranged in three different ways, as shown in Figures 17a, 17b and 17c.

Figure 17a

Figure 17b

Figure 17c

In the space between the magnets in each figure, draw **at least four** magnetic field lines for each arrangement. Attach arrowheads to each field line, showing the direction of the field along each line.

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Question 13 (4 marks)

A 3.0 m long, vertical, copper lightning conductor is located in a region where Earth's magnetic field is horizontal and pointing north. A current of 2000 A flows down the conductor to Earth during an electrical storm. Force detectors measure a force on the lightning conductor of 0.32 N.

a. Calculate the magnitude of Earth's magnetic field acting on the lightning conductor. 2 marks

T

b. Which one of the following (**A.–F.**) is the best description of the direction of the magnetic force acting on the lightning conductor? Explain your answer. 2 marks

A. north
B. south
C. east
D. west
E. vertically up
F. vertically down

Question 14 (5 marks)

Students build a simple electric motor, as shown in Figure 18.

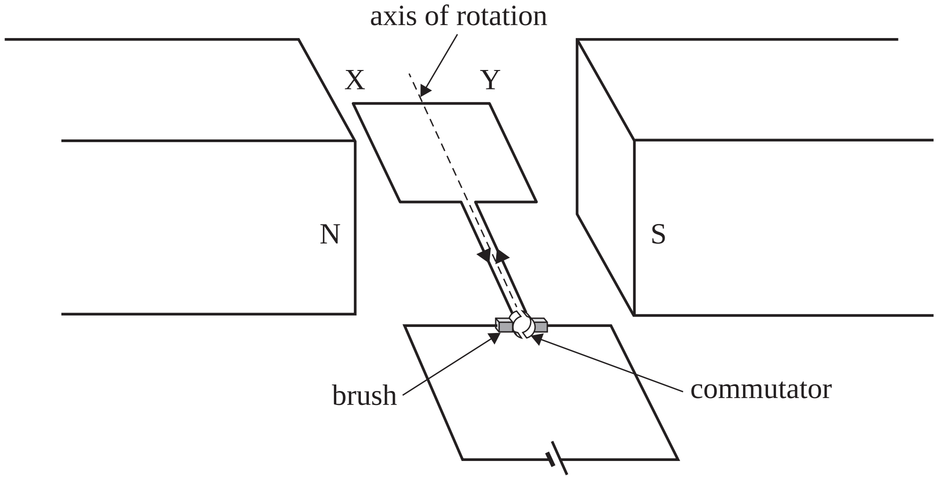

Figure 18

a. At what position(s) (**A.–D.**) of the rotating coil is the magnetic force on the side XY zero? One or more answers may be selected. 1 mark

A. horizontal with the current as shown in Figure 18

B. horizontal with the current in the opposite direction to that shown in Figure 18

C. vertical

D. at all orientations of the coil

b. The students discover that the motor starts moving more easily with the coil in some orientations than in others.

Explain the best orientation(s) for starting the motor to move from rest. 2 marks

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c. To increase the speed of rotation of the motor, the students suggest a number of improvements.

Which suggested improvement(s) (**A.–D.**) is likely to increase the speed of rotation of the coil? One or more answers may be selected. Explain your answer. 2 marks

A. increase the battery voltage

B. replace the single coil of the motor with several turns

C. increase the resistance of the coil

D. reverse one of the poles of the permanent magnets

Question 15 (5 marks)

A coil is wound around a cardboard cylinder, as shown in Figure 19. The cross-sectional area of the coil is $0.0060\ m^2$. There are 1000 turns in the coil (not all are shown in the diagram).

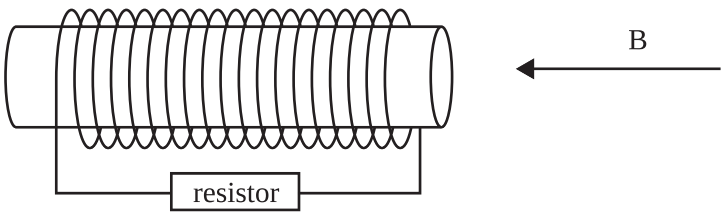

Figure 19

The axis of the coil is immersed in a uniform external magnetic field of strength 0.0050 T and its direction is shown by the arrow labelled B in Figure 19.

a. Calculate the magnitude of the flux through the first turn of the coil. Include an appropriate unit. 2 marks

b. The external magnetic field is now reduced to zero. This results in an emf in the coil.

Describe the direction of the current in the resistor during this time (use the words 'left' and 'right'). Give reasons for your answer. 3 marks

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Question 16 (12 marks)

Ruby and Max are investigating the transmission of electric power using a model system, as shown in Figure 20a. The circuit is shown in Figure 20b.

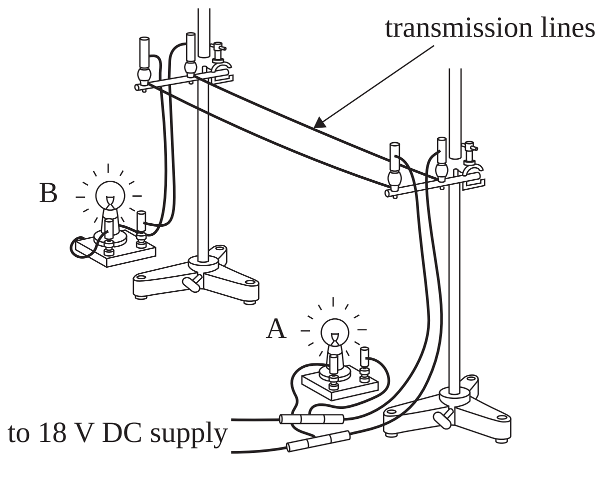

Figure 20a

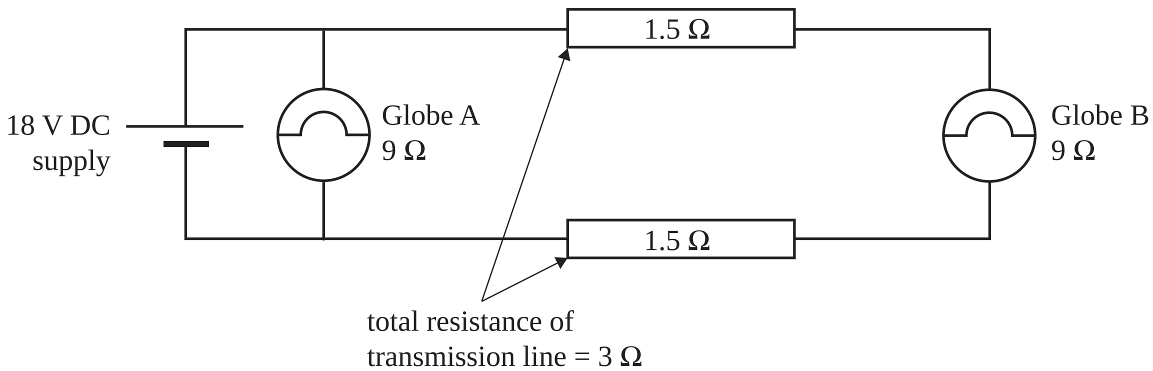

Figure 20b

Ruby and Max use an 18 V DC power supply, as shown in Figure 20b. The two transmission lines have a **total** resistance of 3.0 Ω. Assume that the resistance of the globes is constant at 9.0 Ω and that the other connecting wires have zero resistance.

a. Calculate the power delivered to Globe A. 2 marks

W

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b. Calculate the total voltage drop over the transmission lines. Show your working. 2 marks

V

c. Calculate the power delivered to Globe B. Show your working. 3 marks

W

Ruby has noticed that the voltage supply to houses is AC and that there are transformers involved (on street poles and at the fringes of the city). Ruby and Max next investigate the use of transformers to reduce power losses in transmission.

Ruby and Max have two transformers available – a 1:10 step-up transformer and a 10:1 step-down transformer.

d. In the space provided below, redraw the circuit in Figure 20b with an 18 V AC supply and with the transformers correctly connected. Label the transformers as step up and step down. 2 marks

e. Explain why the transformers would reduce the transmission losses. Your answer should include reference to key physics formulas and principles. 3 marks

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Question 17 (9 marks)

Samira and Mark construct a simple alternator, as shown in Figure 21.

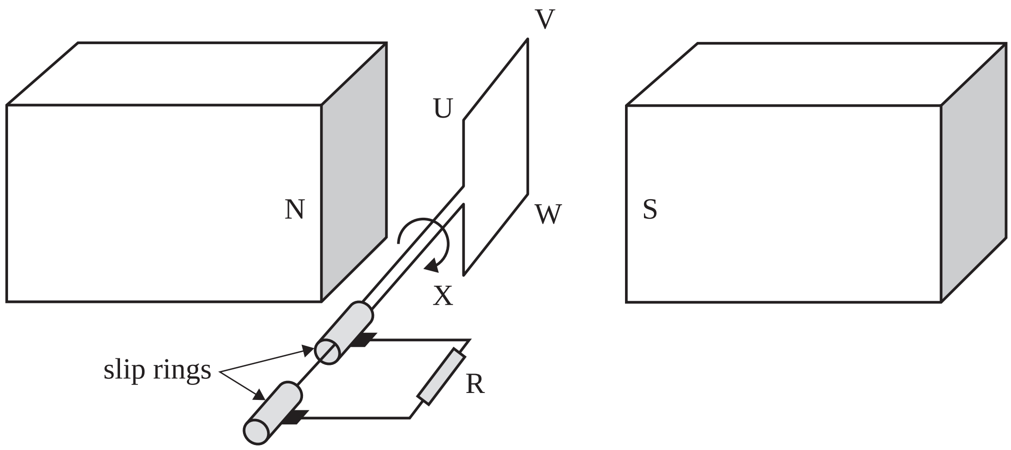

Figure 21

When the coil is rotating steadily, it takes 40 ms for each complete rotation and produces a peak emf of 3.5 V.

a. Calculate the frequency of the AC emf. 2 marks

Hz

b. Calculate the RMS value of the AC emf. 1 mark

V

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c. Describe the orientation(s) of the rotating coil when the magnitude of the emf is at a maximum. Give reasons for your answer. 2 marks

d. To increase the magnitude of the emf produced by the alternator, Mark suggests making a number of changes to the alternator. His suggested changes are given in the table below.

In the spaces provided, indicate whether each suggestion will increase, decrease or have no effect on the emf of the alternator. 4 marks

Suggested change	**emf (increases, decreases, no effect)**
Increase the number of turns in the rotating coil.	
Increase the frequency of rotation of the coil.	
Increase the strength of the permanent magnets.	
Reduce the resistance of the resistor R.	

Area of study – Interactions of light and matter

Question 18 (6 marks)

Amelia and Rajesh conduct an experiment to study interference using a laser and double slits, as shown in Figure 22. X is a dark band as shown.

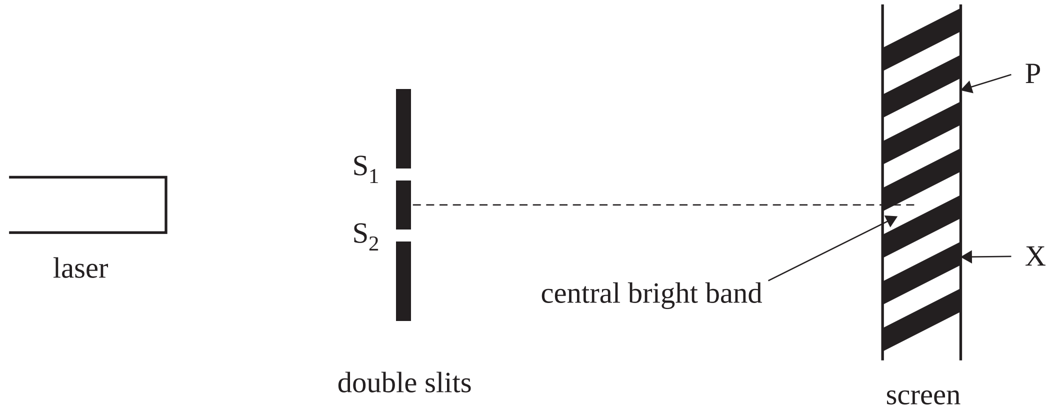


Figure 22

The path difference $S_1X - S_2X$ is found to be 750 nm.

a. Calculate the wavelength of the laser. 2 marks

nm

b. P is a bright band.

Calculate the path difference $S_2P - S_1P$. Show your working. 2 marks

nm

c. Amelia and Rajesh replace the double slits with a single slit of width *w*, as shown in Figure 23. They find that the width of the central maximum of the diffraction pattern is *y*.

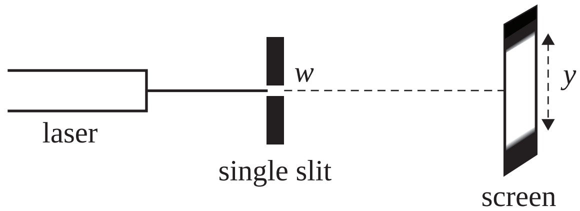


Figure 23

They replace the single slit with another single slit of width 2*w*.

Which one of the following (**A.–D.**) will Amelia and Rajesh observe in the diffraction pattern? Explain your answer. 2 marks

A. The width will be *y*, but twice the intensity.

B. The width will be *y*, but half the intensity.

C. The width will be approximately 2*y*.

D. The width will be approximately $\frac{1}{2}y$.

Question 19 (10 marks)

Emily is conducting an experiment to investigate the photoelectric effect. The apparatus is shown in Figure 24. It consists of a light source, a filter and a photocell (a metal plate with a collecting electrode in a vacuum tube).

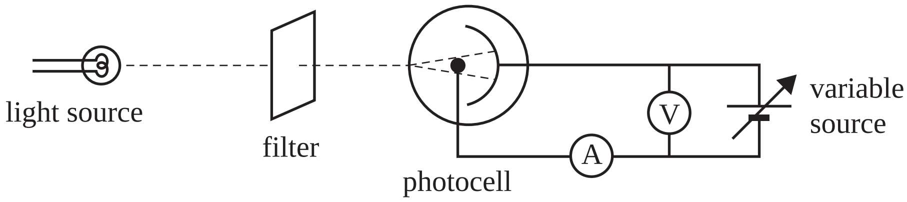


Figure 24

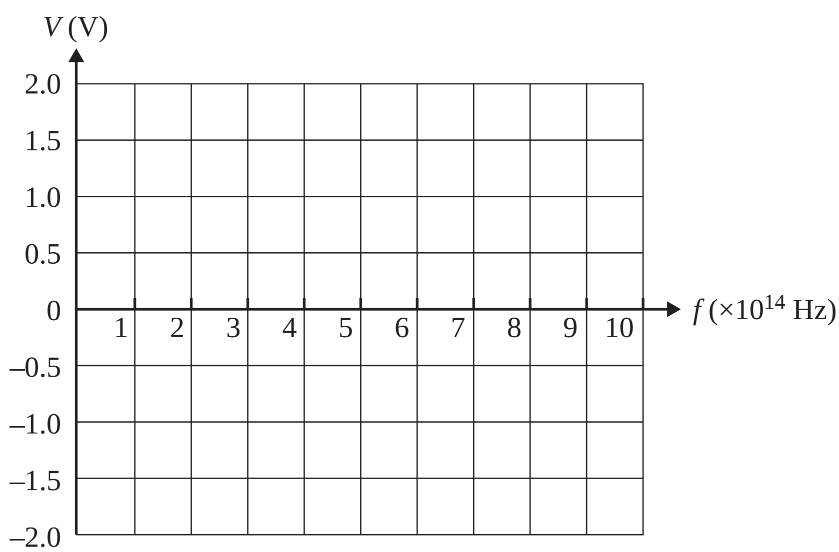
Emily uses various filters to shine a particular wavelength on the photocell.

She increases the voltage (V) until the current just goes to zero and records this voltage. Emily repeats this process for different frequencies.

Her results are shown in the table below.

Frequency (Hz)	Voltage (V)
6.0×10^{14}	0.16
7.0×10^{14}	0.52
8.0×10^{14}	0.88
9.0×10^{14}	1.20

a. On the axes below, plot Emily's data and draw the graph of voltage versus frequency. 2 marks



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b. From the graph, determine the value Emily would have found for each of the following. 3 marks

Planck’s constant	eV s
Threshold frequency	Hz
Work function of the metal	eV

c. Explain how the recorded voltage measurements give information about the emitted photoelectrons. 2 marks

d. For each frequency, Emily doubles the intensity of the incident light.

Describe the graph Emily will now obtain in comparison with the original graph. Do these two graphs support the wave model or particle model of light? Justify your answer. 3 marks

Question 20 (7 marks)

A beam of electrons is produced in an electron gun.

The de Broglie wavelength of each electron is 0.36 nm.

a. Calculate the speed of the electrons. 2 marks

m s^{-1}

An experiment is undertaken to compare the diffraction of these electrons and X-rays. With a similar gap spacing, the diffraction patterns are found to be nearly identical.

b. Calculate the energy of the X-rays. Show each step of your working. 3 marks

eV

c. Explain why similar patterns are observed. 2 marks

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Question 21 (7 marks)

The visible spectrum of the hydrogen atom is observed to emit photons of energy 2.6 eV.

a. Calculate the wavelength of this emission spectral line. 2 marks

nm

The energy levels for the hydrogen atom are shown in Figure 25.

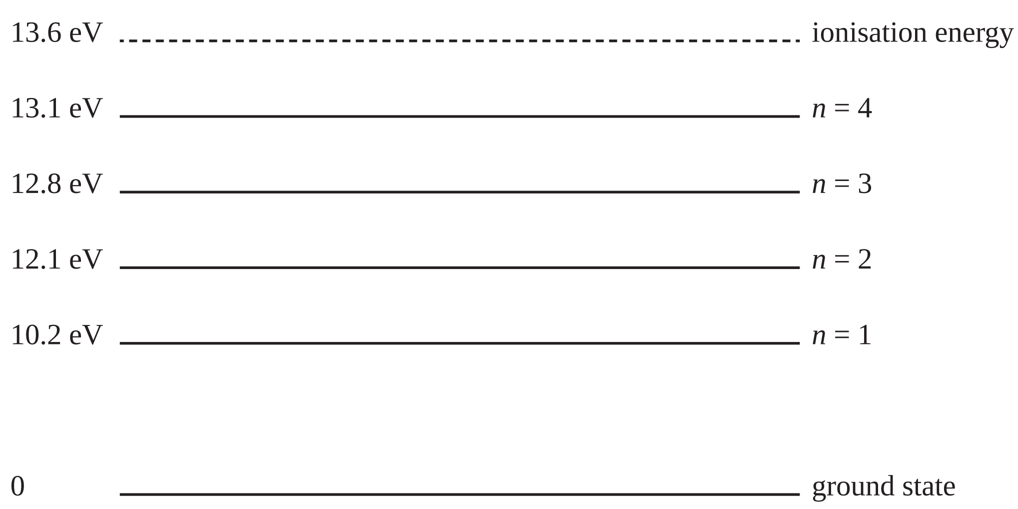

Figure 25
not to scale

b. Draw an arrow on Figure 25 to indicate the transition that could cause the spectral line calculated in **part a.** 2 marks

c. A hydrogen atom is excited to the 12.8 eV energy level.

List the possible photon energies (in eV) that could be emitted as it returns to its ground state. 3 marks

END OF SECTION A
TURN OVER

SECTION B

Instructions for Section B

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Detailed study 1 – Einstein's special relativity

Use the following information to answer Questions 1 and 2.

Anna and Barry have identical quartz clocks that use the precise period of vibration of quartz crystals to determine time. Barry and his clock are on Earth. Anna accompanies her clock on a rocket travelling at constant high velocity, v, past Earth and towards a space lab (which is stationary relative to Earth), as shown in Figure 1.

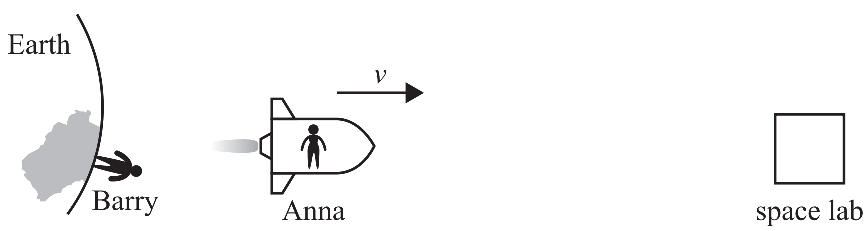

Figure 1

Question 1

Which one of the following statements correctly describes the behaviour of these two clocks?

A. The period of vibration in Anna's clock (as observed by Anna) will be shorter than the period of vibration in Barry's clock (as observed by Barry).

B. The period of vibration in Anna's clock (as observed by Anna) will be longer than the period of vibration in Barry's clock (as observed by Barry).

C. The period of vibration in Anna's clock (as observed by Anna) will be the same as the period of vibration in Barry's clock (as observed by Barry).

D. Only the time on Barry's clock is reliable because it is in a frame that is not moving.

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Question 2

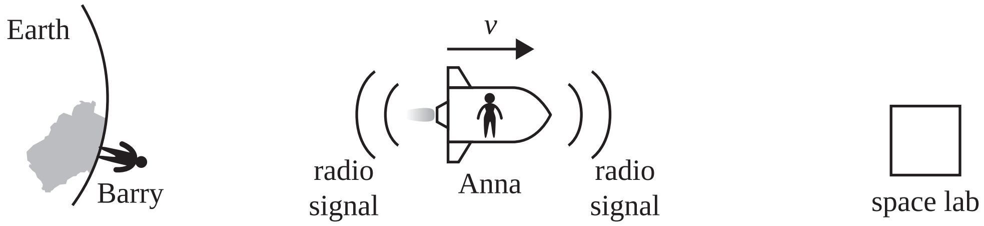

Figure 2

When Anna is halfway between Earth and the space lab, she sends a radio pulse towards Earth and towards the space lab, as shown in Figure 2.

As observed by Anna, which one of the following statements correctly gives the order in which this signal is received by Barry and by the space lab?

A. Barry receives the signal first.

B. The space lab receives the signal first.

C. The signal is received by Barry and the space lab at the same time.

D. It is not possible to predict since special relativity applies to light but not to radio signals.

Question 3

Figure 3 shows Carla moving towards a loudspeaker at a speed of v_C and Han running towards a light source at speed v_H.

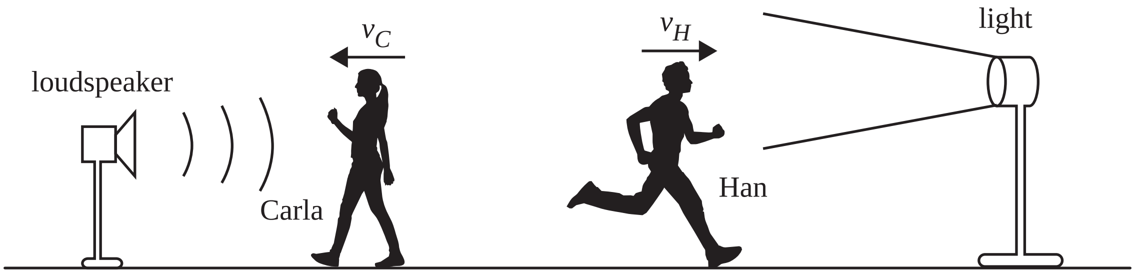

Figure 3

Which of the following correctly shows the speed of sound relative to Carla and the speed of light relative to Han? (The speed of sound in air is v_S.)

	Speed of sound relative to Carla	Speed of light relative to Han
A.	v_S	c
B.	$v_S + v_C$	$c + v_H$
C.	$v_S + v_C$	c
D.	$v_S - v_C$	$c - v_H$

Question 4

Michelson and Morley conducted an important experiment on the propagation of light in 1887. However, the experiment failed to show an effect that was expected by many physicists of that time. A number of theories were proposed to explain this result.

Which one of the following statements best describes the most important step in knowledge of physics that followed from this Michelson–Morley result?

A. Einstein's first postulate on the laws of physics removed the problem of the Michelson–Morley result.

B. Einstein's second postulate on the speed of light directly explained the Michelson–Morley result.

C. The concept of an 'aether' (a medium that allowed light to propagate) was upheld.

D. Maxwell's equations were shown to be incorrect.

Use the following information to answer Questions 5 and 6.

Pions are particles that are present in cosmic rays striking Earth. Pions decay, with a half-life of 26 ns.

The half-life is the time taken for half of a large number of pions to decay.

Question 5

In which frame of reference will the undilated value of the half-life be correctly observed?

A. in the frame of the high-energy source of each pion

B. in each pion's own frame

C. in any inertial frame

D. in Earth's frame

Question 6

Consider one pion approaching Earth at a speed of $0.98c$. It decays 26 ns in its own frame of reference after it is formed.

How long did the pion exist as observed in Earth's frame of reference?

A. 5.2 ns

B. 26 ns

C. 130 ns

D. 650 ns

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Question 7

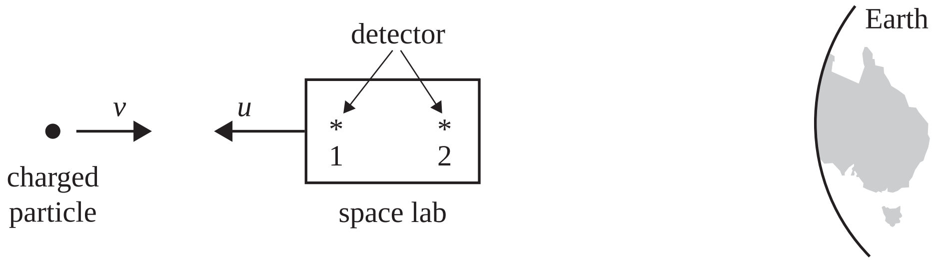

Figure 4

A space lab travelling at $u = 0.8c$ ($\gamma = 1.67$) away from Earth can record high-energy charged particles passing through its detectors. One particle is travelling towards Earth at $v = 0.91c$ ($\gamma = 2.4$) **relative to the space lab**.

Two detectors, numbered 1 and 2 in Figure 4, are 2.0 m apart in the space lab's frame.

How far apart are the two detectors in this particular particle's frame?

A. 0.83 m

B. 1.2 m

C. 3.3 m

D. 4.8 m

Question 8

A linear accelerator is used to increase the speed of a charged particle from rest. The particle is accelerated between two electrodes in a time of 40 ns. The particle reaches a speed at which $\gamma = 1.6$

What is the time taken for this acceleration in the particle's own frame of reference?

A. 40 ns

B. 40 ns divided by the mean value of γ during the trip between the two electrodes

C. 64 ns

D. cannot be determined using special relativity as it does not apply to accelerated frames of reference

Question 9

When a proton is accelerated from rest, it gains a kinetic energy of 1.20×10^{-10} J.

What value of γ is reached? (The rest mass of a proton is 1.67×10^{-27} kg.)

A. 2.2

B. 1.8

C. 1.5

D. 1.3

Question 10

A high-energy proton with $\gamma = 3$ collides with a stationary nucleus and rebounds in the opposite direction to its original motion. The kinetic energy of the proton after the collision is m_0c^2, where m_0 is the rest mass of a proton. The nucleus gains kinetic energy and there is no other change to the energy of the nucleus.

Which one of the following is the kinetic energy of the nucleus after the collision?

A. 0.5 m_0c^2

B. 1.0 m_0c^2

C. 1.5 m_0c^2

D. 2.5 m_0c^2

Question 11

Which statement best describes the speed of light in various media, including a vacuum?

A. The speed of light in a material will vary if the material is moved at a high speed relative to a light source.

B. The speed of light in a material depends only on the amount of length contraction of the material.

C. The speed of light in a medium depends only on the electrical and magnetic properties of the medium.

D. The speed of light in a medium depends directly on the mass density of the material.

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SECTION B

Instructions for Section B

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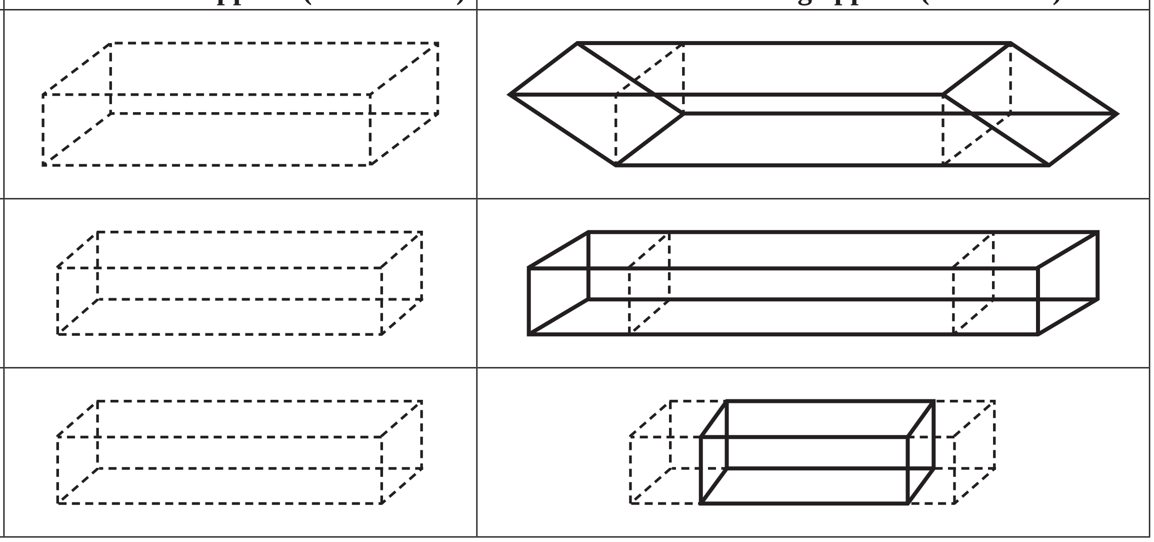
Detailed study 2 – Materials and their use in structures

Question 1

External forces are applied to three identical samples. The shape of each sample before a force is applied is shown in the left column of the table below and the shape of each sample while the force is being applied is shown in the right column.

Sample	Before force is applied (dotted lines)	While force is being applied (solid lines)
1		
2		
3		



Which of the following best shows the type of force applied to each sample?

	Sample 1	Sample 2	Sample 3
A.	shear	compression	compression
B.	compression	shear	tension
C.	shear	tension	compression
D.	tension	compression	shear

Question 2

A bridge across a river consists of a beam supported by a simple truss, as shown in Figure 1.

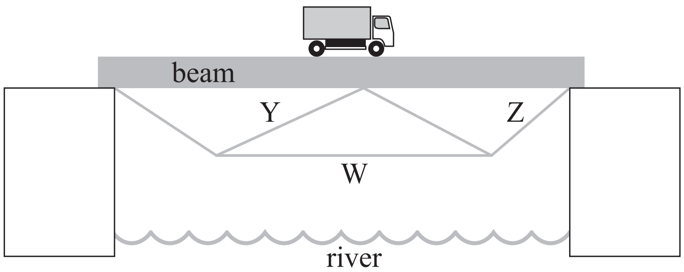


Figure 1

Which of the following best describes the type of force in each of the truss components W, Y and Z?

	W	Y	Z
A.	compression	tension	compression
B.	tension	tension	compression
C.	compression	compression	tension
D.	tension	compression	tension

Use the following information to answer Questions 3 and 4.

A typical arch-shaped bridge is shown in Figure 2.

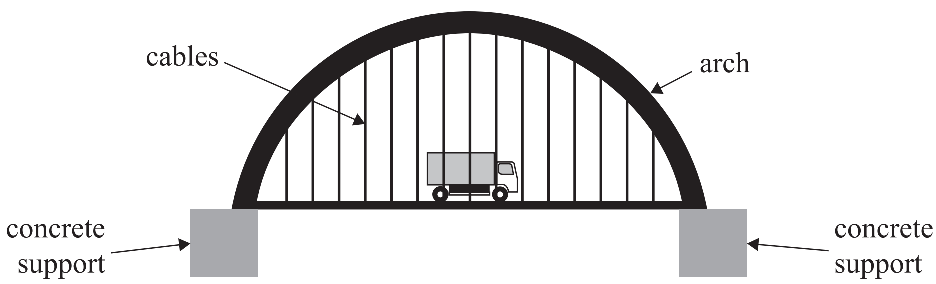


Figure 2

Question 3

Which of the following best shows the type of force in each of the components?

	Cables	Concrete supports	Arch
A.	compression	compression	tension
B.	tension	compression	compression
C.	compression	tension	tension
D.	tension	compression	tension

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Question 4

One of the cables connecting the roadway to the arch has a force of approximately 50 000 N applied to it. The cable is 360 m long with a cross-sectional area of 3.6×10^{-3} m^2. With this load, the cable extends by 0.025 m from its unstretched length.

Which one of the following is closest to the Young's modulus of the cable?

A. 2.0×10^5 Pa

B. 1.3×10^6 Pa

C. 1.5×10^9 Pa

D. 2.0×10^{11} Pa

Question 5

Some engineers were testing the breaking force of a component for a device they were designing. The component has a cross-sectional area of 4.0×10^{-4} m^2. The material data sheet for the material from which the component is made is given below.

tensile strength	1.2×10^8 N m^{-2}
compressive strength	1.8×10^8 N m^{-2}

Which of the following gives the breaking force in tension and compression?

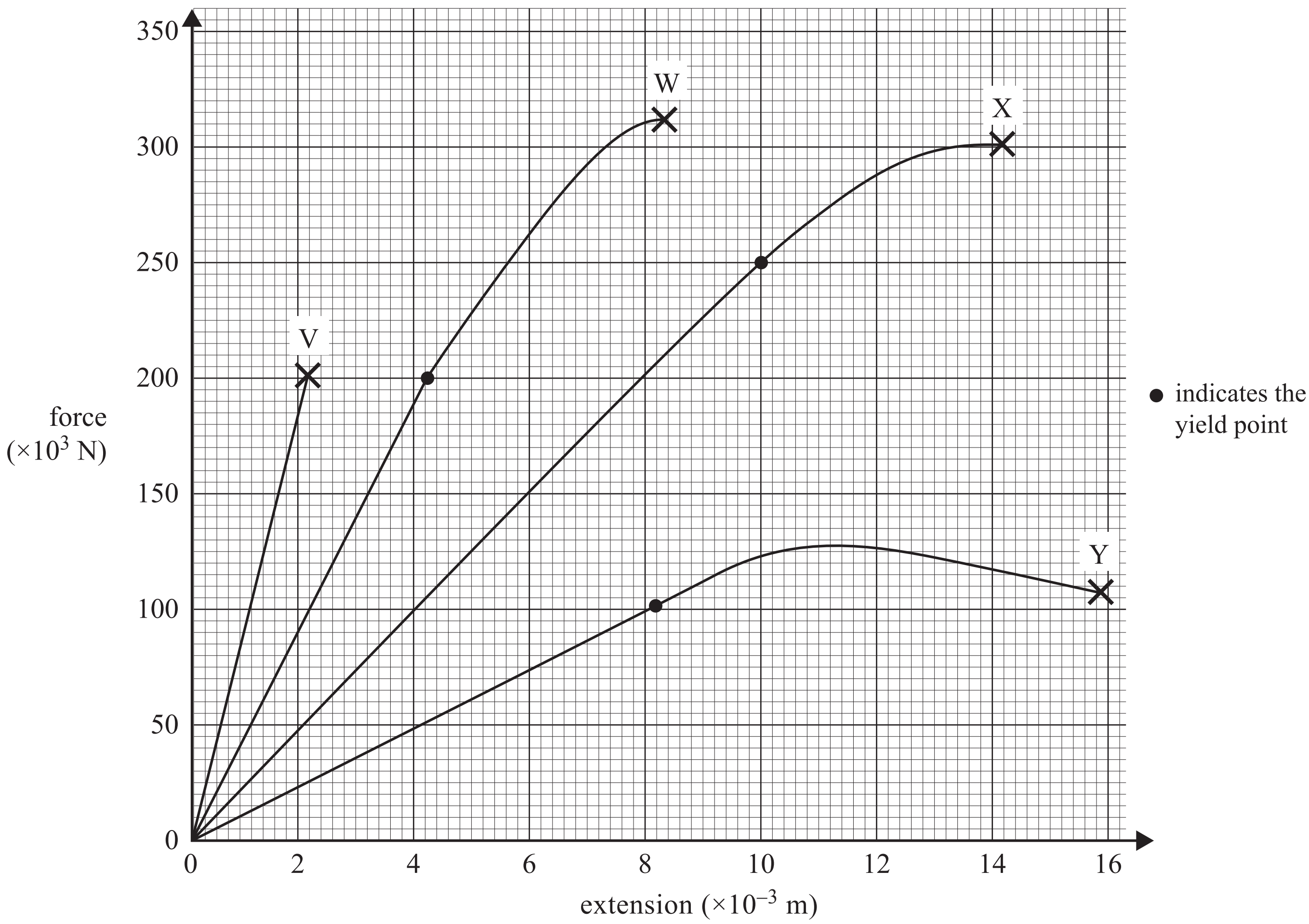
	Tension	Compression
A.	4.8×10^4 N	7.2×10^4 N
B.	4.8×10^4 N	4.5×10^{11} N
C.	3.0×10^{11} N	7.2×10^4 N
D.	3.0×10^{11} N	4.5×10^{11} N

Use the following information to answer Questions 6–8.

Rosemary and Paul decided to set up an experiment to test samples of different materials, V, W, X and Y.

The samples all have an original length of 15 cm and a cross-sectional area of 9.0×10^{-5} m^2.

The force–extension graph for this test is shown below.



Question 6

Which one of the following is true?

A. Material X is tougher than Material W.

B. Young's modulus is greater for Material X than Material V.

C. Material X is more ductile than Material Y.

D. Material X has a greater strength than Material W.

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Question 7

What is the energy required to stretch the sample of Material X to an extension of 10×10^{-3} m?

A. 125 J

B. 250 J

C. 1250 J

D. 2500 J

Question 8

Which one of the materials is the most brittle?

A. V

B. W

C. X

D. Y

Use the following information to answer Questions 9 and 10.

Question 9

Simple concrete park benches were designed as shown in Figure 3. The bench rests without connection on the supports. An engineer suggests that the bench has to be strengthened with steel rods.

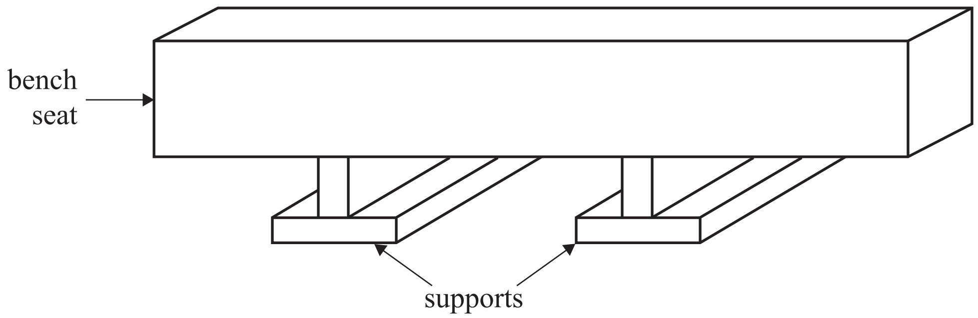
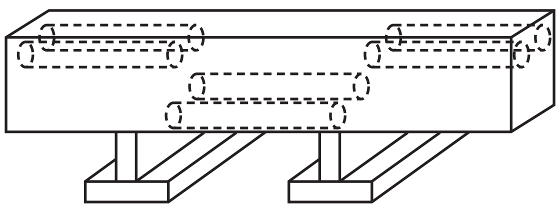


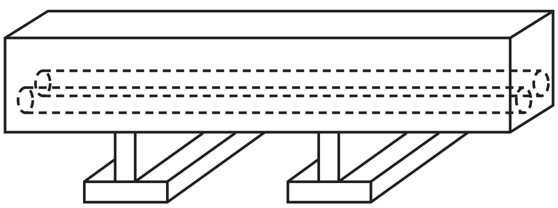
Figure 3

Which one of the following diagrams provides the optimal placement for the steel rods?

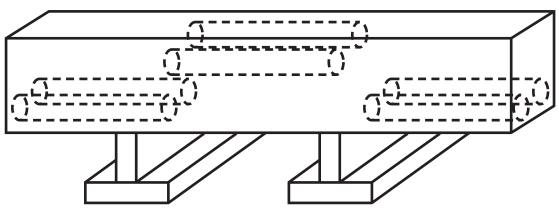
A.



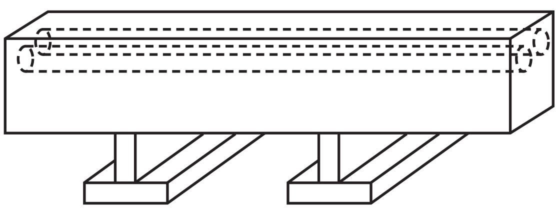
B.



C.



D.



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Question 10

A 70 kg man stands on the end of the park bench, as shown in Figure 4 below.

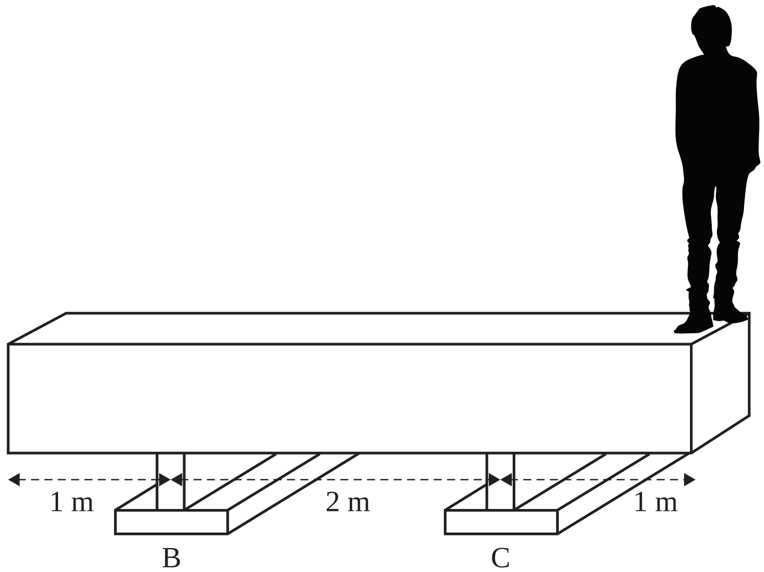

Figure 4

If the bench has a mass of 120 kg and a length of 4.0 m, what is the magnitude of the force exerted by the support at C on the bench?

A. 165 N

B. 700 N

C. 1650 N

D. 2250 N

Question 11

A horizontal beam, BC, is attached to a wall, as shown in Figure 5. The mass of the beam is 0.20 kg and there is a hanging mass of 0.050 kg at point B. The point C is a hinge. Ignore the mass of the cable AB.

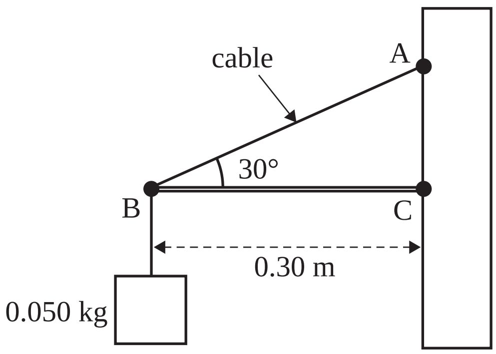

Figure 5

Which one of the following is closest to the tension in the cable AB?

A. 0.45 N

B. 3.0 N

C. 30 N

D. 45 N

End of Detailed study 2

SECTION B

Instructions for Section B

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Detailed study 3 – Further electronics

Use the following information to answer Questions 1–4.

Vanh and Elly are planning to create a 5 V regulated DC power supply using the circuit shown in Figure 1.

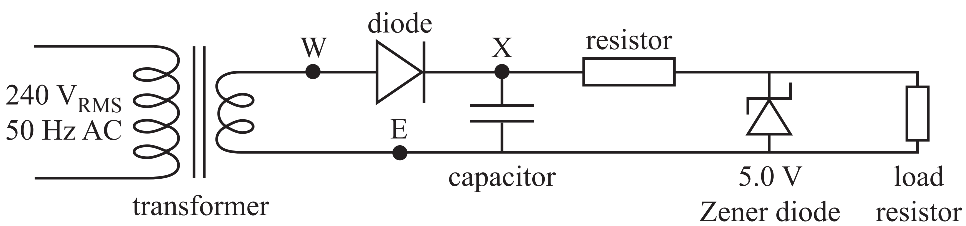

Figure 1

Question 1

In this power supply, electrical safety regulations require that components are insulated.

Which part(s) is most hazardous if touched?

A. the mains wiring to the transformer primary, transformer output and rectifier

B. the mains wiring to the transformer primary

C. the rectifier and capacitor

D. the voltage regulator

Question 2

The transformer output is 8 V_{RMS} and it has 120 secondary turns.

How many **primary** turns does this transformer require?

A. 7200

B. 3600

C. 2400

D. 4

DO NOT WRITE IN THIS AREA

Question 3

The diode is connected between the transformer output at W and the upper side of the capacitor at X.

When does the diode conduct current? (Assume that the diode is ideal.)

A. when the voltage at X is positive (relative to E)

B. when the voltage at W is positive (relative to E)

C. when the voltage at W is higher than the voltage at X

D. when the voltage at X is higher than the voltage at W

Question 4

Elly suggests to Vanh that they use alternative components in their power supply:

- a 5 kHz, 8 V_{RMS} AC supply instead of the 50 Hz mains plus transformer
- a bridge rectifier instead of the single-diode rectifier

Which of the following combinations would give the largest ripple and be the worst choice?

A. 50 Hz mains and transformer, single-diode rectifier

B. 50 Hz mains and transformer, bridge rectifier

C. 5 kHz, 8 V AC supply, single-diode rectifier

D. 5 kHz, 8 V AC supply, bridge rectifier

Question 5

Vanh tries different capacitors in the circuit shown in Figure 2. The load resistor is 400 Ω.

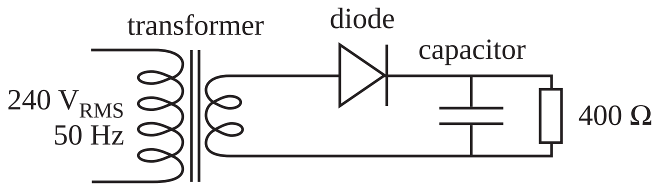

Figure 2

The voltage across the load is shown in Figure 3.

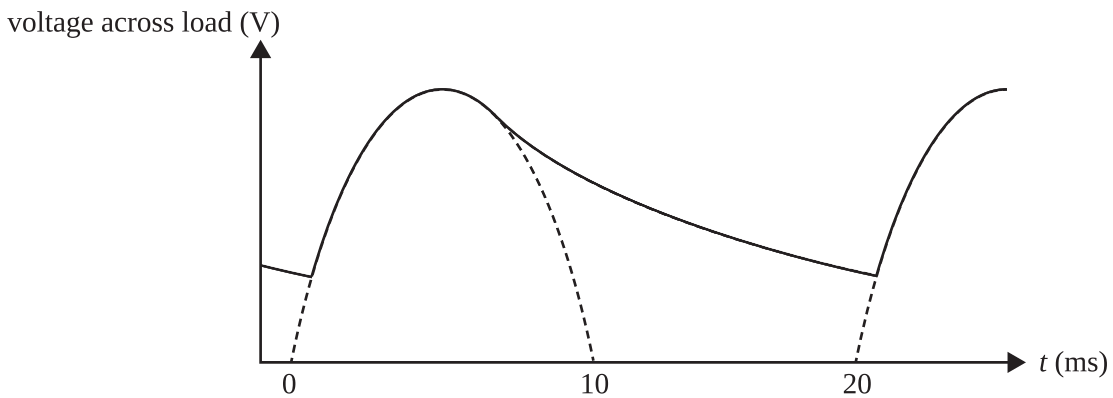

Figure 3

Which one of the following is closest to the value of the capacitor?

A. 0.4 μF

B. 1.5 μF

C. 8 μF

D. 40 μF

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Question 6

The charging of a capacitor is observed using the circuit shown in Figure 4. The time is $t = 0$ at the instant the switch is closed.

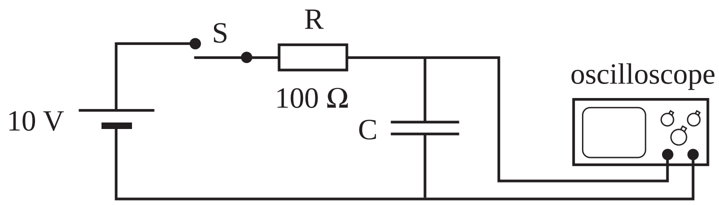
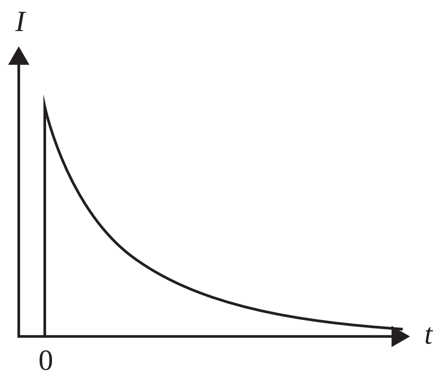


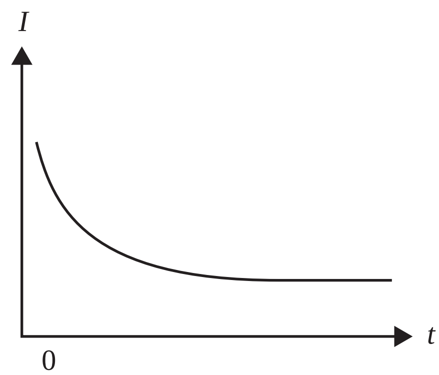
Figure 4

Which one of the following graphs best shows the current flowing into the capacitor?

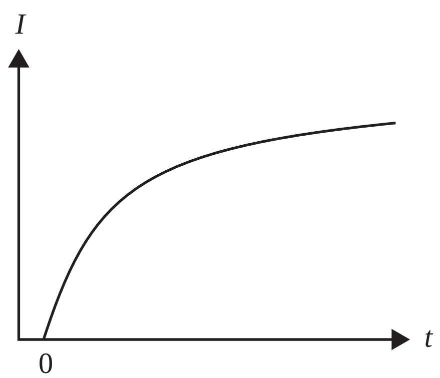
A.



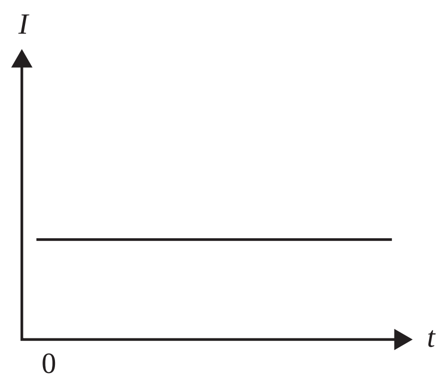
B.



C.



D.



Use the following information to answer Questions 7 and 8.

Elly tests a 5.0 V Zener diode in the circuit shown in Figure 5 using a DC supply voltage, V_i = 9.2 V.

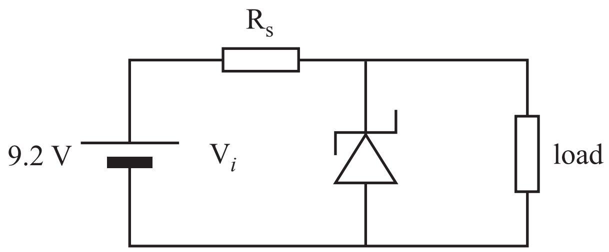


Figure 5

Question 7

When the series resistor R_s = 20 Ω, what is the largest current that can be delivered to the load while the Zener diode has 5.0 V across it?

A. 460 mA

B. 320 mA

C. 250 mA

D. 210 mA

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Question 8

The Zener diode has the characteristics shown in Figure 6.

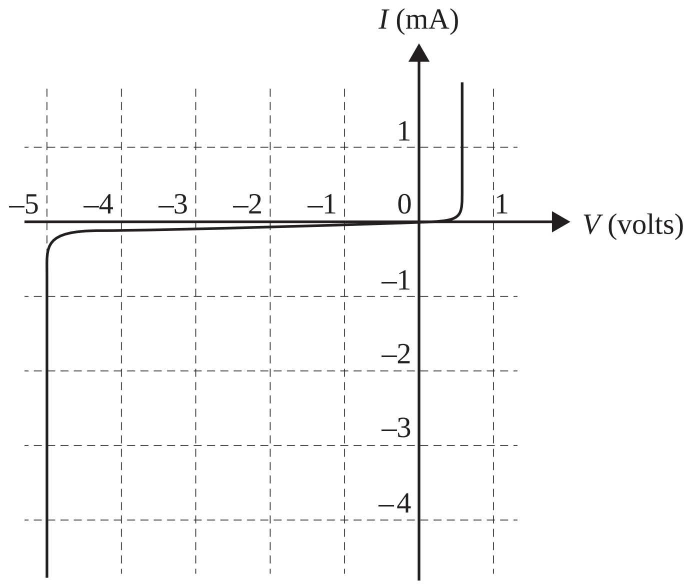


Figure 6

Elly uses a larger load resistor of 1000 Ω. She then tests the circuit using different series resistor values R_s.

Which one of the following is the largest R_s value for which the Zener diode will deliver 5.0 V?

A. 1840 Ω

B. 840 Ω

C. 170 Ω

D. 76 Ω

Question 9

Vanh now tests the completed DC power supply shown in Figure 7 (the same as Figure 1). At first, the circuit behaves correctly, but then the capacitor fails and becomes an open circuit.

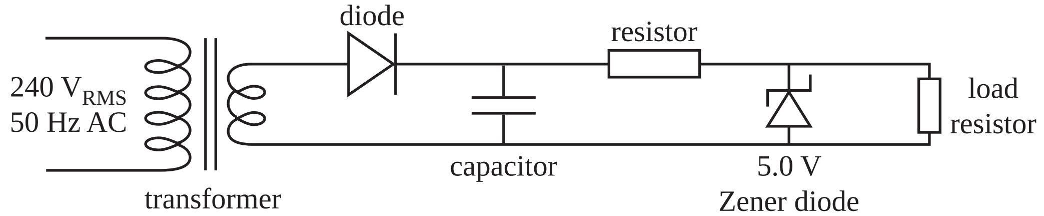
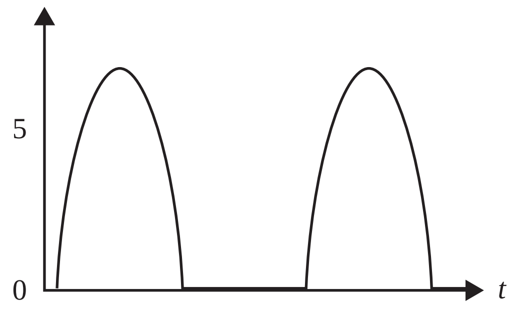


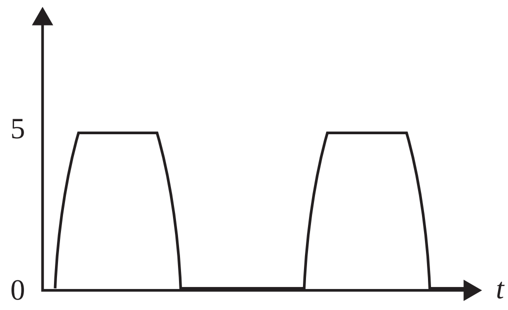
Figure 7

Which one of the following graphs best shows the output voltage across the load?

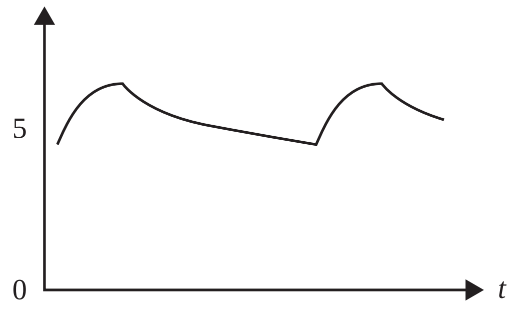
A. *V* (volts)



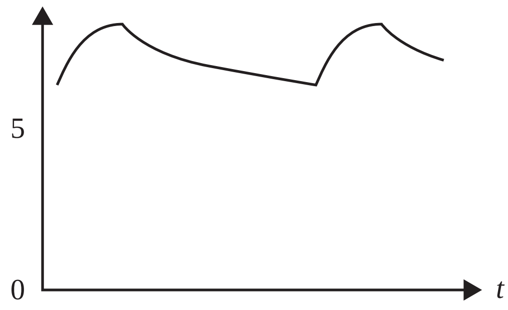
B. *V* (volts)



C. *V* (volts)



D. *V* (volts)



DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 10 and 11.

Elly suggests using an integrated circuit voltage regulator to replace the Zener diode plus series resistor. She tests the integrated circuit voltage regulator in a circuit, as shown in Figure 8. When operating normally, the current into the regulator from the power supply is effectively the same as the current into the load.

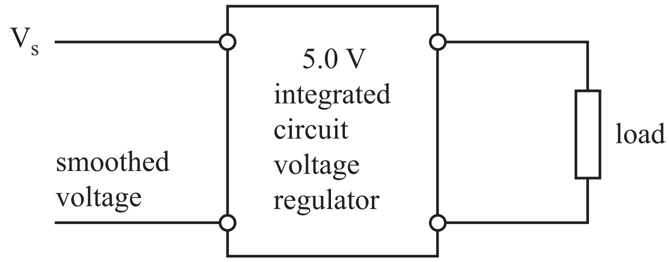


Figure 8

Question 10

The regulator is tested with a smoothed DC supply voltage of 8.0 V and a load of 25 Ω.

What power is dissipated by the regulator itself?

A. 2.6 W
B. 1.6 W
C. 1.0 W
D. 0.6 W

Question 11

Vanh checks the voltage regulator specifications. It can deliver 1.0 A maximum to a load; its maximum heat dissipation is 2.7 W using a suitable heat sink. A minimum supply voltage of 6.2 V is required for correct operation.

Elly and Vanh decide to use a ready-made smoothed DC power supply with the voltage regulator.

Which one of the following smoothed inputs to the voltage regulator can be used so that the regulator delivers 5.0 V at currents up to 1.0 A? (Each smoothed power supply can deliver over 1 A.)

A. a 9 V DC power supply
B. an 8 V DC power supply
C. a 7 V DC power supply
D. a 6 V DC power supply

SECTION B

Instructions for Section B

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Detailed study 4 – Synchrotron and its applications

Question 1

An oscillating ______1______ produces electromagnetic radiation.

______2______ is/are produced when the direction of motion

of a/an ______3______ changes, since the changing electric field

produces a changing magnetic field.

Which of the following shows the missing words in the correct order?

	1	2	3
A.	electron	Electromagnetic radiation	electron
B.	photon	Electromagnetic radiation	photon
C.	electric field	Electrons	light beam
D.	photon	Photons	light beam

Question 2

In the electron gun of a synchrotron, electrons are accelerated from rest over a distance of 12 cm to reach a final speed of 8.0×10^7 m s^{-1}.

What is the accelerating voltage of the electron gun in kilovolts? (Ignore any relativistic effects.)

A. 2.67 kV

B. 5.30 kV

C. 6.67 kV

D. 18.2 kV

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 3 and 4.

A magnetic field of 4.0×10^{-4} T makes electrons travelling at a speed of 8.0×10^{7} m s^{-1} turn through a part of a circle.

Question 3

What is the radius of the circle? (Ignore any relativistic effects.)

A. 1.1 m

B. 0.88 m

C. 2.6 cm

D. 1.1 cm

Question 4

What is the magnitude of the force acting on these electrons that makes them turn?

A. 6.5×10^{-23} N

B. 5.1×10^{-15} N

C. 6.5×10^{-15} N

D. 5.1×10^{-23} N

Question 5

In the Australian Synchrotron, electrons are accelerated in several stages and their final speed approaches the speed of light.

Which of the following best describes the order in which the various components accelerate the electrons?

	First	Second	Third
A.	linac	electron gun	booster ring
B.	linac	booster ring	electron gun
C.	electron gun	linac	booster ring
D.	electron gun	booster ring	linac

Question 6

The main advantage of using X-rays produced by a synchrotron rather than X-rays produced in a conventional X-ray tube in an X-ray machine is that

A. X-rays from an X-ray machine cannot be tuned using a monochromator.

B. X-rays from an X-ray machine can only be used to investigate biological materials.

C. the beamline of a synchrotron can produce an intense single-wavelength X-ray beam.

D. radiation from a synchrotron will scatter more readily than the conventionally produced X-rays.

Question 7

Which one of the following processes best describes the action of a monochromator in the beamline of a synchrotron?

A. The monochromator X-rays are selected by a strong electric field.

B. Thomson scattering is used to select X-rays of a single wavelength.

C. Compton scattering is used to select X-rays of a single wavelength.

D. Bragg diffraction is used to select X-rays of a single wavelength.

Question 8

An X-ray photon with a momentum of 6.6×10^{-23} N s collides with a stationary electron. The electron's momentum gain is 1.1×10^{-22} N s in the same direction as the incident X-ray photon.

Which one of the following is closest to the magnitude of the momentum of the photon after the collision?

A. 1.7×10^{-22} N s

B. 7.7×10^{-22} N s

C. 4.4×10^{-23} N s

D. 7.7×10^{-23} N s

Question 9

Synchrotron radiation is produced as the electron beam is forced to turn through a circular arc by the bending magnets.

The direction of the radiation is

A. along the same circular arc as the electrons.

B. at a tangent to the circular arc taken by the electrons.

C. towards the centre of the circle due to the centripetal force.

D. in all directions with each electron acting as a point source.

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Question 10

X-rays of wavelength 0.30 nm are used to investigate an unknown crystal. This crystal has planes of atoms at distance a_1 and a_2 apart, as shown in Figure 1. A detector is shown in Figure 2. The detector finds the first three peaks in intensity of the diffracted X-rays at angles $\theta = 22°$, 26° and 48°.

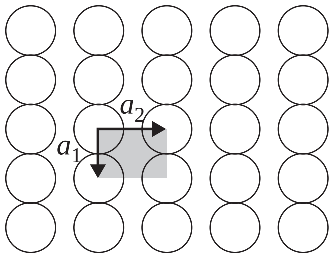

Figure 1

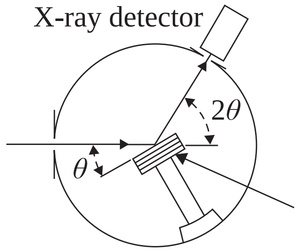

Figure 2

Based on this information, what is the best estimate of the values of a_1 and a_2?

	a_1	a_2
A.	0.20 nm	0.80 nm
B.	0.40 nm	0.64 nm
C.	0.34 nm	0.40 nm
D.	0.34 nm	0.64 nm

Question 11

Incident X-rays are scattered from a crystal sample. The researchers decide that the scattered radiation they detect is due to Thomson scattering.

Which one of the following statements correctly led them to this decision?

A. The scattered X-rays have greater energy than the incident X-rays.

B. The scattered X-rays have the same wavelength as the incident X-rays.

C. The scattered X-rays have a longer wavelength than the incident X-rays.

D. The scattered X-rays have a range of wavelengths, both longer and shorter than the incident X-rays.

SECTION B

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Detailed study 5 – Photonics

Question 1

Which of the following best describes a source and mechanism of wide-spectrum incoherent light emission?

	Source	Mechanism
A.	a star (such as the sun)	stimulated photon emission by electron collisions
B.	an incandescent light	random thermal motion of valence electrons in collisions
C.	a laser	transition of electrons from the valence band
D.	a light-emitting diode (LED)	stimulated emission of photons

Question 2

Light emitted by LEDs is best described as resulting from

A. production of photons when electrons are captured.

B. production of photons from collisions between atoms.

C. transitions of electrons from the conduction band to the valence band.

D. transitions of electrons from the valence band to the conduction band.

Question 3

Students require an LED with a band gap that gives light with a wavelength as close to 550 nm as possible.

Which one of the following band gaps would be the best?

A. 2.61 eV

B. 2.35×10^{-19} J

C. 3.61×10^{-19} J

D. 3.61 eV

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 4–6.

A step-index optical fibre is shown in Figure 1 below. Take n_{air} to equal 1.

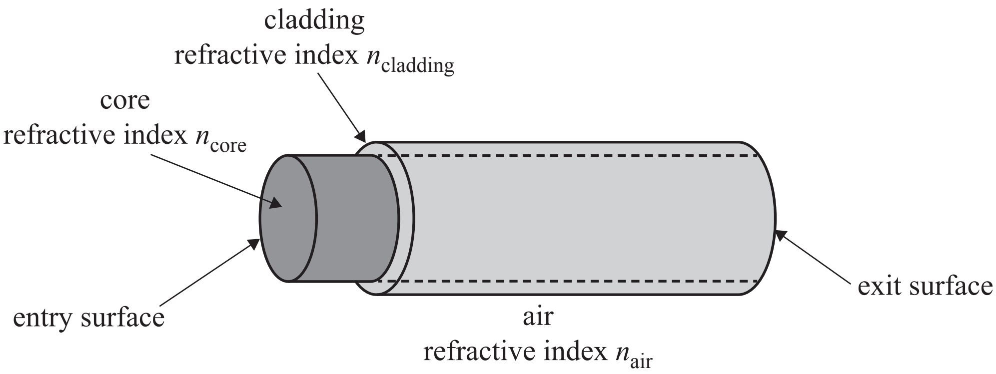


Figure 1

Question 4

Which of the following combinations gives a critical angle for the core and cladding closest to 83°?

A. $n_{core} = 1.31$, $n_{cladding} = 1.32$

B. $n_{cladding} = 1.71$, $n_{core} = 1.73$

C. $n_{core} = 1.71$, $n_{cladding} = 1.73$

D. $n_{cladding} = 1.31$, $n_{core} = 1.32$

Question 5

Another optical fibre has $n_{core} = 1.480$ and an acceptance angle of 15.0°.

Which one of the following is closest to $n_{cladding}$?

A. 1.503

B. 1.457

C. 1.436

D. 1.414

Question 6

Which one of the following best describes light that enters the fibre at smaller angles than the acceptance angle?

A. It is totally internally reflected at the core–cladding interface.

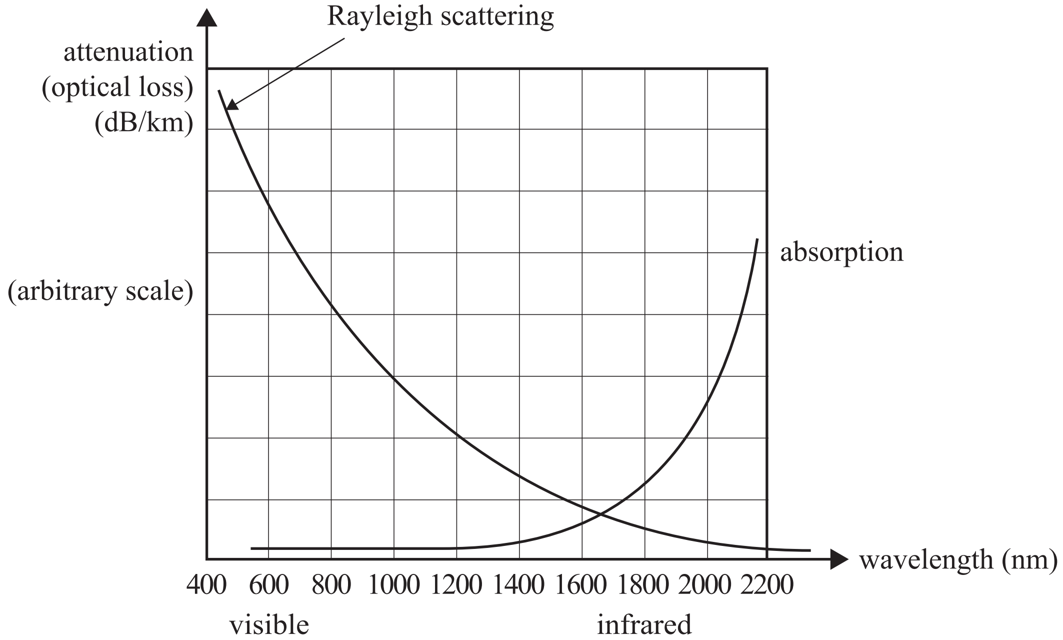
B. It is internally reflected at the core–cladding interface.

C. It is totally externally reflected at the entry surface.

D. It is all absorbed at the core–cladding interface.

Use the following information to answer Questions 7 and 8.

The graph below shows attenuation (optical loss) versus wavelength for a particular material used to make optical fibres.



Question 7

Which one of the following would produce the major attenuation for light of wavelength 1800 nm?

A. modal dispersion

B. material dispersion

C. Rayleigh scattering

D. absorption by the material

Question 8

For a long-distance data link, which one of the following wavelengths would be the **least** suitable in terms of signal loss?

A. 1000 nm

B. 1200 nm

C. 1400 nm

D. 1900 nm

Question 9

Which one of the following would **best** reduce material dispersion?

A. Increase the intensity of the light source.

B. Decrease the frequency of the light source.

C. Increase the coherence of the light source.

D. Reduce the wavelength spread of the light source.

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Question 10

Which one of the following should reduce modal dispersion?

A. Use a fibre with a graded index.

B. Use a fibre with a larger diameter.

C. Use cladding with a lower refractive index.

D. Use cladding with a higher refractive index.

Question 11

Excessive bending of optical fibres (sometimes called 'macrobending') can cause unwanted loss of light signal from the core.

The most likely explanation for this loss of signal is that this excessive bending

A. changes the refractive index of the core.

B. increases the absorption of light due to impurities in the fibre.

C. increases the amount of light that strikes the core–cladding interface at more than the critical angle.

D. increases the amount of light that strikes the core–cladding interface at less than the critical angle.

End of Detailed study 5

SECTION B

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Detailed study 6 – Sound

Question 1

Sound is best described as a

A. longitudinal pressure wave transmitting air particles from a source to a receiver.

B. transverse pressure wave transmitting wave maxima from a source to a receiver.

C. longitudinal pressure wave transmitting energy from a source to a receiver.

D. transverse pressure wave transmitting energy from a source to a receiver.

Use the following information to answer Questions 2–4.

A sound engineer, Dan, is setting up for a concert in a large stadium. In order to test the acoustics of the stadium, he sets up a single speaker in the middle of the stage. This speaker transmits sound equally in all directions. Using a signal generator and amplifier attached to the speaker, he sets the frequency of the sound to 500 Hz. Take the speed of sound to be 350 m s^{-1}.

Question 2

The wavelength of the signal is closest to

A. 0.07 m

B. 0.70 m

C. 1.43 m

D. 2.34 m

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 3 and 4.

Another sound engineer, Limei, investigates the sound intensity level at various points in the stadium. At a distance of 60 m from the speaker, Limei's sound level meter reads 80 dB.

Question 3

The sound intensity at this point is closest to

A. 1.0×10^{-4} W m^{-2}

B. 1.0×10^{4} W m^{-2}

C. 4.0×10^{-4} W m^{-2}

D. 8.0×10^{5} W m^{-2}

Question 4

Limei moves a further 60 m from the speaker.

Her sound level meter will now show a reading closest to

A. 70 dB

B. 74 dB

C. 77 dB

D. 86 dB

Question 5

Which one of the following factors does the loudness (phon) scale specifically take into account?

A. Intensity of sound, as perceived by human hearing, is inversely proportional to distance from the source.

B. The perception of the intensity of sound by human hearing steadily decreases with frequency.

C. There is a very limited range of frequencies that the human ear can hear.

D. The sensitivity of human hearing varies with frequency.

Question 6

The graph in Figure 1 shows the relationship between sound intensity level (dB), frequency (Hz) and loudness. The sound intensity level of a note of 10 000 Hz is measured by a sound meter to be 60 dB.

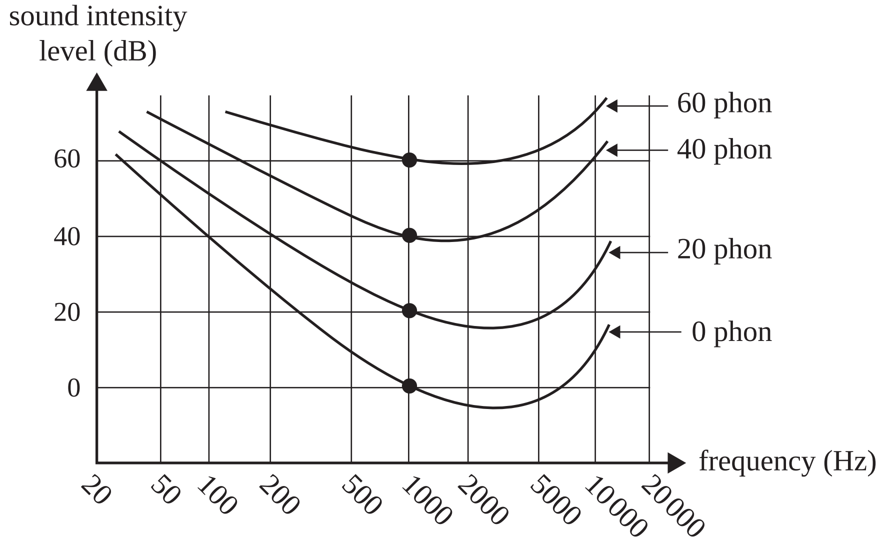

Figure 1

Which one of the values below best gives the loudness at the 10 000 Hz, 60 dB point?

A. 80 phon

B. 60 phon

C. 40 phon

D. 20 phon

Question 7

Yasmin and Paul set up the following experiment in a large open area. They connect two speakers that are facing each other, as shown in Figure 2. Both speakers are connected 10 m apart to the same signal generator and amplifier, which is producing a sound with a wavelength of 1.0 m.

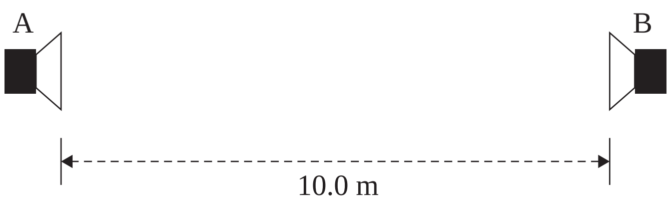

Figure 2

Yasmin stands in the centre, equidistant to speakers A and B. She then moves towards Speaker B and experiences a sequence of loud and quiet regions. She stops at the second region of quietness.

How far is she from Speaker B?

A. 0.75 m

B. 1.25 m

C. 2.75 m

D. 4.25 m

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 8 and 9.

Roger is an instrument-maker who is constructing and testing pipes for a pipe organ.

The pipes can be considered to be uniform tubes open at one end and closed at the other.

He needs to design a pipe to give a wavelength of 0.325 m.

Question 8

Which one of the following is closest to the length Roger should make the pipe?

A. 0.081 m

B. 0.325 m

C. 0.650 m

D. 1.35 m

Question 9

Roger tests a different pipe by placing a loudspeaker attached to a very precise audio signal generator at the open end of the pipe and gradually increases the frequency.

He finds that in addition to the resonance at 256 Hz, there is a higher resonance (the second harmonic).

At which one of the following frequencies will this second harmonic be observed?

A. 128 Hz

B. 512 Hz

C. 768 Hz

D. 1024 Hz

Question 10

Electret-condenser, crystal and dynamic are three types of microphones.

Which of the following matches each type of microphone to its physical property?

	Electret-condenser	**Crystal**	**Dynamic**
A.	piezo-electric effect	electromagnetic induction	capacitance
B.	capacitance	piezo-electric effect	electromagnetic induction
C.	capacitance	electromagnetic induction	piezo-electric effect
D.	electromagnetic induction	piezo-electric effect	electromagnetic induction

Question 11

Millie and Mikio are testing a loudspeaker. They set it up as shown in Figure 3a.

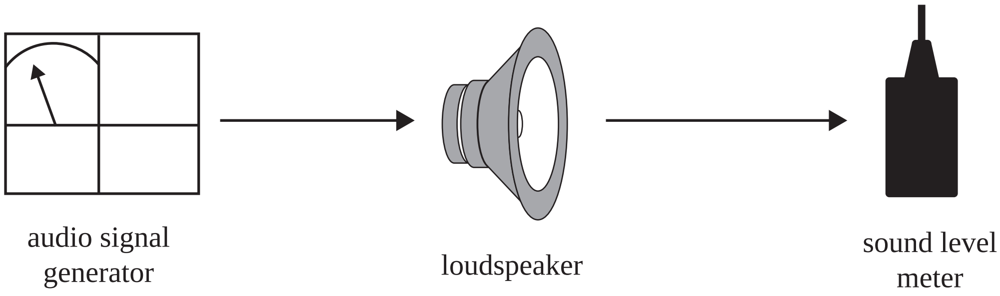

Figure 3a

The sound is not sufficiently loud. They add a large baffle board, as shown in Figure 3b. The intensity of the sound at the sound level meter increases.

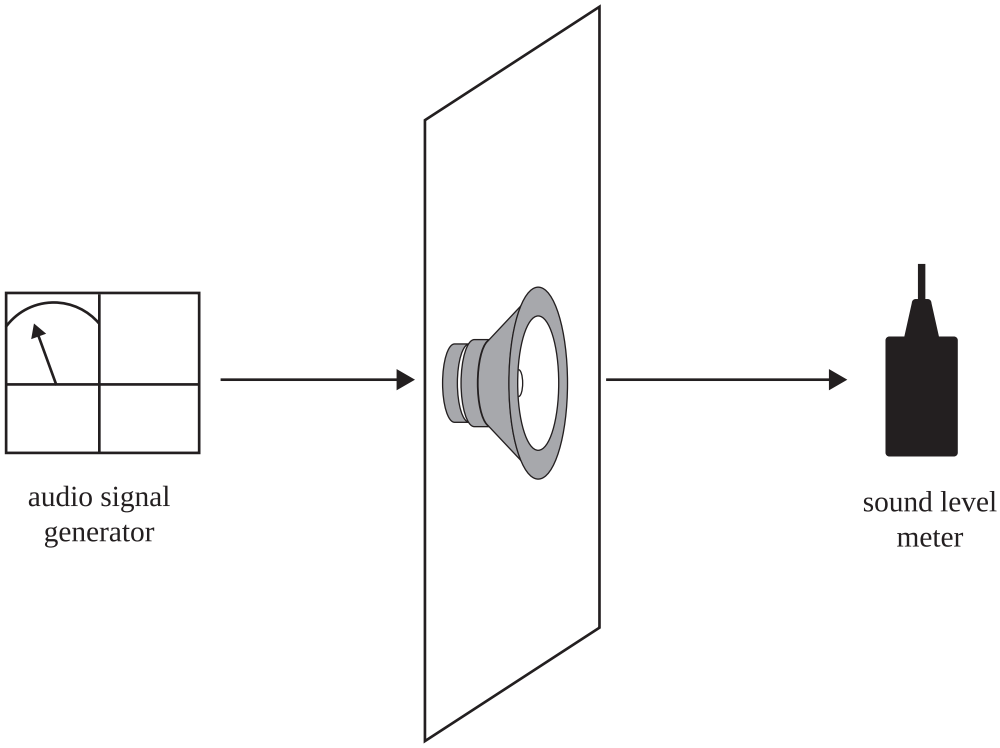

Figure 3b

What is the best explanation for the increase in the intensity of the sound?

A. The baffle board prevents interference between waves from the front and back of the loudspeaker.

B. The baffle board prevents sound travelling out vertically and so more sound reaches the meter.

C. The baffle board also oscillates with the loudspeaker, thus sending out more sound waves.

D. There is resonance between the baffle board and the loudspeaker.

DO NOT WRITE IN THIS AREA

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2016

PHYSICS

Written examination

Wednesday 9 November 2016
Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

FORMULA SHEET

Instructions

- A question and answer book is provided with this formula sheet.

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

1	velocity; acceleration	$v = \dfrac{\Delta x}{\Delta t}; \quad a = \dfrac{\Delta v}{\Delta t}$
2	equations for constant acceleration	$v = u + at$ $x = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2ax$ $x = \frac{1}{2}(v+u)t$
3	Newton's second law	$\Sigma F = ma$
4	circular motion	$a = \dfrac{v^2}{r} = \dfrac{4\pi^2 r}{T^2}$
5	Hooke's law	$F = -kx$
6	elastic potential energy	$\frac{1}{2}kx^2$
7	gravitational potential energy near the surface of Earth	mgh
8	kinetic energy	$\frac{1}{2}mv^2$
9	Newton's law of universal gravitation	$F = G\dfrac{M_1 M_2}{r^2}$
10	gravitational field	$g = G\dfrac{M}{r^2}$
11	acceleration due to gravity at Earth's surface	$g = 10 \text{ m s}^{-2}$
12	voltage; power	$V = RI \qquad P = VI = I^2R$
13	resistors in series	$R_T = R_1 + R_2$
14	resistors in parallel	$\dfrac{1}{R_T} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$
15	transformer action	$\dfrac{V_1}{V_2} = \dfrac{N_1}{N_2}$
16	AC voltage and current	$V_{RMS} = \dfrac{1}{\sqrt{2}}V_{peak} \qquad I_{RMS} = \dfrac{1}{\sqrt{2}}I_{peak}$
17	magnetic force	$F = I\,l\,B$

18	electromagnetic induction	emf: $\varepsilon = -N\dfrac{\Delta\Phi}{\Delta t}$ flux: $\Phi = BA$
19	transmission losses	$V_{\text{drop}} = I_{\text{line}} R_{\text{line}}$ $P_{\text{loss}} = I^2_{\text{line}} R_{\text{line}}$
20	mass of the electron	$m_e = 9.1 \times 10^{-31}$ kg
21	charge on the electron	$e = -1.6 \times 10^{-19}$ C
22	Planck's constant	$h = 6.63 \times 10^{-34}$ J s $h = 4.14 \times 10^{-15}$ eV s
23	speed of light	$c = 3.0 \times 10^8$ m s^{-1}
24	photoelectric effect	$E_{K\max} = hf - W$
25	photon energy	$E = hf$
26	photon momentum	$p = \dfrac{h}{\lambda}$
27	de Broglie wavelength	$\lambda = \dfrac{h}{p}$
28	speed, frequency and wavelength	$v = f\lambda$
29	energy transformations for electrons in an electron gun (<100 keV)	$\frac{1}{2}mv^2 = eV$
30	radius of electron path	$r = \dfrac{mv}{eB}$
31	magnetic force on a moving electron	$F = evB$
32	Bragg's law	$n\lambda = 2d\sin\theta$
33	electric field between charged plates	$E = \dfrac{V}{d}$
34	band gap energy	$E = \dfrac{hc}{\lambda}$
35	Snell's law	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
36	intensity and level	sound intensity level (in dB) $L(\text{dB}) = 10\log_{10}\left(\dfrac{I}{I_0}\right)$ where $I_0 = 1.0 \times 10^{-12}$ W m^{-2}

37	Lorentz factor	$\gamma = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}$
38	time dilation	$t = t_o\gamma$
39	length contraction	$L = \dfrac{L_o}{\gamma}$
40	relativistic mass	$m = m_o\gamma$
41	total energy	$E_{total} = E_k + E_{rest} = mc^2$
42	stress	$\sigma = \dfrac{F}{A}$
43	strain	$\varepsilon = \dfrac{\Delta L}{L}$
44	Young's modulus	$E = \dfrac{\text{stress}}{\text{strain}}$
45	capacitors	time constant : $\tau = \mathrm{RC}$
46	universal gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
47	mass of Earth	$M_E = 5.98 \times 10^{24}$ kg
48	radius of Earth	$R_E = 6.37 \times 10^6$ m
49	mass of the electron	$m_e = 9.1 \times 10^{-31}$ kg
50	charge on the electron	$e = -1.6 \times 10^{-19}$ C
51	speed of light	$c = 3.0 \times 10^8$ m s^{-1}

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 FORMULA SHEET