VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2014

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER | | | | | | | | | Letter

PHYSICS
Written examination

Wednesday 12 November 2014

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		5	5	39
Electronics and photonics		6	6	25
Electric power		7	7	38
Interactions of light and matter		5	5	26
	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, one folded A3 sheet or two A4 sheets of notes 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 81 pages. A 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.

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

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SECTION A – Core studies

Instructions for Section A

Answer **all** questions in this section in the spaces provided. Write using black or blue 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, diagrams are not to scale.

Area of study – Motion in one and two dimensions

Question 1 (9 marks)

A small locomotive is used in a railway yard to arrange rail trucks on trains. The locomotive has a mass of 40 tonnes (40 000 kg).

In one situation, the locomotive is pulling two trucks, each of mass 10 tonnes, as shown in Figure 1.

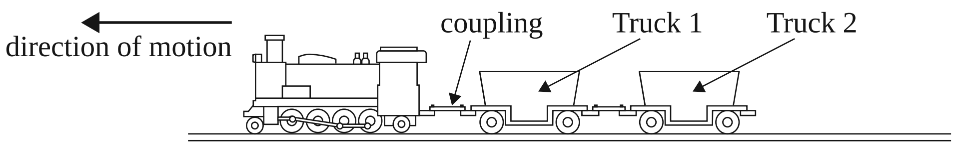

Figure 1

They start from rest and accelerate at 0.20 m s^{-2} for 5 s.

a. Calculate the distance travelled after 5 s. 2 marks

m

b. Calculate the tension in the coupling between the locomotive and Truck 1 as they accelerate. 2 marks

N

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In another situation, the locomotive is moving at a constant 4.0 m s^{-1} when it collides with four stationary trucks, each with a mass of 10 tonnes. They couple together and then move off together, as shown in Figure 2.

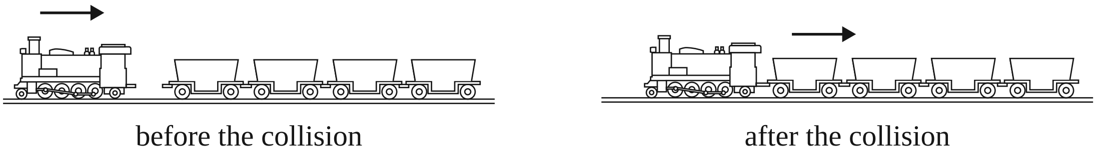

Figure 2

c. Calculate the speed of the combined locomotive and trucks immediately after the collision. 2 marks

m s^{-1}

d. Is the collision between the locomotive and the trucks elastic or inelastic? Justify your answer by calculation. 3 marks

Question 2 (11 marks)

Jo and Sam are conducting an experiment using a mass attached to a spring. The spring has an unstretched length of 40 cm. The situation is shown in Figure 3a.

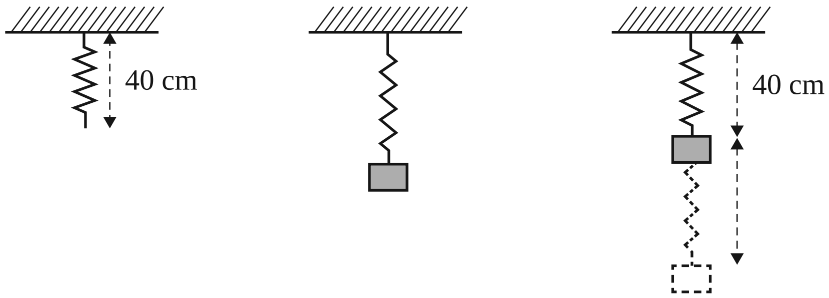

Figure 3a **Figure 3b** **Figure 3c**

They begin their experiment by measuring the spring constant of the spring by progressively adding 50 g masses to it, as shown in Figure 3b. They measure the resultant length of the spring with the mass stationary and record the following data.

Number of 50 g masses	0	1	2	3
Length of spring	40 cm	50 cm	60 cm	70 cm

a. Show that the spring constant is equal to 5.0 N m^{-1}. 2 marks

Jo and Sam now attach four 50 g masses to the spring and release it from its unstretched position, which is a length of 40 cm. They allow the masses to oscillate freely, as shown in Figure 3c.

b. Find the **extension** of the spring at the lowest point of its oscillation (when it is momentarily stationary). Ignore frictional losses. Show your reasoning. 3 marks

m

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Jo and Sam measure the position of the four masses as they oscillate freely up and down, as described previously. From this data, they plot graphs of the gravitational potential energy and spring potential energy. Their results are shown in Figure 4.

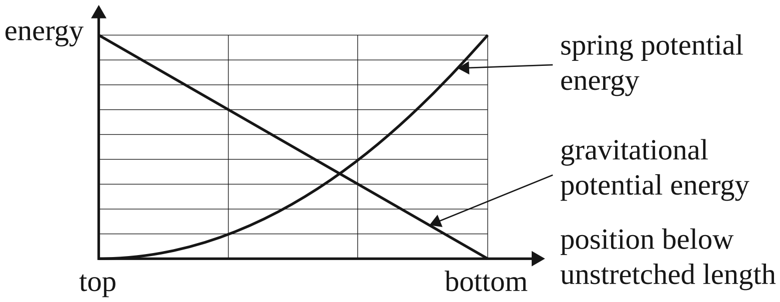

Figure 4

Jo says their calculation must be wrong because the graphs should add to a constant amount, the total energy of the system. However, Sam says that the graphs are correct.

c. Explain why Jo is incorrect. Your explanation should include the reason that the spring potential energy and the gravitational potential energy do not add to a constant amount at each point. 2 marks

d. Calculate the maximum speed of the masses during the oscillation. Show your working. 4 marks

m s^{-1}

Question 3 (5 marks)

In a cricket game, a batsman hits a ball at an angle of 30° to the horizontal at a speed of 20 m s^{-1}. The playing area and the area around it are perfectly flat, and the ball is assumed to be at ground level when the batsman hits it. Ignore air resistance.

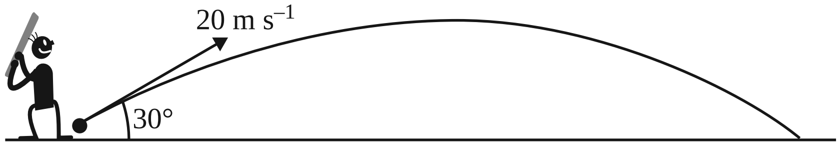

Figure 5

a. Calculate the maximum height reached by the ball. Show your working. 2 marks

m

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Later, the batsman hits the ball in exactly the same way on a smaller playing area. The ball strikes a vertical advertising board on the side of the ground, 26 m from the batsman, as shown in Figure 6.

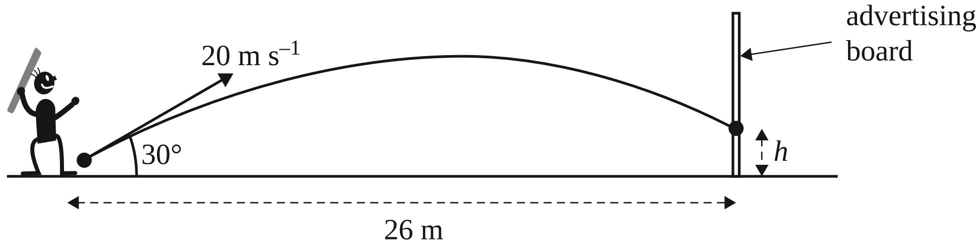

Figure 6
not to scale

b. How far vertically above ground level, h, does the ball strike the board? Show your working. 3 marks

m

Question 4 (8 marks)

Mary and Bob are riding in a car on a roller-coaster. The roller-coaster is designed so that the riders will feel 'weightless' at the top of the ride (point A).

It can be assumed that the track is circular in shape at and near the points A and B. The radius of these circular paths at A and B is 20 m. This is shown in Figure 7. Ignore air resistance and frictional forces.

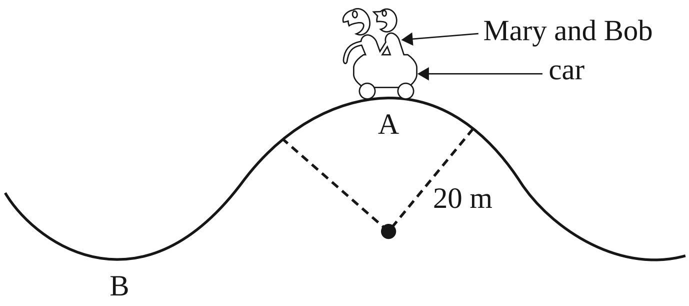

Figure 7

a. Calculate the minimum speed at which Mary and Bob must be moving at point A for them to feel weightless. 2 marks

m s^{-1}

b. Explain why Mary and Bob feel weightless at point A at this speed. 3 marks

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c. Figure 8 shows the car at the lowest point, B, of the track. Assume the track is frictionless and there is no air resistance.

Assume the car, including Mary and Bob, is a single object.

On Figure 8, draw and label all the forces on the single object in solid lines and, using a dotted line, show the resultant force on it. Use arrows to indicate force directions. 3 marks

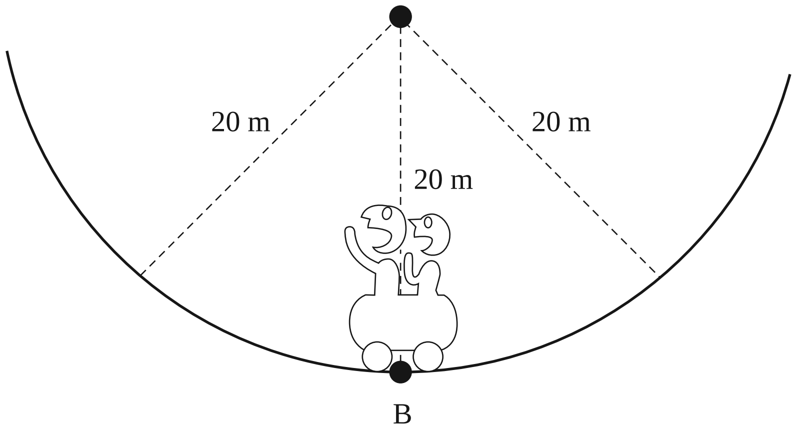

Figure 8

Question 5 (6 marks)

A distant star has a planet orbiting it. The period of the planet's circular orbit is 1200 hours. The radius of the planet's orbit is measured to be 7.0×10^{10} m.

a. Use the data above to calculate the mass of the star. Show your working. 4 marks

kg

b. Is it possible to determine the mass of this planet from the data above? Give a reason for your answer. 2 marks

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Area of study – Electronics and photonics

Question 6 (3 marks)

Students construct the circuit shown in Figure 9.

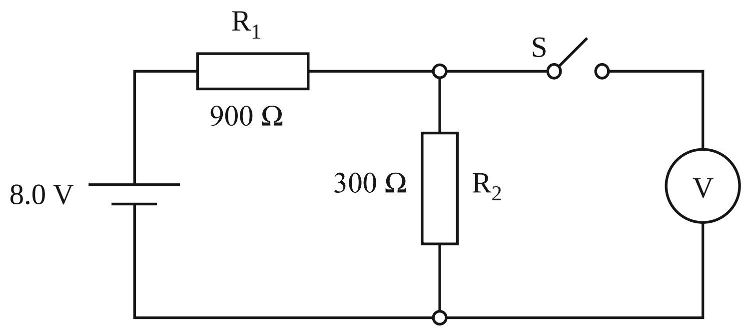

Figure 9

The battery voltage is 8.0 V, and the values of the resistors are 900 Ω (R_1) and 300 Ω (R_2).

a. What is the expected reading on the voltmeter in the circuit when the switch S remains open? 1 mark

____

____

[V]

b. The students close the switch S.

What is the voltage that should now be measured by the voltmeter? 2 marks

____

____

____

[V]

Question 7 (5 marks)

Students build a circuit to power a light-emitting diode (LED). The circuit is shown in Figure 10. The current-voltage characteristic of the LED is shown in Figure 11. The power is supplied by an 11 V battery. The power dissipated in the LED is 300 mW.

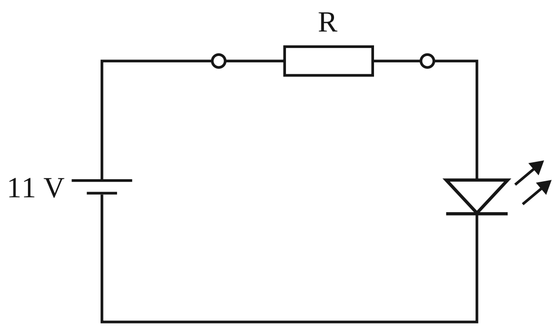

Figure 10

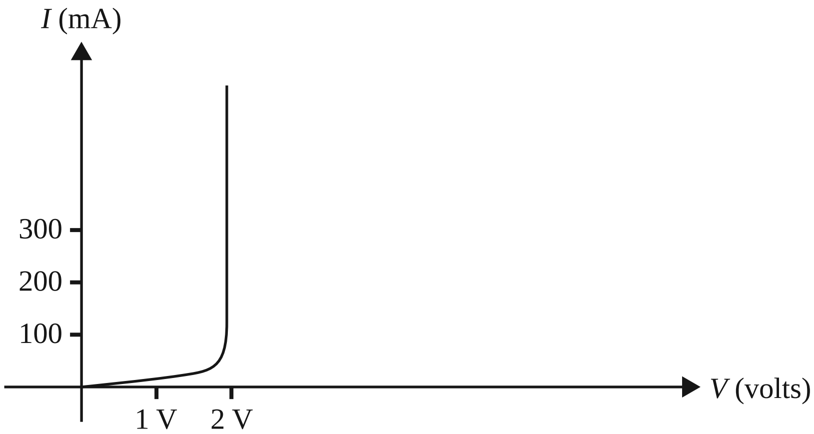

Figure 11

a. Calculate the value of the resistor R. Show your working. 3 marks

Ω

b. The students then connect another LED into a different circuit. This circuit is shown in Figure 12. The voltmeter reads 3.0 V.

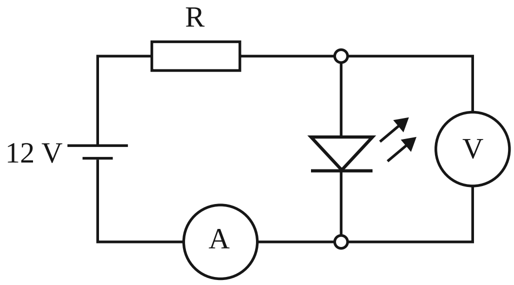

Figure 12

The current measured by the ammeter in this circuit is 500 mA.

Calculate the power dissipated by the resistor R. 2 marks

W

Question 8 (5 marks)

Students are using a photodiode as a source of electricity. They use the circuit in Figure 13 and shine a light of constant intensity onto the photodiode. With the switch S closed, current flows around the circuit. The ammeter has zero resistance and the voltmeter has infinite resistance.

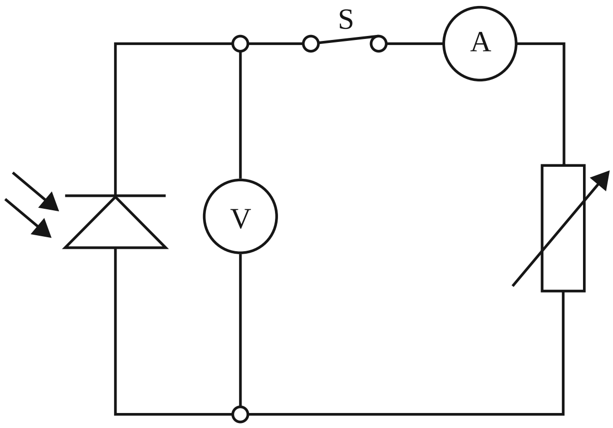

Figure 13

With the switch S closed, the students vary the size of the variable resistor, measuring the voltage across the photodiode and the current through it. They obtain the I–V graph for the photodiode as shown in Figure 14.

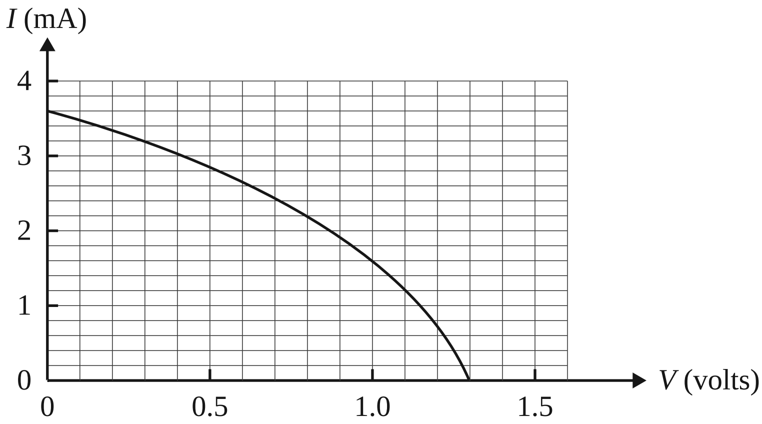

Figure 14

a. What is the current in the photodiode when the measured voltage across it is zero? 1 mark

mA

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b. What is the voltage across the photodiode when the switch S is opened and the current flowing in the circuit is zero? 1 mark

V

c. The students want to operate the photodiode at 1.0 V.

Use the graph in Figure 14 to calculate the required value for the variable resistor. Show your working. 3 marks

Ω

Question 9 (2 marks)

Students are investigating the use of light intensity modulation. The signal to be transmitted is shown in Figure 15. The carrier wave consists of light pulses, as shown in Figure 16.

Draw the shape of the modulated wave intensity on the graph grid provided in Figure 17.

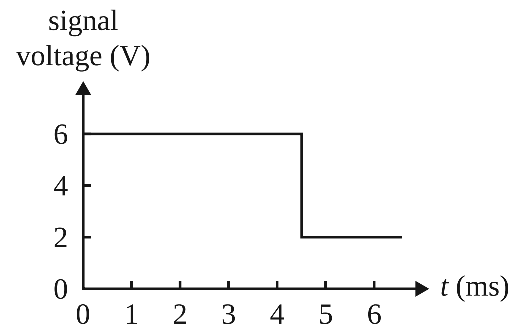

Figure 15

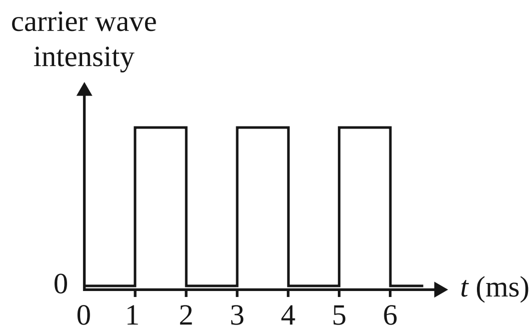

Figure 16

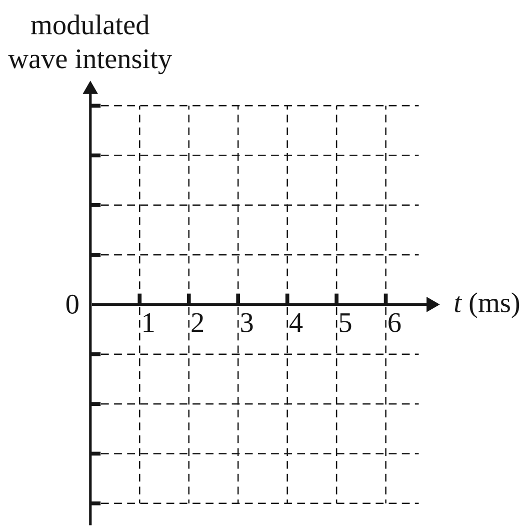

Figure 17

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Question 10 (6 marks)

Huyen and Sam are investigating a non-inverting amplifier. In its linear region, it has an amplification of ×200. Outside this region, its voltage output is constant.

The maximum magnitude of the voltage output of the signal is 1.0 V, whether positive or negative.

a. On Figure 18, draw the input-output characteristic of the amplifier for inputs from –15 mV to +15 mV. Put values on both axes. 3 marks

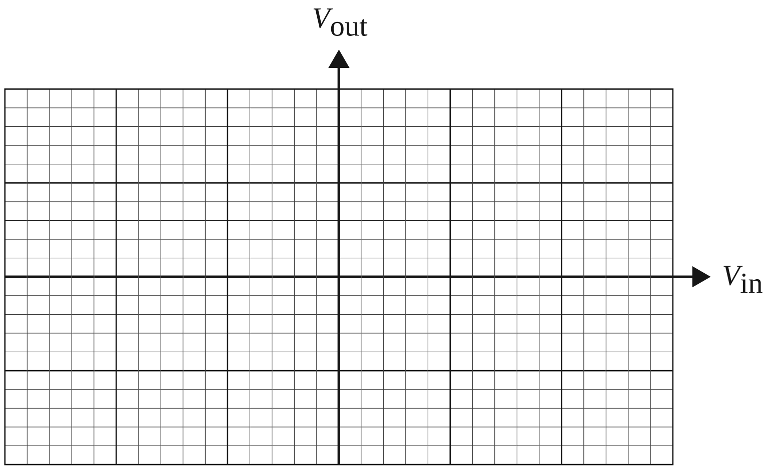

Figure 18

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b. Huyen and Sam apply a sinusoidal wave signal at the input of the amplifier. This signal is shown in Figure 19.

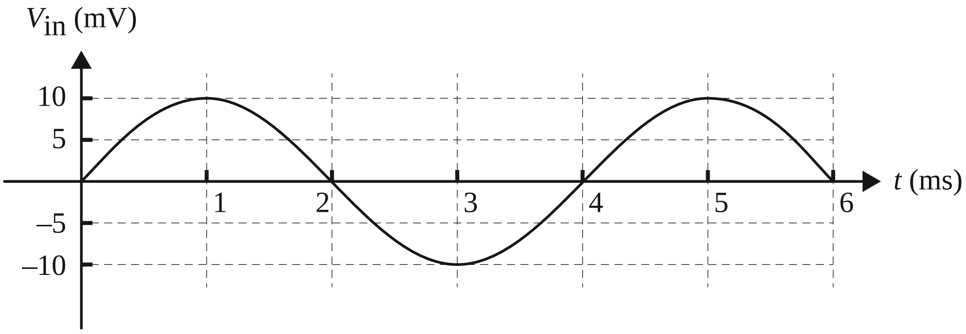

Figure 19

On Figure 20, draw the output signal that will result. Assign a correct scale to the vertical axis in volts. 3 marks

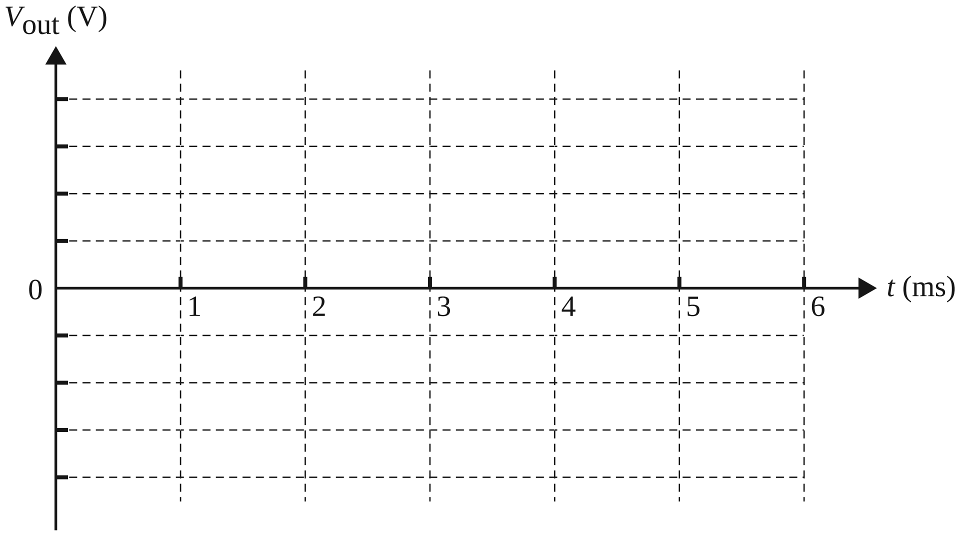

Figure 20

Question 11 (4 marks)

Shane and Alice are analysing the functioning of an automatic system that is used to turn a light globe on during the night and off during the day. It consists of a light-dependent resistor (LDR), used as a light sensor, and a control system.

The arrangement is shown in Figure 21.

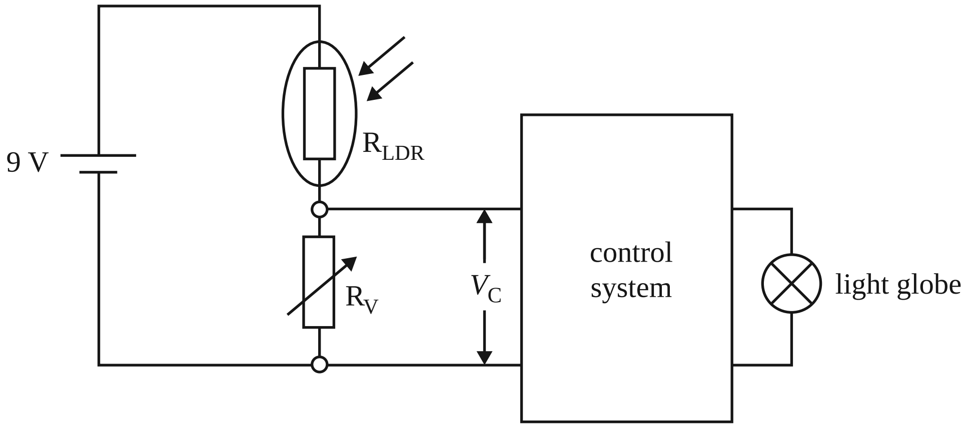

Figure 21

The LDR sensor is labelled R_{LDR}. R_V is a variable resistor that sets the on/off level. The control system turns the light globe on when V_C is between 0 and 4 volts, and off when V_C is between 4 and 9 volts.

The LDR characteristic is shown in Figure 22.

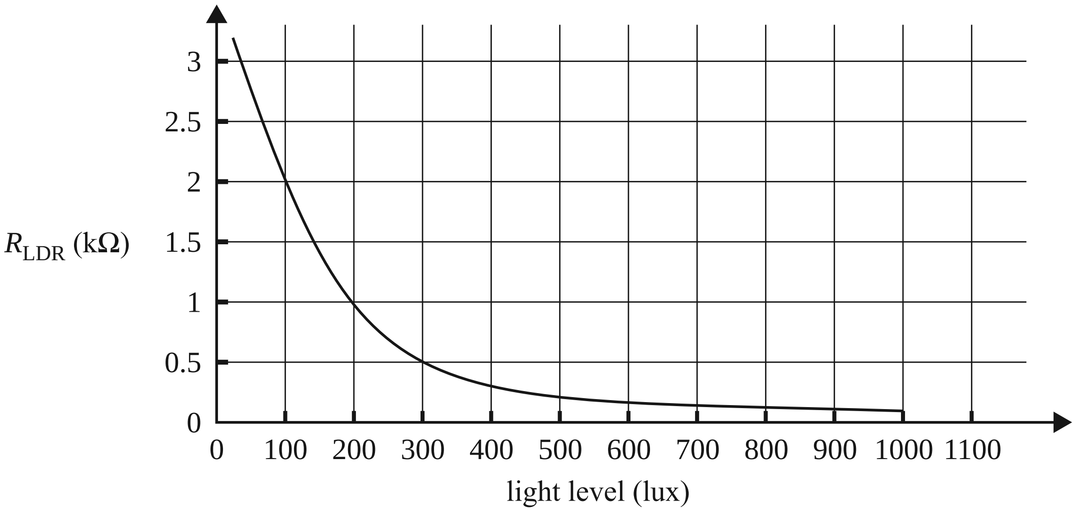

Figure 22

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Calculate the required value of R_V in order to turn the light on or off at 300 lux. Show your working.

Ω

Area of study – Electric power

Question 12 (2 marks)

Figure 23 shows a coil placed next to a straight wire. When both the coil and the wire carry an electric current, there is a force exerted on the wire. The directions of the currents are shown by arrows on the diagram. The point X lies on the axis of the coil.

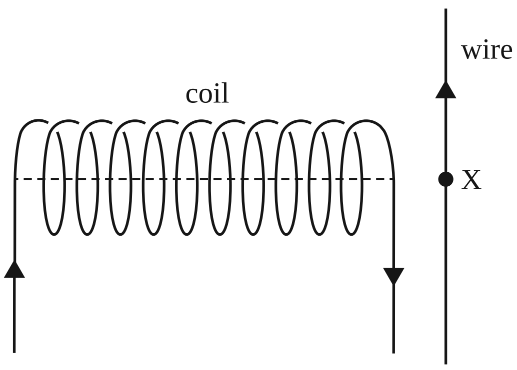

Figure 23

a. Which one of the following best describes the direction of the **magnetic field of the coil** at point X? 1 mark

A. left **B.** right **C.** up
D. down **E.** out of the page **F.** into the page

b. Which one of the following best describes the direction of the **force on the wire** at point X? 1 mark

A. left **B.** right **C.** up
D. down **E.** out of the page **F.** into the page

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Question 13 (7 marks)

A horizontal square conducting metal loop of one turn is placed in a uniform, steady magnetic field between two poles of an electromagnet, as shown in Figure 24. The plane of the loop is perpendicular to the magnetic field.

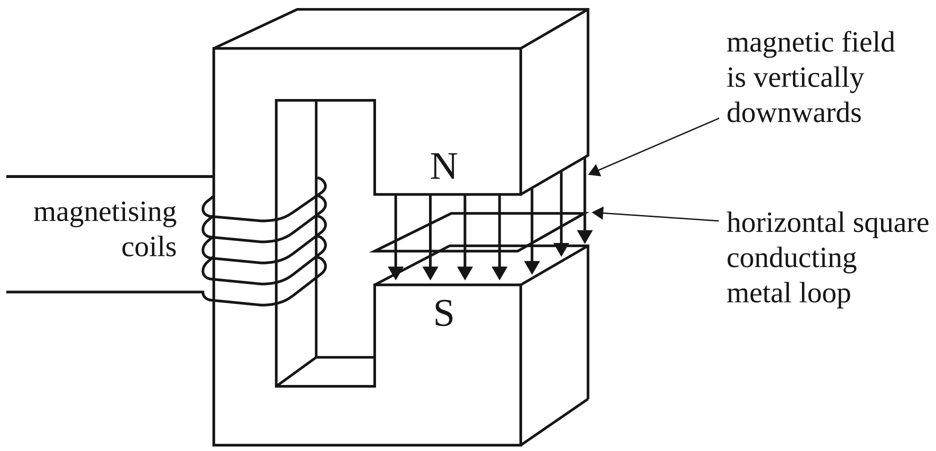


Figure 24

a. Students discuss different methods of causing a current to flow in the loop.

Choose **one or more** of the following options that would cause a current to flow in the loop. 1 mark

A. moving the loop directly upwards in the field towards the N pole

B. moving the loop sideways (to the left) but keeping it completely inside the field

C. moving the loop sideways (to the right) so that it moves out of the magnetic field

D. rotating the loop about a horizontal axis

b. The uniform field of the magnet between its poles is initially equal to 0.050 T. The current in the electromagnet is then adjusted so that the field reduces to zero in 10 ms.

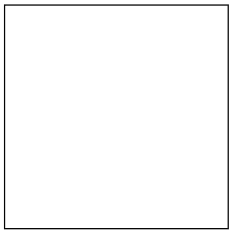
An average current of 0.020 A flows in the loop. The area of the loop is 0.080 m^2.

Calculate the resistance of the loop. Show your working. 3 marks

Ω

c. The magnetic field is reduced to zero.

On Figure 25, indicate the direction of the resulting induced current in the loop. Explain your reasoning. 3 marks



loop as viewed from above

Figure 25

Question 14 (3 marks)

An ideal transformer has 130 turns in the primary coil and 5200 turns in the secondary coil.

a. A DC voltage signal of 12 V is connected to the primary coil.

State the value of the steady voltage at the output of the secondary coil. 1 mark

V

b. An AC voltage signal is then connected to the primary coil and an AC RMS voltage of 400 V appears at the output of the secondary coil.

Calculate the **peak** value of the voltage at the input of the primary coil. 2 marks

V

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Question 15 (6 marks)

Jemima is planning to operate an electric light globe in a building some distance from her house. To do this, she connects two long wires from a variable voltage DC power supply in the house to an electric light globe in the building.

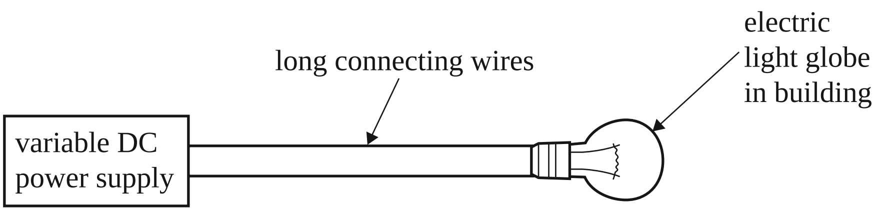

Figure 26
not to scale

The wires have a total resistance of 5.0 Ω. The DC power supply produces a constant output voltage of 13 V. The light globe in the building is designed to operate at 6.0 V. Assume that its resistance is a constant 1.5 Ω.

When Jemima switches on the circuit, she measures the voltage at the light globe to be only 3.0 V.

a. Calculate the voltage loss in the long connecting wires. 1 mark

V

b. Calculate the power output of the light globe at this voltage. 1 mark

W

c. Calculate the current flowing in the long connecting wires. 1 mark

A

D O   N O T   W R I T E   I N   T H I S   A R E A

d. Jemima knows that more brightness can be achieved if she sets the DC power supply to a higher constant voltage. However, she also knows that it is unwise to run the light globe at greater than 6.0 V as it will probably fail.

Calculate the greatest voltage that Jemima can set the DC power supply at, without exceeding 6.0 V across the light globe in the building. Show your working. 3 marks

V

Question 16 (4 marks)

Efficient transmission of electric power over long distances often involves the use of step-up and step-down transformers.

Outline how the use of these transformers reduces transmission losses. Include relevant physics formulas.

Question 17 (9 marks)

A model DC motor using permanent magnets is shown in Figure 27. The coil of the motor is formed from 75 turns of wire. Each turn is rectangular, having a length of 40 cm (sides WX and YZ) and a width of 15 cm (sides XY and WZ).

The magnetic field is uniform and has a value of 0.020 T. The coil can rotate freely between the magnets. The axis of the motor and the direction of the magnetic field are shown.

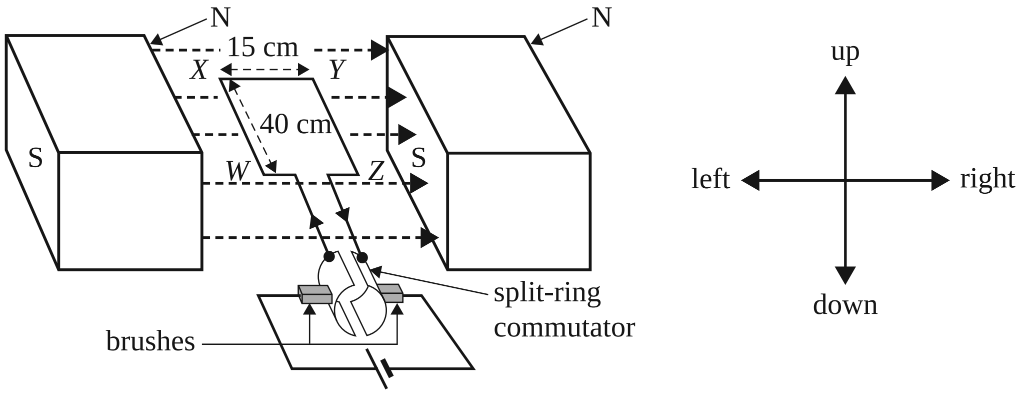

Figure 27

a. In the table below, describe the direction of the forces on all four sides of the coil. Assume that the coil is in the horizontal position and the current direction is as shown in Figure 27. Use the words 'up', 'down', 'left', 'right' or 'no force'. 2 marks

Side	Force direction
WX	
XY	
YZ	
ZW	

b. What is the magnitude of the force on the side WX of the 75-turn coil when the coil is horizontal and the current is 2.0 A? 2 marks

N

DO NOT WRITE IN THIS AREA

c. The motor is switched on when the coil is stationary in the horizontal position, and the coil starts to rotate.

Explain why this rotation occurs. 2 marks

d. As the coil rotates from its starting position, it travels through a vertical position, when its plane is perpendicular to the magnetic field.

In the table below, indicate the direction of the current in the side WX (if there is a current) at the three positions listed. Use only the following directions:

- from W to X
- from X to W
- no current

3 marks

Position	**Current in side WX**
before the vertical position	
at the vertical position	
after the vertical position	

Question 18 (7 marks)

A sketch of a small model generator is shown in Figure 28. The magnetic field is supplied by two permanent magnets. The output of the generator is fitted with slip rings and is connected to an oscilloscope.

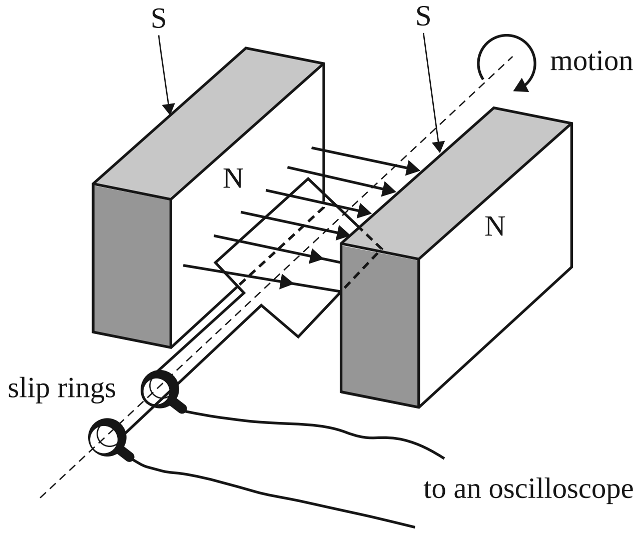

Figure 28

a. The display on the oscilloscope shows an AC signal.

Explain why the signal is AC rather than DC. 3 marks

b. The coil of the generator makes one half turn (180°) every 25 ms.

Calculate the frequency of the AC signal produced by the generator. 2 marks

Hz

c. The speed of rotation of the coil is increased so that it completes one half turn every 10 ms.

State whether this will increase, decrease or not change the magnitude of the voltage output of the generator. Give a reason for your answer. 2 marks

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Area of study – Interactions of light and matter

Question 19 (3 marks)

A group of students carries out a two-slit interference experiment using light with a wavelength of 420 nm. The arrangement of the students' apparatus and the resulting interference pattern are shown in Figure 29.

The point M on the screen is at the centre of the interference pattern. There is a bright band at point P on the screen. It is the second bright band to the right of M, as shown.

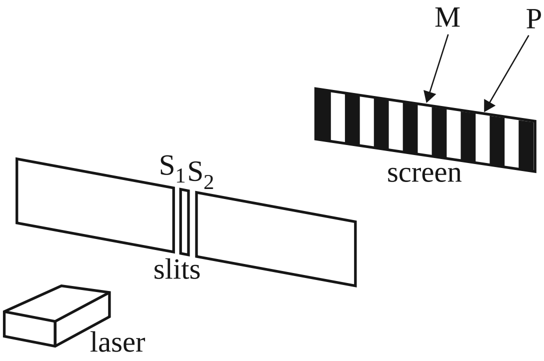

Figure 29

a. Calculate the path difference $S_1P - S_2P$. 1 mark

____

____

nm

b. The students repeat the experiment using light of a different wavelength. They find that, at the point P on the screen, there is now a **dark** band. It is the second dark band to the right of M.

Calculate the wavelength of this light. Show your working. 2 marks

____

____

____

____

nm

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Question 20 (5 marks)

A group of students carry out an experiment where light of various frequencies is shone onto a metal plate. The maximum kinetic energy of the emitted electrons for each frequency is recorded and the results are plotted to produce the graph shown in Figure 30. Take Planck's constant as 6.63×10^{-34} J s.

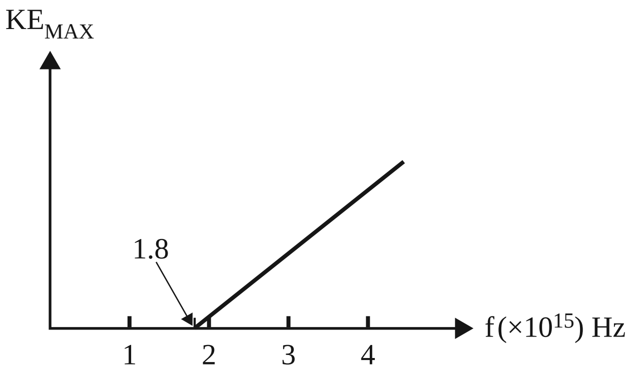


Figure 30

a. Calculate the work function of the metal in joules. 2 marks

J

b. The intensity of the light is increased and the experiment is repeated with the same frequencies. The students find that the graph of frequency against maximum kinetic energy for this second experiment is exactly the same as for the first experiment.

Explain why this result provides evidence for the particle-like nature of light. 3 marks

Question 21 (8 marks)

Thuy is doing some experiments on the diffraction of photons. She is using a beam of photons with an energy of 4.1 eV.

a. Calculate the wavelength of a photon in this light beam. 2 marks

m

The beam is incident on a small circular aperture and the resulting diffraction pattern is produced on a photon-sensitive screen behind the aperture. This pattern is shown in Figure 31.

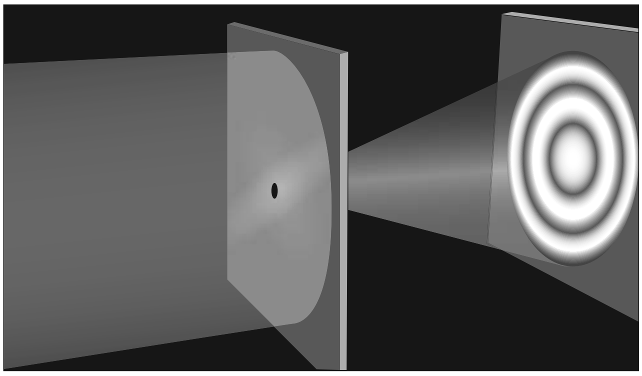


Figure 31

b. A second experiment is then performed with the same light beam incident on a circular aperture with a larger diameter.

Complete the following sentence by circling the correct words that are shown in **bold** font. 1 mark

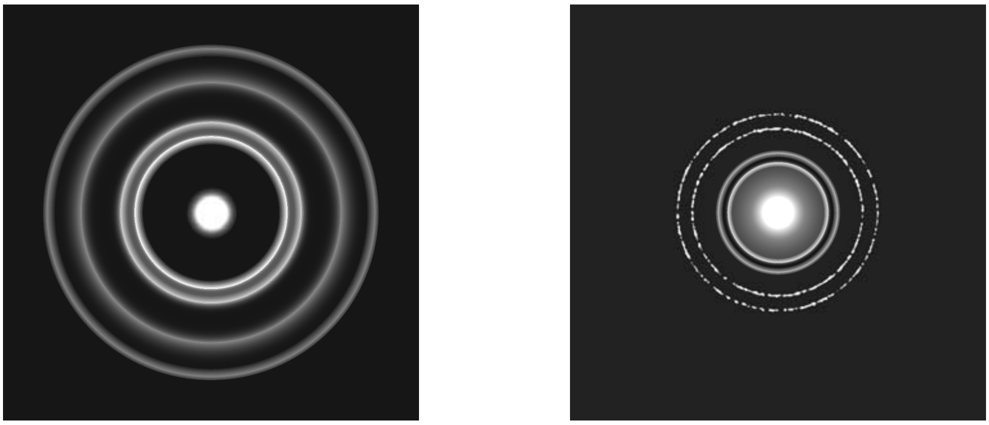
Corresponding rings in the second diffraction pattern would have diameters that are **larger than / the same size as / smaller than** the rings in the original pattern.

c. Give your reasoning for your answer to **part b.** 2 marks

d. Thuy now carries out another experiment, comparing the diffraction of X-ray photons and electrons.

A beam of X-ray photons is incident on a small circular aperture. The experiment is then performed with a beam of electrons incident on the same aperture.

The X-ray photons and electrons have the same energy. The diffraction patterns (shown in Figure 32) have the same general shape, but very different spacings.



X-ray photon diffraction electron diffraction

Figure 32
not to scale

Explain why the electron diffraction pattern has a different spacing from the X-ray diffraction pattern, even though the electrons and the photons have the same energy. 3 marks

Question 22 (5 marks)

A simplified diagram of the energy levels for a mercury atom is shown in Figure 33.

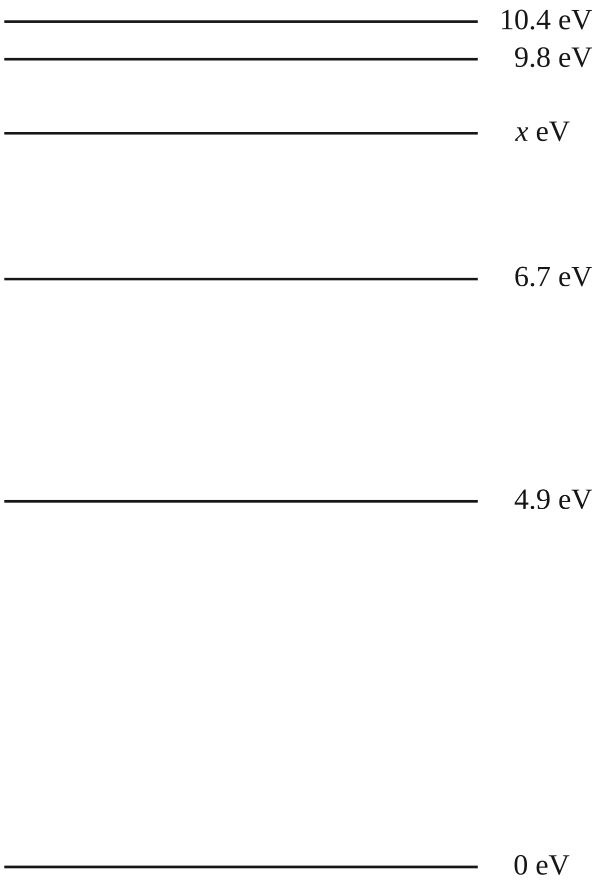


Figure 33

a. Explain why a mercury atom, while in the first excited state, is able to absorb a 1.8 eV photon, but cannot emit a photon of this energy. 2 marks

D O N O T W R I T E I N T H I S A R E A

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b. In a sample of excited mercury atoms, all of the energy levels shown in Figure 33 are occupied. One of the energy levels in Figure 33 is labelled *x* eV. The emission spectrum of mercury shows lines at approximately 0.9 eV, 1.5 eV and 2.2 eV.

Use this information and Figure 33 to calculate *x*. Give your reasoning. 3 marks

eV

Question 23 (5 marks)

According to one model of atoms, electrons in atoms move in stable circular orbits around the nucleus.
In an atom modelled in this way, an electron is moving at 2.0×10^{6} m s^{-1}. Take the mass of an electron as 9.1×10^{-31} kg.

a. Calculate the de Broglie wavelength of this electron. Give your answer in nm. 2 marks

nm

b. Describe how the wave nature of electrons can be used to explain the quantised energy levels in atoms. 3 marks

END OF SECTION A

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SECTION B

Instructions for Section B

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Detailed study 1 – Einstein's special relativity

Question 1

The concept of an 'inertial frame' is widely used in physics.

Which one of the following statements best describes an inertial frame?

A. a frame in which relativistic effects do not occur

B. a frame in which Newton's first law of physics is always obeyed

C. a frame in which all time measurements result in proper time

D. a frame whose acceleration is small compared to g

Question 2

A number of experiments have played a part in the history of the theory of relativity.

Which one of the following is true about the Michelson–Morley experiment?

A. More accurate versions of this experiment produced results that were significantly different from the original results.

B. It was only ever interpreted as confirming Einstein's postulate regarding the speed of light.

C. It was designed to prove Einstein's postulate regarding the speed of light.

D. It did not detect a difference between the speed of light in directions parallel to Earth's motion through space and in directions perpendicular to that motion.

Question 3

A person moving parallel to the length of a 2.00 m ruler observes the change of length of this ruler due to relativity to be 0.010 m.

What is the person's speed relative to the ruler?

A. $0.0050c$

B. $0.010c$

C. $0.10c$

D. $0.90c$

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Use the following information to answer Questions 4–6.

Two spacecraft travel in opposite directions, with spacecraft *Ajax* travelling at a speed of 0.5c and spacecraft *Hector* travelling at a speed of 0.4c. Both are travelling relative to the inertial frame of the galaxy. The situation is shown in Figure 1.

Figure 1

A radio signal is emitted by *Ajax* towards *Hector*. The navigator of *Hector* uses the classical physics understanding of radio waves travelling at a speed relative to a medium fixed with respect to the galaxy.

Question 4

Using this classical understanding, the speed of the radio signal relative to *Hector* is expected to be

A. c

B. 0.6c

C. 0.5c

D. 0.1c

Question 5

Measured in the frame of *Ajax*, the radio signal reaches *Hector* 0.0100 s after it is emitted by *Ajax*.

According to the navigator of *Ajax*, who is correctly using special relativity, how far did the radio signal travel between leaving *Ajax* and reaching *Hector*?

A. 3000 km

B. 300 km

C. 4200 km

D. 1500 km

Question 6

How can proper time be measured for the interval between the radio signal being emitted on *Ajax* and the signal reaching *Hector*?

A. Use measurements made by the crew on *Ajax*.

B. Use measurements made by the crew on *Hector*.

C. Use measurements made by an observer stationary at the point where the signal was emitted.

D. No single observer can measure proper time for this case.

Use the following information to answer Questions 7–9.

An astronaut takes a clock in her spacecraft and measures the clock's period while the spacecraft is stationary in the inertial frame of our galaxy. She then measures its period when the spacecraft is moving at a constant velocity of $0.60c$, relative to the galaxy's frame.

Question 7

The period of the clock as measured in the **moving** spacecraft

A. is smaller than when the spacecraft was stationary in our galaxy's inertial frame.

B. is the same as when the spacecraft was stationary in our galaxy's inertial frame.

C. is greater than when the spacecraft was stationary in our galaxy's inertial frame.

D. depends on the particular details of the clock mechanism.

The clock was built using two mirrors between which a pulse of light is repeatedly reflected, as shown in Figure 2. The proper length between the two mirrors is 5.00 m. The spacecraft's velocity ($0.60c$ relative to our galaxy; $\gamma = 1.25$) is in the direction AB.

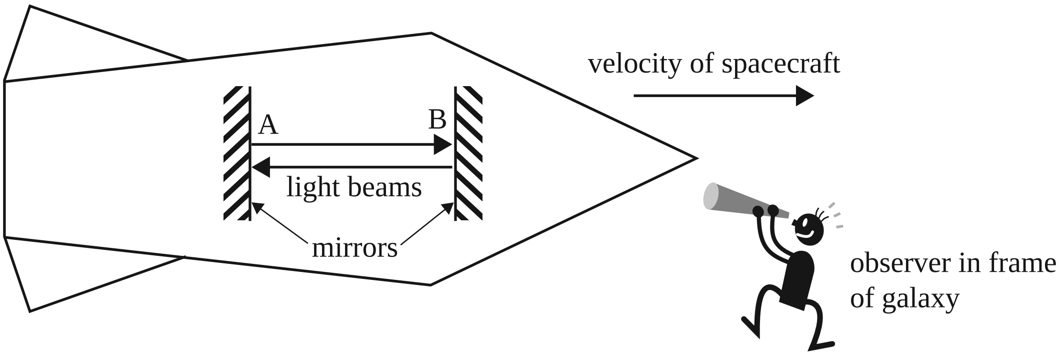

Figure 2

Question 8

According to an observer in the frame of our galaxy, the distance between the mirrors is closest to

A. 7.25 m

B. 5.00 m

C. 4.00 m

D. 3.00 m

Question 9

One period of this clock is the time taken for light to travel from A to B and back to A.

According to an observer in the frame of our galaxy, the period of this clock is closest to

A. 42 ns

B. 27 ns

C. 21 ns

D. 13 ns

DO NOT WRITE IN THIS AREA

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Use the following information to answer Questions 10 and 11.

A pion and its antiparticle, each at rest, annihilate to produce two photons whose total energy is 4.5×10^{-11} J. Apart from the two photons, nothing else is produced in this process. The masses of a pion and its antiparticle are the same.

Question 10

The rest mass of the pion is

A. 1.3×10^{-28} kg
B. 2.5×10^{-28} kg
C. 5.0×10^{-28} kg
D. 7.5×10^{-20} kg

Question 11

The pion is now accelerated from rest before colliding with its antiparticle.

What work must be done on one pion so that it has γ equal to 3.00?

A. 4.5×10^{-11} J
B. 2.2×10^{-11} J
C. 1.1×10^{-11} J
D. 9.0×10^{-11} J

SECTION B

Instructions for Section B

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Detailed study 2 – Materials and their use in structures

Use the information below to answer Questions 1–6.

Students conduct an experiment with different kinds of metal wires. The apparatus used in the experiment is shown in Figure 1. It enables the students to measure the extensions, Δx, for different masses.

Each sample of wire has a cross-section (assumed to be constant throughout the experiment) of 4.0×10^{-8} m^2. At the start of each set of readings, the wire sample has a length of 2.00 m. The students add successive 50 g masses. There is no friction at the pulley.

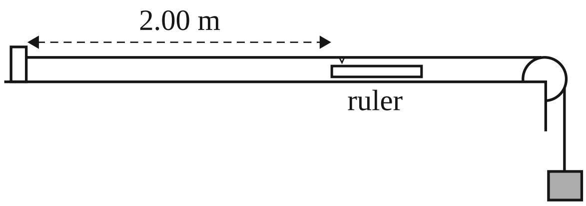

Figure 1

For a sample of copper wire, the students record the following set of readings.

Number of 50 g masses	Extension (mm)
0	0
1	0.5
2	1.0
3	1.5
4	2.0
5	2.8
6	3.8
7	5.0
8	wire breaks

Question 1

Which one of the following best gives the strain, ε, when four masses are attached?

A. 1.0×10^{-3}

B. 2.0×10^{-3}

C. 1.0×10^{-6}

D. 2.0×10^{-6}

Question 2

Which one of the following best gives the stress, σ, when four masses are attached?

A. 2.0 MPa

B. 5.0 MPa

C. 50 MPa

D. 5000 MPa

The students repeat the experiment for nichrome wire and tungsten wire, resulting in the graphs shown in Figure 2.

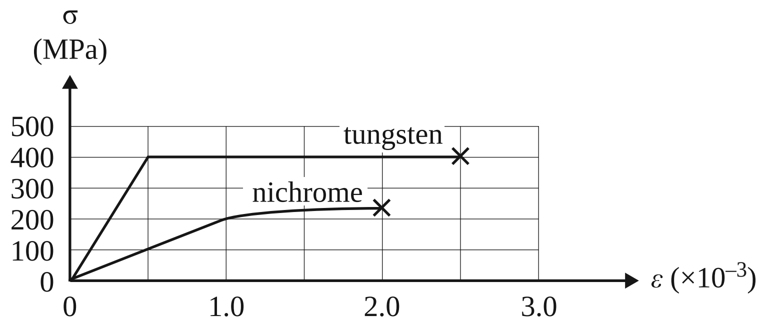

Figure 2

Question 3

Which one of the following best gives the value of Young's modulus for nichrome?

A. 2.5×10^{6} N m^{-2}

B. 4.0×10^{8} N m^{-2}

C. 2.0×10^{11} N m^{-2}

D. 4.0×10^{11} N m^{-2}

Question 4

Which one of the following is the best measure of the toughness of tungsten?

A. 900 J m^{-3}

B. 1.0×10^{5} J m^{-3}

C. 4.0×10^{5} J m^{-3}

D. 9.0×10^{5} J m^{-3}

Question 5

Which one of the following best describes the relative properties of tungsten and nichrome?

A. Tungsten is less brittle and stronger than nichrome.

B. Tungsten is more brittle and less strong than nichrome.

C. Tungsten is less brittle and less strong than nichrome.

D. Tungsten is more brittle and stronger than nichrome.

Question 6

A particular different sample of the tungsten wire has a cross-sectional area of 1.0×10^{-8} m^2.

What is the maximum number of 50 g masses that could be suspended from the tungsten wire before it breaks?

A. 4

B. 8

C. 20

D. 80

Use the following information to answer Questions 7–9.

In an experiment, students set up the cantilever structure shown in Figure 3a below and attach it to the wall PQ. The pivot at X is a freely rotating hinge. The mass of the beam XY is 50 g and the string ZW can be considered to have no mass.

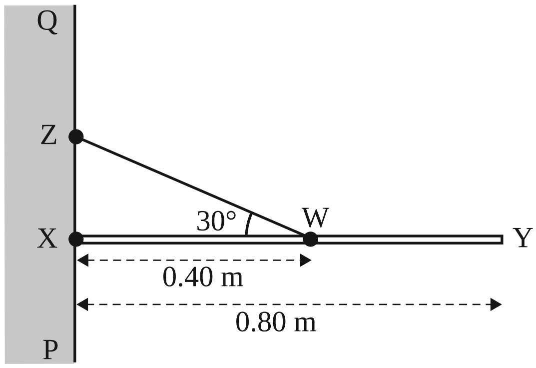

Figure 3a

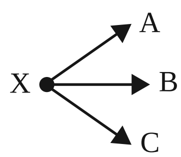

Figure 3b

not to scale

Question 7

Which one of the following is the best estimate of the tension in the string ZW?

A. 0.10 N

B. 1.0 N

C. 2.0 N

D. 4.0 N

Question 8

Using Figure 3b as a direction reference, which one of the following best describes the direction of the force of the wall PQ on the beam XY at point X?

A. in direction A

B. in direction B

C. in direction C

D. no direction is relevant, no force at point X from PQ

Question 9

A 150 g hanging mass is now attached at point Y, as shown in Figure 4.

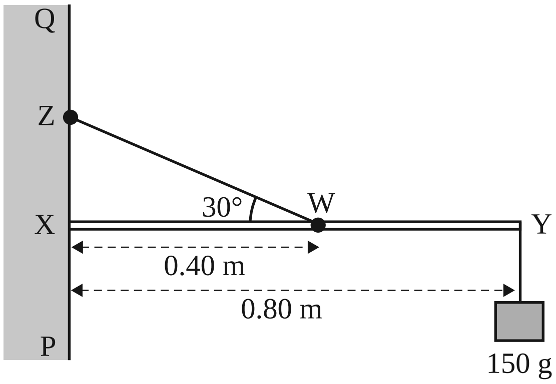

Figure 4
not to scale

Which one of the following is the best estimate of the torque on the beam about point X due to the 150 g hanging mass?

A. 0.15 N m

B. 1.2 N m

C. 1.5 N m

D. 120 N m

Question 10

An engineer is designing an ornamental arch bridge. The arch consists of a number of shaped concrete blocks, as shown in Figure 5. There is no adhesive required between the blocks to keep the bridge stable.

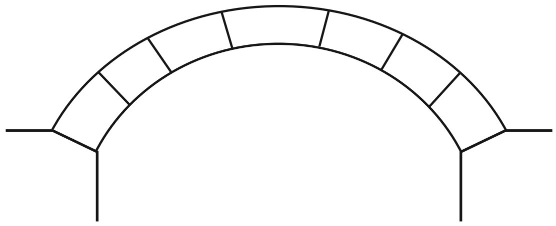

Figure 5

An advisor working with the engineer says that concrete structures are always reinforced by steel rods embedded in them and that the engineer should incorporate these.

Which one of the following statements is true?

A. Rods are needed near the top of each block.

B. Rods are needed near the bottom of each block.

C. Rods are needed at the middle of each block.

D. Rods would serve no useful purpose.

Question 11

An engineer is designing a truss bridge. The design is shown in Figure 6.

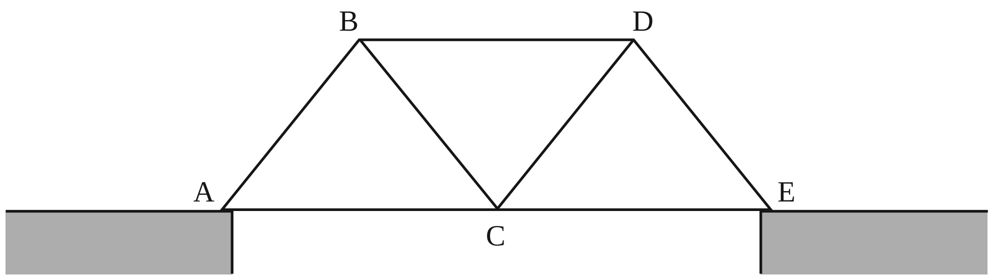

Figure 6

The engineer intends to use steel beams for all the sections. However, the design is found to be too heavy. An advisor suggests that they could lighten the structure and save on costs by replacing some of the steel beams with steel cables.

Which of the following could safely be replaced with steel cables?

A. BD only

B. BD, BC and CD

C. AB and DE

D. BC and CD

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SECTION B

Instructions for Section B

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Detailed study 3 – Further electronics

Use the following information to answer Questions 1 and 2.

Students are designing, building and testing a smoothed regulated DC power supply as shown in Figure 1.

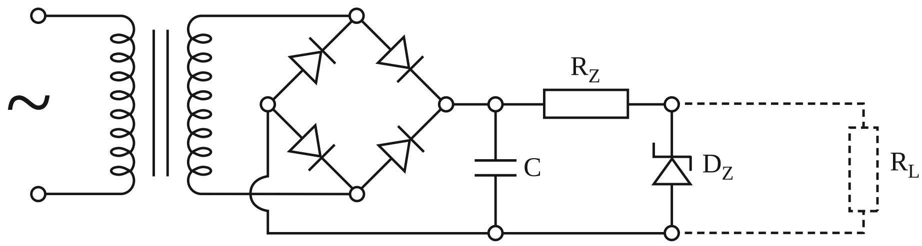

Figure 1

Question 1

The students are considering whether to provide power for their supply direct from the 240 V_{RMS} mains supply or from the 24 V_{RMS} school network, each using a different transformer.

Supplying their power source from the 24 V_{RMS} school network offers which one of the following advantages?

A. It will allow a greater range of resistive loads to be powered by the source.

B. It will have a smoother output voltage.

C. It will require fewer components.

D. It is a safer alternative.

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Question 2

The students decided to use the 24 V_{RMS} school network as the input to the power supply. This means that they will need a transformer to step down the voltage to 6 V_{RMS} before rectification.

Which one of the following specifications will best provide this?

A. a primary coil of 500 turns and a secondary coil of 2000 turns

B. a primary coil of 500 turns and a secondary coil of 125 turns

C. a primary coil of 125 turns and a secondary coil of 500 turns

D. a primary coil of 2500 turns and a secondary coil of 500 turns

Question 3

The students investigate the functioning of the capacitor to be used in the circuit. They set up the circuit shown in Figure 2. Initially the switch is open and then it is closed.

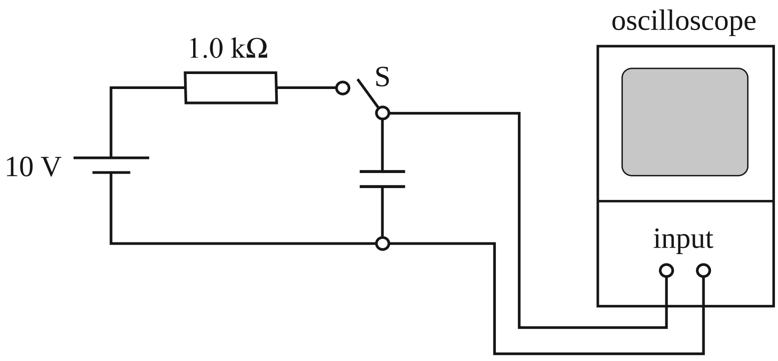

Figure 2

The shape of the signal across the capacitor is shown in Figure 3.

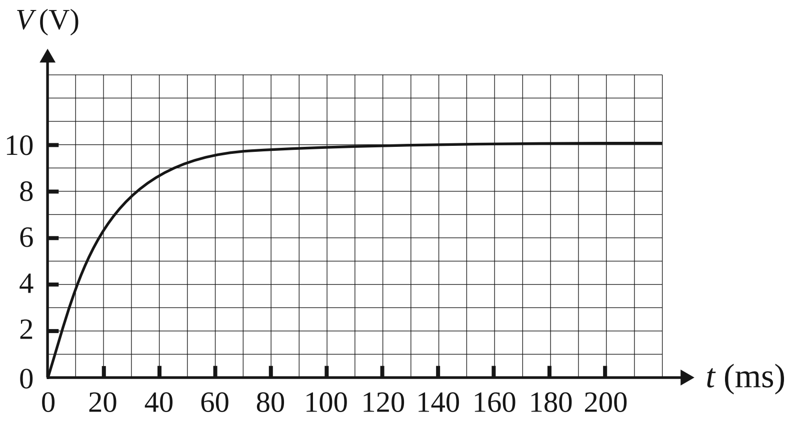

Figure 3

The value of the capacitor is closest to

A. 40 μF

B. 400 μF

C. 20 μF

D. 200 μF

Use the following information to answer Questions 4–6.

The students decide to test the effect of the size of a capacitor on the smoothing of the power supply. They set up the circuit shown in Figure 4.

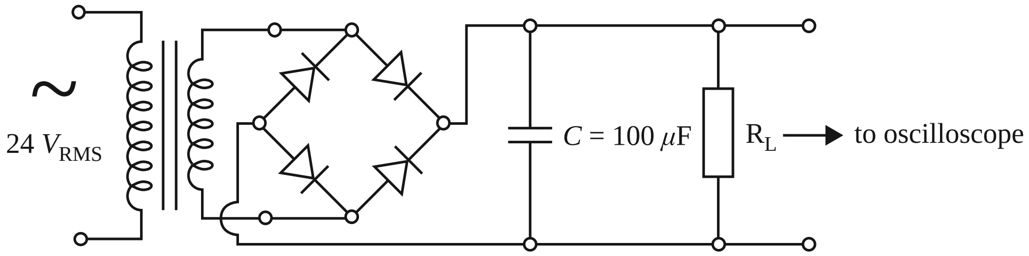

Figure 4

After completing the circuit, the voltage across the load is measured with an oscilloscope. The display on the oscilloscope is shown in Figure 5. The diodes are ideal (infinite reverse resistance and zero forward resistance).

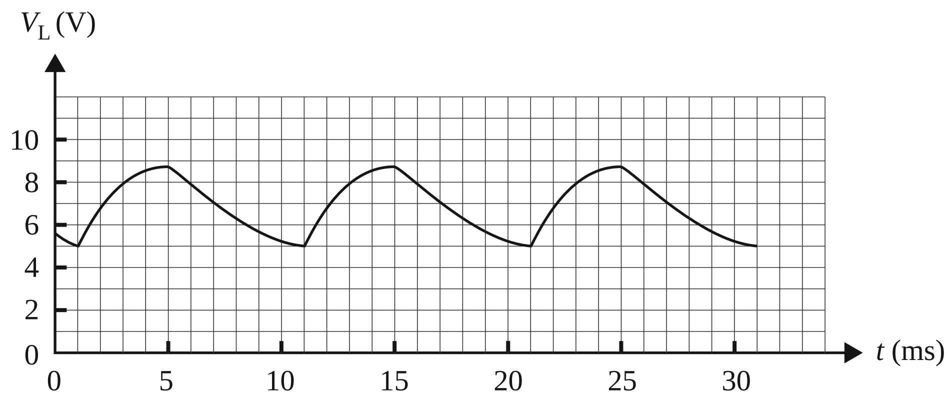

Figure 5

Question 4

The frequency of the ripple voltage shown in Figure 5 across the load is closest to

A. 100 Hz

B. 50 Hz

C. 20 Hz

D. 10 Hz

Question 5

The peak voltage of the voltage shown in Figure 5 is closest to

A. 7 V

B. 8.5 V

C. 12 V

D. 3.5 V

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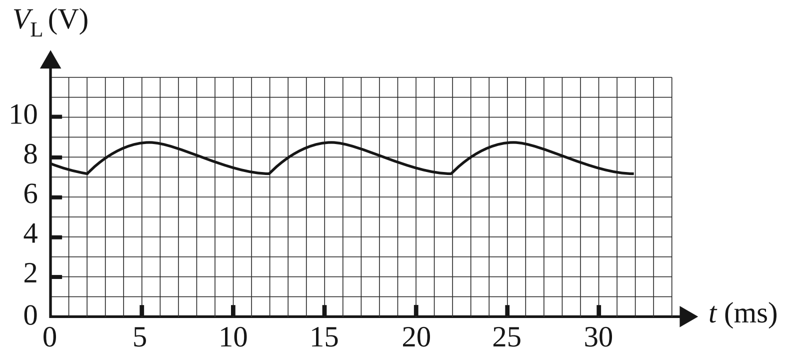
Question 6

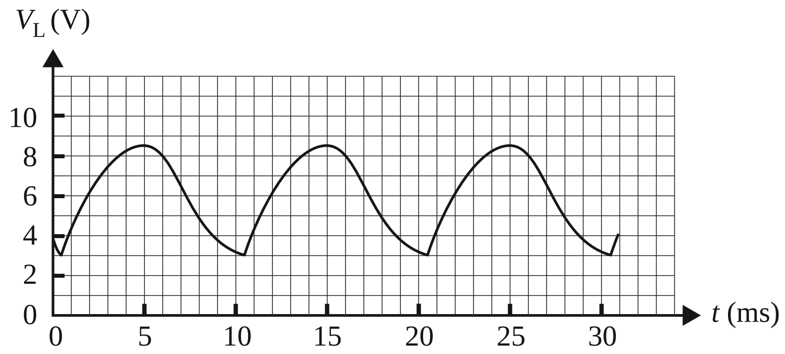
The students then replace the 100 μF capacitor with a 300 μF capacitor.

The resulting voltage is most likely to look like which one of the following?

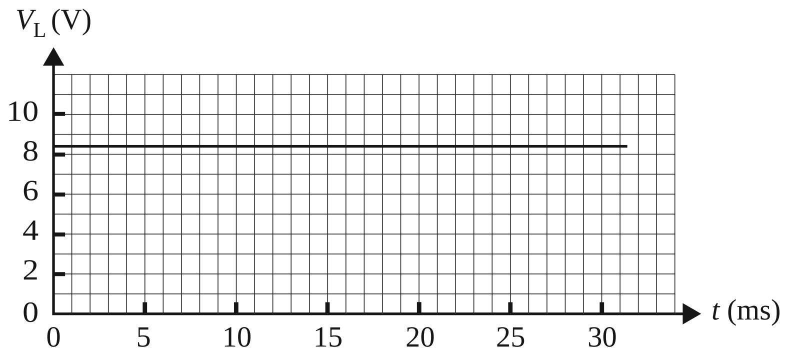
A.



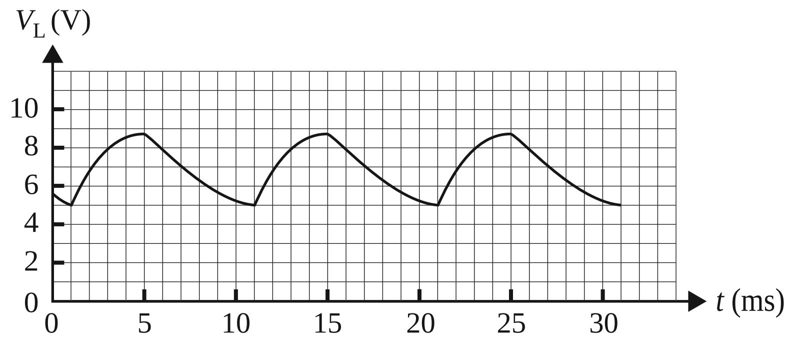
B.



C.



D.



Question 7

The students investigate the use of a Zener diode as the voltage regulator for the power supply. They use the circuit shown in Figure 6. The input voltage is 10 V. The characteristic of the Zener diode is shown in Figure 7.

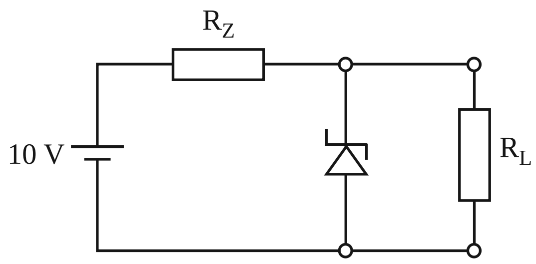


Figure 6

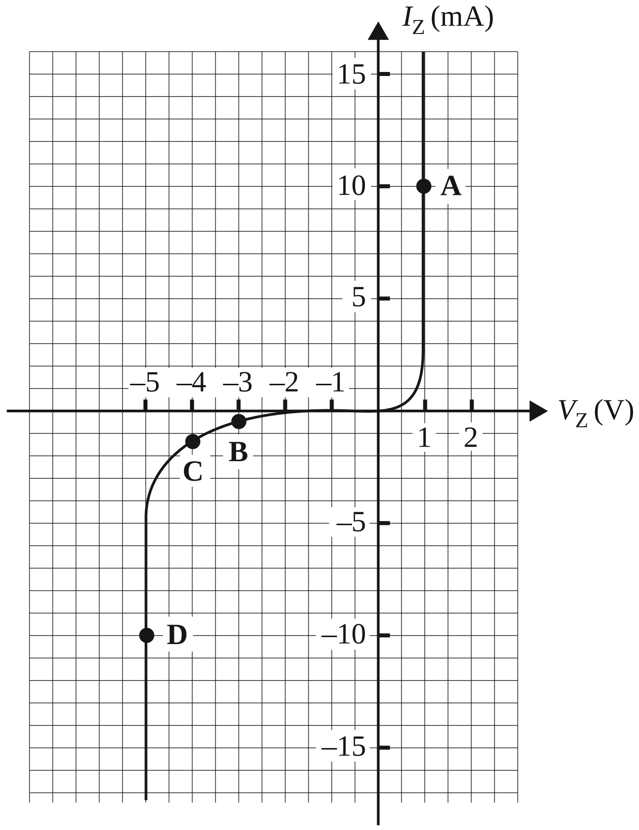


Figure 7

At which point on the graph does the Zener diode need to operate to best perform its regulating function?

A. point A

B. point B

C. point C

D. point D

Question 8

The students investigate the use of an integrated circuit voltage regulator, as shown in Figure 8. A heat sink is attached to the regulator to prevent overheating.

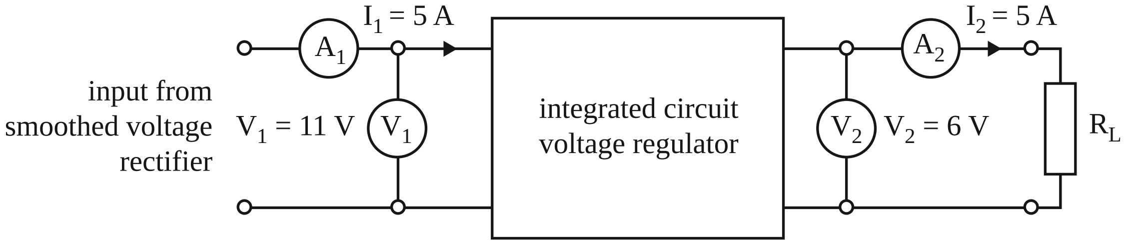


Figure 8

The voltages and currents measured by the meters in the circuits are as follows: $I_1 = 5$ A, $V_1 = 11$ V, $I_2 = 5$ A, $V_2 = 6$ V.

Based on the data provided, the minimum power that the heat sink should be able to dissipate is closest to

A. 45 W

B. 25 W

C. 20 W

D. 30 W

Use the following information to answer Questions 9–11.

Figure 9 represents the electric circuit of the working power supply.

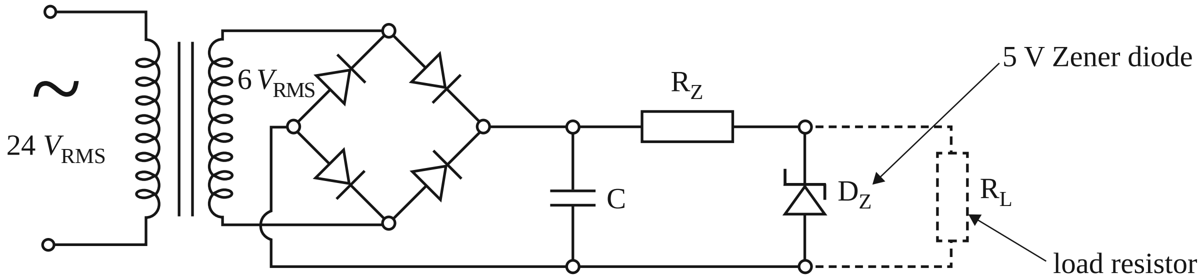


Figure 9

Question 9

The students now test the circuit shown in Figure 9 in order to investigate factors affecting the ripple voltage.

Which one of the following changes will increase the amplitude of the ripple voltage?

A. increasing the capacitance of the capacitor

B. increasing the frequency of the supply voltage

C. decreasing the frequency of the supply voltage

D. increasing the resistance of the load

Question 10

The students now investigate the effect of the value of the load resistor on the ripple voltage.

Which one of the following load resistors will have a ripple voltage with the smallest amplitude?

A. 1 Ω

B. 10 Ω

C. 100 Ω

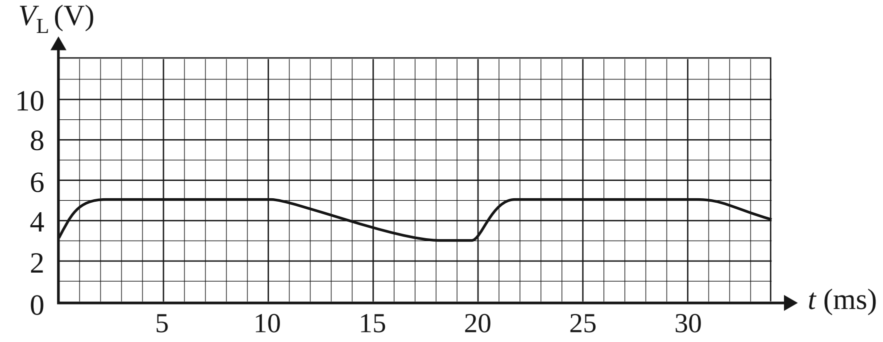
D. 1000 Ω

Question 11

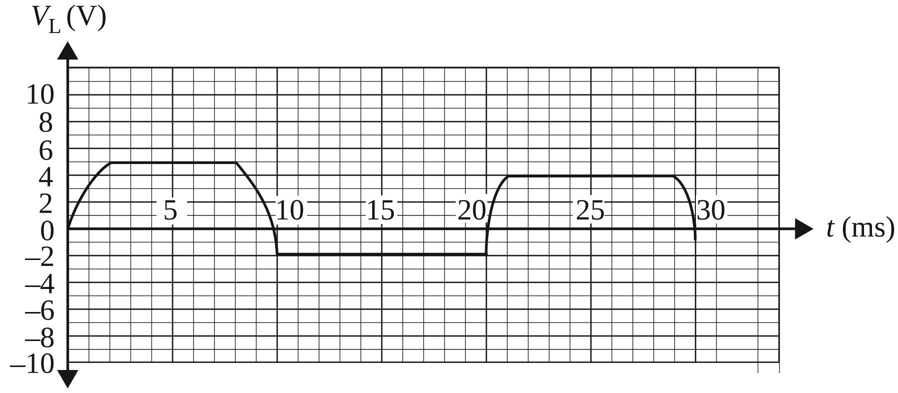
After a short time of correct operation, one of the diodes in the bridge rectifier in the circuit (shown in Figure 9) becomes faulty and its resistance becomes infinite (open circuit).

Which one of the following signals now best represents the signal across the load resistor R_L?

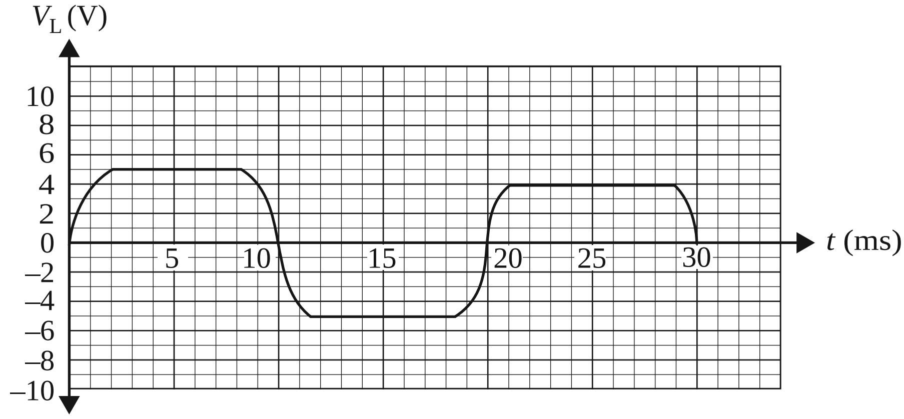
A.



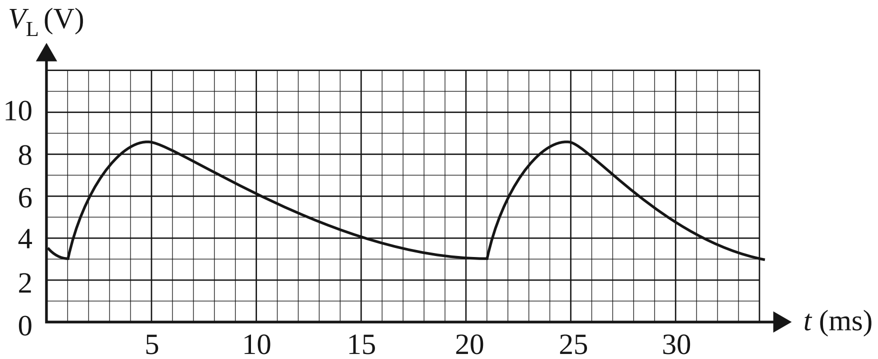
B.



C.



D.



End of Detailed study 3
SECTION B – continued
TURN OVER

SECTION B

Instructions for Section B

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Detailed study 4 – Synchrotron and its applications

Question 1

A simplified diagram of the electron gun in the Australian Synchrotron is shown in Figure 1.

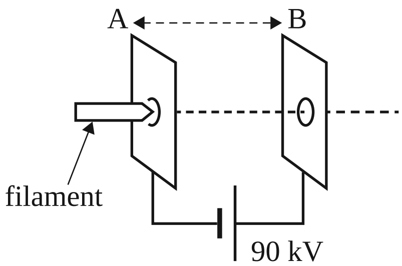

Figure 1

An electron leaving the filament at A is accelerated through a potential difference of 90 kV to B. In the space between A and B, the electron experiences a force of 7.2×10^{-14} N.

Which one of the following is closest to the magnitude of the electric field between A and B?

A. 4.5×10^{5} V m^{-1}

B. 4.5×10^{4} V m^{-1}

C. 9.0×10^{4} V m^{-1}

D. 9.0×10^{5} V m^{-1}

Question 2

Synchrotron radiation, as used in the Australian Synchrotron, is produced in the

A. storage ring.

B. booster ring.

C. linac.

D. beamlines.

Use the following information to answer Questions 3 and 4.

In Figure 2, a beam of electrons is moving to the right at a speed of 2.5×10^8 m s^{-1}. The beam enters a magnetic field of 0.27 T that is directed into the page, as shown.

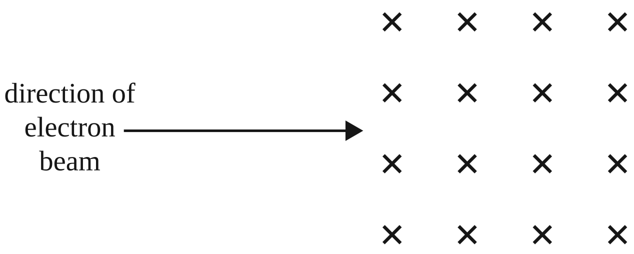

Figure 2

Question 3

After entering the magnetic field, each electron experiences an acceleration closest to

A. 1.1×10^{-11} m s^{-2}

B. 1.2×10^{19} m s^{-2}

C. 4.2×10^{22} m s^{-2}

D. 5.1×10^{23} m s^{-2}

Question 4

The radius of the electron's circular path after entering the magnetic field is closest to

A. 5.7×10^{-12} m

B. 1.9×10^{-5} m

C. 1.4×10^{-3} m

D. 5.3×10^{-3} m

Question 5

Insertion devices are used in the Australian Synchrotron. These devices force electrons in the synchrotron to oscillate and produce radiation. Figure 3 shows the relationships between brightness and the range of energies of the radiation produced by two such devices, A and B.

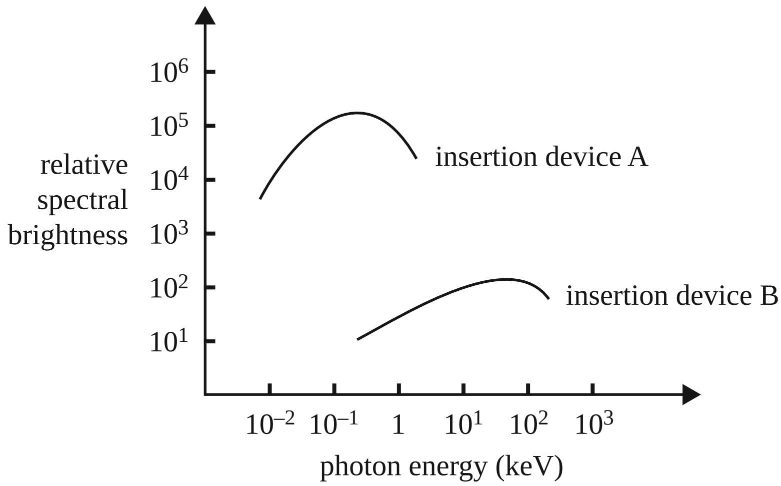

Figure 3

Based on Figure 3, which one of the following best describes the radiation produced by electrons passing through these particular devices?

A. The maximum frequency of radiation produced by device A is lower than the maximum frequency of radiation produced by device B.

B. Radiation produced in these two devices shows no relationship between intensity and frequency.

C. The maximum frequency of radiation produced by device A is higher than the maximum frequency of radiation produced by device B.

D. The maximum intensity produced in device B is approximately 10 000 times the maximum intensity produced in device A.

Question 6

When electrons move along a circular path, what is the direction of the radiated energy?

A. It is along the electrons' circular path.

B. It is towards the centre of the electrons' circular path.

C. It is along a tangent to the electrons' circular path.

D. It can be in all directions from the electrons' circular path.

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 7 and 8.

An X-ray photon with a frequency of 2.30×10^{18} Hz is involved in a collision with a free electron that is initially at rest. After the collision, the scattered photon has a frequency of 2.22×10^{18} Hz and is moving in the direction opposite to that of its original motion.

Question 7

The speed of the electron after the collision is

A. 7.3×10^{5} m s^{-1}

B. 1.1×10^{7} m s^{-1}

C. 2.2×10^{14} m s^{-1}

D. 3.1×10^{15} m s^{-1}

Question 8

Which one of the following best describes the difference between a Compton interaction and a Thomson interaction?

A. Compton scattered photons have no change in frequency, but Thomson scattered photons have an increase in frequency.

B. Compton scattered photons have no change in wavelength, but Thomson scattered photons have an increase in wavelength.

C. Thomson scattered photons have no change in frequency, but Compton scattered photons have an increase in frequency.

D. Thomson scattered photons have no change in wavelength, but Compton scattered photons have an increase in wavelength.

Use the following information to answer Questions 9 and 10.

Researchers are studying crystal diffraction in experiments at the Australian Synchrotron.

Question 9

The separation of the planes of ions in the researchers' crystal sample is 2.7×10^{-10} m. A beam of X-rays is incident on the sample. The X-ray photons have a wavelength of 0.082 nm. A detector registers several intensity peaks.

The smallest angle between the beam and the planes of ions in the crystal for which an intensity peak is detected is

A. 5.3°

B. 8.7°

C. 9.2°

D. 17.7°

Question 10

In another experiment, a sample of a different crystal is studied. The beam of photons has the same wavelength as before. The separation of the planes of ions in this second crystal is half as great as in the first crystal. The crystal is rotated so that the angle between the beam and the planes of ions in the crystal varies from 0° to 90°.

The number of intensity peaks formed is

A. zero.

B. the same as for the first crystal.

C. less than for the first crystal.

D. greater than for the first crystal.

Question 11

The researchers have access to a laser, but have decided to use synchrotron light for their experiments.

Which one of the following is the most likely reason for this?

A. Laser light is very divergent and can provide only one wavelength.

B. Laser light is extremely intense and consists of several wavelengths.

C. Synchrotron light is extremely intense and a range of single wavelengths can be selected.

D. Synchrotron light is very divergent and a range of single wavelengths can be selected.

DO NOT WRITE IN THIS AREA

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SECTION B

Instructions for Section B

Select **one** Detailed study and answer **all** questions within that Detailed study in pencil on the answer sheet provided for multiple-choice questions.

Show the Detailed study you are answering by shading the matching box on your multiple-choice answer sheet and writing the name of the Detailed study in the box provided.

Choose the response that is **correct** for the question.

A correct answer scores 2, an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Detailed study 5 – Photonics

Use the following information to answer Questions 1 and 2.

A step-index optical fibre has an acceptance angle of 15°. The refractive index of its core for yellow light is 1.40. Figure 1 is a diagram of the optical fibre.

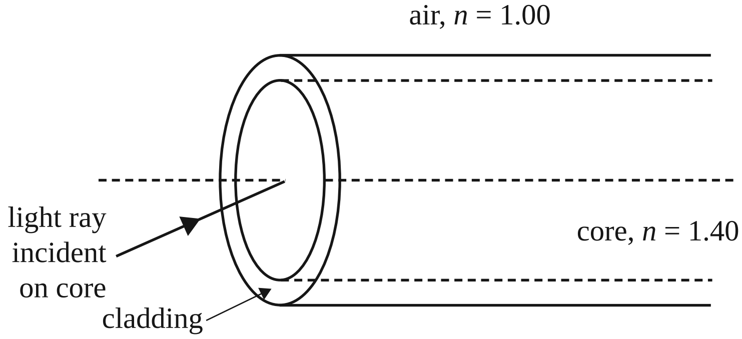

Figure 1

Question 1

The critical angle for internal reflection of yellow light within this optical fibre is closest to

A. 84°

B. 79°

C. 69°

D. 60°

Question 2

The user requires that the optical fibre has a smaller critical angle.

This can be achieved by

A. using a ray entering the core at an angle of incidence greater than the acceptance angle.

B. using a ray entering the core at an angle of incidence less than the acceptance angle.

C. increasing the refractive index of the cladding.

D. decreasing the refractive index of the cladding.

Question 3

Students are warned **not** to look directly into a laser beam. The danger is due to the lens of the eye focusing light onto the retina.

The reason laser light is more dangerous than normal light of the same power is that

A. the light from a laser is much more monochromatic than the light from other sources.

B. a laser produces a coherent beam of light.

C. all the light from a laser is in a narrow beam.

D. all the light from a laser is in a broad divergent beam.

Use the following information to answer Questions 4 and 5.

When sufficient current passes through a semiconductor laser diode, it emits laser light of wavelength 800 nm.

Question 4

The energy gap of the semiconductor is closest to

A. 1.0 eV

B. 1.5 eV

C. 2.0 eV

D. 3.0 eV

Question 5

Which one of the following best describes the production of coherent laser light in this laser system?

A. Photons are emitted spontaneously as electrons transition from an upper state to a lower state.

B. Photons whose direction is along the laser beam stimulate the emission of further photons.

C. Photons that have been emitted incoherently are stimulated by the current to be in phase with other photons.

D. The current stimulates electrons to make transitions in the direction of the laser beam.

Question 6

A light-emitting diode (LED) is connected into a circuit, as shown in Figure 2. The LED is emitting light.

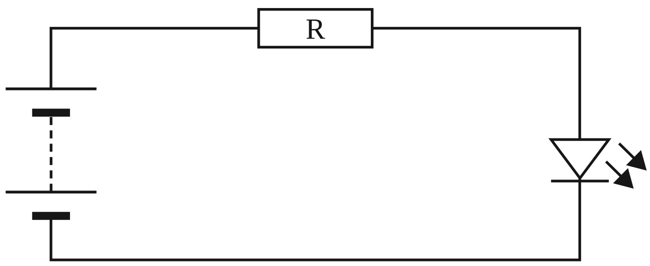

Figure 2

If the resistance R is halved, the emitted light has

A. a shorter wavelength and higher intensity.

B. a longer wavelength and higher intensity.

C. an unchanged wavelength and higher intensity.

D. a shorter wavelength and the same intensity.

Question 7

Mercury streetlights emit light with a wide range of wavelengths.

This light is best described as

A. incoherent because each atom emits photons individually.

B. coherent but not monochromatic.

C. incoherent because photons are emitted in all directions.

D. coherent because all mercury atoms are stimulated by light emitted by other mercury atoms.

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Question 8

A scientist is designing an endoscope using a bundle of optical fibres. Each fibre in the bundle receives light reflected from a particular circular section of the surface to be imaged.

Figure 3 shows **one** fibre aligned with the centre of the corresponding circular section.

Each circular area has a diameter of 2.0 mm and the ends of the fibres are 10 mm from the surface to allow good illumination of the surface. The more light collected by each fibre, the better the resulting image.

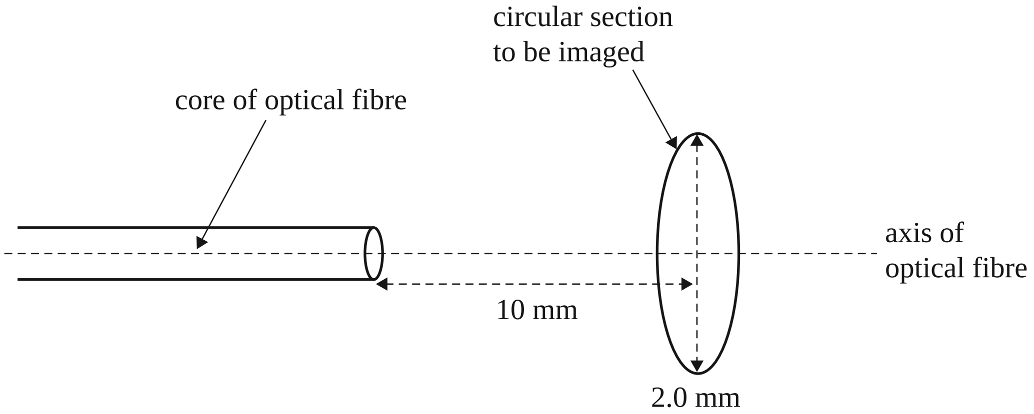

Figure 3

Four fibres are available.

Which one of the following fibres best suits the purpose outlined above?

A. a wide fibre with an acceptance angle of 5.7°

B. a wide fibre with an acceptance angle of 11.5°

C. a narrow fibre with an acceptance angle of 5.7°

D. a narrow fibre with an acceptance angle of 11.5°

Question 9

A pulse of monochromatic infrared light enters a step-index optical fibre that is several kilometres long. This initial pulse has a duration of 2 ns. However, the emerging light pulse is spread over many nanoseconds.

The initial and emerging shapes are shown in Figure 4.

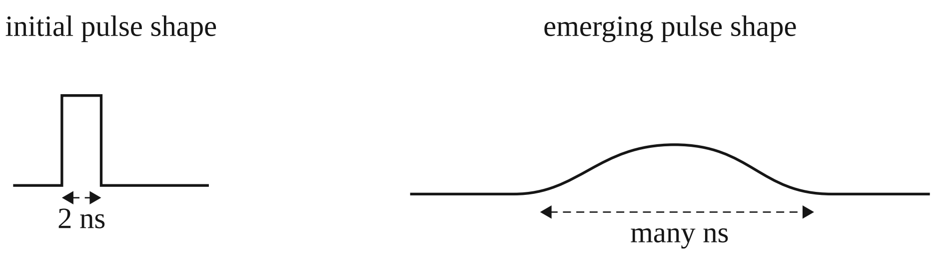

Figure 4

The reason for the pulse being spread over a longer period of time is

A. different wavelengths travel at slightly different speeds in the fibre.

B. Rayleigh scattering delays some of the light so it is more spread out.

C. some light rays enter the cladding and are delayed relative to rays in the core.

D. light rays travel at different angles through the fibre so that some rays travel further and arrive later.

Question 10

A fibre for long-distance communication is made from silica of very high purity with the least possible non-uniformity. Figure 5 shows a graph of attenuation versus wavelength for this material for Rayleigh scattering and absorption.

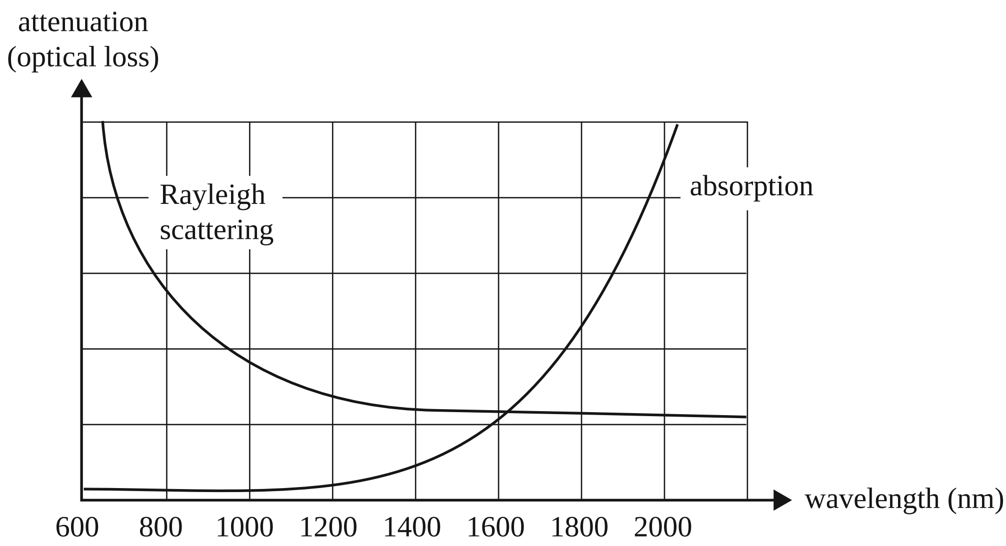

Figure 5

For light of wavelength 1800 nm, what is the main cause of attenuation in this fibre?

A. absorption by impurities such as metallic ions and H_2O

B. scattering by tiny variations in the density of the fibre at the molecular level

C. a tiny fraction of the light escaping into the cladding

D. absorption by the silica itself

Question 11

In long-distance optical communication systems, laser diodes are used as the source of light pulses rather than LEDs. A key disadvantage of LEDs is

A. arrival of the light pulse will be spread in time due to the range of wavelengths from the LEDs.

B. modal dispersion is greater when using light from LEDs.

C. pulses from LEDs cannot be as short as pulses from a laser diode.

D. LED light experiences greater scattering in fibres.

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SECTION B

Instructions for Section B

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Detailed study 6 – Sound

Use the following information to answer Questions 1 and 2.

Richard is standing at a distance of 10 m from a loudspeaker that is radiating sound of frequency 500 Hz evenly in all directions. Take the speed of sound in air to be 340 m s^{-1}.

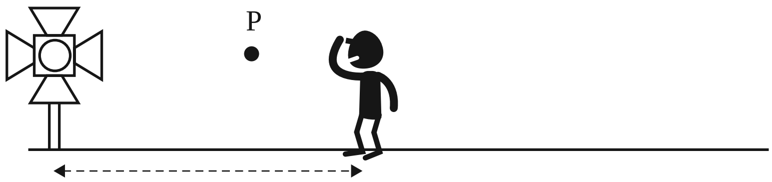

Figure 1

Question 1

Which one of the following statements best describes the motion of the air particles at point P?

A. Air particles are oscillating at 500 Hz in a direction parallel to the line between the loudspeaker and Richard.

B. Air is moving away from the loudspeaker at 340 m s^{-1}.

C. Air particles are oscillating at 500 Hz in a direction at right angles to the line between the loudspeaker and Richard.

D. Air particles are oscillating in a direction along the line between the loudspeaker and Richard at an average speed of 340 m s^{-1}.

Question 2

The sound intensity level at Richard's position is measured to be 60 dB.

Which one of the following best gives the sound intensity at Richard's position?

A. 1.0×10^{-12} W m^{-2}

B. 6.0×10^{-11} W m^{-2}

C. 1.0×10^{-6} W m^{-2}

D. 6.0×10^{-6} W m^{-2}

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Question 3

Justin is standing 20 m from the loudspeaker.

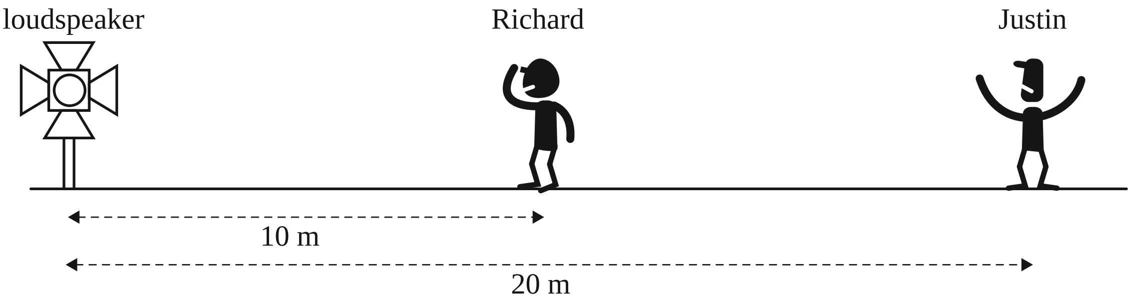

Figure 2

Which one of the following best gives the sound intensity level at Justin's position?

A. 15 dB

B. 30 dB

C. 54 dB

D. 57 dB

Question 4

Richard, who is still 10 m from the loudspeaker, has a sound level meter. The frequency of the loudspeaker is increased to 5000 Hz. The meter shows that the sound intensity level remains unchanged at 60 dB.

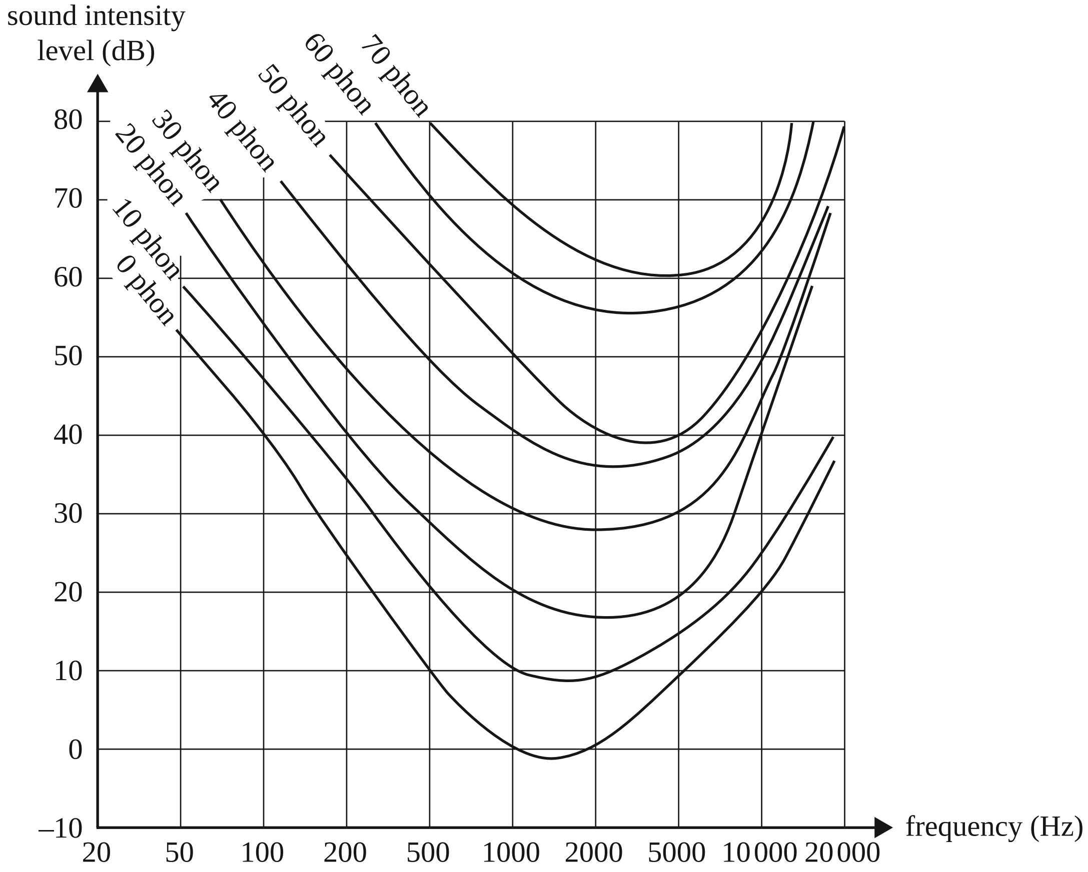

Figure 3

Based on Figure 3, at what loudness does Richard hear the sound?

A. 50 phon

B. 55 phon

C. 60 phon

D. 70 phon

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Use the following information to answer Questions 5–8.

Students are conducting an experiment to observe sound standing waves in an air column in a hollow tube, as shown in Figure 4. The length of the tube is 1.7 m and it is open at both ends. A sine wave signal generator drives a loudspeaker mounted at the end of the tube. A frequency meter measures the frequency. Take the speed of sound in air to be 340 m s^{-1}.

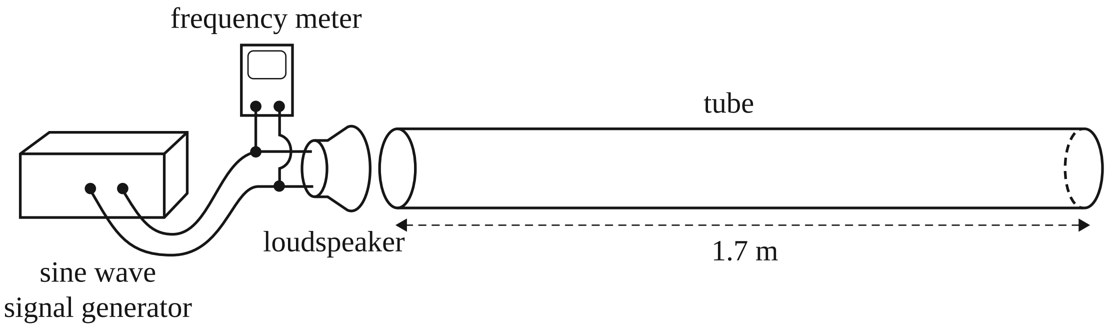

Figure 4

The students increase the frequency from zero until they detect the first resonance (first harmonic).

Question 5

Which physical observation will best enable the students to identify when the first resonance occurs?

A. a decrease in the current through the loudspeaker

B. a sudden increase in the frequency

C. a sudden decrease in the sound intensity

D. a sudden increase in the sound intensity

Question 6

Which one of the following best describes the frequency at which the students will observe this first resonance?

A. 17 Hz

B. 50 Hz

C. 100 Hz

D. 170 Hz

Question 7

The students place a cap on the end of the tube furthest from the loudspeaker so that it is now closed at one end and open at the other. They increase the frequency until they observe the first resonance, then they increase it again until they observe the next resonance.

Which one of the following best describes the frequency at which the students will observe the second resonance?

A. 170 Hz

B. 150 Hz

C. 100 Hz

D. 50 Hz

DO NOT WRITE IN THIS AREA

Question 8

The students now investigate the variation of pressure in a sound standing wave in another tube. A standing wave is set up at 80 Hz.

One student has a pressure sensor that measures the pressure above atmospheric pressure (a positive reading) or below atmospheric pressure (a negative reading).

The apparatus is shown in Figure 5. The sensor is placed at a pressure node.

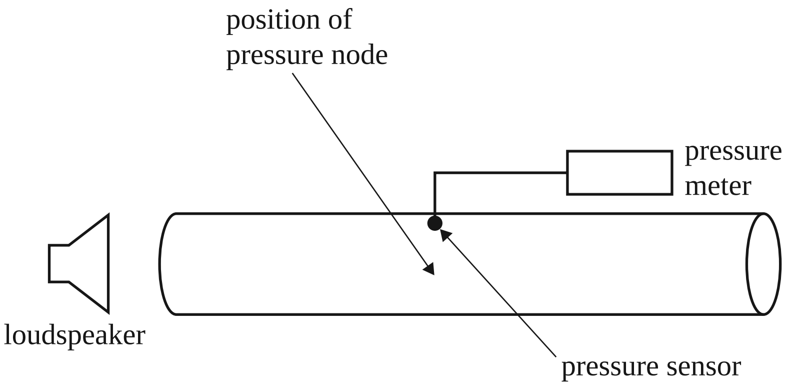

Figure 5

Which one of the following best describes the pressure the student will measure?

A. The reading will remain at a constant and positive value.

B. The reading will go from zero to a positive value 80 times per second.

C. The reading will go from a negative to a positive value 80 times per second.

D. The reading will be a constant zero.

Use the following information to answer Questions 9 and 10.

John compares the sound from a loudspeaker with and without a baffle board, as shown in Figures 6a and 6b.

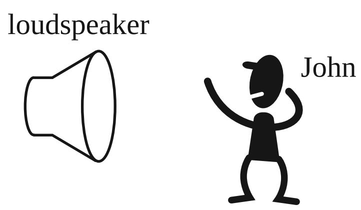

Figure 6a

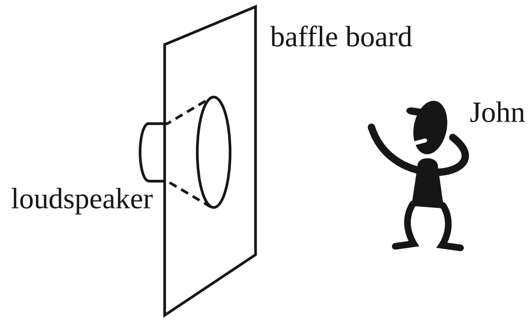

Figure 6b

Question 9

Which one of the following changes will John most likely hear when he puts the baffle board in place?

A. He will hear all frequencies more softly.

B. He will hear the lower frequencies more loudly.

C. He will hear the higher frequencies more loudly, but the lower frequencies more softly.

D. He will hear the lower frequencies more softly.

Question 10

In addition to diffraction, which one of the following best describes the key physics principle that explains the changes John hears with and without the baffle board?

A. interference

B. refraction

C. inverse square law

D. total internal reflection

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Question 11

A band is marching along a street. The musicians are spread out, with the lower-frequency instruments leading at the front and the higher-frequency instruments towards the rear. All the instruments are played with the same loudness. The band passes the entrance to a narrow lane, where John is standing. He can hear each separate instrument. The situation is shown in Figure 7.

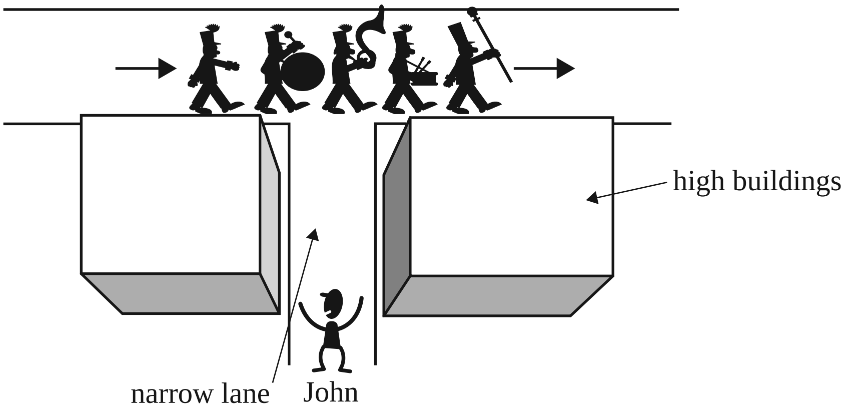

Figure 7

Which one of the following best describes what John hears as the instruments pass?

A. He will hear each instrument for the same length of time.

B. He will hear the lower-frequency instruments for a longer time than the higher-frequency instruments.

C. He will hear the lower-frequency instruments for a shorter time than the higher-frequency instruments.

D. The length of time that he hears each different instrument depends only on the speed of sound on the day.

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2014

PHYSICS

Written examination

Wednesday 12 November 2014
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

Directions to students

- 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	$v = \frac{\Delta x}{\Delta t}; \quad a = \frac{\Delta v}{\Delta t}$
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	$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$
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	$F = G\frac{M_1 M_2}{r^2}$
10	gravitational field	$g = G\frac{M}{r^2}$
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	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$
15	transformer action	$\frac{V_1}{V_2} = \frac{N_1}{N_2}$
16	AC voltage and current	$V_{RMS} = \frac{1}{\sqrt{2}}V_{peak} \qquad I_{RMS} = \frac{1}{\sqrt{2}}I_{peak}$
17	magnetic force	$F = I\,l\,B$

18	electromagnetic induction	emf: $\varepsilon = -N\dfrac{\Delta\Phi}{\Delta t}$ flux: $\Phi = BA$
19	transmission losses	$V_{drop} = I_{line}R_{line}$ $P_{loss} = I_{line}^2 R_{line}$
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 : $\tau = \text{RC}$
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