Neap:

Trial Examination 2007

VCE Physics Unit 3

Written Examination

Question and Answer Booklet

Reading time: 15 minutes
Writing time: 1 hour 30 minutes

Student's Name: ______________________________

Teacher's Name: ______________________________

Structure of Booklet

Section	Number of questions	Number of questions to be answered	Number of marks
A Core – Areas of study			
1. Motion in one and two dimensions	16	16	40
2. Electronics and photonics	14	14	25
B Detailed studies			
1. Einstein's special relativity (page 16) **OR**	13	13	25
2. Investigating materials and their use in structures (page 20) **OR**	10	10	25
3. Further electronics (page 24)	12	12	25
			Total 90

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

Materials supplied

Question and answer booklet of 28 pages with a detachable data sheet in the centrefold.

Instructions

Detach the data sheet from the centre of this booklet during reading time.

Please ensure that you write your **name** and your **teacher's name** in the space provided on this booklet.

Answer all questions in the spaces provided.

Always show your working where space is provided.

Where an answer box has a unit printed in it, give your answer in that unit.

All written responses must be in English.

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

Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2007 VCE Physics Unit 3 Written Examination.

SECTION A – CORE

Instructions for Section A

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

You should take the value of g to be 10 m s^{-2}.

Area of study 1 – Motion in one and two dimensions

Sarah, a celebrity physicist, and Mick, a professional ice-dancer, are rehearsing an ice-dancing routine for a reality TV program. Sarah and Mick skate towards each other, and then Mick picks up Sarah and lifts her above his head, both of them moving in the direction in which Mick was originally travelling.

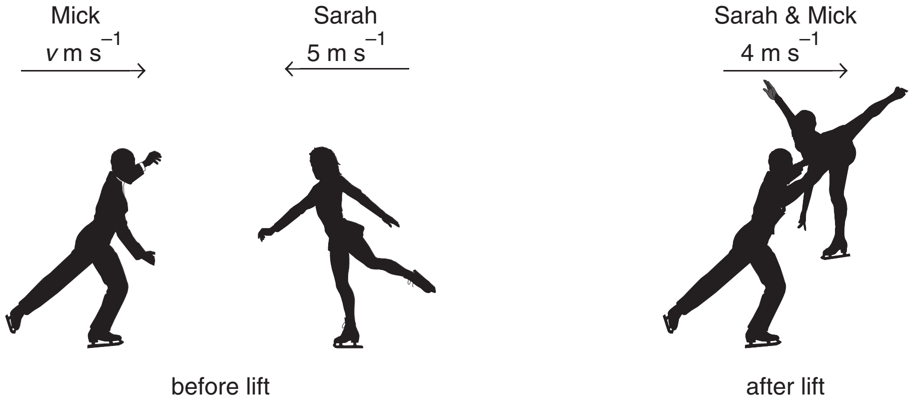

Figure 1

Sarah's mass is 55 kg and Mick's mass is 80 kg. Before the lift, Sarah is skating towards Mick at 5 m s^{-1}, and immediately afterward they are both travelling at 4 m s^{-1}.

Question 1

At what speed was Mick travelling immediately before he lifted Sarah?

m s^{-1}

2 marks

Question 2

Calculate the magnitude of the horizontal impulse exerted by Mick on Sarah.

N s

2 marks

In the actual performance, Sarah and Mick perform the move perfectly. Fred, one of the judges, comments that the move is an excellent example of an elastic collision. Sarah disagrees.

Question 3

Use calculations to show that Sarah is correct and that the collision was not elastic.

3 marks

A power boat of mass 1500 kg accelerates from rest. As it accelerates, the total resistive forces acting on the boat (due to drag from the water and air resistance) increase according to the graph shown in Figure 2.

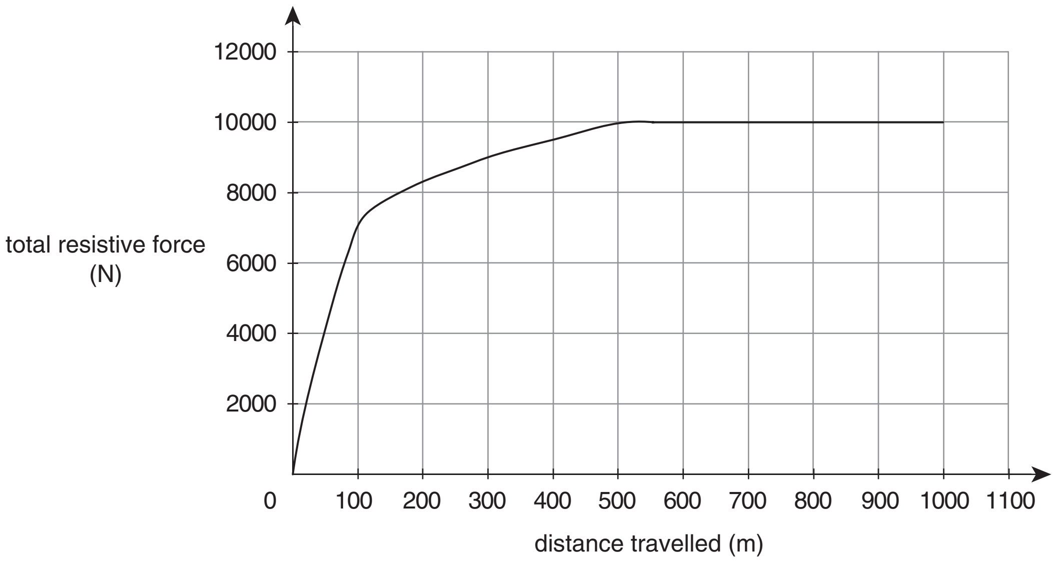

Figure 2

After travelling 500 m, the boat is moving at a constant velocity. The boat engine exerts a constant driving force throughout the motion.

Question 4

Calculate the magnitude of the net force acting on the boat when it has travelled 100 m.

N

2 marks

Question 5

Calculate the speed of the boat after it has travelled 500 m.

m s^{-1}

3 marks

The power boat is now used to tow a water-skier along a river. The skier is directly behind the boat and the boat travels in a straight line at a constant speed of 90 km h^{-1}.

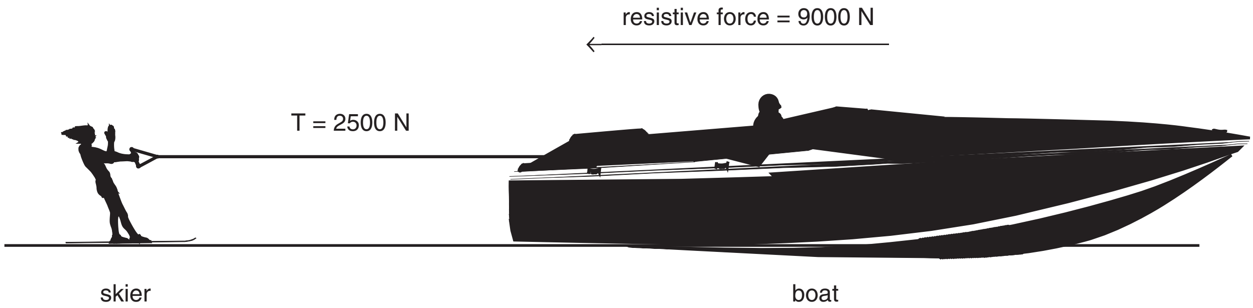

Figure 3

The total mass of the skier and his ski is 85 kg. The tension in the ski rope is 2500 N and the total resistive force acting against the **boat** is 9000 N.

Question 6

Calculate the total resistive force acting on the water ski.

N

2 marks

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Question 7

Find the average power being exerted by the boat engine when the boat and skier are travelling at a constant speed of 90 km h^{-1}.

W

3 marks

A passenger train is travelling at 90 km h^{-1} along the river bank in the same direction as the boat and water-skier. Melissa, a passenger on the train, watches out of the train window as the water-skier goes over a ski ramp and completes a jump.

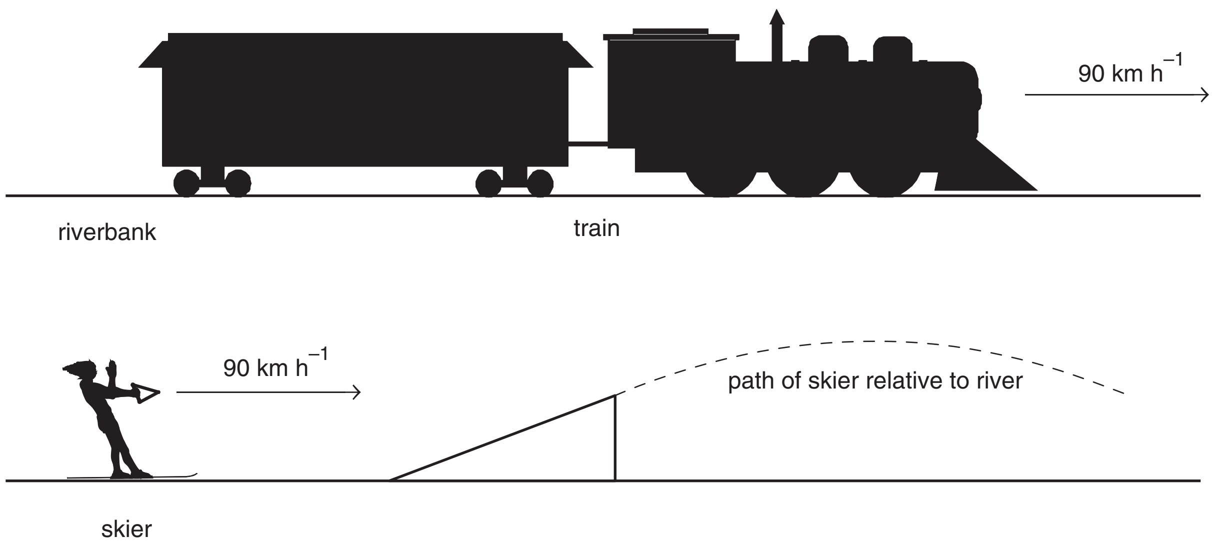

Figure 4

Question 8

Describe the motion of the water-skier as observed in Melissa's frame of reference. Ignore the effects of air resistance on the water-skier and his ski.

2 marks

Jack has been given a ‘tether tennis’ game for Christmas. It consists of a tennis ball attached to a 1.25 m piece of light string, which is attached to the top of a pole driven into the ground. When Jack hits the ball, it moves in a horizontal circle. The mass of the ball is 80 g and the tension in the string is 2.4 N. The string makes an angle of 70.5° with the pole. The effects of air resistance can be ignored.

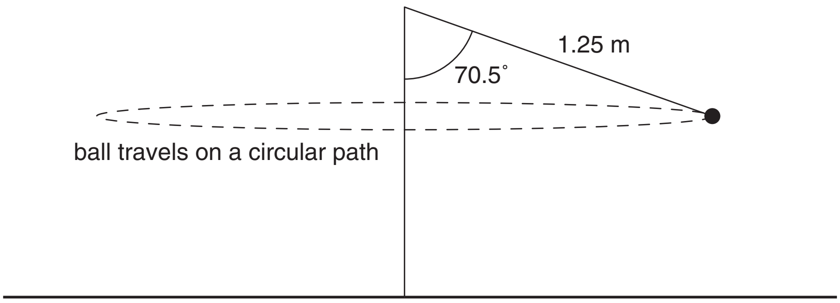

Figure 5

Question 9

On Figure 5, clearly label **all** forces acting on the tennis ball **and** show the direction of the net force.

3 marks

Question 10

Calculate the period of rotation of the tennis ball.

s

3 marks

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Simon has a toy cannon which can launch a toy cannonball of mass 50 g into the air. The cannon has a spring inside which can be pulled back and released in order to launch the cannonball.

The graph of force versus extension for the spring is shown in Figure 6.

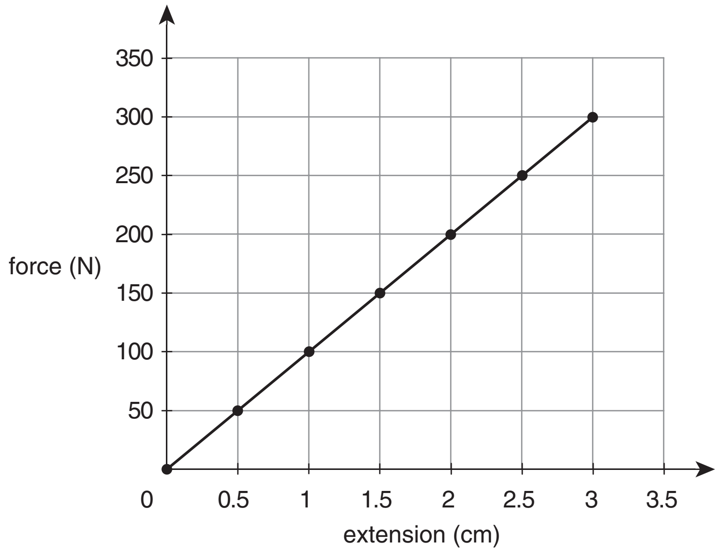

Figure 6

Question 11

By how much should the spring be extended in order to launch the cannonball with an initial velocity of 5 m s^{-1}?

cm

3 marks

Simon places the toy cannon on a table so that the top of the cannon is 0.80 m above the ground.
The cannonball is launched with an initial velocity of 5.0 m s^{-1} at an angle of 35° to the horizontal.

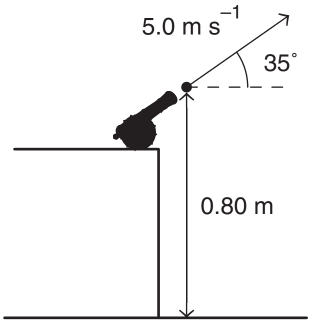

Figure 7

Ignore the effects of air resistance in Questions 12 and 13.

Question 12

Calculate the maximum height above the **floor** that the cannonball will reach.

m

2 marks

Question 13

Calculate the magnitude of the velocity of the cannonball and the angle that the velocity makes with the floor at the instant when the ball reaches the floor.

m s^{-1}	°

4 marks

The planet Mars has two moons in circular orbits. They are named Phobos and Deimos. The following data relates to these moons.

mass of Phobos	1.08×10^{16} kg
mass of Deimos	1.80×10^{15} kg
distance from centre of Mars to centre of Phobos	9.40×10^{6} m
distance from centre of Mars to centre of Deimos	2.35×10^{7} m
universal gravitational constant, *G*	6.67×10^{-11} N m^2 kg^{-2}
period of orbit of Deimos around Mars	30.3 h

Question 14

Calculate the period of orbit of Phobos around Mars.

h	

2 marks

Question 15

Use the data provided to show that the mass of Mars is equal to 6.46×10^{23} kg.

2 marks

A graph of the strength of the gravitational field due to Mars versus distance from the centre of Mars has the shape shown in Figure 8 below.

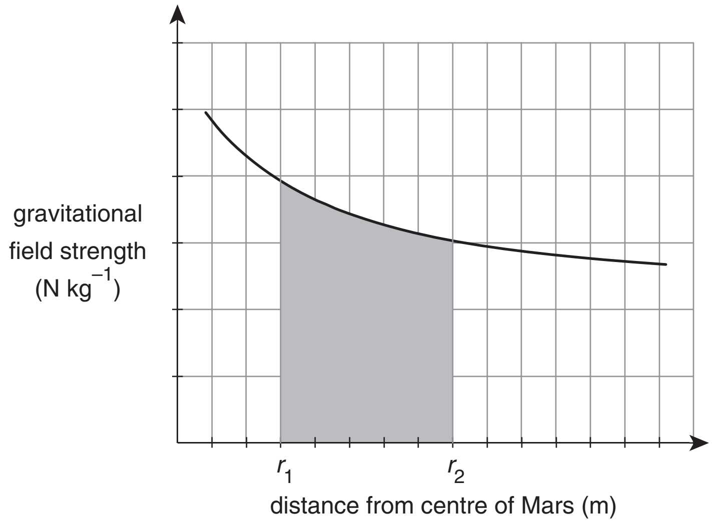

Figure 8

Question 16

The shaded area under the graph between r_1 and r_2 represents

A. the impulse Mars exerts on a 1.0 kg object when the object moves from a distance r_2 to a distance r_1 from the centre of Mars.

B. the increase in potential energy and the decrease in kinetic energy when an object moves from a distance r_1 to a distance r_2 from the centre of Mars.

C. the work done by Mars on an object as it moves from a distance r_2 to a distance r_1 from the centre of Mars.

D. the increase in kinetic energy and the decrease in potential energy of a 1.0 kg object as the object moves from a distance of r_2 to a distance r_1 from the centre of Mars.

2 marks

END OF AREA OF STUDY 1

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Area of study 2 – Electronics and photonics

A simple DC voltage-divider circuit is shown in Figure 1.

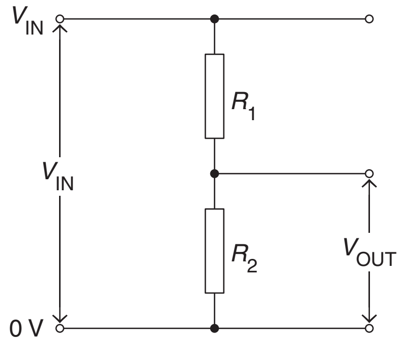

Figure 1

Question 1

Calculate the output voltage (V_{OUT}) if V_{IN} = 20 V, R_1 = 1.5 kΩ and R_2 = 2.5 kΩ.

V

2 marks

Question 2

To turn on a fire alarm, V_{OUT} needs to be exactly 15 V. Calculate the value of R_2 that will give this output if all the other values are kept the same. Show your working.

kΩ

2 marks

A simple LED (light-emitting diode) circuit and the LED's current–voltage characteristic graph are shown in Figure 2 below.

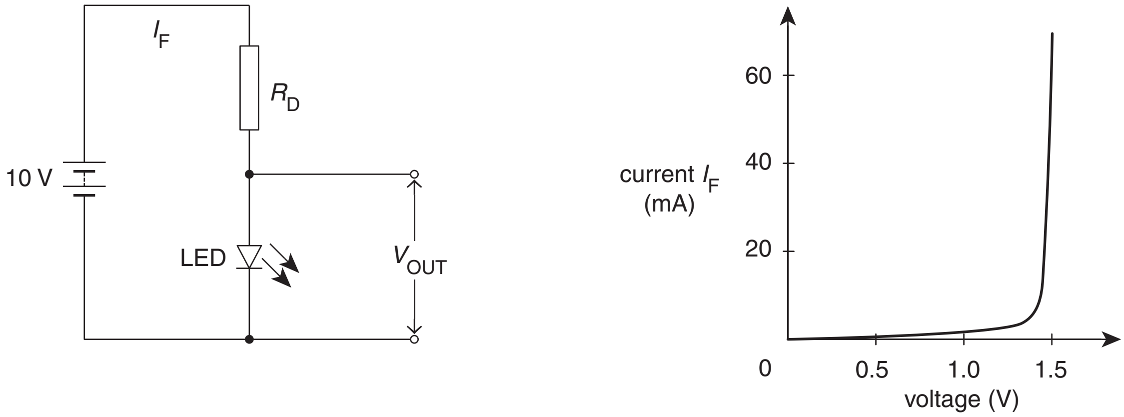

Figure 2

Question 3

The LED shown in Figure 2 is an example of an electro-optical converter. Explain what this means.

2 marks

Question 4

Calculate the value of the resistance R_D that gives a forward current through the LED of 40 mA.

Ω

2 marks

Question 5

The value of R_D is now decreased slightly from the value calculated in Question 4.

Will the light output of the LED decrease, stay the same or increase?

1 mark

Question 6

Justify your answer to Question 5.

2 marks

Figure 3 shows the output voltage versus the input voltage for one particular type of amplifier.

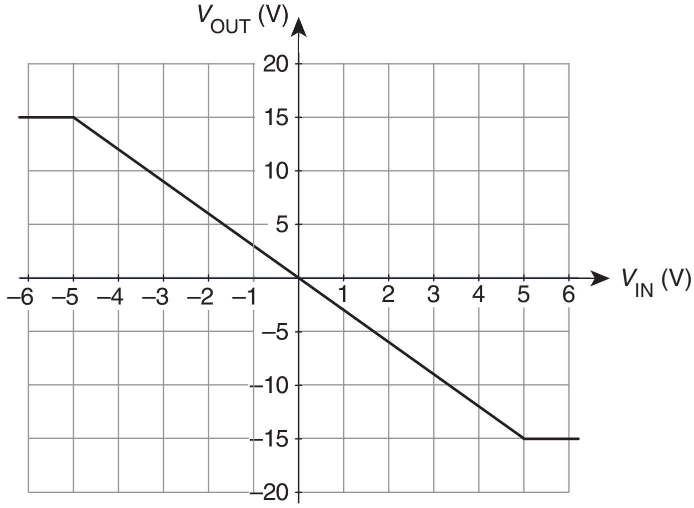

Figure 3

Question 7

Is the amplifier whose characteristics are shown in Figure 3 an inverting or non-inverting amplifier?

1 mark

Question 8

Justify your answer to Question 7.

1 mark

Question 9

Calculate the gain of this amplifier in the linear region.

2 marks

Question 10

A sinusoidal input voltage signal with a peak voltage of 6.0 V and period of 40 ms is fed into the amplifier circuit. On Figure 4 below, draw the output voltage graph for this sinusoidal input voltage signal, clearly indicating the appropriate values of the voltage on the vertical axis.

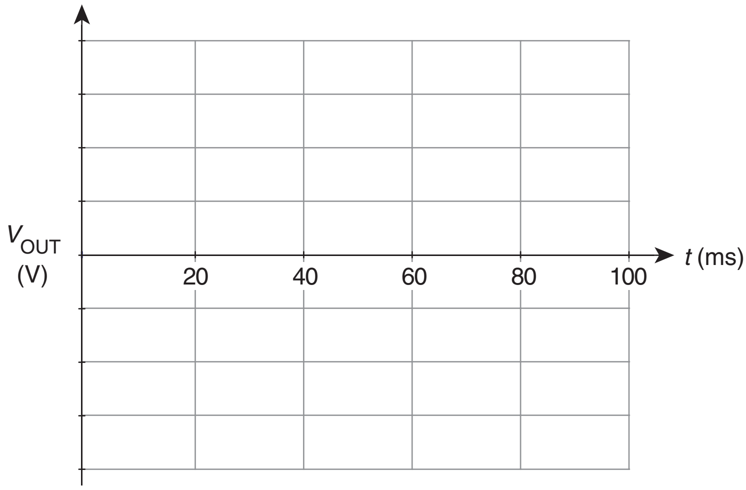

Figure 4

3 marks

The circuit shown in Figure 5 uses an n–p–n transistor amplifier to amplify a 10 mV (peak-to-peak) 2000 Hz signal voltage coming from an MP3 player's output. The standard convention is used where DC voltages and currents are indicated using capitals (*V*, *I*) while AC voltages and currents are indicated using lower case (*v*, *i*).

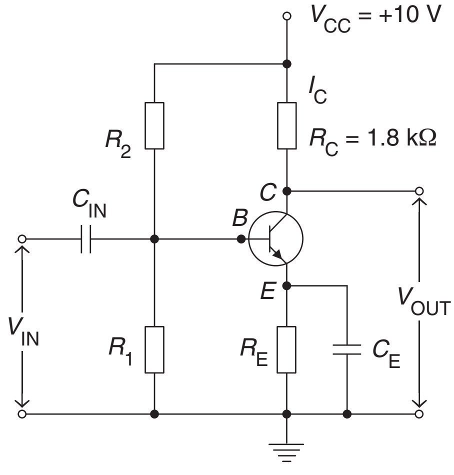

Figure 5

Initially the input from the MP3 player is disconnected, so V_{IN} = 0 V, and the DC collector current I_C = 2.0 mA.

Question 11

Calculate the transistor DC output voltage, V_{OUT}.

V

2 marks

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Neap:

Trial Examination 2007

VCE Physics Unit 3

Written Examination

Data Sheet

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

Physics Unit 3 Data Sheet

1	velocity; acceleration	$v = \frac{\Delta x}{\Delta t}$; $a = \frac{\Delta v}{\Delta t}$
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	$F = ma$
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 the 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	stress	$\sigma = \frac{F}{A}$
12	strain	$\varepsilon = \frac{\Delta L}{L}$

13	Young's modulus	$E = \frac{\text{stress}}{\text{strain}}$
14	transformer action	$\frac{V_1}{V_2} = \frac{N_1}{N_2}$
15	AC voltage and current	$V_{\text{RMS}} = \frac{1}{2\sqrt{2}} V_{\text{peak to peak}}; \; I_{\text{RMS}} = \frac{1}{2\sqrt{2}} I_{\text{peak to peak}}$
16	voltage; power	$V = IR; \; P = VI$
17	resistors in series	$R_T = R_1 + R_2$
18	resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$
19	capacitors	time constant: $\tau = RC$
20	Lorentz factor	$\gamma = \frac{1}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$
21	time dilation	$t = t_0 \gamma$
22	length contraction	$L = \frac{L_0}{\gamma}$
23	relativistic mass	$m = m_0 \gamma$
24	universal gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
25	mass of Earth	$M_E = 5.98 \times 10^{24}$ kg

26	radius of Earth	$R_E = 6.37 \times 10^6$ m
27	mass of the electron	$m_e = 9.1 \times 10^{-31}$ kg
28	charge on the electron	$q = -1.6 \times 10^{-19}$ C
29	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 DATA SHEET

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The output from the MP3 player is now connected to the amplifier. v_{IN} = 10 mV (peak-to-peak). The input signal causes a 2000 Hz sinusoidal variation in the collector current which has a peak-to-peak value of i_C = 1.2 mA. The amplified output voltage is given by $v_{OUT} = i_C R_C$.

Question 12

Calculate v_{OUT} (peak-to-peak).

V

1 mark

Question 13

Explain the purpose of the capacitor C_{IN} in this transistor amplifier circuit.

2 marks

Question 14

Calculate the voltage gain of this transistor amplifier circuit.

2 marks

END OF AREA OF STUDY 2

SECTION B – DETAILED STUDIES

Instructions for Section B

Choose **one** of the following **Detailed studies**. Answer **all** the questions on the Detailed study you have chosen. You should take the value of g to be 10 m s^{-2}.

Detailed study 1 – Einstein's special relativity

Einstein's theory of special relativity utilizes the notion of the Lorentz length contraction.

Question 1

Explain what is meant by the Lorentz length contraction.

____

____

____

2 marks

Figure 1 shows a square with sides of length 30 cm moving to the right at $0.95c$ relative to an observer at O.

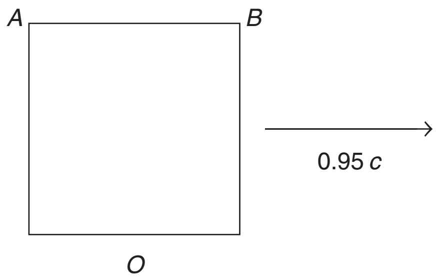

Figure 1

Question 2

Use the Lorentz length contraction formula $L_0 = \gamma L$ to calculate the length of side AB of the square as seen in an inertial reference frame that is stationary relative to the observer at O.

m

2 marks

Question 3

In the space below, draw what the square would look like to the observer.

1 mark

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The formula $E = mc^2$ is contained within Einstein's theory of special relativity.

Question 4

Explain the implications of Einstein's $E = mc^2$ formula with relation to a moving electron.

2 marks

An electron is accelerated in a linear accelerator from rest using 2.0 GeV of energy.
The electron has a rest mass of 9.1×10^{-31} kg.

Question 5

Calculate the increase in the mass of this electron.

kg

2 marks

Question 6

Calculate the velocity at which the electron would have to travel if it were given 2.0 GeV of energy and the equations of classical Newtonian mechanics applied.

m s^{-1}

2 marks

Question 7

Explain the implications of your answer to Question 6.

2 marks

The Michelson–Morley experiment of 1887 is considered to have been a very important experiment in physics. A simplified diagram of the experiment is shown in Figure 2 below.

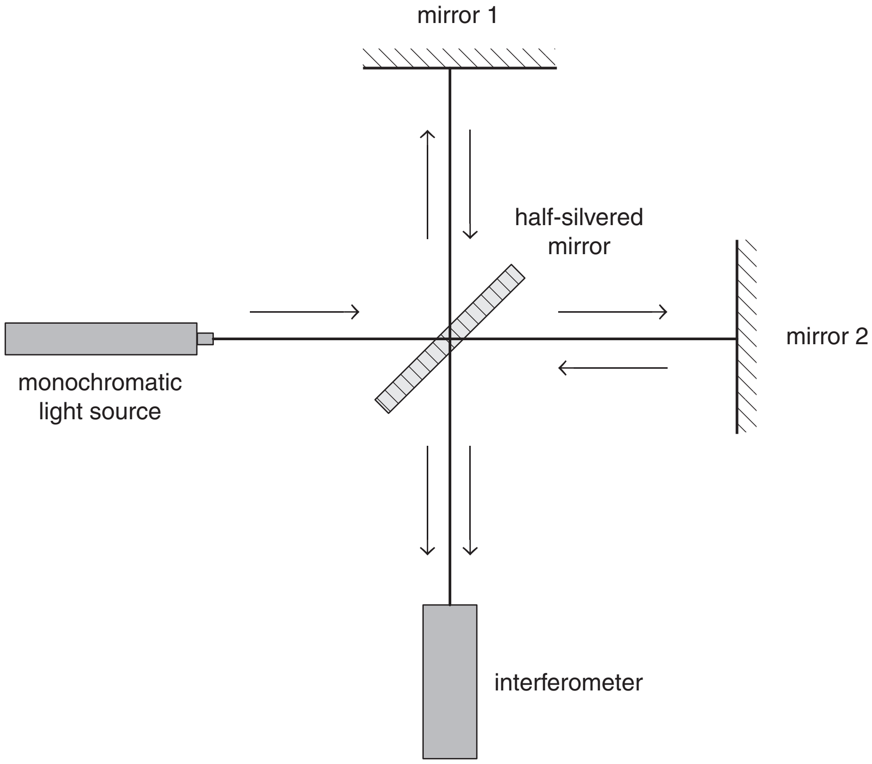

Figure 2

The apparatus is arranged so that light travelling towards mirror 2 is moving in the direction of Earth's motion around the Sun and light travelling towards mirror 1 is moving perpendicular to Earth's motion around the Sun. It was believed that as the Earth travels around the Sun it must travel through the 'aether'.

Question 8

Explain what the 'aether' was in the context of the Michelson–Morley experiment.

2 marks

Question 9

Explain what Michelson and Morley expected to see at the interferometer.

2 marks

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Question 10

What did Michelson and Morley actually see at the interferometer?

2 marks

Question 11

Explain what the results of the Michelson–Morley experiment demonstrated.

2 marks

A new linear particle accelerator is 2.0 km long. It can accelerate protons up to speeds of 0.999995 c. These protons leave the accelerator and are then aimed at specific targets. The mass of a proton is 1.67×10^{-27} kg.

Question 12

Calculate the Lorentz factor for these protons.

2 marks

Question 13

Calculate the kinetic energy of one of these protons as it leaves the accelerator.

J

2 marks

END OF DETAILED STUDY 1

Detailed study 2 – Investigating materials and their use in structures

Use the data in Figure 1 to answer Questions 1–6.

Over the last 50 years, professional game fisherman have predominantly used nylon for their fishing lines. In recent years, however, a fibre called high-modulus polyethylene (HMPE) has been used as an alternative for the fishing line. The stress–strain graph for both of these materials is shown in Figure 1.

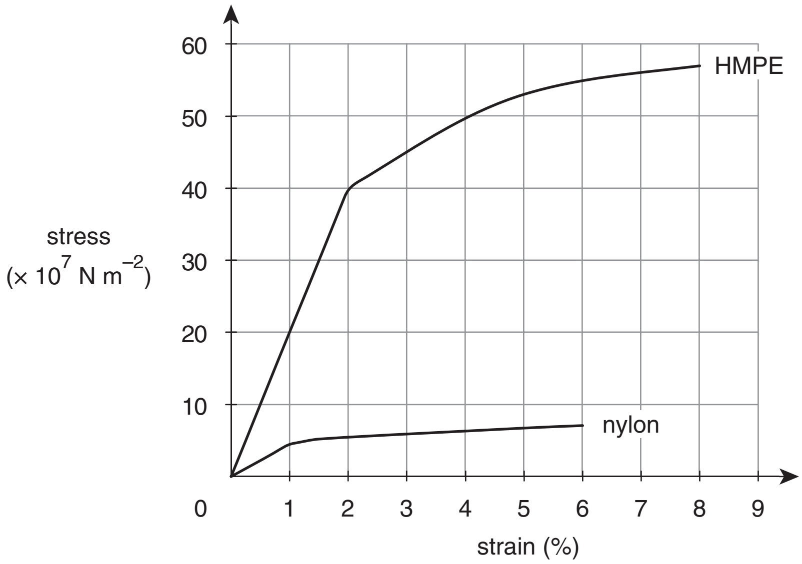

Figure 1

Nylon breaks when the stress is equal to $\mathbf{7.2 \times 10^7}$ **N m^{-2}** and **HMPE** breaks when the stress is equal to $\mathbf{5.7 \times 10^8}$ **N m^{-2}**. Bob and Martin have fishing lines of the same diameter. Bob's line is made of HMPE and Martin's is nylon. Martin claims that his nylon line is stiffer, as it only stretches to 6%, whereas the HMPE stretches to 8%. Bob disagrees.

Question 1

Which material is stiffer? Explain your answer by referring to the relevant features of the graph in Figure 1.

___

___

___

___

2 marks

Question 2

Which of the following statements comparing the two materials can be made using the information provided on the graph?

A. Nylon is tougher than HMPE.
B. HMPE is stronger than nylon.
C. HMPE breaks more easily than nylon.
D. HMPE is more flexible than nylon.

2 marks

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Bob catches a shark of mass 100 kg using his HMPE fishing line. The shark is suspended from the fishing line above the water surface and is stationary. The diameter of the HMPE line is 4.0 mm, and the length of HMPE from the tip of the fishing rod to the shark is 3.0 m.

Figure 2

Question 3

Calculate the extension of the HMPE fishing line.

m

3 marks

Question 4

Would the HMPE fishing line undergo permanent deformation under this load? Explain your answer.

2 marks

Martin also catches a 100 kg shark using his **nylon** fishing line of diameter 5.0 mm.
The maximum stress that nylon can withstand is 7.2×10^7 N m^{-2}.

Question 5

Calculate the maximum upward acceleration with which Martin could raise the shark using the **nylon** line described without breaking the line. (Assume that the shark is out of the water.)

m s^{-2}

3 marks

During a laboratory test, a **nylon** line of length 1.5 m and diameter **5.0 mm** is stretched until it breaks.

Question 6

Calculate the amount of energy required to break the nylon line.

J

4 marks

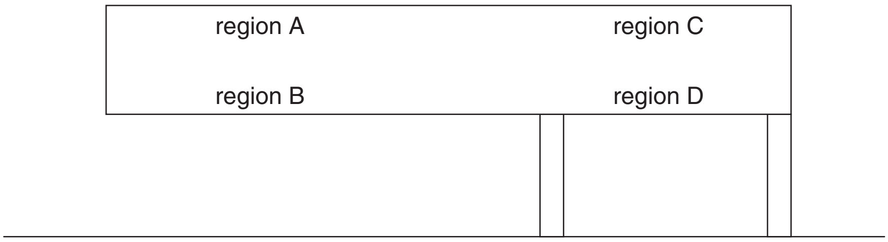

Figure 3

Question 7

The paragraph below refers to the concrete structure shown in Figure 3. Options to complete each sentence are given within the brackets. Circle the correct option in each case.

Concrete is weak in [**tension / compression**]. Hence, steel reinforcement should be placed in [**Regions A and D / Regions B and C**].

2 marks

Students construct a model of the structure shown in Figure 3 to investigate its stability. In the model, the length of the horizontal beam is 1.2 m and the beam has a mass of 30.0 kg. The distance between points *X* and *Y* is 0.4 m.

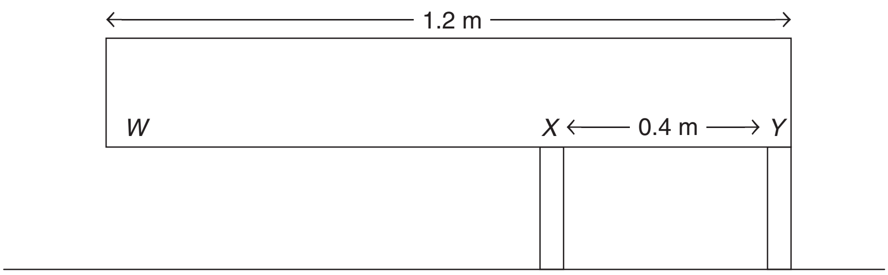

Figure 4

Question 8

On Figure 4, label all of the forces acting on **the horizontal beam**, showing the direction of each and the point at which it acts.

2 marks

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Question 9

Calculate the magnitude of the force exerted on the horizontal beam by the column supporting the beam at point *X*.

N

2 marks

The maximum force that can be exerted at **point *Y*** without the structure failing is 1000 N.

Question 10

Calculate the minimum distance from **point *W*** along the beam at which a 200 kg load can be placed if the structure is to remain in equilibrium. (Assume the 200 kg load is placed somewhere between points *W* and *X*.)

m

3 marks

END OF DETAILED STUDY 2

Detailed study 3 – Further electronics

A student doing an experiment on a low-voltage power supply sketches Figure 1 in his practical logbook from observing the trace on a cathode-ray oscilloscope (CRO).

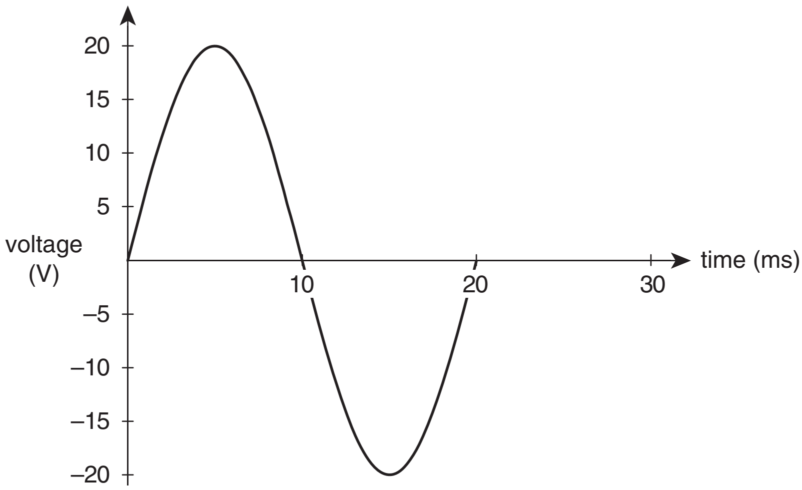

Figure 1

Question 1

Use the CRO trace shown in Figure 1 to determine the frequency of the AC voltage.
Show your working.

Hz

2 marks

Question 2

Calculate the RMS voltage of the power supply.

V

2 marks

Sally, who is studying Further Electronics in Year 12, is building a full-wave rectification bridge. She uses a transformer as shown in Figure 2 below.

Figure 2

The first part of her design involves using the transformer to transform the mains voltage to the voltage output shown below in Figure 3.

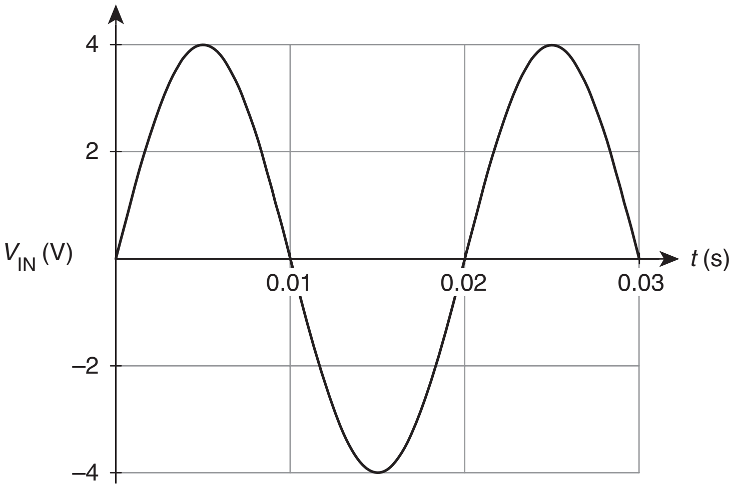

Figure 3

Question 3

Calculate the ratio of the number of turns in the primary coil to the number of turns in the secondary coil of the transformer.

[ ]

2 marks

The input power to the transformer is 0.24 W.

Question 4

Calculate the RMS current in the primary coils of the transformer.

[mA]

2 marks

Question 5

Calculate the RMS current in the secondary coils of the transformer.

[mA]

2 marks

Figure 4 shows the low-voltage full-wave bridge rectifier circuit designed by Sally which is connected to the output of the secondary coils of the transformer. A resistive load R_L is placed across V_{OUT}.

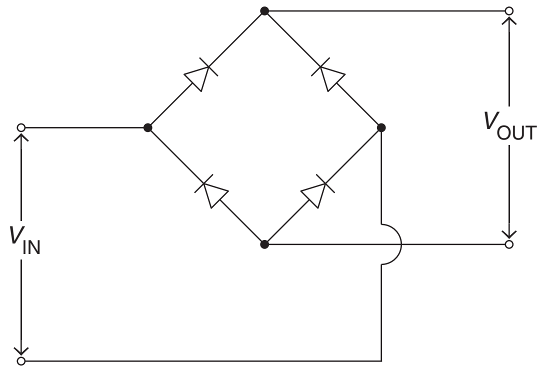

Figure 4

Figure 5 shows the input 4.0 V peak signal voltage.

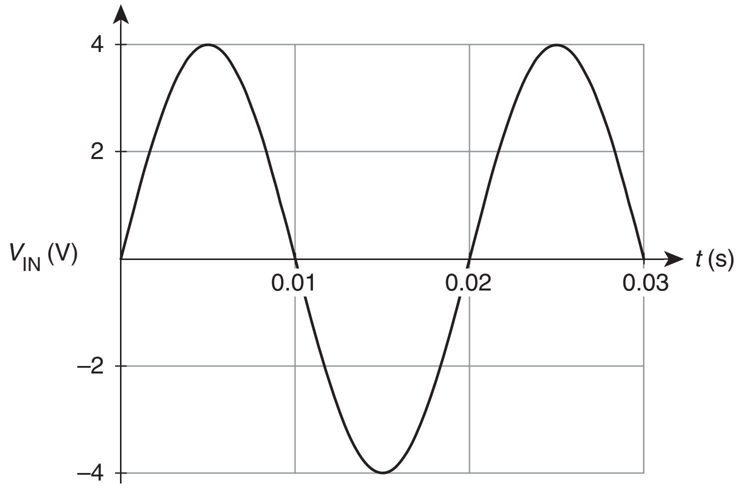

Figure 5

Question 6

On Figure 6 below, draw the output voltage as seen on the CRO across the load resistor R_L.

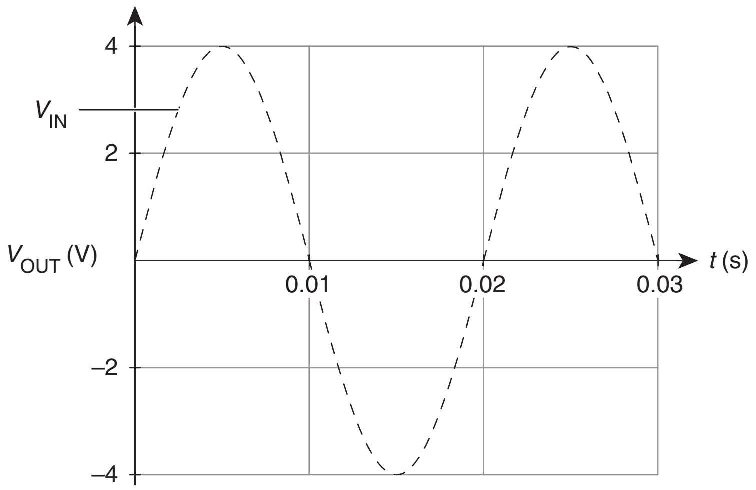

Figure 6

3 marks

The student now places a 10 μF capacitor in parallel with the 20 kΩ resistive load R_L.

Question 7

Calculate the time constant for the RC circuit. Show your working.

s

2 marks

Question 8

On Figure 7 below, draw the output voltage as seen on the CRO across the parallel capacitor–resistor circuit for one cycle of the input voltage.

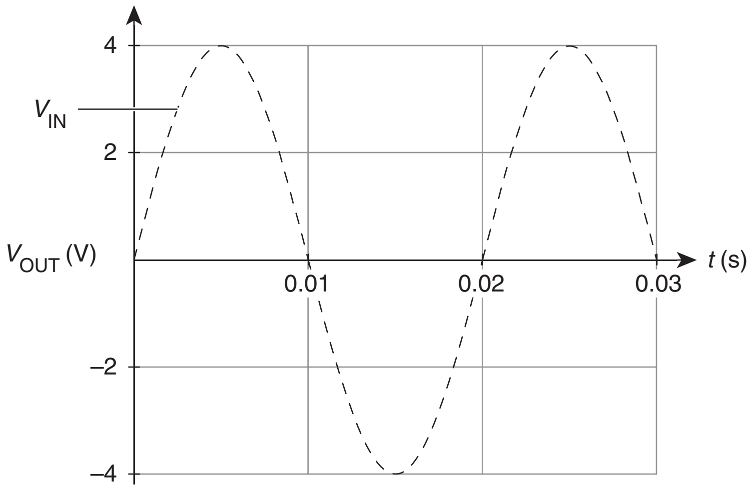

Figure 7

2 marks

Question 9

The output voltage is not smooth enough for the purpose Sally intended for it.

Which one or more of the following (**A**–**D**) will make the output voltage smoother?

A. decreasing the capacitance and keeping the resistance the same
B. increasing the capacitance and keeping the resistance the same
C. decreasing the resistance and keeping the capacitance the same
D. increasing the resistance and keeping the capacitance the same

2 marks

Figure 8 shows the current–voltage characteristic graph for a particular type of voltage regulator.

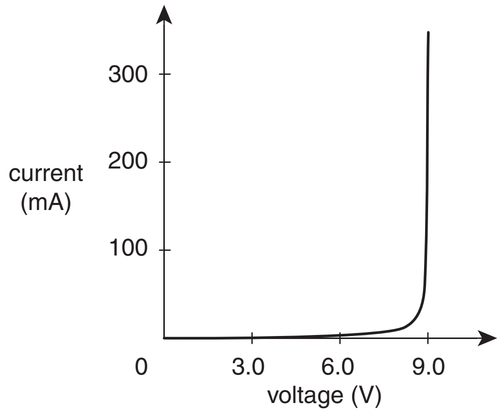

Figure 8

The output current through a resistive load is measured at 300 mA.

Question 10

Calculate the value of the resistive load. Show your working.

Ω

2 marks

Question 11

Explain why voltage regulators are important for certain kinds of circuit.

2 marks

Fin radiators or cooling fans are often designed for voltage regulators to keep them cool.

Question 12

Explain why voltage regulators need to be kept cool.

2 marks

END OF QUESTION AND ANSWER BOOKLET