VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2006

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

									Letter
Figures									
Words									

PHYSICS
Written examination 1

Monday 5 June 2006

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

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A – Core – Areas of study			
1. Motion in one and two dimensions	16	16	40
2. Electronics and photonics	9	9	25
B – Detailed studies			
1. Einstein's special relativity (page 17)	11	11	25
OR			
2. Investigating materials and their use in structures (page 23)	11	11	25
OR			
3. Further electronics (page 29)	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 sheets of paper and/or white out liquid/tape.

Materials supplied
- Question and answer book of 35 pages with a detachable data sheet in the centrefold.

Instructions
- Detach the data sheet from the centre of this book during reading time.
- Write your **student number** in the space provided above on this page.
- Answer all questions in the spaces provided.
- **Always** show your working where space is provided.
- 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.

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

A cyclist is towing a small trailer along a level bike track (Figure 1). The cyclist and bike have a mass of 90 kg, and the trailer has a mass of 40 kg. There are opposing **constant** forces of 190 N on the rider and bike, and 70 N on the trailer. These opposing forces do not depend on the speed of the bike.

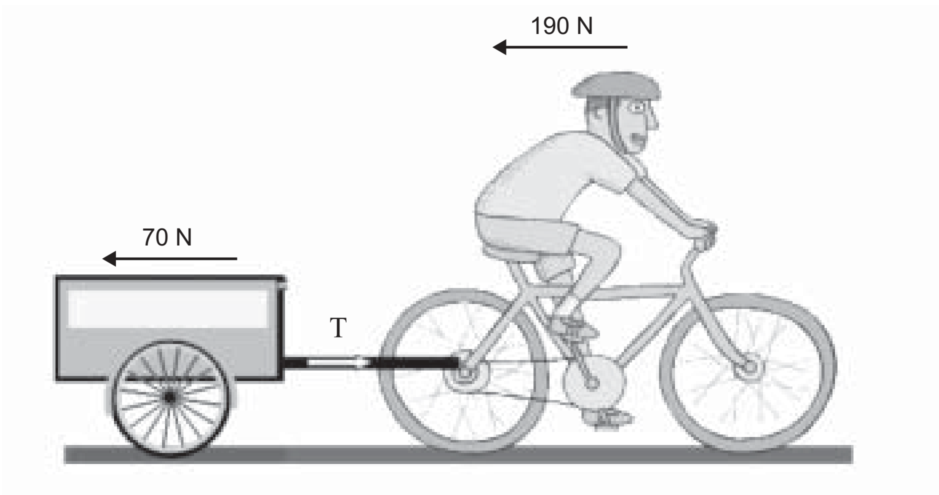


Figure 1

The bike and trailer are initially travelling at a constant speed of 6.0 m s^{-1}.

Question 1

What driving force is being exerted on the road by the **rear** tyre **of the bicycle**?

N

2 marks

Question 2

What is the tension, T, in the bar connecting the bike to the trailer?

N

2 marks

The cyclist stops pedalling, and the bike and trailer slow down.

Question 3

How far will the bike and trailer travel before they come to rest?

m

3 marks

Vivian, who weighs 60 kg, is at a fair ground and takes a ride on the 'Rotor'. The Rotor is a large cylinder which, when spinning, pins riders against the internal wall. Figure 2a is a sketch of the situation. Initially Vivian is standing on the floor, and the Rotor speeds up. She feels the wall pushing harder and harder against her back. When the friction between the wall and her back is large enough, the floor is lowered. Vivian is held against the wall, and does not slip down.

The **diameter** of the Rotor is 15 m.

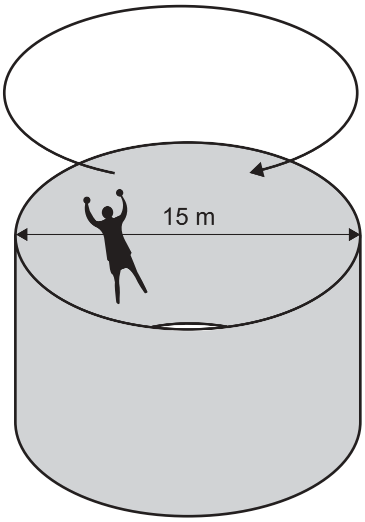


Figure 2a

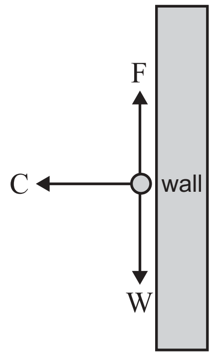


Figure 2b

Figure 2b is a force diagram showing all the forces acting on Vivian: force of wall on Vivian (C), weight force (W) and friction force (F).

Question 4

When the Rotor is moving **just fast enough** to stop Vivian slipping, what is the magnitude of force F?

N

2 marks

The Rotor **continues to speed up** so that its final speed at the wall is 11 m s^{-1}.

Question 5

What is the magnitude of the force (C) of the wall on Vivian?

N

2 marks

A rocket of mass 0.50 kg is set on the ground, pointing **vertically** up, as shown in Figure 3. When ignited, the gunpowder burns for a period of 1.5 s, and provides a constant force of 22 N. The mass of the gunpowder is very small compared to the mass of the rocket, and can be ignored. The effects of air resistance can also be ignored.

Figure 3

Question 6

What is the magnitude of the resultant force on the rocket?

N

2 marks

Question 7

After 1.5 s, what is the height of the rocket above the ground?

m

2 marks

A second **identical** rocket, that again provides a constant force of 22 N for 1.5 s, is now launched **horizontally** from the top of a 50 m tall building. Assume that in its subsequent motion the rocket always points horizontally.

Question 8

After 1.5 s, what is the **speed** of the rocket, and at what **angle** is the rocket moving relative to the ground?

speed = $\quad\quad$ m s^{-1}	angle = $\quad\quad$ °

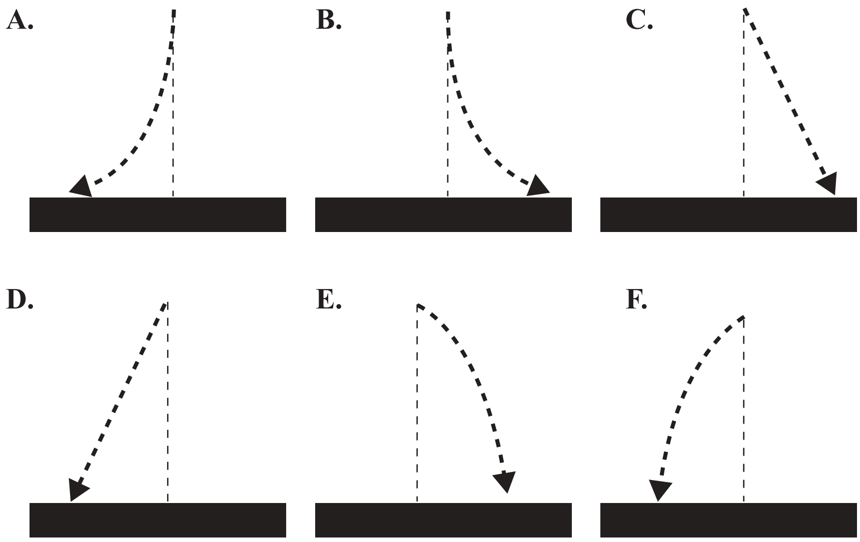
4 marks

John is standing on a railway station and drops a ball from a height of 1.25 m (Figure 4). Mary is in a train that is passing **through** the station at a constant speed, and observes the falling ball.

Figure 4

Question 9

Which of the diagrams (**A–F**) below best represents the path of the ball as seen by Mary?



2 marks

Figure 5 shows a space shuttle docking with the international space station.

Imagine that you are an astronaut floating in space **at rest relative to the international space station**. You watch the space shuttle, of mass 6000 kg, dock. You observe the shuttle approaching the space station with a speed of 5.00 m s^{-1}.

After docking, the space station's speed has increased by 0.098 m s^{-1}.

Figure 5

Question 10

Show that the mass of the space station is 3×10^5 kg.

3 marks

After first making contact, it takes 20 s for the shuttle to come to rest with the space station.

Question 11

Calculate the average force exerted on the shuttle by the space station.

N

3 marks

A student, Sam, of mass 70 kg, is bungee jumping from a platform at the top of a tower (Figure 6). He reaches the top of the tower by being towed up a slide of length L. The friction between Sam and the slide provides a constant force of 300 N that opposes the motion. The **total work** done in dragging Sam up the slide to the top of the tower is 22 720 J. At the top of the tower Sam's **potential energy** was greater by 13 720 J than it was on the ground.

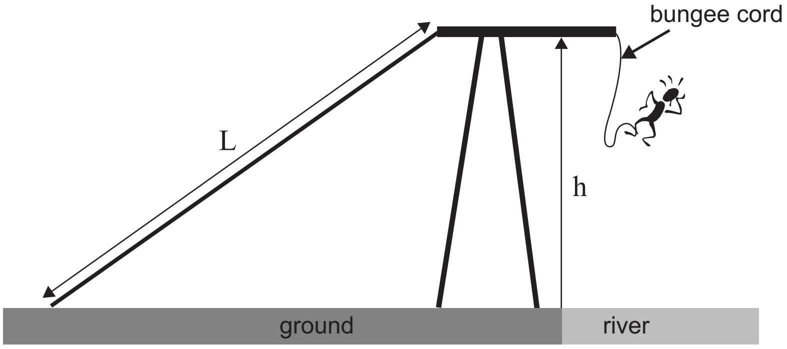


Figure 6

Question 12

Show that the length of the slide, L, is 30 m.

3 marks

Question 13

What is the height, h, of the tower?

m

2 marks

The natural length of the bungee cord is 10 m.

Sam stops falling and first comes to rest momentarily when the length of the bungee cord is 18 m.

Question 14

What is the spring constant of the bungee cord?

$N\ m^{-1}$

3 marks

The planet Mars has a mass of 6.4×10^{23} kg, which is approximately $\frac{1}{10}$ that of Earth, and its radius is approximately half that of Earth.

Question 15

Which of the following (**A–D**) gives the best value for the acceleration due to gravity at the surface of Mars?

A. 1 m s^{-2}

B. 2.5 m s^{-2}

C. 4 m s^{-2}

D. 5 m s^{-2}

2 marks

The Mars probe that was launched in August 2005 is now orbiting Mars in an orbit with an average radius of 3.00×10^7 m (Figure 7).

Figure 7

Question 16

What is the period of the orbit in seconds?

s

3 marks

END OF AREA OF STUDY 1

Area of study 2 – Electronics and photonics

Figure 1 below shows the circuit for a single stage npn transistor amplifier.

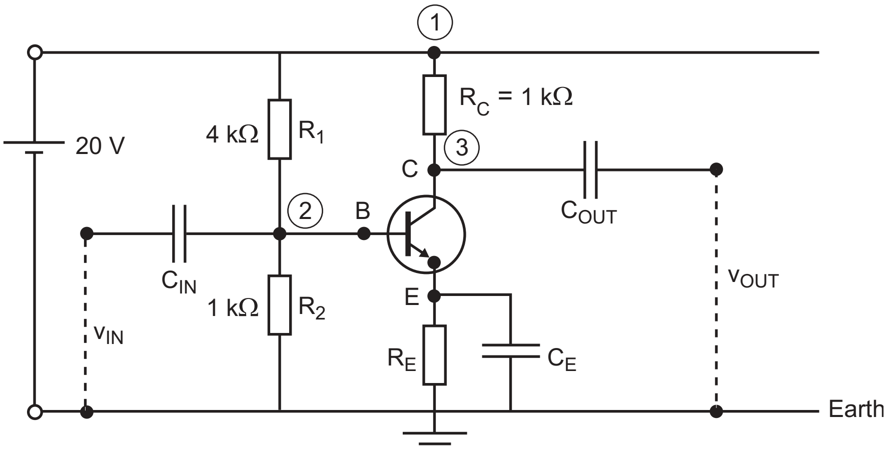


Figure 1

The collector current is 8 mA. With no input signal, v_{IN}, a student uses a multimeter set on volts DC to measure the DC voltage relative to ground (Earth) at a number of points in the circuit.

Question 1

In the table below, list the voltages measured at each of the points 1, 2 and 3.

Point	Voltage measurement (above Earth) (V)
1	
2	
3	

3 marks

The voltage gain of the amplifier is 200.

A small AC voltage signal, v_{IN}, of 50 $mV_{peak\ to\ peak}$ is now applied to the input. v_{IN} is shown below (Figure 2).

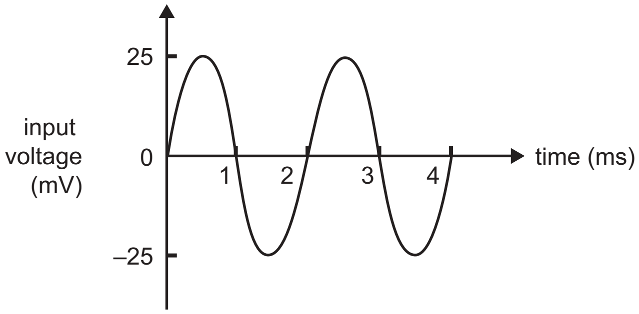


Figure 2

Question 2

What is the peak to peak variation, Δi_c, in the collector current? Show your working.

mA_{p-p}

3 marks

The input signal is now increased to 0.30 V_{p-p} as shown in Figure 3.

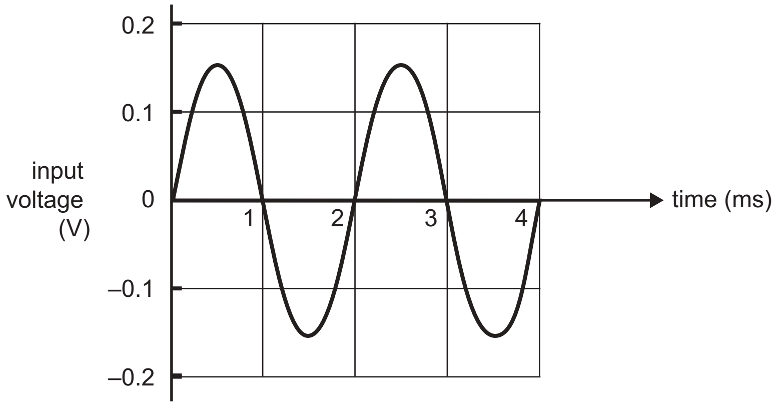


Figure 3

Question 3

On Figure 4 below sketch the wave-form you would expect to see at the output (v_{OUT}).

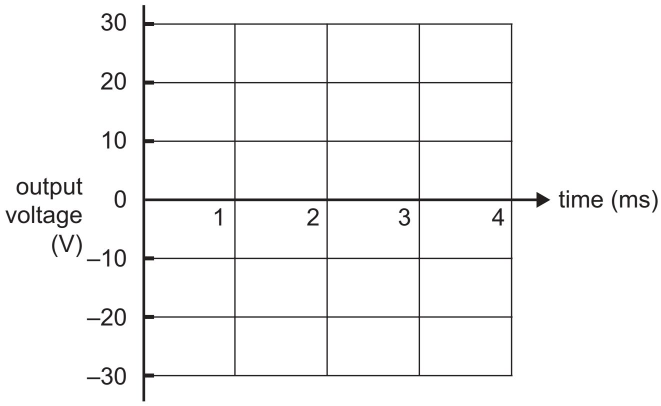


Figure 4

4 marks

Question 4

Explain the role of a decoupler in a transistor amplifier, and how a capacitor fulfils this role.

3 marks

The current-voltage characteristic of a diode is shown in Figure 5.

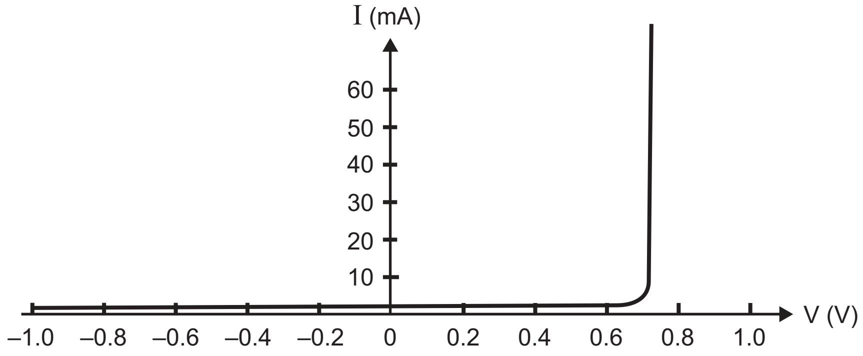


Figure 5

The diode above is placed in the circuit shown in Figure 6 below.

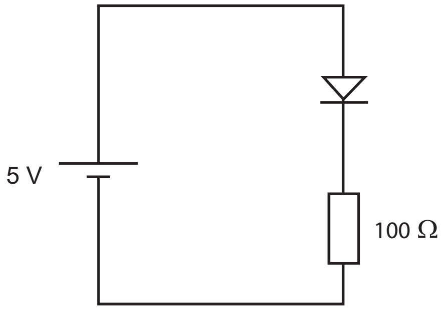


Figure 6

Question 5

Calculate the current flowing in the circuit. Express your answer in mA.

mA

2 marks

The characteristic curve of a thermistor is shown in Figure 7 below.

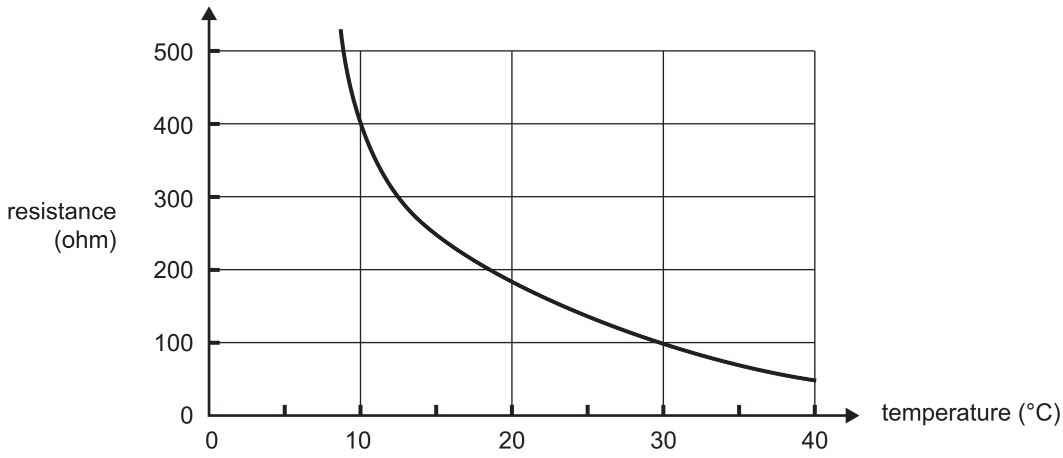


Figure 7

Question 6

What is the resistance of the thermistor when it is at a temperature of 30°C?

Ω

1 mark

A refrigerator is required to maintain its temperature below 10°C. The cooling unit of the refrigerator is controlled by a thermistor using the circuit shown in Figure 8. To turn the cooling unit on, a voltage (v_{OUT}) of 4.0 V is required.

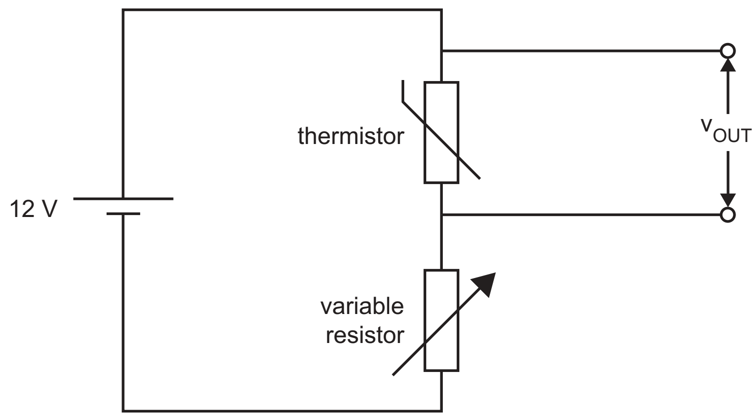


Figure 8

Question 7

What is the value of the variable resistor in Figure 8 when the output voltage (v_{OUT}) is 4.0 V?

Ω

3 marks

Figure 9 is a sketch of an electro-optical system that allows sound to be transmitted over a distance via a fibre-optic cable, using light.

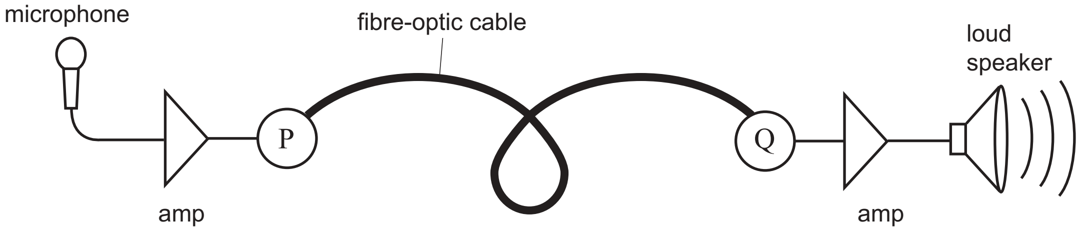


Figure 9

Question 8

Explain the terms 'modulation' and 'demodulation' as they apply to the transmission of sound by this system.

Modulation ____

____

____

Demodulation ____

____

____

4 marks

Question 9

From the list of components below (**A–D**) select the one that would be most suitable for use in the circuit shown in Figure 9 at position P **and** the one most suitable for use at position Q.

A. LDR (light dependent resistor)

B. LED (light emitting diode)

C. transistor

D. diode

P	Q

2 marks

END OF SECTION A

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

Speed of light $c = 3.0 \times 10^8$ m s^{-1}

In 1887 Michelson and Morley undertook an experiment to test Clerk Maxwell's theory that light waves propagated through a medium, *ether*, that filled all of space.

Question 1

Explain how this experiment tested whether or not there was an ether medium throughout space.

3 marks

Question 2

Explain what is meant by an 'inertial frame of reference'.

2 marks

Two space travellers, Kris and Bob, are in rocket ships that are travelling towards each other with a relative velocity, v, that is close to the speed of light.

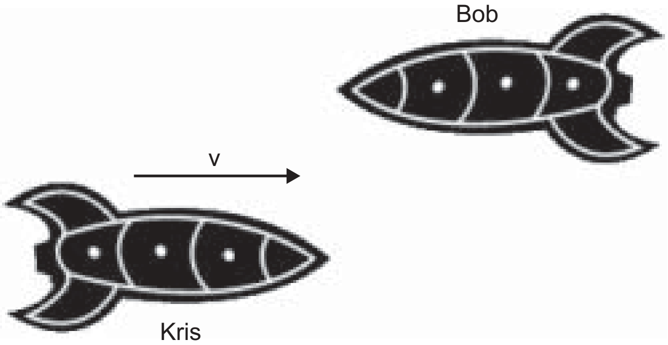


Figure 1

They agree to measure the length of Kris's rocket ship using two different methods. Kris measures her ship with a metre stick, and gets a value of L. Bob decides to determine the length of Kris's rocket ship using a stopwatch to measure the time interval for Kris's ship to pass Bob's ship. Bob starts his watch as the front of Kris's rocket ship reaches him, and stops it as the rear passes him. The time interval he measures is Δt. He calculates the length of Kris's rocket ship as $L' = v\,\Delta t$.

Although both measurements L and L' are correct, one of them is known as the 'proper' length.

Question 3

In the space below indicate which one is the proper length, and explain why this is so.

2 marks

Question 4

Which of the following (**A–D**) is the correct relationship between the length of Kris's rocket ship as measured by Kris and by Bob?

A. $L = L'$

B. $L = L'\dfrac{1}{\sqrt{1 - v^2/c^2}}$

C. $L = L'\sqrt{1 - v^2/c^2}$

D. $L = L'\sqrt{\dfrac{1 - v^2/c^2}{1 + v^2/c^2}}$

2 marks

A burglar alarm is sounding at house number 42. Lee and Sung are in cars travelling as shown in Figure 2. They are able to measure the speed of the sound emitted from the alarm sirens on top of the house. The air is at rest, and the speed of sound through the air is 340 m s^{-1}.

Figure 2

Question 5

In the box below write the speed of sound as measured by Lee and by Sung.

Lee m s^{-1}	Sung m s^{-1}

2 marks

A space station is emitting light from lasers fixed to it. Nilofa and Hadi are situated on two planets that are at rest relative to each other. They measure the speed of the light emitted from the lasers on the space station. Hadi is travelling towards the space station with a speed of 0.25c. Nilofa is travelling away from the space station with a speed of 0.25c. The speed of light through space is c.

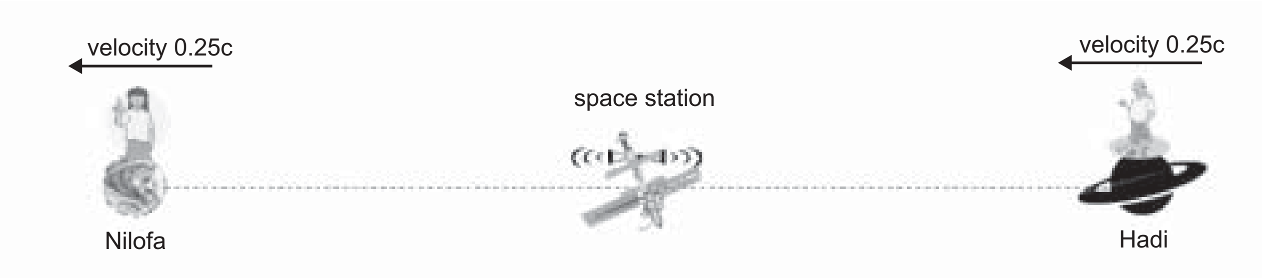


Figure 3

Question 6

Which of the statements (**A–D**) below gives the correct values for the velocity of light as measured by Nilofa and by Hadi?

A. Nilofa measures c and Hadi measures c.

B. Nilofa measures c and Hadi measures 1.5c.

C. Nilofa measures 1.25c and Hadi measures 0.75c.

D. Nilofa measures 0.75c and Hadi measures 1.25c.

2 marks

Muons are elementary particles created in the upper atmosphere by cosmic rays. They are unstable, and decay with a half-life of 2.2 μs (2.2×10^{-6} s) when measured at rest. This means that in the reference frame of the muons, half of them decay in each time interval of 2.2 μs.

In an experiment, 1000 muons with a velocity of 0.995c were observed to pass the top of a mountain of height 2627 m. Experimenters measured the number of these reaching ground level.

The experimenters calculated the time that a muon would take to travel from the top of the mountain to the ground. The calculated value was much longer than the muon half-life. Thus the experimenters expected that only a few muons should reach the ground. In fact they detected many more than expected. The reason for the difference is that, relative to the experimenters, the muons were moving at close to the speed of light, and their half-life, **as measured by the experimenters**, increased.

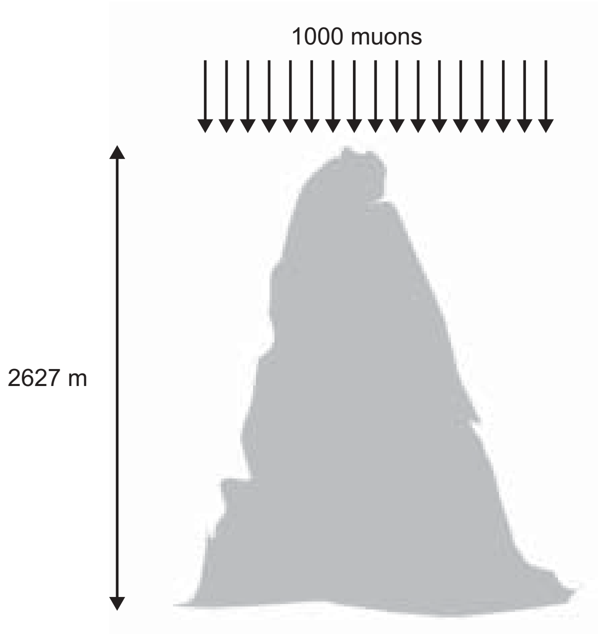


Figure 4

Question 7

Show that the lifetime of the moving muons, as measured from the ground, is approximately 22 μs.

3 marks

From their reference frame, the muons see the ground rushing upwards at a speed of 0.995c.

Question 8

What would be the height of the mountain as measured by the muons?

m

2 marks

Relativistic effects are not easily detectable in everyday situations.

Question 9

At what speed would an object have to be moving for a change of 1% in its length to be observed?

$m\ s^{-1}$

3 marks

A linear accelerator (LINAC) is a device that is used to accelerate electrons using electromagnetic fields. As the electron energy increases, the speed of the electron approaches c (*the speed of light*).

Question 10

Which of the following (**A–D**) is true with regard to the electron's speed, and its mass, **as the speed of the electron approaches c**?

A. Its speed increases slightly while its mass remains fixed at 9.11×10^{-31} kg.

B. Its speed increases slightly while its mass increases substantially.

C. Its speed increases substantially while its mass increases slightly.

D. Both its speed and its mass continue to increase at a steady rate.

2 marks

Question 11

Which of the statements (**A–D**) below best describes the 'mass-energy' ($E = mc^2$) of the electron?

A. It is the rest energy.

B. It is the kinetic energy of the electron.

C. It is the sum of the rest energy and the kinetic energy of the electron.

D. It is the difference between the rest energy and the kinetic energy of the electron.

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.

The stress-strain graph for two polymers, acrylic and polyethylene, are shown in Figure 1. Acrylic is a transparent polymer that is often used as a glass substitute. Polyethylene is a polymer from which plastic carrier bags are made.

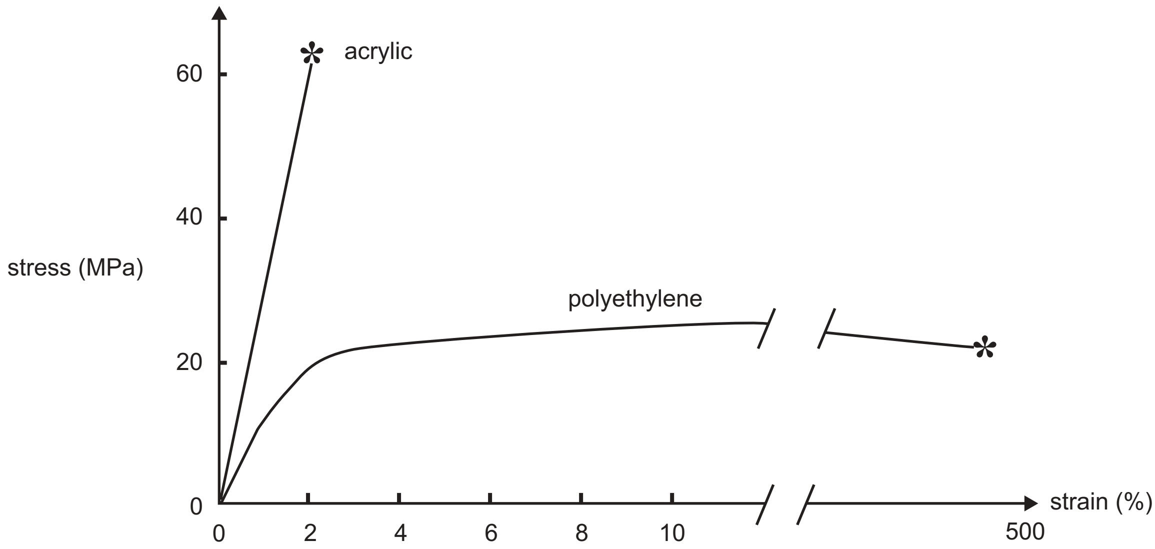


Figure 1

Stress is measured in the unit MPa (10^6 N m^{-2}).

full scale not shown

Question 1

Which one of the statements (**A–D**) below concerning the properties of the polymers is true?

A. Acrylic is tougher than polyethylene.

B. Acrylic is more brittle than polyethylene.

C. Acrylic is more flexible than polyethylene.

D. Acrylic breaks more easily than polyethylene.

2 marks

Question 2

Which **one** of the two polymers is tougher? Support your answer with evidence from the graphs.

2 marks

A strip of polyethylene of length 5.0 m is placed under a tensile stress of 20 MPa.

Question 3

By how much does the strip stretch?

m

3 marks

Question 4

What is the value of Young's modulus for acrylic? Give your answer in units of MPa.

MPa

2 marks

An acrylic rod that is 2.0 m long, and has a cross sectional area of 2.0×10^{-4} m^2, is used to suspend items in a window display.

Question 5

What is the greatest mass that can be suspended from the rod before it breaks?

kg

2 marks

Question 6

Calculate the total work done on the acrylic rod up to the point of fracture.

J

3 marks

Beams used to support brickwork over openings, such as windows or doorways, are often made of concrete. Concrete is strong in compression and weak under tension. To improve its properties, the concrete beams are reinforced with steel rods.

Figure 2

Question 7

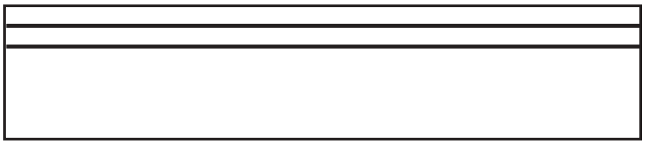
Explain why steel rods are used for this reinforcement.

2 marks

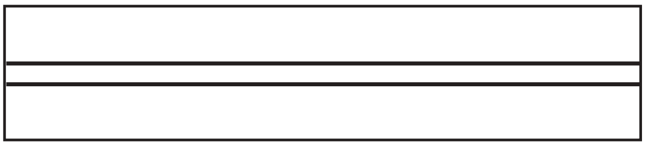
Question 8

Which sketch (**A–D**) below shows the best placement of reinforcing steel rods (represented by the pairs of thick black lines) in order to provide the maximum strength for such a beam?

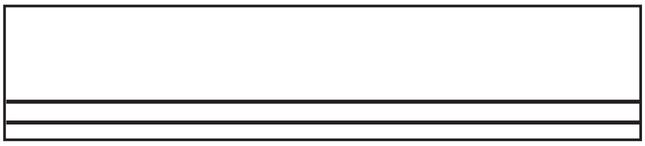
A.



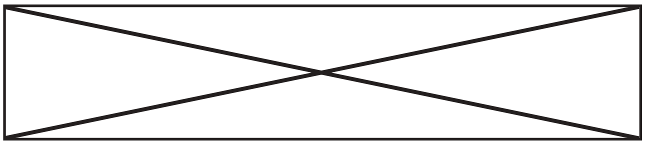
B.



C.



D.



2 marks

A sketch of the viewing platform in Victoria's Otway Range is shown in Figure 3. The walkway can be considered as a long beam which extends 10.0 m beyond two vertical supports, to which the beam is attached. The supports A and B are 8.0 m apart. The beam is uniform and has a mass of 0.50 tonne.

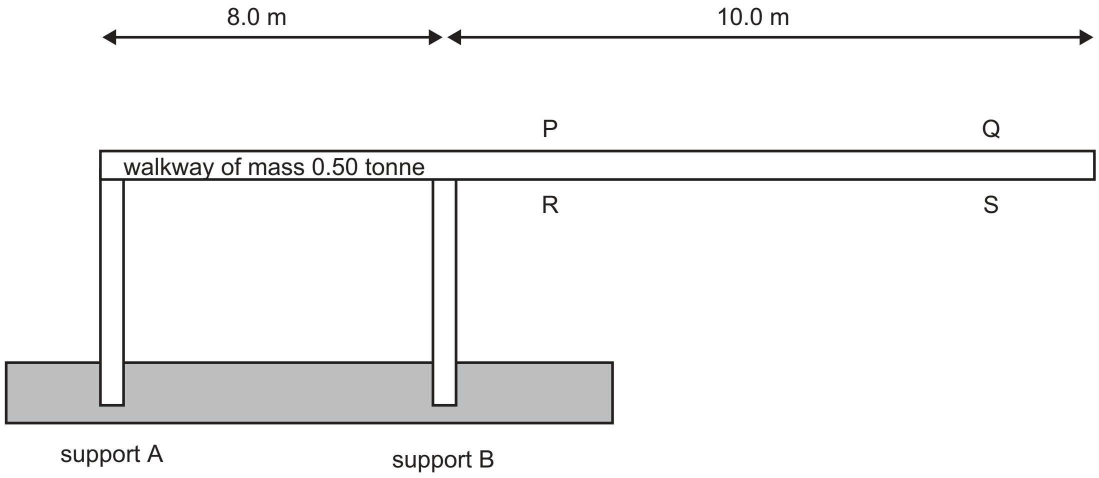


Figure 3

Question 9

Which of the statements (**A–D**) below is correct?

A. Both supports A and B are under compression.

B. Both supports A and B are under tension.

C. Support A is under compression and support B is under tension.

D. Support A is under tension and support B is under compression.

2 marks

Question 10

Calculate the magnitude of the reaction force at the point where support A is attached to the walkway. In your calculation you should assume the supports have no width.

You must show your working.

N

3 marks

Question 11

Which of the positions on the walkway (P, Q, R, S in Figure 3) is under the greater tension, and which is under the greater compression?

Select your answer from the statements (**A–D**) below.

A. Position R has the greater compression, and position Q has the greater tension.

B. Position S has the greater compression, and position P has the greater tension.

C. Position P has the greater compression, and position R has the greater tension.

D. Position R has the greater compression, and position P has the greater tension.

2 marks

END OF DETAILED STUDY 2

Detailed study 3 – Further electronics

Figure 1 shows a correctly set up and operating rectified, smoothed, and regulated 12 V DC power supply. Four sets of points are shown (1a and 1b, 2a and 2b, 3a and 3b, and 4a and 4b) across which test equipment can be connected. A student, Robin, is testing the circuit and has available a multimeter and a Cathode Ray Oscilloscope (CRO).

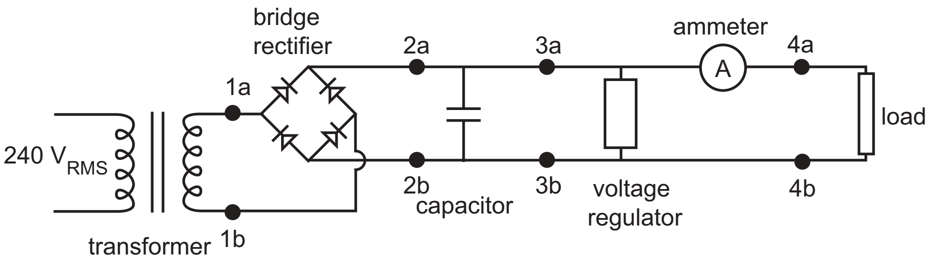


Figure 1

Question 1

How much power is dissipated in the load if its resistance is 240 Ω?

W

2 marks

Robin connects the multimeter (set on AC volts) between points 1a and 1b, and it reads 18 V_{RMS}. The primary winding of the transformer has 4800 turns, and can be considered to be ideal. The input to the transformer is 240 V, 50 Hz.

Question 2

How many turns are there in the secondary winding?

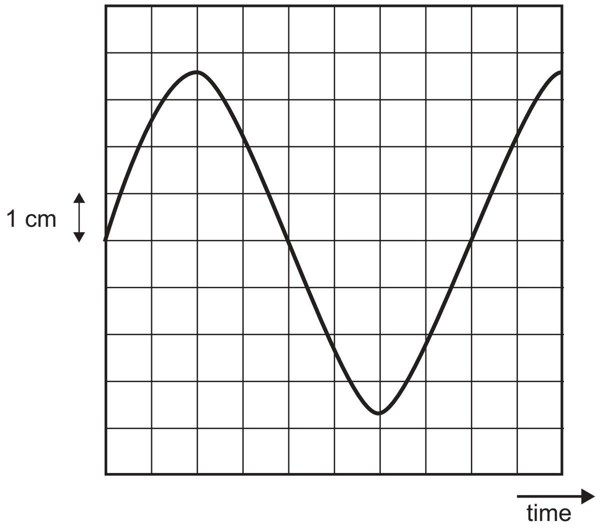
2 marks

Robin next tests the circuit using the CRO. The vertical scale is set to 5 V/cm, and the horizontal scale is set to 0.0025 s/cm (2.5 ms/cm). Robin connects the CRO between the points 1a and 1b.

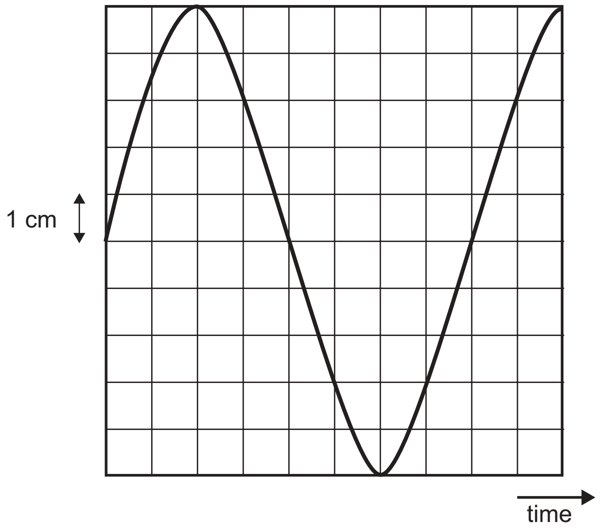
Question 3

Which of the following sketches (**A–D**) is most likely to be the display seen on the screen of the CRO?

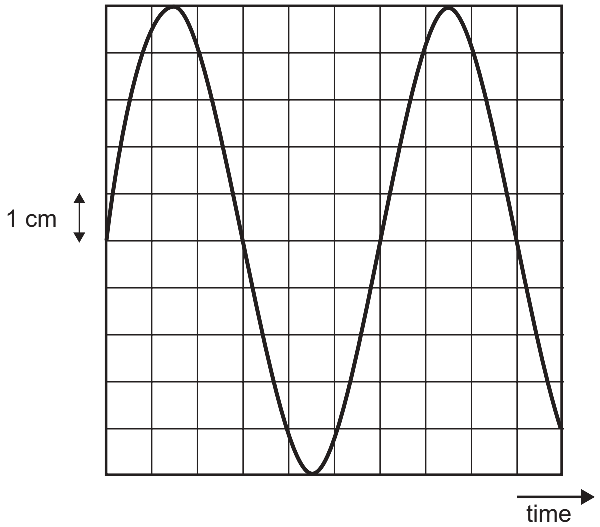
A.



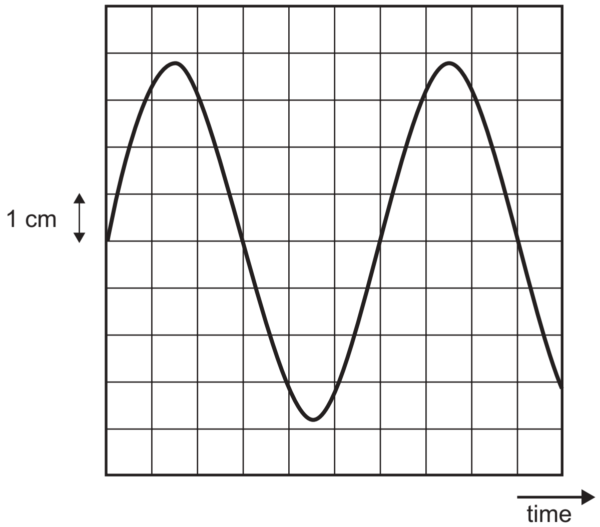
B.



C.



D.



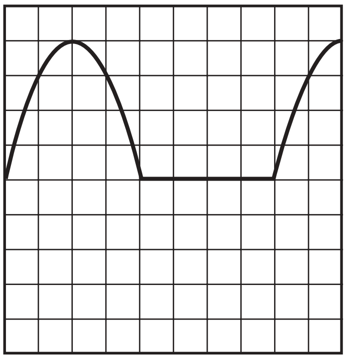
2 marks

Robin now connects the CRO between points 2a and 2b.

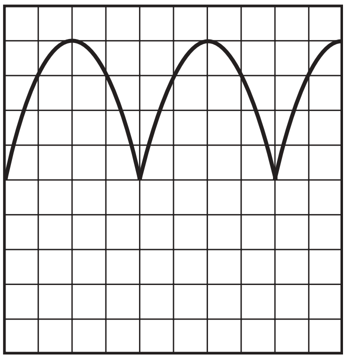
Question 4

Which of the following sketches (**A–D**) is now most likely to be the display seen on the screen of the CRO?

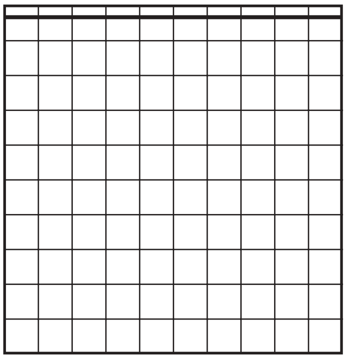
A.



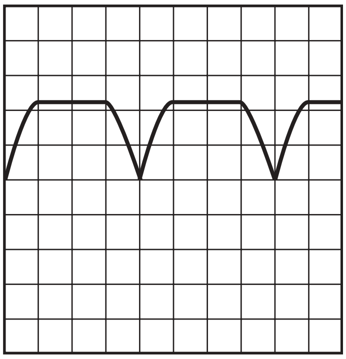
B.



C.



D.



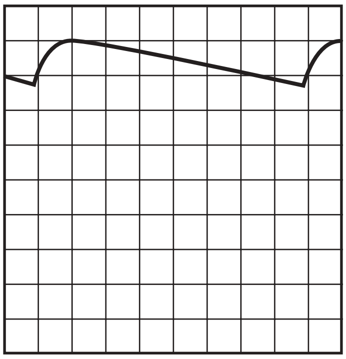
2 marks

Robin now connects the CRO between points 3a and 3b.

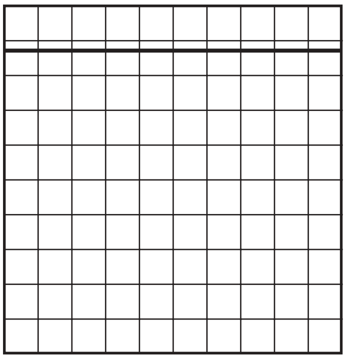
Question 5

Which of the following sketches (**A–D**) is now most likely to be the display seen on the screen of the CRO?

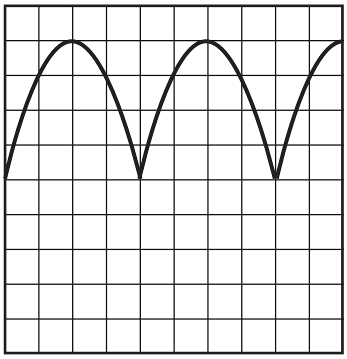
A.



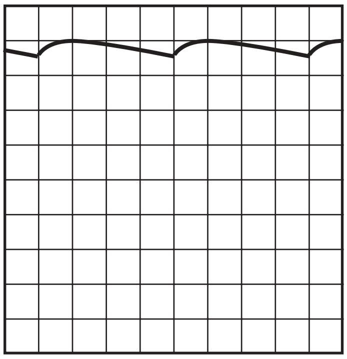
B.



C.



D.



2 marks

The AC supply voltage at the school varies considerably. At a particular time, the school electrician measures it to be 300 V_{RMS} instead of the usual 240 V_{RMS}.

Question 6

What would be the approximate DC output voltage of the power supply, as measured between points 4a and 4b?

V

2 marks

At a later time, the AC supply voltage has fallen to 140 V_{RMS}.

Question 7

What is the effect of this voltage drop on the output of the power supply? Give reasons for this effect in terms of the output of the transformer and the operation of the voltage regulator.

3 marks

Question 8

Which of the measuring devices (**A–D**) below should be placed between points 3a and 3b to study the ripple voltage?

A. a CRO

B. a DC voltmeter

C. an AC ammeter

D. a DC ammeter

2 marks

As a final test of the power supply, Robin reduces the load resistor from 240 Ω to 60 Ω.

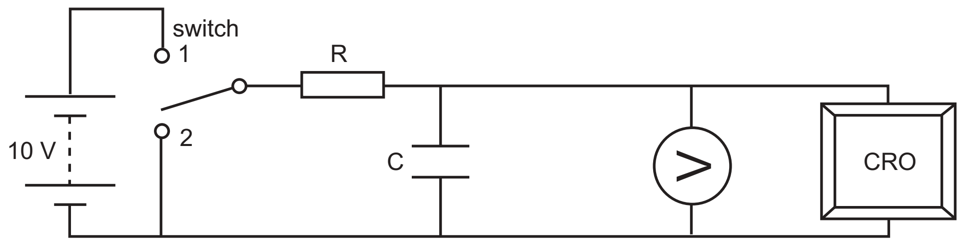
Question 9

What effect would this have on the output current, and the output voltage? Write your answer in the spaces below.

Effect on output current
Effect on output voltage

2 marks

Another student, Morgan, is studying the operation of a capacitor in a timing circuit using the circuit shown in Figure 2.



initially R = 2 000 Ω and C = 10 000 μF

Figure 2

Question 10

What is the time constant of the RC circuit?

s

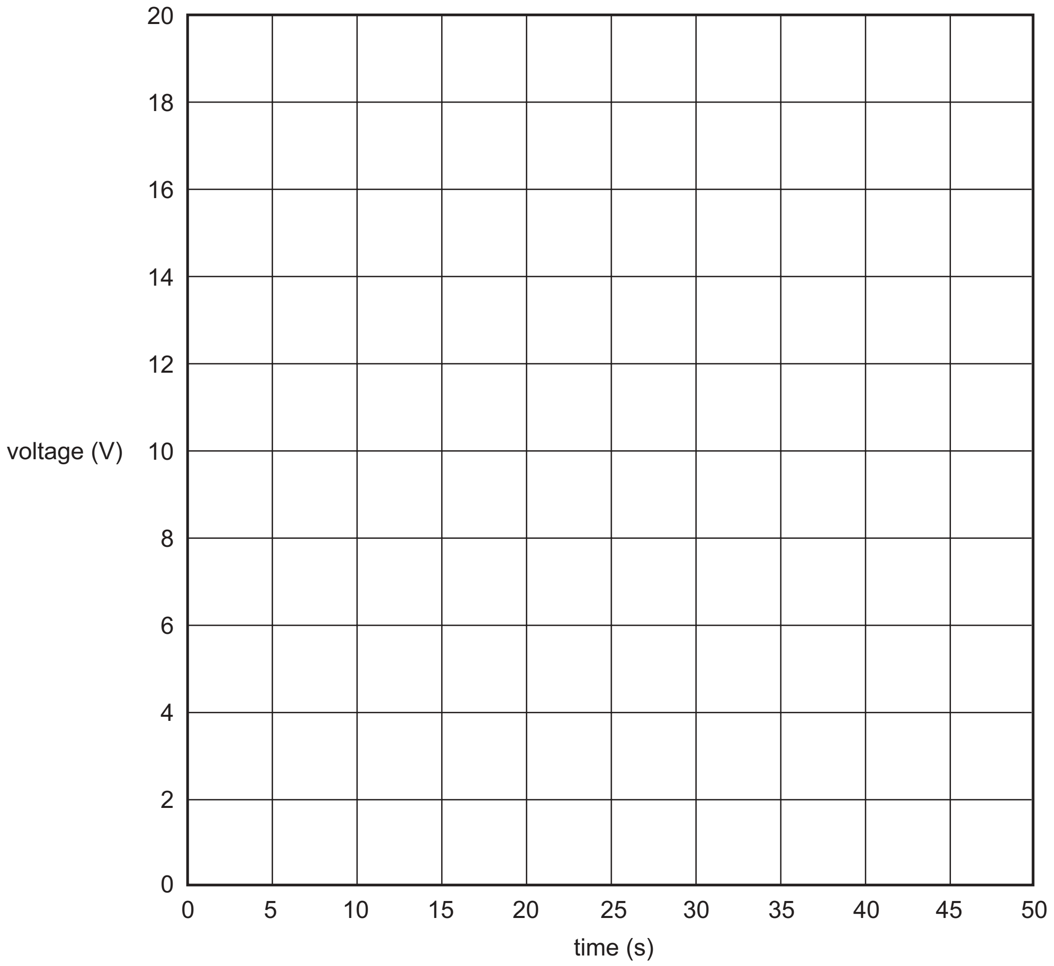
2 marks

The time constant is adjusted to be 10 s, and the switch in Figure 2 is set to position 2, **with the capacitor discharged**.

At time t = 0 s, Morgan moves the switch **from position 2 to position 1**.

Question 11

On the grid below sketch the trace that Morgan would see on the CRO.



2 marks

In a further experiment the switch is **initially in position 1** so that the capacitor becomes fully charged. Morgan then moves the switch **from position 1 to position 2**.

Question 12

What will be the reading on the voltmeter after 10 s?

V

2 marks

END OF QUESTION AND ANSWER BOOK

PHYSICS

Written examination 1

DATA SHEET

Directions to students

Detach this data sheet before commencing the examination.

This data sheet is provided for your reference.

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	gravitional 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	$V_{\text{RMS}} = \frac{1}{2\sqrt{2}}V_{\text{p-p}}$ $I_{\text{RMS}} = \frac{1}{2\sqrt{2}}I_{\text{p-p}}$
16	voltage; power	$V = RI$ $P = VI$

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	$t = t_o\gamma$
22	length contraction	$L = L_o/\gamma$
23	relativistic mass	$m = m_o\gamma$
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