Neap

Trial Examination 2023

VCE Physics Units 1&2

Written Examination

Question and Answer Booklet

Reading time: 15 minutes
Writing time: 2 hours 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	20	20	20
B	13	13	110
			Total 130

Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape) and one scientific calculator.

Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

Materials supplied

Question and answer booklet of 31 pages

Formula sheet

Answer sheet for multiple-choice questions

Instructions

Write your **name** and your **teacher's name** in the space provided above on this page, and on the answer sheet for multiple-choice questions.

Unless otherwise indicated, the diagrams in this booklet 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 booklet.

You may keep the formula sheet.

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

SECTION A – MULTIPLE-CHOICE QUESTIONS

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; 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.

Unless otherwise indicated, the diagrams in this booklet are **not** drawn to scale.

Take the value of g to be 9.8 m s^{-2}.

Use the following information to answer Questions 1–3.

The Sun emits a continuous spectrum of visible light that ranges between approximately 250 nm and 2500 nm in length. The wavelength emitted with the greatest intensity has a length of 502 nm.

Question 1

What is the surface temperature of the Sun?

A. 5.78×10^{3} K

B. 1.16×10^{4} K

C. 1.73×10^{5} K

D. 2.06×10^{17} K

Question 2

What is the highest frequency of light emitted by the Sun?

A. 1.20×10^{14} Hz

B. 4.00×10^{14} Hz

C. 5.98×10^{14} Hz

D. 1.20×10^{15} Hz

Question 3

Stars with a lower temperature than the Sun have been observed to emit their peak wavelengths at lower energy.

Which part of the electromagnetic spectrum are these wavelengths likely to be emitted in?

A. gamma ray

B. X-ray

C. ultraviolet

D. infrared

Use the following information to answer Questions 4 and 5.

During fission reactions inside nuclear reactors, uranium-235 absorbs a neutron before splitting. One of the possible fission reactions occurs according to the following equation.

$$ {}^{1}_{0}n + {}^{235}_{92}\text{U} \rightarrow {}^{100}_{44}\text{Ru} + {}^{130}_{48}\text{Cd} + 6\,{}^{1}_{0}n $$

Each fission reaction releases approximately 365 MeV of energy.

Question 4

Which one of the following statements best explains why a neutron is needed to cause the fission of uranium-235?

A. The neutron increases the atomic number of the nucleus, decreasing its stability.

B. The neutron increases the electrostatic repulsion present in the nucleus, decreasing its stability.

C. The neutron increases the binding energy of the nucleus, making the nucleus fissile.

D. The neutron increases the separation between nucleons, reducing the amount of repulsion in the nucleus.

Question 5

Which one of the following statements best explains the role of the six neutrons released during the fission reaction in a nuclear reactor?

A. The neutrons carry excess kinetic energy away from the fission products to ensure they are stable.

B. The neutrons increase the number of particles present in the sample to ensure it remains above critical mass.

C. The neutrons are unbound and therefore act to absorb heat generated by the reactor.

D. The neutrons sustain the chain reaction by initiating other fission reactions.

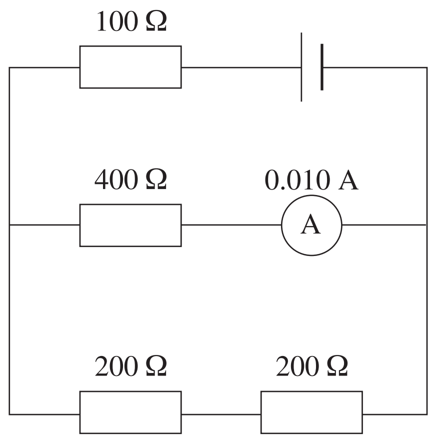
Question 6

Which of the following best summarises the viability of nuclear energy in Australia if the fission products are radioisotopes?

	Viability	Explanation
A.	low	The necessary safe storage and disposal sites for radioisotope waste are not yet readily available.
B.	high	Radioisotopes are a byproduct of nuclear energy; this waste can be repurposed for many uses.
C.	high	The amount of energy released per nucleus far exceeds the amount of energy needed to process and store any potential waste products.
D.	high	As the radioisotopes are likely to have short half-lives, only short-term storage would be needed before the radioisotopes can be safely deposited into landfill.

Use the following information to answer Questions 7–10.

The diagram below shows a circuit containing resistors that are connected to a battery.



Question 7
What is the equivalent resistance of the circuit?

A. 100 Ω

B. 300 Ω

C. 400 Ω

D. 900 Ω

Question 8
What magnitude of voltage does the 400 Ω resistor use?

A. 2.5 V

B. 4.0 V

C. 6.0 V

D. 9.0 V

Question 9
What magnitude of current flows through the 200 Ω resistors?

A. 0.0050 A

B. 0.010 A

C. 0.020 A

D. 0.040 A

Question 10

Which one of the following statements best explains why the battery supplies more voltage than is used by the 400 Ω resistor?

A. The 200 Ω resistor branch is supplied with equal voltage; therefore, the battery supplies double the voltage used by the 400 Ω resistor.

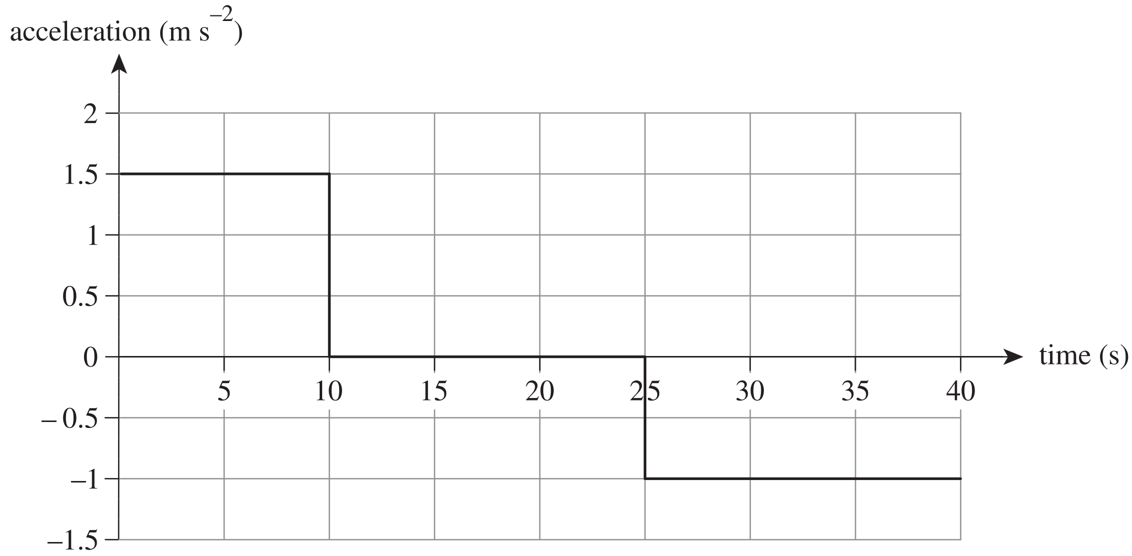
B. The 200 Ω resistor branch provides two additional circuit elements to the closed loop; therefore, more voltage needs to be supplied for current to move through them.

C. The 100 Ω resistor in series with the parallel branches uses some of the voltage supplied by the battery before the current reaches the parallel branches.

D. There are multiple junctions in the circuit, each requiring additional voltage to allow the current to split and follow each path.

Use the following information to answer Questions 11 and 12.

A car initially travelling at 5.0 m s^{-1} undergoes acceleration according to the graph below.



Question 11

During which time interval is the car travelling at a constant speed?

A. 0–10 s

B. 10–25 s

C. 25–40 s

D. 0–40 s

Question 12

What is the final speed of the car after the 40 seconds shown?

A. 0 m s^{-1}

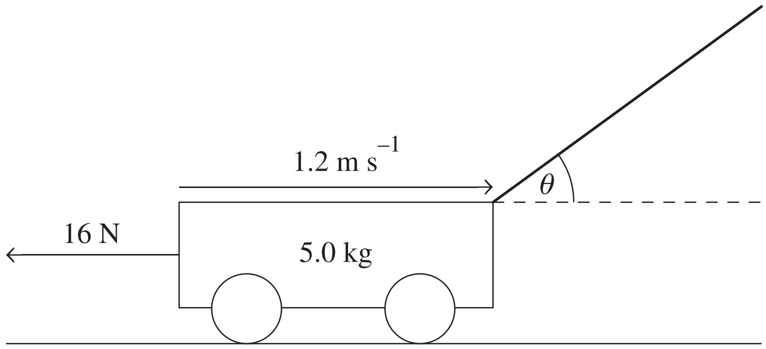
B. 5.0 m s^{-1}

C. 15 m s^{-1}

D. 35 m s^{-1}

Use the following information to answer Questions 13–16.

The diagram below shows a 5.0 kg cart being towed along a road by a rope. The rope is inclined above the road at an angle, θ. The cart travels horizontally at a constant speed of 1.2 m s^{-1} and experiences resistive forces of 16 N acting against its motion.



Question 13

The rope holds a tension of 24 N.

At what angle is the rope inclined above the road?

A. 34°

B. 42°

C. 48°

D. 56°

Question 14

What is the momentum of the cart?

A. 1.2 N s

B. 4.2 N s

C. 6.0 N s

D. 10 N s

Question 15

What amount of power is dissipated by the resistive forces acting against the cart's motion?

A. 19 W

B. 29 W

C. 60 W

D. 80 W

Question 16

In accordance with Newton's third law, which one of the following forces forms an action–reaction force pair with the force of the rope pulling on the cart?

A. the resistive forces acting against the cart's motion

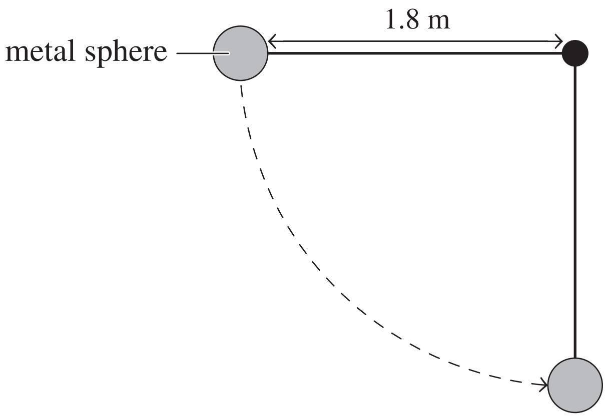
B. the normal force pushing upwards on the cart

C. the gravitational force pulling the cart downwards

D. the cart pulling on the rope against the direction of the rope

Use the following information to answer Questions 17 and 18.

The diagram below shows a metal sphere attached to a 1.8 m long rigid pole, which can rotate around a pivot point. The sphere is released from a horizontal position and oscillates until it comes to rest in a vertical position. When at rest in the vertical position, the pole holds a tension of 2450 N.



Question 17

What is the mass of the sphere?

A. 245 kg

B. 250 kg

C. 2450 kg

D. 24 010 kg

Question 18

What is the magnitude of the torque that the sphere exerts on the pole?

A. 450 N m

B. 2450 N m

C. 4410 N m

D. 40 500 N m

Use the following information to answer Questions 19 and 20.

A group of Physics students investigate the spring constant of a spring inside an adjustable chair in their classroom. The students measure the height of the chair's seat before adding any masses. The students then place different masses onto the seat, ensuring the mass is directly above the spring, and measure the seat's height with a ruler after each mass is added. The students' data is shown in the table below.

Mass (kg)	Average seat height (cm)
0	50
20	49.3
40	48.2
60	46.9

Question 19

Which one of the following needs to be kept constant to maintain the investigation's validity?

A. the increment by which the masses increase in each trial

B. the position of each mass on the seat

C. the number of trials conducted for each mass

D. the direction that the ruler is viewed from when measuring the seat's height

Question 20

In this investigation, the students should conduct multiple trials for each mass to

A. improve the reproducibility of the investigation.

B. enhance the resolution of the measurement.

C. increase the validity of the investigation.

D. reduce the impact of random error.

END OF SECTION A

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided.
Where an answer box is provided, write your final answer in the box.
If an answer box has a unit printed in it, give your answer in that unit.
In questions where more than one mark is available, appropriate working **must** be shown.
Unless otherwise indicated, the diagrams in this booklet are **not** drawn to scale.
Take the value of g to be 9.8 m s^{-2}.

Question 1 (9 marks)

On a hot summer day, Minh leaves a 125 g bowl of ice cream out in the sun. Over time, Minh observes that the ice cream melts at 0°C and then begins to heat up once it becomes a liquid. In its liquid state, the ice cream has a specific heat capacity of 2100 J kg^{-1} K^{-1}.

a. Identify the method of heat transfer that occurs when heat is transferred from the Sun to the ice cream. Justify your response. 2 marks

b. To melt the sample of ice cream, 34.4 kJ of heat energy is absorbed.

Determine the latent heat of fusion of the ice cream. Show your working. 2 marks

J kg^{-1}

c. Explain why a phase change allows the temperature of the ice cream to increase above 0°C. Refer to the kinetic energy of particles in your response. 2 marks

d. When the sample is at 10°C, Minh begins to measure the energy absorbed by the ice cream. They stop measuring once the ice cream absorbs 3150 J of energy.

Calculate the final temperature of the liquid ice cream, expressing your answer in kelvin. Show your working. 3 marks

K

Question 2 (7 marks)

The leaves of forest plants can reflect light more readily than concrete or brick buildings. When urbanisation occurs in coastal areas, forests are cleared and replaced with buildings. The buildings have a lower specific heat capacity than forest vegetation. Buildings and the roads that connect them are often dark in colour.

a. Evaluate how the urbanisation of coastal areas affects the temperature in the area. Refer to the absorption of energy in your response. 3 marks

b. Local convection currents often form when the land and sea are at different temperatures due to the uneven heating of air.

Evaluate how the urbanisation of coastal areas affects convection currents. In your response, explain the processes that facilitate the formation of convection currents. 4 marks

Question 3 (13 marks)

Positron emission tomography (PET) is a type of medical diagnostic scan. PET utilises the radioisotope fluorine-18 to image organs such as the brain. Fluorine-18 emits β^+ particles and has a half-life of approximately 2 hours. It is injected into patients so that the radioisotope can travel to the organ being imaged. When the β^+ particles collide with electrons inside the organ, annihilation occurs and produces a pair of gamma rays that each have an energy of 511 keV. The gamma rays travel out of the patient's body and are captured by a detector.

a. Write a decay equation to represent the β^+ decay of fluorine-18. 2 marks

b. Explain why gamma rays are able to leave the patient's body and evaluate the risk this poses to the patient. 3 marks

A patient has a brain scan and is injected with a dose of fluorine-18 with an initial activity of 0.20 GBq. The patient's brain mass is 1.3 kg. Once the scan is complete, the radioisotope leaves the patient's body via the kidneys and bladder. The table below shows the weighting factors of these organs.

Organ	**Weighting factor**
brain	0.01
kidney	0.009
bladder	0.04

The β^+ radiation has a quality factor of 1.

c. The patient's brain receives a dose equivalent of 16 mSv.

Determine the energy absorbed by the brain due to β^+ particles. Show your working. 3 marks

J

d. The kidney and bladder each absorb 12 mSv of radiation.

Determine the total effective dose absorbed by the patient in their brain, kidney and bladder. Show your working. 2 marks

mSv

e. The patient is advised not to interact with other people until their activity drops below 12.5 MBq.

Determine the amount of time the patient needs to wait. Show your working. 3 marks

hours

Question 4 (11 marks)

Antonio uses his blender for 12 minutes each day while he is preparing dinner. The blender has a power rating of 1200 W and is connected to a power supply of 240 V.

a. Calculate the resistance of the blender. Show your working. 2 marks

Ω

b. Determine the magnitude of charge that flows through the blender in 12 minutes. Show your working. 3 marks

C

c. Determine the magnitude of energy used by the blender in 12 minutes. Express your answer in kW h. Show your working. 3 marks

kW h

d. A circuit breaker protects the circuit the blender is plugged into.

Explain the role that the circuit breaker plays in the circuit and why the circuit breaker is placed on the active wire. 3 marks

Question 5 (8 marks)

Figure 1 shows a characteristic graph of the current that flows through an LED when the voltage across it is varied.

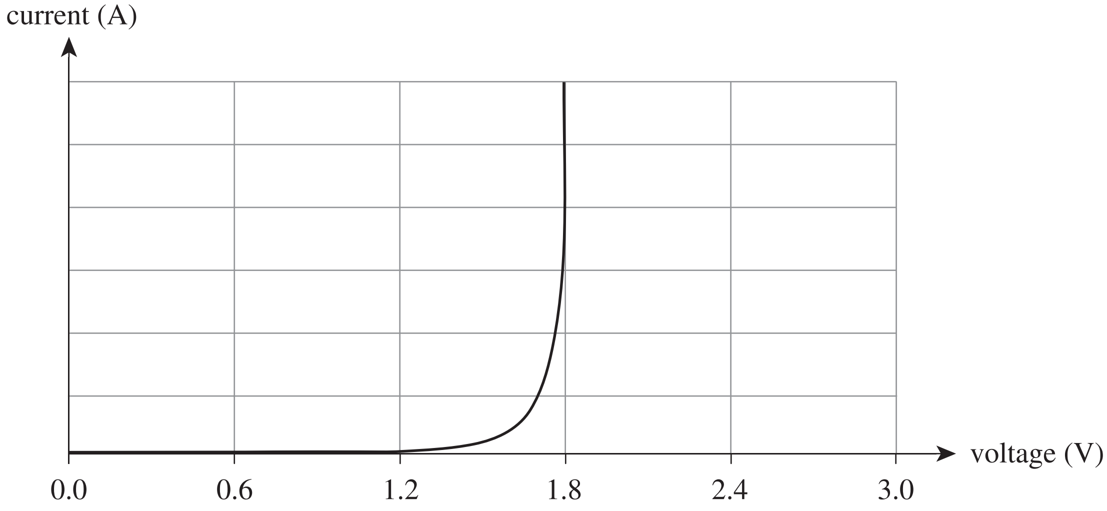


Figure 1

The LED is placed into the circuit shown in Figure 2.

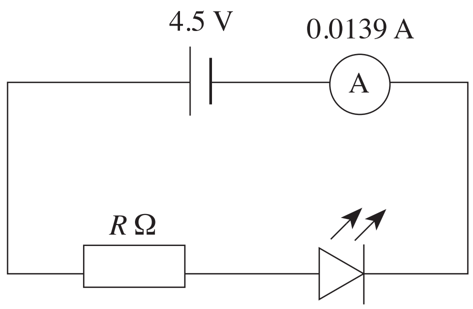


Figure 2

a. With reference to the graph in Figure 1, explain why the LED is a non-ohmic device. 2 marks

b. Determine the resistance of the limiting resistor, *R*. Show your working. 2 marks

Ω

c. Calculate the power output of the LED. Show your working. 2 marks

W

d. Describe the effect that reducing the resistance of the limiting resistor, *R*, would have on the operation of the circuit. 2 marks

Question 6 (7 marks)
A thermistor is able to respond to external temperature conditions. Figure 3 shows the temperature characteristic graph of the thermistor.

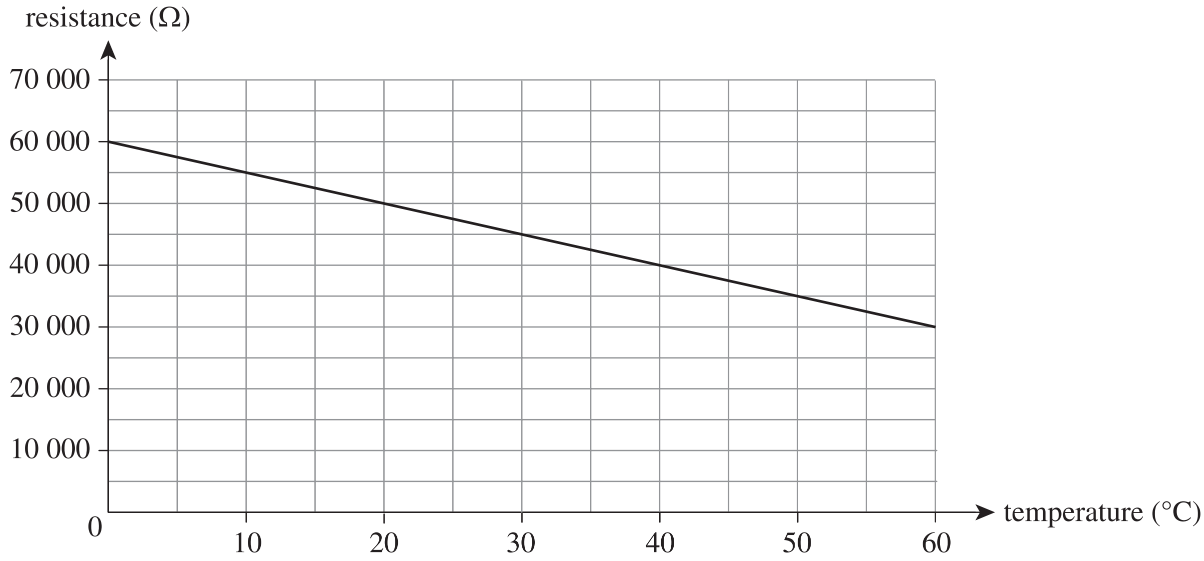


Figure 3

The thermistor is used in a device that activates when the external temperature reaches 30°C. In the device, the thermistor is placed in series with a variable resistor, as shown in Figure 4.

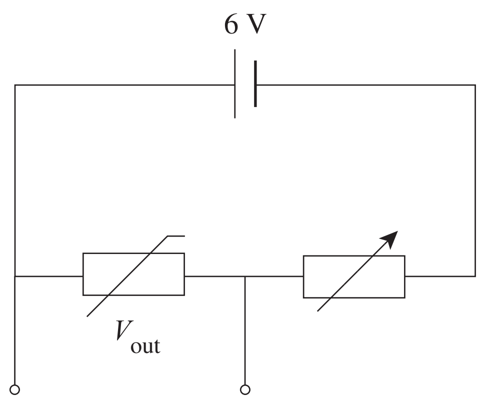


Figure 4

a. Determine the resistance of the thermistor at 30°C. 1 mark

Ω

b. When the voltage output, V_{out}, has a value of less than 1.5 V, the device connected across the terminals switches on.

Determine the resistance of the variable resistor at which the device switches on at 30°C. Show your working. 3 marks

Ω

c. The resistance of the variable resistor is now changed to 157.5 kΩ.

Determine the temperature at which the device connected to the output will switch on. Show your working. 3 marks

°C

Question 7 (9 marks)

Angie is riding an electric scooter. She accelerates at a constant rate away from her starting point for 80 seconds, then decelerates and comes to rest after 40 seconds. Angie waits for 20 seconds before turning around and accelerating at a constant rate towards her starting point. She arrives at her starting point 80 seconds later. Figure 5 shows the velocity versus time graph for Angie's journey.

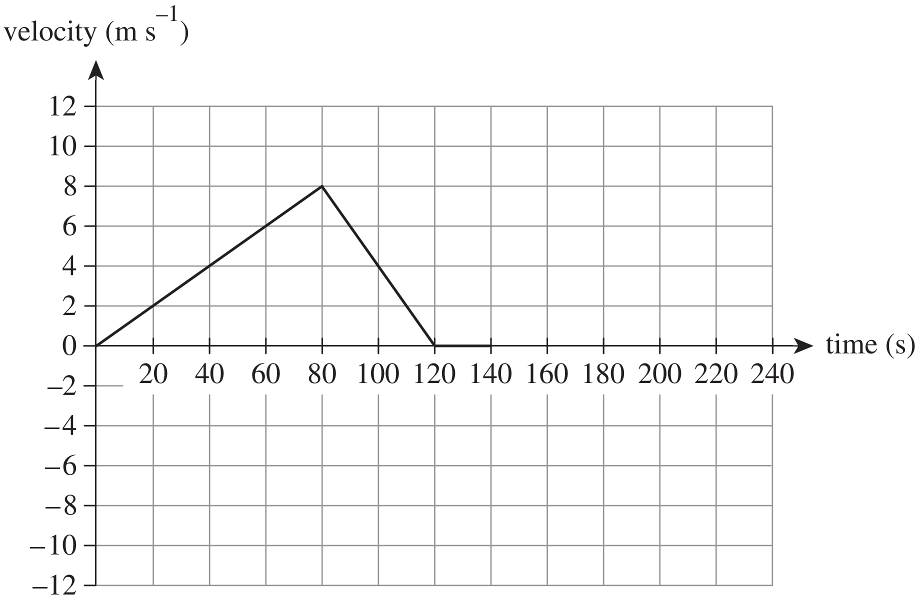


Figure 5

a. Show that Angie has travelled 480 m away from her starting point when she comes to rest. 1 mark

b. What is Angie's average speed during the first 120 seconds of her journey? 1 mark

$m\ s^{-1}$

c. Determine the magnitude of Angie's acceleration as she travels back towards her starting point. Show your working. 2 marks

$m\ s^{-2}$

d. At what speed is Angie travelling as she returns to her starting point? Show your working. 2 marks

$m\ s^{-1}$

e. Complete the graph in Figure 5 to show Angie's return journey. 1 mark

f. Describe how the speed versus time graph of Angie's journey would differ from the graph in Figure 5. Justify your response. 2 marks

Question 8 (6 marks)

Zoe is standing on the ground beneath a bridge and Jay is standing directly above her on the bridge. Zoe throws a ball vertically upwards to Jay at a speed of 16 m s^{-1}.

a. Determine the maximum height that the ball reaches above the ground. Show your working. 2 marks

m

b. Jay catches the ball when it is moving downwards at a speed of 4.6 m s^{-1}.

Calculate the height of the bridge above the ground. Show your working. 2 marks

m

c. How long is the ball in the air before Jay catches it? Show your working. 2 marks

s

Question 9 (11 marks)

Josephine and her bicycle have a combined mass of 80 kg. Figure 6 shows Josephine gliding down a hill with an incline of 25°. No resistive forces act on Josephine as she travels.

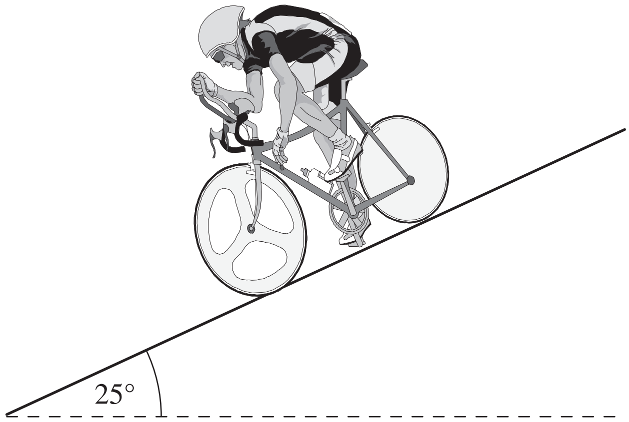


Figure 6

a. On Figure 6, draw the forces acting on Josephine using labelled arrows. 2 marks

b. Explain why Josephine does **not** accelerate at 9.8 m s^{-2} when gliding down the hill. 2 marks

Josephine applies the brakes on her bicycle so that she travels down the hill at a constant speed.

c. Determine the magnitude of the force exerted by the brakes. Show your working. 2 marks

N

d. Explain why the force exerted by the brakes is **not** considered to be an action–reaction force pair with the force causing Josephine to accelerate down the hill. 2 marks

e. While Josephine is travelling down the hill, the normal force exerted by the ground is less than when Josephine travels on a horizontal surface.

Explain why the normal force is reduced when Josephine is travelling down the hill. Use a calculation to support your answer. 3 marks

Question 10 (6 marks)

A train of mass 160 tonnes initially travels at 5.0 m s^{-1} after it leaves the platform at a train station. The train driver begins to accelerate gradually before increasing the amount of thrust produced by the engines. As the train moves, a constant resistive force of 2.0×10^4 N acts against its motion. The train reaches its final speed after travelling 400 m. Figure 7 shows the force versus distance graph for the force exerted by the train's engines.

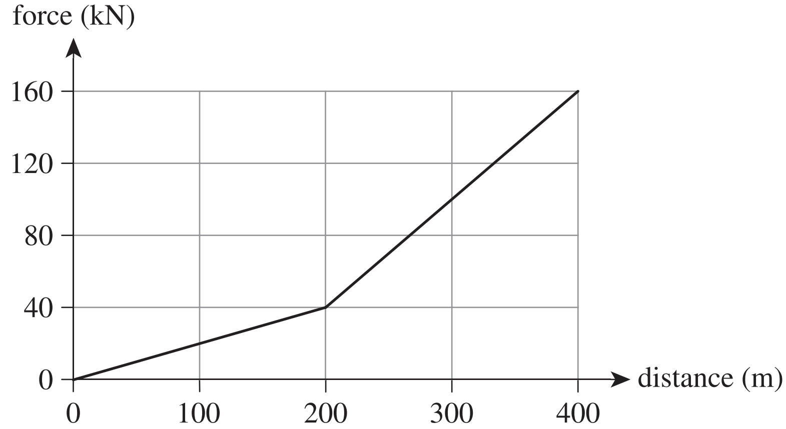


Figure 7

a. Calculate the work done by the train's engines during the 400 m acceleration. Show your working. 2 marks

J

b. Determine the final speed of the train. Show your working. 4 marks

m s^{-1}

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Question 11 (4 marks)

Figure 8 shows a decorative clock hanging from a ceiling by two identical ropes. The horizontal component of the force exerted by each rope is 2100 N.

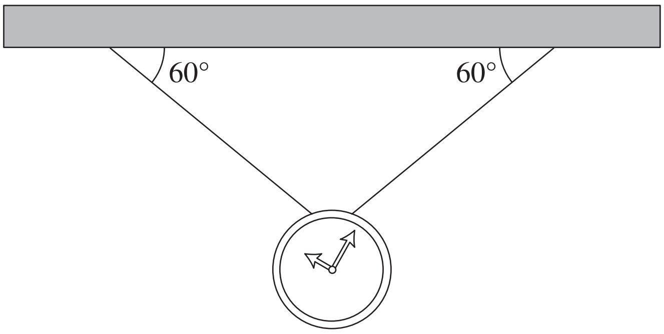


Figure 8

a. Calculate the tension in each rope. Show your working. 2 marks

N

b. Determine the mass of the clock. Show your working. 2 marks

kg

Question 12 (6 marks)

Figure 9 shows a partially constructed bridge that is supported by two pylons. The bridge has a length of 50 m and a mass of 2500 kg. The pylons are separated by a distance of 20 m.

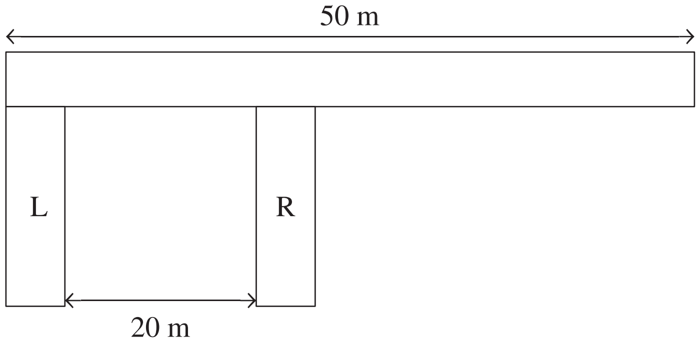


Figure 9

a. Calculate the magnitude of the force exerted on the bridge by each pylon. Show your working. 4 marks

Left pylon N	Right pylon N

b. A pylon can only exert a downwards force on the bridge if it is attached to the bridge using screws.

Identify which pylon needs to be screwed to the bridge. Justify your answer using evidence from **part a.** 2 marks

Question 13 (13 marks)

Gerald constructs a small electric boat that is able to vary the magnitude of thrust it produces. Gerald measures the boat's acceleration when different magnitudes of thrust are applied using an accelerometer, which shows the acceleration in increments of 0.05 m s^{-2} on an analogue dial. They conduct three trials and collect the data shown in Table 1.

Table 1

Thrust (N)	Acceleration (m s^{-2})			
	Trial 1	Trial 2	Trial 3	Average
50	0.25	0.30	0.30	
200	0.45	0.50	0.50	
250	0.60	0.55	0.60	
300	0.70	0.65	0.95	
400	1.25	1.35	1.50	

a. Complete Table 1 by calculating the average acceleration for each magnitude of thrust. Round your answers to the nearest 0.05 m s^{-2}. 1 mark

b. Explain why conducting multiple trials for each magnitude of thrust enhances the precision of the data but does not enhance its resolution. 2 marks

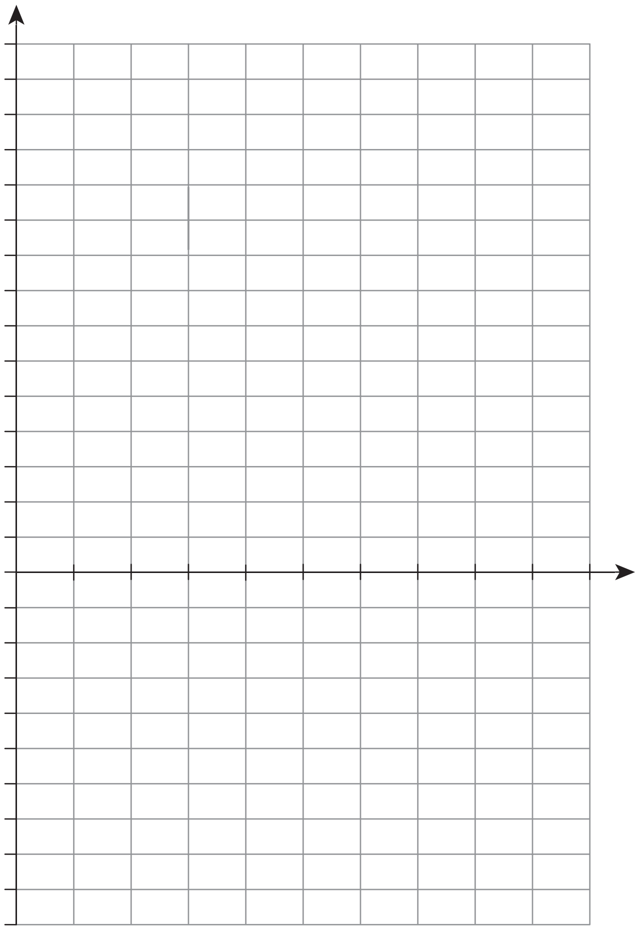
Gerald decides to analyse their data graphically. They use the equation $a = \dfrac{T - R}{m}$, where:

- T is the thrust in N
- R is the resistive forces in N
- m is the mass in kg.

c. On the axes provided below, plot an acceleration versus torque graph using the average acceleration calculated in **part a.** In your graph:

- include a scale and label on each axis, including units
- plot all data points
- include uncertainty bars of ±0.05 m s^{-2}
- sketch a line of best fit.

6 marks



d. Gerald weighs the boat and finds that its mass is 240 kg.

Using the gradient of the line of best fit from **part c.**, evaluate the accuracy of the investigation. 2 marks

e. Determine the magnitude of the resistive force that acts against the boat's motion in each trial. 2 marks

END OF QUESTION AND ANSWER BOOKLET

Neap

Trial Examination 2023

VCE Physics Units 1&2

Written Examination

Multiple-choice Answer Sheet

Student's Name: ______________________________

Teacher's Name: ______________________________

Instructions

Use a **pencil** for **all** entries. If you make a mistake, **erase** the incorrect answer – **do not** cross it out.
Marks will **not** be deducted for incorrect answers.
No mark will be given if more than **one** answer is completed for any question.

All answers must be completed like this example: A B C D

Use pencil only

1	A	B	C	D	11	A	B	C	D
2	A	B	C	D	12	A	B	C	D
3	A	B	C	D	13	A	B	C	D
4	A	B	C	D	14	A	B	C	D
5	A	B	C	D	15	A	B	C	D
6	A	B	C	D	16	A	B	C	D
7	A	B	C	D	17	A	B	C	D
8	A	B	C	D	18	A	B	C	D
9	A	B	C	D	19	A	B	C	D
10	A	B	C	D	20	A	B	C	D

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Neap

Trial Examination 2023

VCE Physics Units 1&2

Written Examination

Formula Sheet

Instructions

This formula sheet is provided for your reference.
A question and answer booklet 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.

PHYSICS FORMULAS

wave equation	$v = f\lambda$
frequency and period	$f = \frac{1}{T}$
Snell's law	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
critical angle	$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$
refractive index	$n = \frac{c}{v}$
refractive index and wave speed	$n_1 v_1 = n_2 v_2$
specific heat	$Q = mc\Delta t$
latent heat	$Q = mL$
Wien's law	$\lambda_{\text{max}} T = 2.9 \times 10^{-3}$ mK
Stefan–Boltzmann law	$P = \sigma T^4$ where Stefan–Boltzmann constant $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^4
absorbed dose	$\frac{E}{m}$
equivalent dose	absorbed dose × quality factor
effective dose	$\sum$ equivalent dose × weighting factor
mass–energy equivalence	$E = mc^2$
power	$P = \frac{E}{t}$
electrical charge	$Q = It$
electrical work	$W = QV$
voltage	$\ddot{u} =$
electrical power	$P = VI = I^2 R$
resistors in series	$R_T = R_1 + R_2$
resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$
velocity; acceleration	$v = \frac{\Delta s}{\Delta t}$; $a = \frac{\Delta v}{\Delta t}$

equations for constant acceleration	$v = u + at$ $s = ut + \frac{1}{2}at^2$ $s = vt - \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ $s = \frac{1}{2}(v + u)t$
Newton's second law	$\Sigma F = ma$
gravitational potential energy near the surface of Earth	$mg\Delta h$
kinetic energy	$\frac{1}{2}mv^2$
mechanical work	$W = Fs$
Hooke's law	$F = -k\Delta x$
elastic potential energy	$\frac{1}{2}k\left(\Delta x\right)^2$
torque	$\tau = F \times r$
momentum	mv
impulse	$F\Delta t$
efficiency	$\text{efficiency (\%)} = \frac{\text{useful energy output}}{\text{energy input}} \times 100$

Data

speed of light in a vacuum	$c = 3.0 \times 10^8$ m s^{-1}
1 eV	1.6×10^{-19} J
charge on the electron	$e = 1.6 \times 10^{-19}$ C
acceleration due to gravity at Earth's surface	$g = 9.8$ m s^{-2}

Prefixes/Units

p = pico = 10^{-12}	n = nano = 10^{-9}	μ = micro = 10^{-6}	m = milli = 10^{-3}
k = kilo = 10^3	M = mega = 10^6	G = giga = 10^9	t = tonne = 10^3 kg

Periodic table of the elements

Key: 79 (atomic number) Au (symbol of element) 197.0 (relative atomic mass) gold (name of element)

1 H 1.0 hydrogen																	2 He 4.00 helium
3 Li 6.9 lithium	4 Be 9.0 beryllium											5 B 10.8 boron	6 C 12.0 carbon	7 N 14.0 nitrogen	8 O 16.0 oxygen	9 F 19.0 fluorine	10 Ne 20.2 neon
11 Na 23.0 sodium	12 Mg 24.3 magnesium											13 Al 27.0 aluminium	14 Si 28.1 silicon	15 P 30.1 phosphorus	16 S 32.1 sulfur	17 Cl 35.5 chlorine	18 Ar 39.9 argon
19 K 39.1 potassium	20 Ca 40.1 calcium	21 Sc 45.0 scandium	22 Ti 47.9 titanium	23 V 50.9 vanadium	24 Cr 52.0 chromium	25 Mn 54.9 manganese	26 Fe 55.8 iron	27 Co 58.9 cobalt	28 Ni 58.7 nickel	29 Cu 63.5 copper	30 Zn 65.4 zinc	31 Ga 69.7 gallium	32 Ge 72.6 germanium	33 As 74.9 arsenic	34 Se 79.0 selenium	35 Br 79.9 bromine	36 Kr 83.8 krypton
37 Rb 85.5 rubidium	38 Sr 87.6 strontium	39 Y 88.9 yttrium	40 Zr 91.2 zirconium	41 Nb 92.9 niobium	42 Mo 96.0 molybdenum	43 Tc (98) technetium	44 Ru 101.1 ruthenium	45 Rh 102.9 rhodium	46 Pd 106.4 palladium	47 Ag 107.9 silver	48 Cd 112.4 cadmium	49 In 114.8 indium	50 Sn 118.7 tin	51 Sb 121.8 antimony	52 Te 127.6 tellurium	53 I 126.9 iodine	54 Xe 131.3 xenon
55 Cs 132.9 caesium	56 Ba 137.3 barium	57–71 lanthanoids	72 Hf 178.5 hafnium	73 Ta 180.9 tantalum	74 W 183.8 tungsten	75 Re 186.2 rhenium	76 Os 190.2 osmium	77 Ir 192.2 iridium	78 Pt 195.1 platinum	79 Au 197.0 gold	80 Hg 200.6 mercury	81 Tl 204.4 thallium	82 Pb 207.2 lead	83 Bi 209.0 bismuth	84 Po (210) polonium	85 At (210) astatine	86 Rn (222) radon
87 Fr (223) francium	88 Ra (226) radium	89–103 actinoids	104 Rf (261) rutherfordium	105 Db (262) dubnium	106 Sg (266) seaborgium	107 Bh (264) bohrium	108 Hs (267) hassium	109 Mt (268) meitnerium	110 Ds (271) darmstadtium	111 Rg (272) roentgenium	112 Cn (285) copernicium	113 Nh (280) nihonium	114 Fl (289) flerovium	115 Mc (289) moscovium	116 Lv (292) livermorium	117 Ts (294) tennessine	118 Og (294) oganesson

57 La 138.9 lanthanum	58 Ce 140.1 cerium	59 Pr 140.9 praseodymium	60 Nd 144.2 neodymium	61 Pm (145) promethium	62 Sm 150.4 samarium	63 Eu 152.0 europium	64 Gd 157.3 gadolinium	65 Tb 158.9 terbium	66 Dy 162.5 dysprosium	67 Ho 164.9 holmium	68 Er 167.3 erbium	69 Tm 168.9 thulium	70 Yb 173.1 ytterbium	71 Lu 175.0 lutetium
89 Ac (227) actinium	90 Th 232.0 thorium	91 Pa 231.0 protactinium	92 U 238.0 uranium	93 Np (237) neptunium	94 Pu (244) plutonium	95 Am (243) americium	96 Cm (247) curium	97 Bk (247) berkelium	98 Cf (251) californium	99 Es (252) einsteinium	100 Fm (257) fermium	101 Md (258) mendelevium	102 No (259) nobelium	103 Lr (262) lawrencium

The value in the brackets indicates the mass number of the longest-lived isotope.

END OF FORMULA SHEET