THE SCHOOL FOR EXCELLENCE (TSFX)

UNIT 3 PHYSICS 2008

WRITTEN EXAMINATION 1

Reading Time: 15 minutes
Writing Time: 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 Studies**			
	Motion	16	16	37
	Electronics and Photonics	15	15	27
B	**Detailed Studies**			
	1. Einstein's Special Relativity **OR**	13	13	26
	2. Further Electronics **OR**	13	13	26
	3. Structures and Materials	13	13	26
				Total 90

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SECTION A – CORE STUDIES

Instructions For Section A

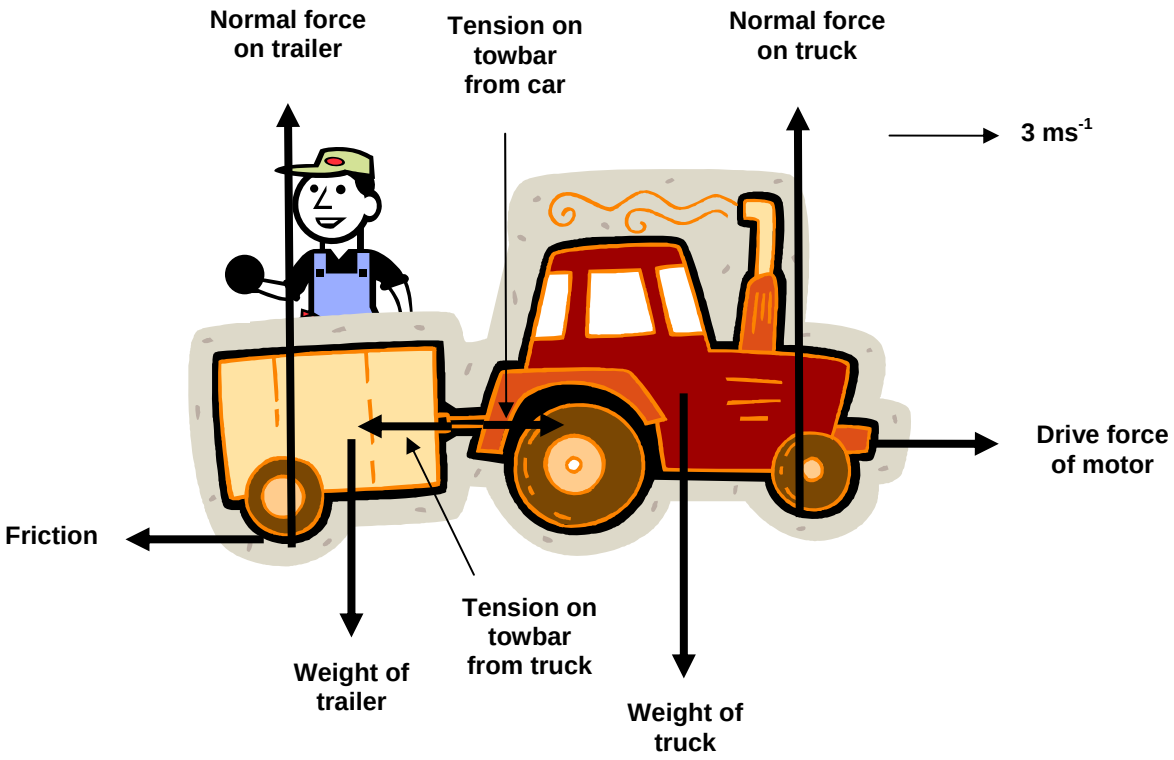
Answer **all** questions for **both** Areas of Study in this section of the paper.
You should take the value of *g* to be 10 ms^{-2}.
Unless stated otherwise, ignore air resistance.

AREA OF STUDY 1: MOTION IN ONE AND TWO DIMENSIONS

Questions 1 to 4 refer to the following information:

Farmer Frank is sitting in the middle of a trailer which is being towed by a tractor at a constant speed of 3 ms^{-1} as shown in Figure 1 below. The forces acting on the trailer and car are included.

Figure 1



QUESTION 1
Which of the following pairs of forces (A-D) are an action-reaction pair according to Newton's third law?

A. Normal force on the trailer – Weight of the trailer
B. Drive force of motor – Friction
C. Drive force of motor – Tension on towbar from truck
D. Tension on towbar from truck - Tension on towbar from trailer

2 marks

Farmer Frank now throws his ball from the floor of the trailer directly upwards with a speed of 5 ms^{-1}.

QUESTION 2
Find the speed of the ball relative to the ground just after it has been thrown into the air.

1 mark

ms^{-1}

QUESTION 3
How far will Farmer Frank travel by the time the ball reaches the floor of the trailer again?

3 marks

m

QUESTION 4

If the ball was thrown from the centre of the trailer and the trailer is 3 m in length, which of the following positions (A-D) best describes where the ball landed?

A. On the truck roof.
B. On the ground behind the trailer.
C. The centre of the trailer.
D. At the back of the trailer.

2 marks

Questions 5 and 6 refer to the following information:

Jo and Andy are conducting an experiment to look at the normal force, measured by a set of scales. The object is placed on the scales which is then accelerated vertically downwards. The data recorded from their experiment so far is presented in the graph below, Figure 2. They discover that when the object and the scales are dropped from a height, the scales read zero. Andy hypothesises that if they throw the object and scales down rather than let it drop and **then** take a reading, they will measure a negative normal force on the scales. Jo does not agree.

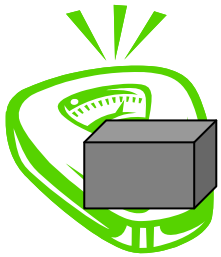
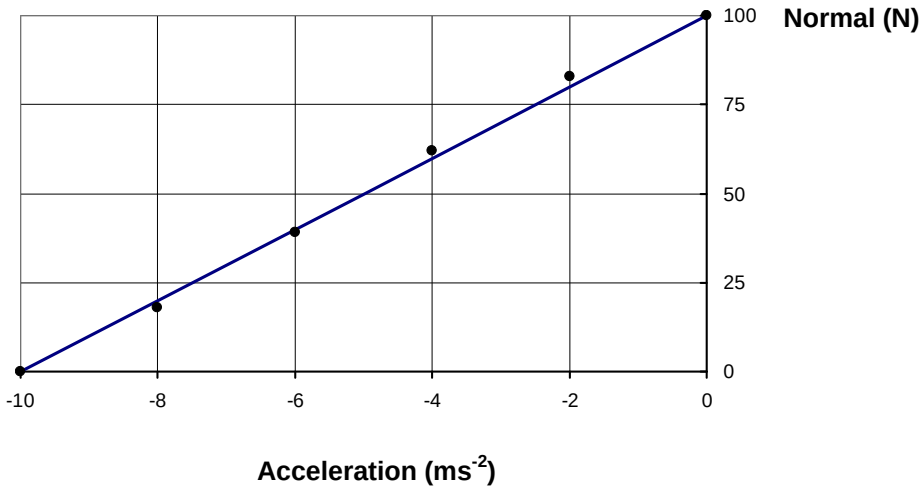


Figure 2



QUESTION 5
Which student is correct? Explain your answer.

Student

3 marks

QUESTION 6
Determine the mass of the object.

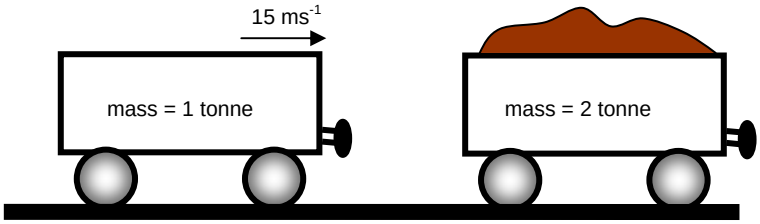
1 mark

kg

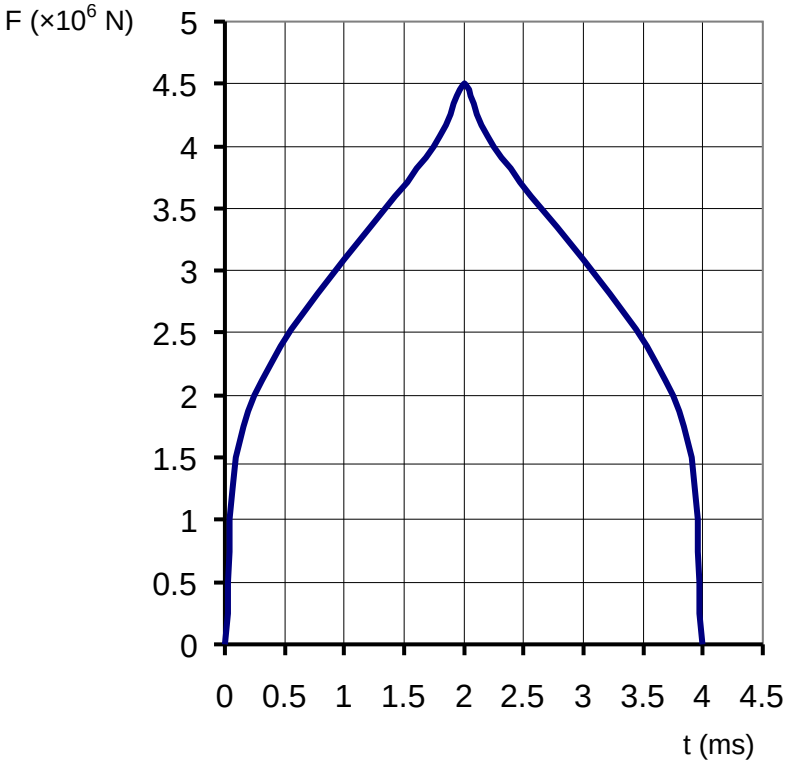
Questions 7 - 10 refer to the following information:

An empty rail car travelling at a constant speed of 15 ms^{-1} to the right and mass of 1 tonne collides with a stationary rail car loaded with sand, such that its mass is 2 tonne, as shown in Figure 3 below. Both rail cars are identical when not carrying a load and have a buffer bar at the front which behaves like a ideal spring. Upon the collision the buffer bar contracts by 5 cm.

Figure 3



Graph of the force applied by the empty rail car over time during the collision.



QUESTION 7
Show the spring constant is 9×10^7 Nm^{-1} at maximum contraction.
You must show all working.

2 marks

QUESTION 8
Determine the impulse of the empty rail car during the collision.

3 marks

Ns

QUESTION 9
After the collision, the loaded rail car travels at a speed of 6 ms^{-1} to the right. Determine the speed and direction of the **empty** rail car after the collision.

3 marks

Magnitude ms^{-1}

Direction

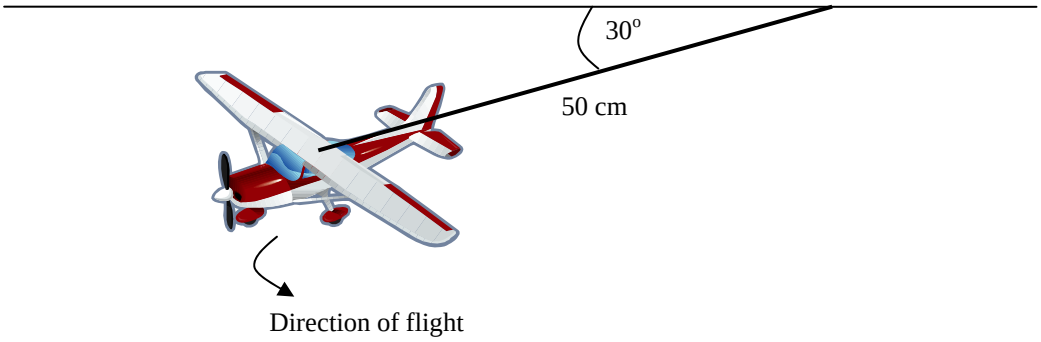
QUESTION 10
If the rail cars were **coupled** together after their collision, would the collision have been elastic or inelastic? *Use calculations to support your answer.*

3 marks

Questions 11 - 13 refer to the following information:

A toy plane is attached to the ceiling by a light string of 50 cm in length. When turned on, the plane flies in a circle with a frequency of 0.5 Hz and the string makes an angle of 30^o to the ceiling. A diagram of the toy plane during flight is shown below in Figure 4.

Figure 4



QUESTION 11
Determine the acceleration of the plane.

3 marks

ms^{-2}

QUESTION 12
If the tension in the string is 2 N, determine the mass of the toy plane.

2 marks

kg

QUESTION 13
Which one of the following directions (A-D) best describes the direction of the **change in velocity** of the plane shown in Figure 4?

A. Along the string.
B. Into the page.
C. Out of the page.
D. To the centre of the circle.

2 marks

Questions 14 to 16 refer to the following information:

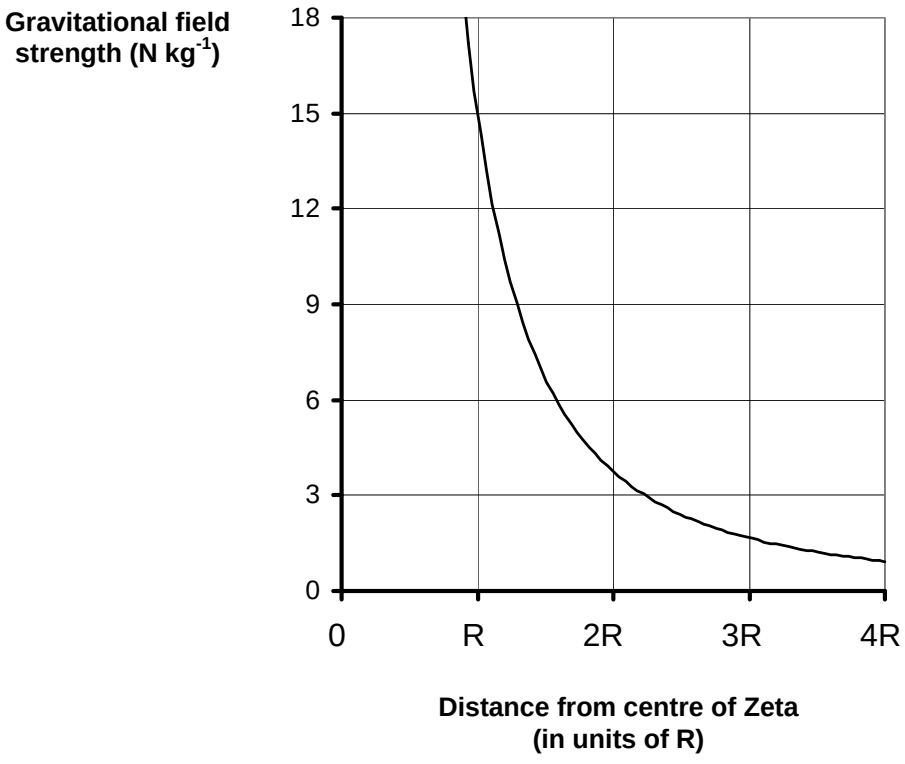
A satellite is being prepared for take-off on the surface of the fictitious planet Zeta. The planet Zeta has a radius of *R* and the satellite experiences a gravitational force, *F*, from the planet at the surface. A single moon, Eta, completes one orbit of the planet every 50 days at a distance of 5*R* from the centre of the planet.

The satellite is now placed into orbit 2*R* from the surface of the planet.

QUESTION 14

In terms of *F*, show that the gravitation force now experienced on the satellite is $\frac{1}{9}F$.

2 marks



QUESTION 15
Determine the work per unit mass done against the force of gravity by the satellite to reach its orbit in terms of *R.*

3 marks

J kg^{-1}

QUESTION 16
Determine the period of the satellite.

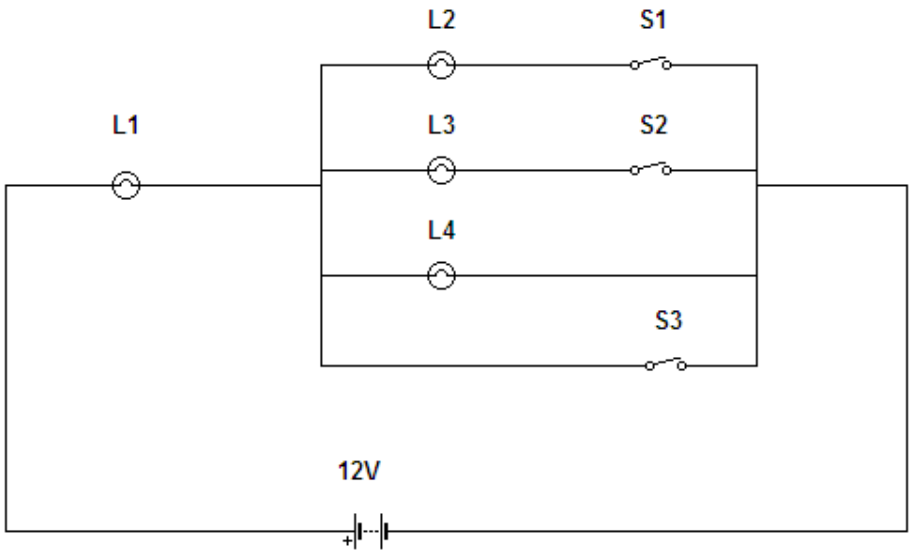
2 marks

days

End of Section on Motion in One and Two Dimensions

AREA OF STUDY 2: ELECTRONICS AND PHOTONICS

QUESTION 1
The following circuit consists of four identical lamps (L1 to L4) and three switches (S1 to S3) in an arrangement with a 12 volt battery.



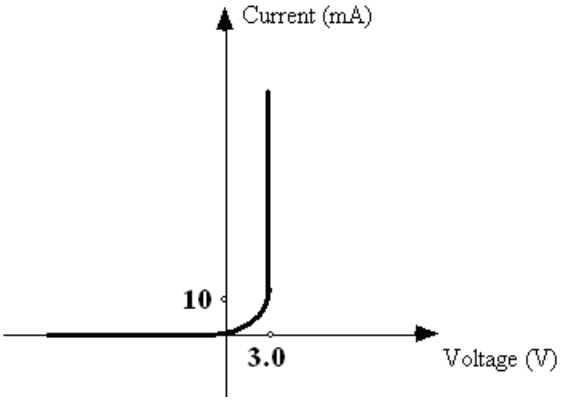
Which combination of switch positions would give the brightest illumination for **L4** ?

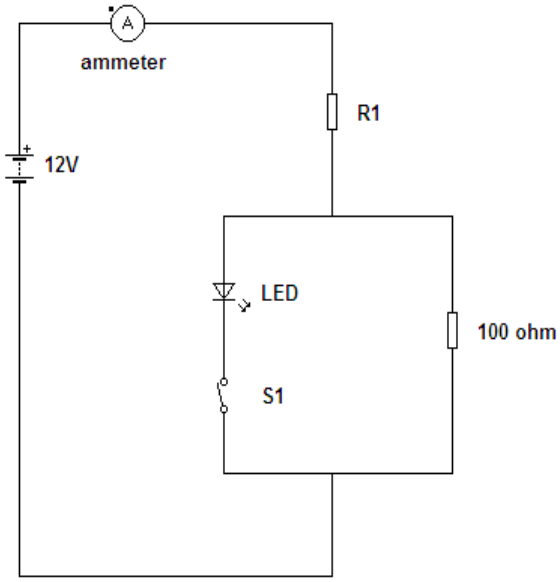
A. S1 and S2 closed, S3 open
B. S1 closed, S2 and S3 open
C. S1, S2 and S3 closed
D. All switches open

2 marks

The following information refers to Questions 2 to 5:

Voltage – current characteristics
for the light emitting diode.





QUESTION 2
With switch S1 closed, what is the potential difference across the light emitting diode (LED)?

1 mark

V

QUESTION 3
With switch S1 closed, what value for resistor R1 would produce a current of 45 mA through the ammeter?

2 marks

ohms

QUESTION 4
With switch S1 closed, what current flows through the light emitting diode?

_____

_____

_____

_____

_____

_____

2 marks

mA

QUESTION 5
With switch S1 open, what current flows through the ammeter?

_____

_____

_____

_____

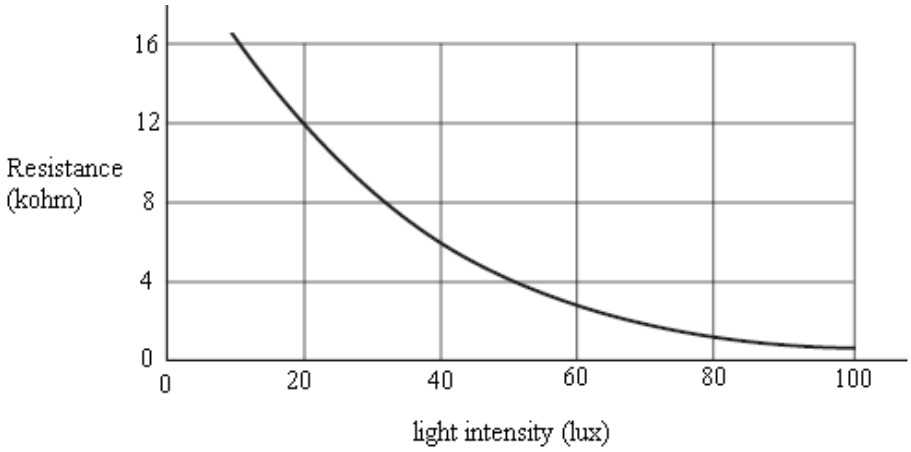
_____

2 marks

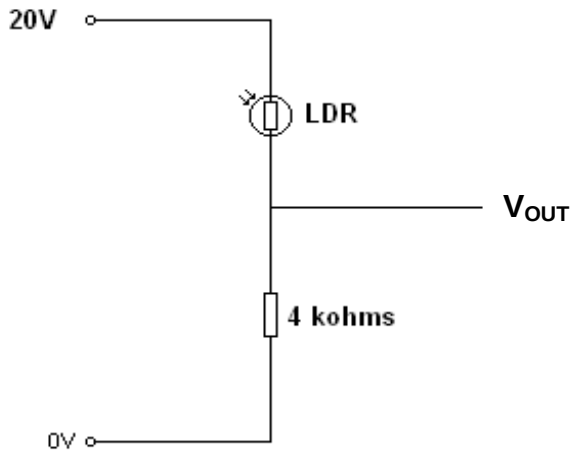
mA

The following information refers to Questions 6 to 8:

A light dependent resistor (LDR) has the characteristics shown below:



The LDR is arranged in a voltage divider as shown.



QUESTION 6

What is the resistance of the LDR when the light level is 40 lux?

1 mark

kohms

QUESTION 7
What is V_{OUT} when the light level is 40 lux?

_____

_____

_____

_____

_____

_____

2 marks

V

QUESTION 8
As light levels drop from 40 lux to 10 lux, by how much does V_{OUT} change? Show your working.

_____

_____

_____

_____

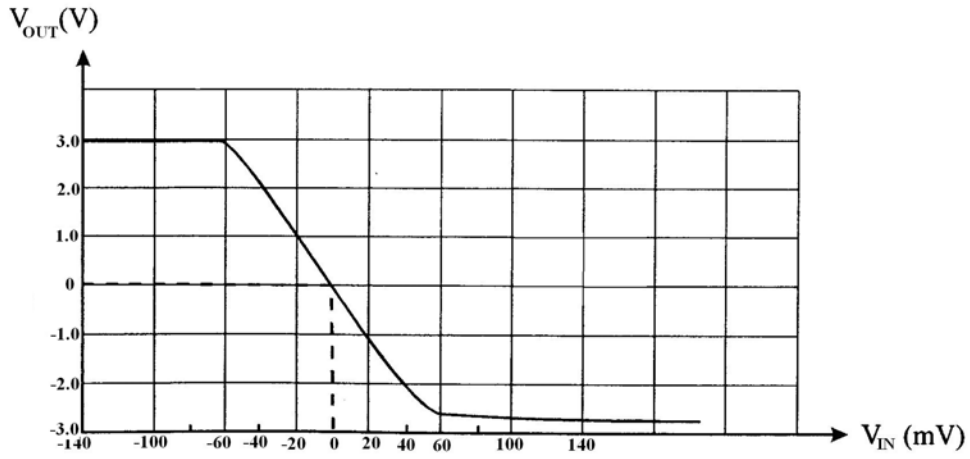
_____

2 marks

V

The following information applies to Questions 9 to 12:

The following is the V_{IN} versus V_{OUT} transfer characteristic for a voltage amplifier.



QUESTION 9
What is the voltage gain of this amplifier?

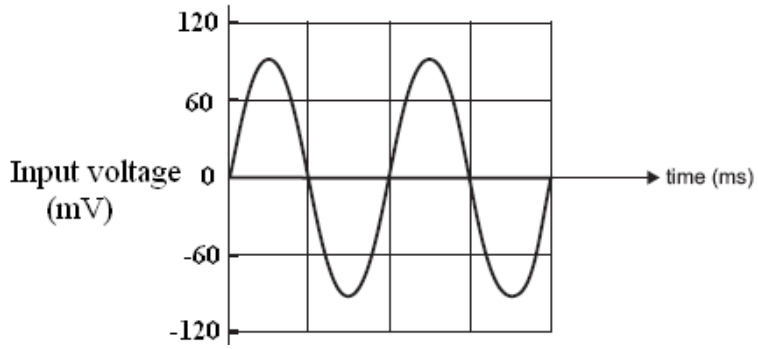
2 marks

QUESTION 10
What is V_{OUT} when V_{IN} is -40 mV?

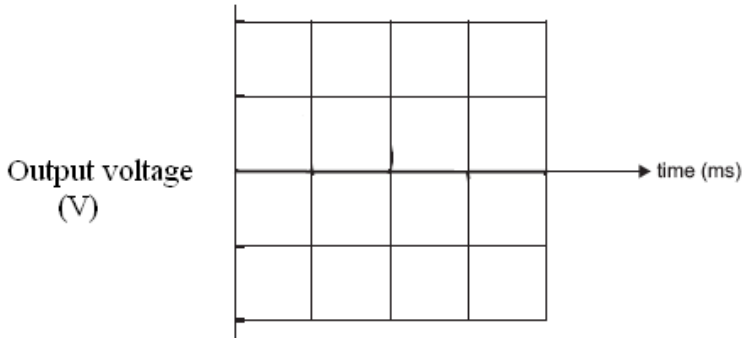
1 mark

V

The AC input signal to the transistor amplifier is shown below

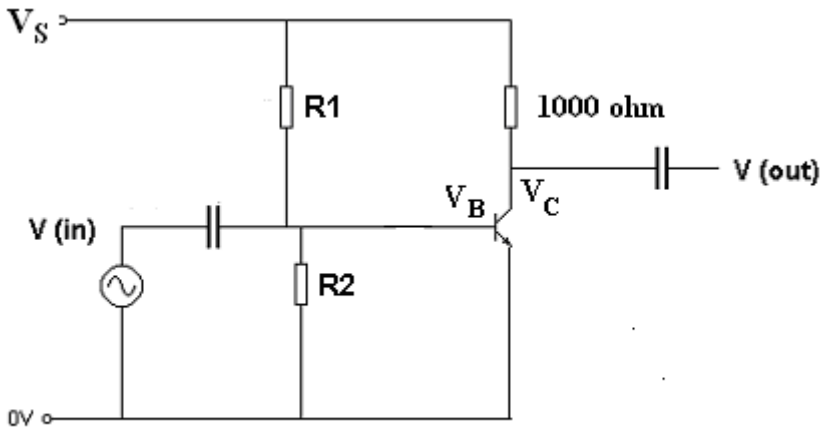


QUESTION 11
On the axes drawn below, draw the corresponding output voltage (V_{OUT}).



3 marks

The actual circuit for the voltage amplifier is shown below:



Voltage amplifier circuit

The transistor circuit has a **current gain** of 100.

QUESTION 12
What is the change in V_{OUT} when there is a peak to peak variation in current to the base of the transistor of 10 μ A?

_____

_____

_____

_____

2 marks

V

QUESTION 13
Briefly describe TWO benefits in using laser diodes, rather than light emitting diodes, as the light source in optical fibre digital communication.

_____

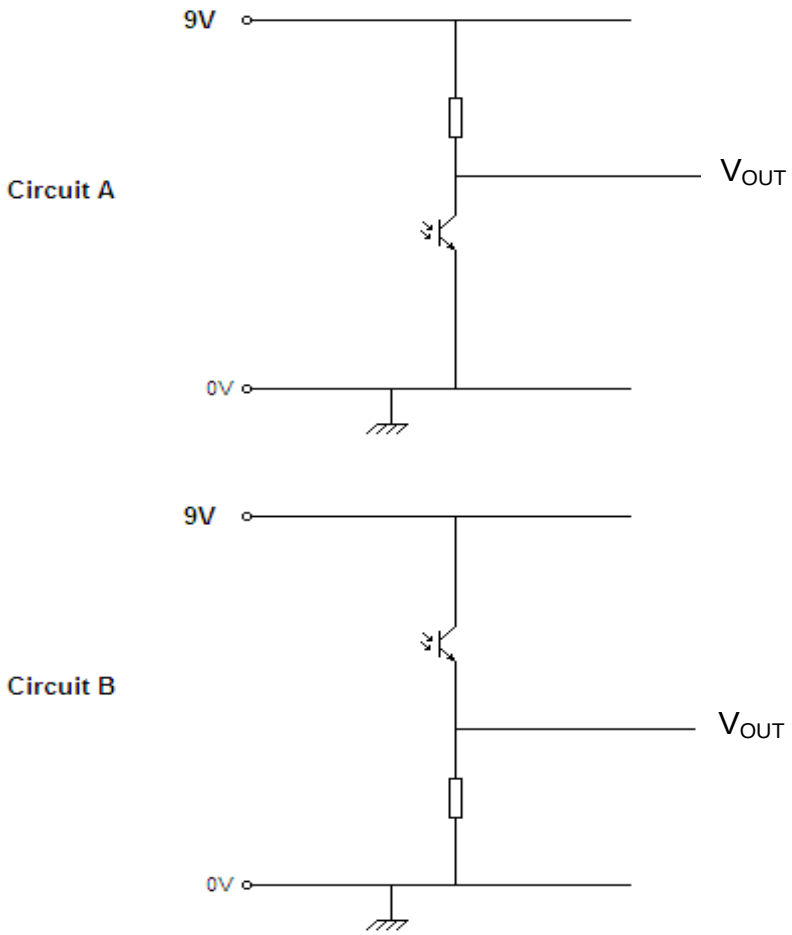
_____

_____

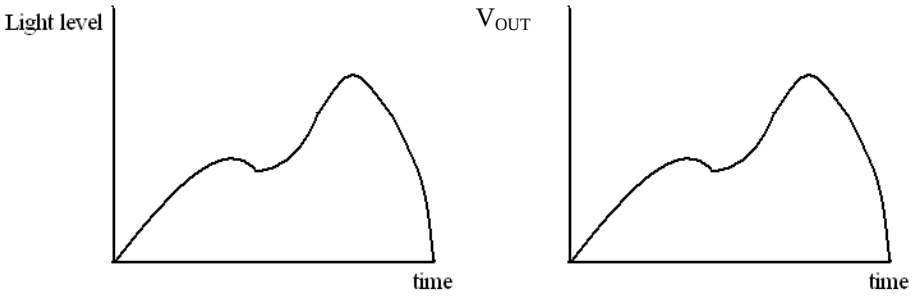
_____

2 marks

QUESTION 14
The following shows two possible arrangements for obtaining an output voltage from a phototransistor.



Light is incident upon a phototransistor. Changing light levels from **ONE** of the above circuits results in a time-varying voltage measured at V_{OUT} as shown below.



Which circuit, A or B, would best produce a time-varying voltage that mirrors changes to light levels? Explain your choice.

_____

_____

_____

_____

_____

_____

_____

_____

3 marks

End of Electronics and Photonics Section

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.

DETAILED STUDY 1 – EINSTEIN'S SPECIAL RELATIVITY

QUESTION 1
Which of the following answers (A-D) best describes an **inertial reference frame** relative to the Earth?

A. A school laboratory.
B. A spaceship taking off into space.
C. A car turning a corner at a constant speed.
D. A bike rider coming to a stop.

2 marks

QUESTION 2
Galileo and Newton presented a principle of relativity centuries before Einstein developed his postulates. Which **one or more** of the following statements (A-D) demonstrates how Einstein's theory differed from Newton's?

A. The laws of physics are the same for all inertial reference frames.
B. Speed of light is the same for all inertial reference frames.
C. There is an absolute velocity.
D. There is no absolute velocity.

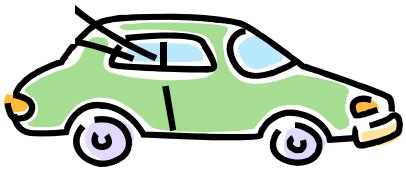
2 marks

QUESTION 3
The Michelson-Morley experiment was one of many designed to determine the absolute velocity of the Earth. Which one of the following statements (A-D) best describes the findings according to Michelson and Morley?

A. The ether does exist.
B. The ether does not exist.
C. There was a shift in the interference pattern.
D. There was no shift in the interference pattern.

2 marks

QUESTION 4
A car is traveling at a constant speed of 60 kmh^{-1} South. A motorcycle is travelling at a constant speed of 70 kmh^{-1} North as shown below.



Which of the following velocities (A-D) is the velocity of the car relative to the motorcycle?

A. 60 kmh^{-1} South
B. 10 kmh^{-1} North
C. 130 kmh^{-1} South
D. 130 kmh^{-1} North

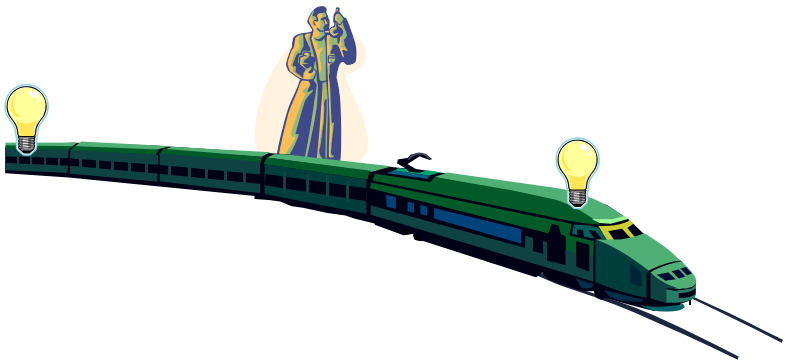
2 marks

QUESTION 5
Which of the following distances (A-D) represents 3.5 light years in meters?

A. 3.5 m
B. 1.1×10^{9} m
C. 3.8×10^{11} m
D. 3.3×10^{16} m

2 marks

QUESTION 6
A student is observing a train go by at a relativistic speed. Just as the centre of the train passes the student, two lights (one at the front of the train and one at the rear) turn on simultaneously.



A passenger sitting at the centre of the train also saw the lights turn on. Which of the following (A-D) will occur according to the passenger on the train?

A. Both lights will turn on at the same time.
B. The rear light will turn on before the front light.
C. The front light will turn on before the rear light.
D. Only the rear light will be seen to turn on.

2 marks

The following information applies to Questions 7 to 10:

Muons are subatomic particles created at the top of the Earth's atmosphere and have a lifetime of just 2.2×10^{-6} s. Due to their high speeds and relativity, many of these muons reach the surface of the Earth in their short lifetime. Consider a muon travelling at $\frac{9}{10}$ of the speed of light.

QUESTION 7
Which of the following values (A-D) best estimate the value of γ for the muon?

A. 0.44
B. 2.3
C. 3.2
D. 5.3

2 marks

QUESTION 8
Which of the following times (A-D) best estimates the lifetime of a muon according to an observer on Earth?

A. $9{,}5 \times 10^{-7}$ s
B. 2.2×10^{-6} s
C. 5.1×10^{-6} s
D. 1.0×10^{6} s

2 marks

QUESTION 9
The distance covered by the muons during their lifetime as perceived by an observer on Earth can be represented by *L*. Which of the following equations (A-D) represents the distance travelled as perceived by the muons?

A. $L\left(\sqrt{1-\frac{v^2}{c^2}}\right)$

B. $\frac{L}{\sqrt{1-\frac{v^2}{c^2}}}$

C. $\frac{\sqrt{1-\frac{v^2}{c^2}}}{L}$

D. $\frac{1}{L\left(\sqrt{1-\frac{v^2}{c^2}}\right)}$

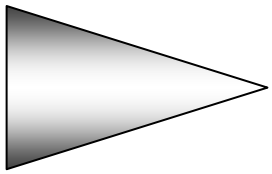
2 marks

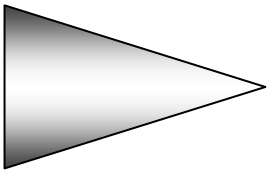
QUESTION 10
Which of the following statements (A-D) is true of how length and time are perceived by the muons and observers on Earth?

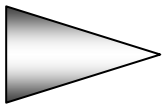
	Muons	**Earth observer**
A.	Length contracted	Proper time
B.	Proper length	Proper time
C.	Length contracted	Time dilated
D.	Proper length	Time dilated

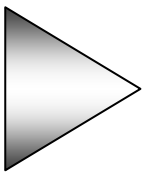
2 marks

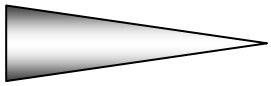
QUESTION 11
A triangular spaceship is travelling past the Earth at a relativistic speed. The spaceship is shown in the diagram to the right at rest. Which of the following diagrams (A-D) best represents the shape of the spaceship as seen by an observer on Earth as it flies by?



A. 

C. 

B. 

D. 

2 marks

The following information applies to Questions 12 and 13:

An electron is travelling at a relativistic speed of 0.999 times the speed of light. The rest mass of an electron is 9.1×10^{-31} kg.

QUESTION 12
Which of the following masses (A-D) best represents the relativistic mass of the electron?

A. 4.1×10^{-32} kg
B. 2.5×10^{-31} kg
C. 9.1×10^{-31} kg
D. 2.0×10^{-29} kg

2 marks

QUESTION 13
Which of the following energies (A-D) best represents the rest energy of the electrons in Joules?

A. 1.0×10^{-47} J
B. 2.7×10^{-22} J
C. 8.2×10^{-14} J
D. 9.9×10^{46} J

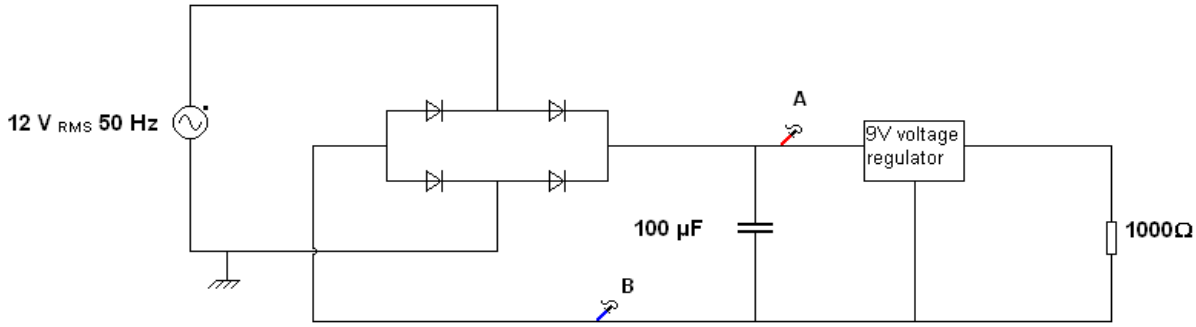
2 marks

End of Einstein's Special Relativity Section

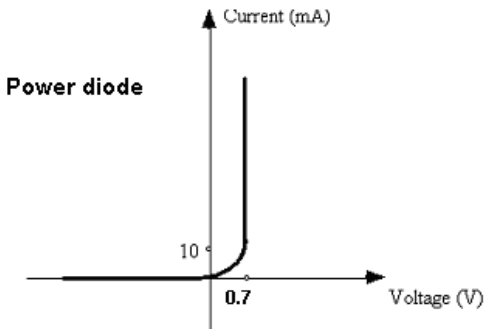
DETAILED STUDY 2 – FURTHER ELECTRONICS

The following information applies to Questions 1 to 7:

The following circuit is designed to provide a constant 9V DC supply to a 1000Ω load.



The diode characteristics are shown below:



QUESTION 1

A transformer is to be used to reduce the 240VRMS AC supply to the required value.

What is the value of the ratio $\frac{\text{number of primary coils}}{\text{number of secondary coils}}$?

A. 0.05
B. 4.8
C. 20
D. 27

2 marks

QUESTION 2
The function of the IC voltage regulator is to (one or more correct statements):

A. Maintain constant voltage across a load despite small changes to V_{AC}.
B. Maintain constant voltage across a load despite changes to the load's resistance.
C. Ensure all power from the supply is dissipated across the load.
D. Produce a constant voltage across the load that is determined by the voltage of the AC supply.

2 marks

QUESTION 3
Which of the following is the best representation for the current through the 1000Ω load?

A. 9 mA
B. 12 mA
C. 17 mA
D. 100 mA

2 marks

QUESTION 4
The peak voltage received at the voltage regulator would be closest to:

A. 10.4 V
B. 12.0 V
C. 15.6 V
D. 16.3 V
E. 17.0 V

2 marks

QUESTION 5
When a cathode ray oscilloscope was placed across **points A and B** the $V_{peak\text{-}peak}$ ripple was determined to be 3.0 V. Which of the following alternatives best represents the average power dissipated across the voltage regulator?

A. 20 mW
B. 46 mW
C. 65 mW
D. 140 mW

2 marks

QUESTION 6
The load resistance of the illustrated circuit is reduced to 100 Ω and the smoothing capacitor is increased to 500 µF. Which of the following is the best representation of the change to $V_{peak\text{-}peak}$ ripple?

A. Inceases by $\sqrt{2}$
B. Reduces by $\sqrt{2}$
C. Halves
D. Doubles

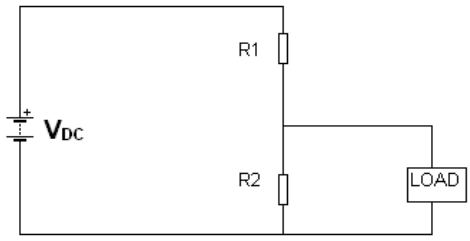
2 marks

QUESTION 7
A **new** smoothing capacitor is to be selected so that its discharging time constant is five times the period of the supply to it. An appropriate value for the smoothing capacitor would be:

A. 50 µF
B. 100 µF
C. 50 mF
D. 100 mF

2 marks

QUESTION 8



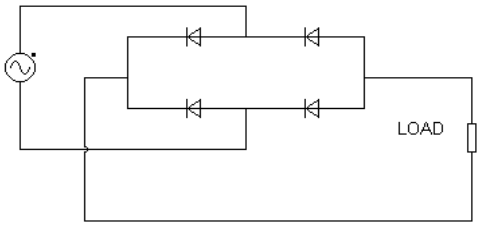
A voltage divider is used to provide a DC voltage to a LOAD of a value less than the DC supply. The potential across the LOAD is **NOT** an example of a regulated DC power supply because (one or more correct statements):

A. The resistances of R1 and R2 may be too low.
B. Changes to load resistances causes changes of potential difference across the load.
C. Small changes to V_{DC} causes small changes to the voltage across the load.
D. Only a portion of the current passing through V_{DC} passes through the load.

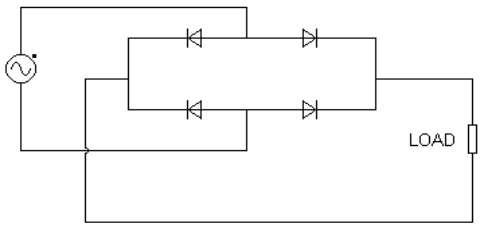
2 marks

QUESTION 9

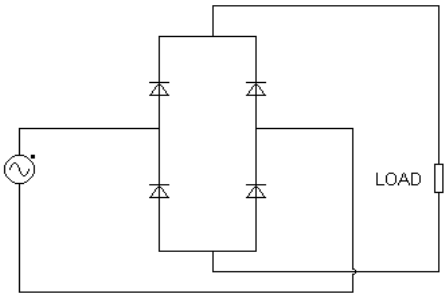
CIRCUIT A



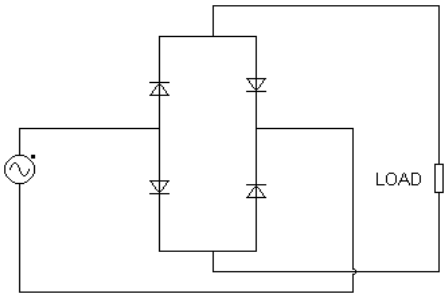
CIRCUIT B



CIRCUIT C



CIRCUIT D



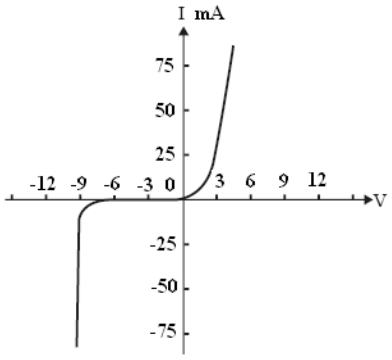
In which **one or more** of the circuits drawn above would the arrangement of diodes provide a full wave rectified voltage to the load?

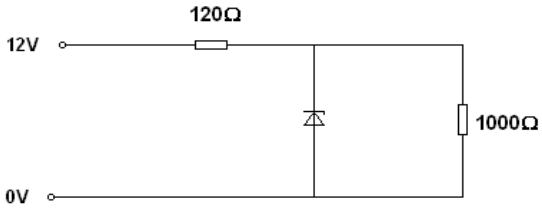
A. Circuit A
B. Circuit B
C. Circuit C
D. Circuit D

2 marks

The following information applies to Questions 10 and 11:

The following graph shows the voltage – current characteristics for a zener diode as well as a circuit in which it is incorporated.



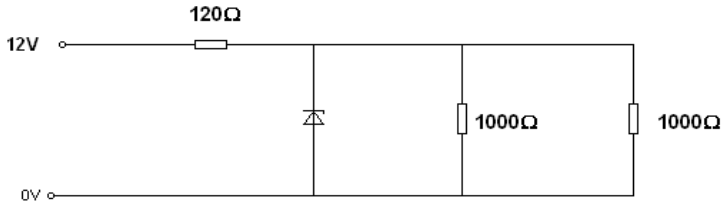


QUESTION 10
What would be the value of the potential difference across the 1000 Ω resistor?

A. 0 V
B. 3 V
C. 9 V
D. 12 V

2 marks

QUESTION 11
Another 1000 Ω resistor is added parallel to the original 1000 Ω resistor as shown.

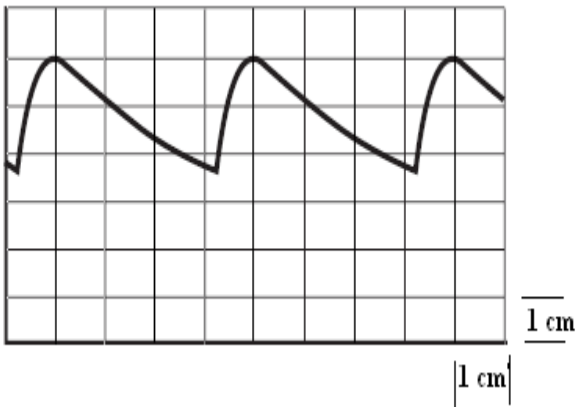


The current that passes through the 120 Ω resistor is now

A. More than before
B. Less than before
C. The same as before

2 marks

QUESTION 12
The following diagram is the view on the screen of a cathode ray oscilloscope which is connected across a filtered and rectified power supply.



The voltage adjustment of the cathode ray oscilloscope is set at 2.0 Vcm^{-1}
The time sweep adjustment is set at 10ms cm^{-1}.

The frequency of the power supply is:

A. 8 Hz
B. 25 Hz
C. 50 Hz
D. 100 Hz

2 marks

QUESTION 13
Which **one or more** of the following are correct statements about cathode ray oscilloscopes?

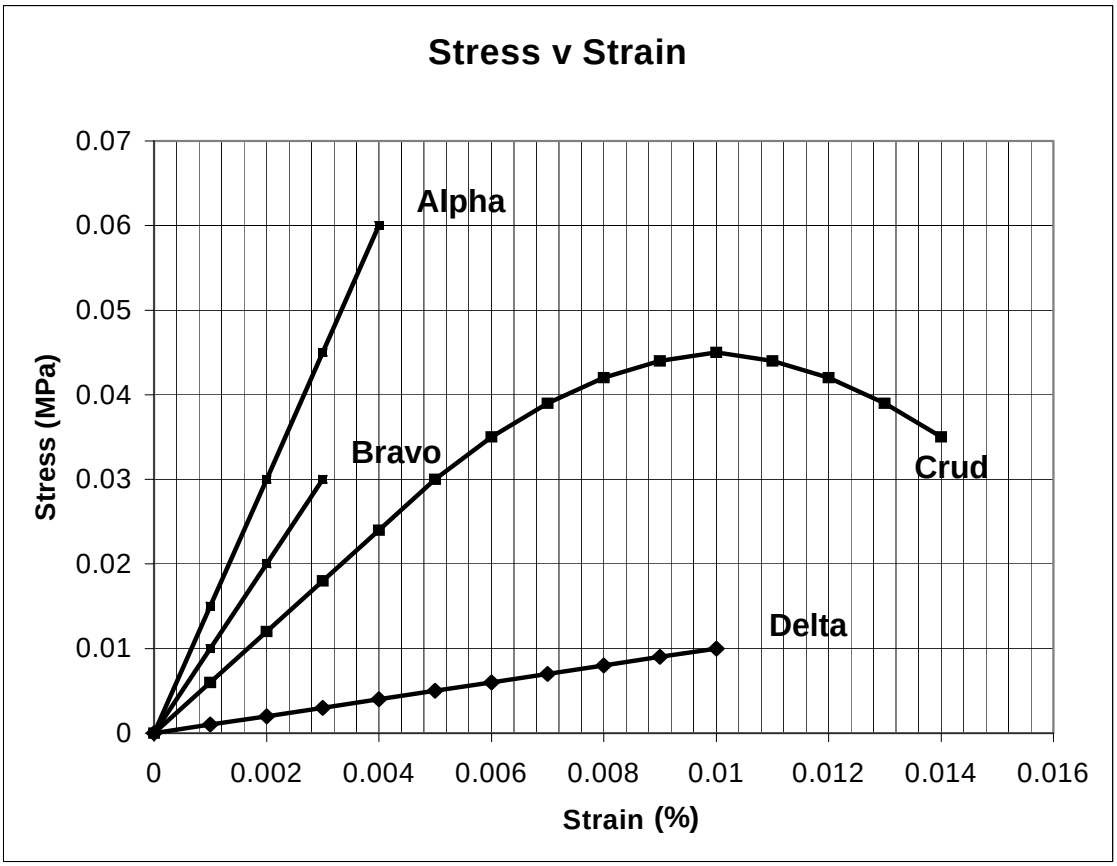
A. It is a type of ammeter with a time scale.
B. It is a type of voltmeter with a time scale.
C. Has a low resistance that enables it to be arranged in parallel across a component.
D. Can be used to measure the resistance of a component.

2 marks

End of Further Electronics Section

DETAILED STUDY 3: MATERIALS AND STRUCTURES

Questions 1 to 6 refer to the following stress-strain graph for four different materials; Alpha, Bravo, Crud and Delta, all extended to their respective point of fracture:



QUESTION 1
Which material (A, B, C or D) would be considered to be the stiffest?

A. Alpha
B. Bravo
C. Crud
D. Delta

2 marks

QUESTION 2
Which material (A, B, C or D) would be considered to be the toughest?

A. Alpha
B. Bravo
C. Crud
D. Delta

2 marks

QUESTION 3
The Young's Modulus for material Bravo is closest to:

A. 10 Pa
B. 1×10^3 Pa
C. 1×10^5 Pa
D. 1×10^7 Pa
E. 1×10^9 Pa

2 marks

QUESTION 4
Which material (A, B, C or D) would be considered to be the most brittle?

A. Alpha
B. Bravo
C. Crud
D. Delta

2 marks

QUESTION 5
Two samples of material Delta are found to differ in volume. Which of the following properties will NOT be the same for both samples when taken to the point of fracture?

A. their "stiffness".
B. the amount of energy absorbed by each.
C. the area under the stress-strain graph for each.
D. the energy absorbed per volume for each.
E. their Young's modulus.

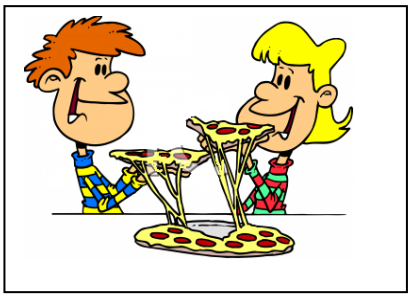
2 marks

QUESTION 6
Given that material Alpha is in the shape of a 2 m long cylinder of radius 20 cm, what work had to be done to extend material Alpha to the point of fracture?:

A. 0.60 J
B. 6.0 J
C. 60 J
D. 600 J
E. 6000 J

2 marks

QUESTION 7
In the picture below, two children are eating pizza and enjoying the stringy mozzarella cheese.



Which of the following properties is being exhibited by the cheese in this picture?

A. malleability
B. ductility
C. rigidity
D. compressive strength
E. brittleness

2 marks

QUESTION 8
Which of the following is **NOT** a composite material?

A. iron
B. steel
C. pre-stressed concrete
D. reinforced concrete
E. mud & straw bricks

2 marks

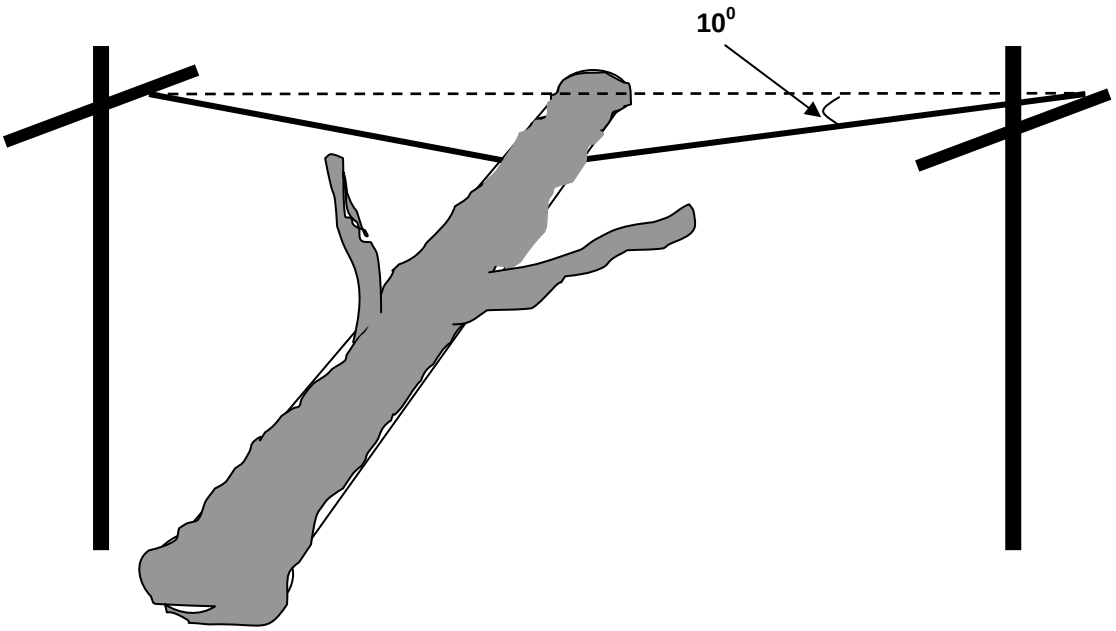
QUESTION 9
For an object or structure to be in "static equilibrium" it must:

A. be in stable equilibrium in each of the three dimensions.
B. have a stationary centre of mass.
C. have a net force of zero acting on it in each of the three dimensions.
D. be in both translational equilibrium and rotational equilibrium.
E. be in either translational equilibrium or rotational equilibrium.

2 marks

Questions 10 to 13 refer to the following information:

Due to a storm a tree trunk falls across a power cable. The weight on the cable is the equivalent of 8000 N and it acts on the mid-point of the cable, half way between two power poles where the cable remains attached. The cable has a diameter of 8 mm and is normally 40 m long. Its normal position is indicated by a dotted line and the stretched cable makes an angle of 10^0 with its original position at BOTH poles.



QUESTION 10
Which of the following is closest to the new length of the stretched cable?

A. 40.21 m
B. 40.31 m
C. 40.42 m
D. 40.62 m

2 marks

QUESTION 11
What statement best describes one of the power poles?

A. a horizontal cantilever experiencing shear stress.
B. a horizontal cantilever experiencing tensile stress.
C. a vertical cantilever experiencing shear stress.
D. a vertical cantilever experiencing compressive stress.

2 marks

QUESTION 12
Which of the following is closest to the tension in the cable?

A. 20 kN
B. 21 kN
C. 22 kN
D. 23 kN

2 marks

QUESTION 13
Which of the following is closest to the Young's Modulus for the material of the cable?

A. 1.0×10^{10} Pa
B. 2.0×10^{10} Pa
C. 3.0×10^{10} Pa
D. 4.0×10^{10} Pa

2 marks

End of Structures and Materials Section

End of Paper