THE SCHOOL FOR EXCELLENCE (TSFX)

UNIT 3 PHYSICS 2010

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	18	18	37
	Electronics and Photonics	16	16	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

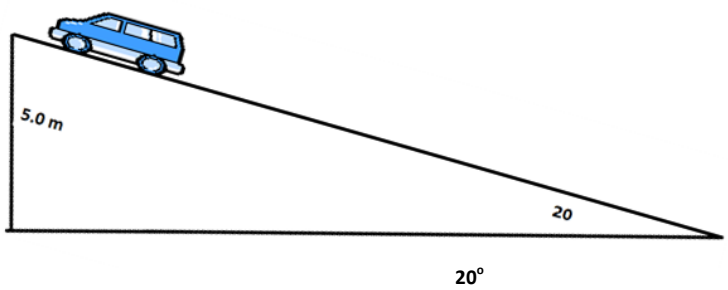
Instructions For Section A

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 3 refer to the following information:

A 1000 kg car is parked on a 20° incline.



QUESTION 1
What is the magnitude of the normal reaction force exerted on the car?

2 marks

N

QUESTION 2
The handbrake fails to completely hold and the car begins to roll downhill. By the time the car has reached the bottom of the hill it has gained a speed of 6.0 ms^{-1}. How much work has been done by friction on the vehicle?

2 marks

J

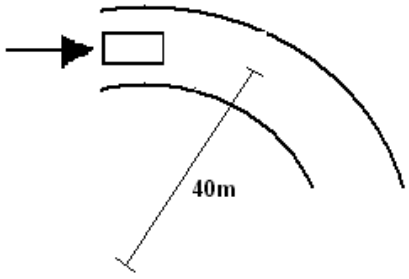
QUESTION 3
What is the average frictional force exerted on the car?

2 marks

N

Questions 4 to 6 refer to the following information:

A 1.2 tonne car is travelling around a bend in the road as shown below. The car is moving at a constant speed in a circular path of radius 40 m, and the road surface is horizontal.



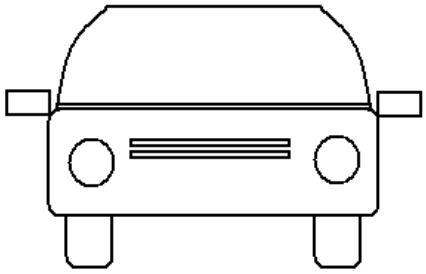
QUESTION 4
What force must be exerted by the road in order for the car to safely travel around the bend at 20 ms^{-1}?

2 marks

N

QUESTION 5
The diagram below depicts the front of the vehicle as it is travelling around the bend of the road. Draw labelled arrows on the diagram to show all the forces acting on the car.

3 marks



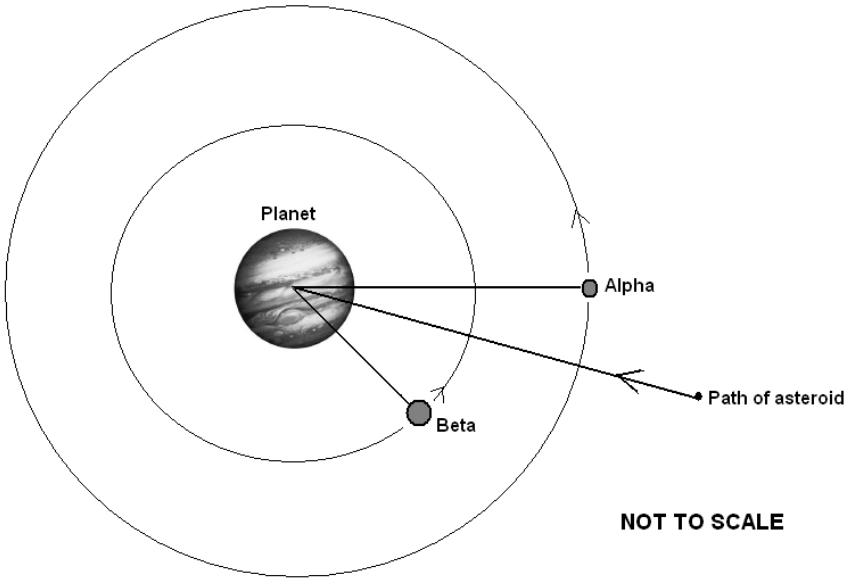
QUESTION 6
Because many cars fail to take the bend safely and skid off the road, engineers decide to bank the road for a design speed of 15 ms^{-1}. At this speed there would be no sideways frictional force necessary for the car to travel around the bend. Determine the angle that the road should be banked.

2 marks

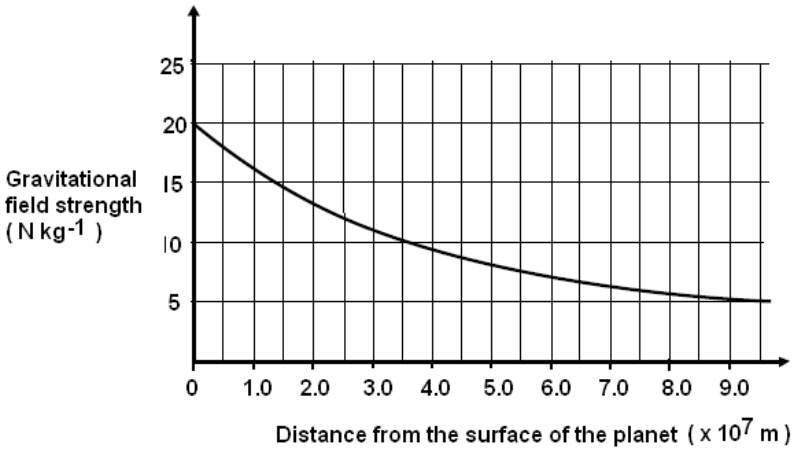
degrees

Questions 7 to 13 refer to the following information:

A planet discovered outside our Solar system was found to have a number of moons in circular orbit around it. Two of these moons were named Alpha and Beta. A 24 tonne asteroid was also observed on a collision course with the planet.



The following graph shows the gravitational field above the surface of the planet.



QUESTION 7
What is the gravitational field strength at an altitude of 9.5×10^7 m above the planet's surface?

1 mark

	N kg^{-1}

QUESTION 8
As the 24 tonne asteroid passes the orbit of Alpha it has an altitude of 9.5×10^7 m and a velocity of 3.6×10^3 ms^{-1}. What is the kinetic energy of the asteroid?

2 marks

	J

QUESTION 9
What energy transformation occurs as the asteroid approaches the surface of the planet?

1 mark

QUESTION 10
Determine the gain in kinetic energy of the asteroid as it moves from an altitude of 9.5×10^7m to the point where it impacts the planet's surface.

3 marks

	J

QUESTION 11
What will be the speed of the asteroid as it slams into the surface of the planet?

2 marks

	m s^{-1}

Below is astronomical data that may be used in Question 12:

The orbital radius of Alpha's orbit is 1.9×10^8 m.
Mass of planet = 2.7×10^{27} kg

QUESTION 12
Determine the period of Alpha's orbit.

2 marks

	s

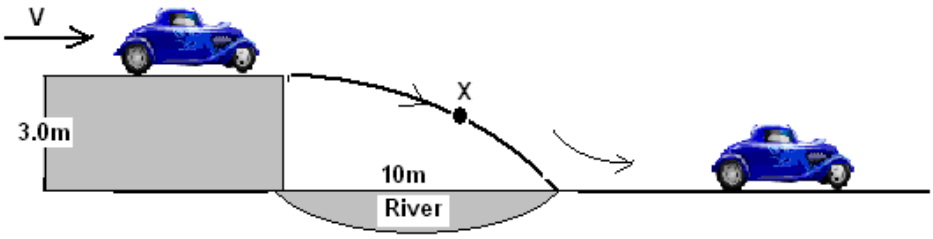
QUESTION 13
This question considers the orbital speeds of the planet's moons. Select the *best* alternative:

A. The speed of Alpha is greater than the speed of Beta.
B. The speed of Alpha is less than the speed of Beta.
C. Alpha and Beta will have similar speeds.
D. It is not possible to determine the relative speeds as the mass of the moons has not been provided.

2 marks

Questions 14 to 18 refer to the following information:

A car travelling at V ms^{-1} drives off a 3.0 m high horizontal ramp in order to jump across a 10 m river. Ignore the effects of wind resistance in this problem. The mass of the car is 1200 kg, and the mass of the driver is 80 kg.

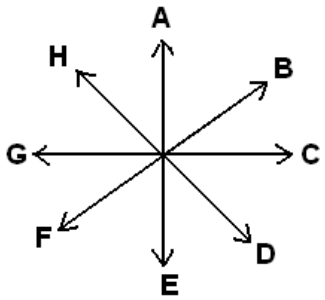


QUESTION 14
Calculate the minimum speed that the car should leave the ramp in order to land on the road across the river.

3 marks

m s^{-1}

QUESTION 15
Write the letter for the arrow that best represents the net force acting on the car at point 'X'.



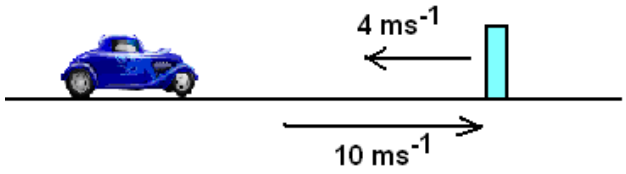
2 marks

QUESTION 16
Assume the car leaves the ramp with a speed of 13 ms^{-1}. What is the magnitude of the velocity of the car as it impacts the road on the other side of the river?

2 marks

m s^{-1}

After crossing the river, the car travelling at 10 ms^{-1} collides into a flexible safety barrier and rebounds at 4 ms^{-1}. The period of the impact of the car with the safety barrier was 0.4 seconds.



QUESTION 17
Determine the average force acting on the **driver** during the impact with the safety barrier.

2 marks

N

QUESTION 18
Was the collision with the safety barrier elastic or inelastic? Justify your answer.

2 marks

End of Section on Motion in One and Two Dimensions

AREA OF STUDY 2: ELECTRONICS AND PHOTONICS

Questions 1 to 4 refer to the following information:

Matthew has only four **10 Ω** resistors available.

QUESTION 1
Determine the maximum resistance Matthew can create using these four resistors.

Ω

1 mark

QUESTION 2
Determine the minimum resistance Matthew can create using these four resistors.

Ω

1 mark

QUESTION 3
Which of the following effective resistances **cannot** be created using all four of the resistors?

A. 6.7Ω
B. 10.0 Ω
C. 13.3 Ω
D. 25.0 Ω

2 marks

Matthew now replaces **one** of the **10 Ω** resistors with a **20 Ω** resistor.

QUESTION 4
Determine the maximum current Matthew can now draw from a 12 V battery when all four resistors are simultaneously in a circuit.

A

2 marks

Questions 5 to 8 refer to the following information:

Emily is designing a circuit to function as a warning system on her campsite refrigerator. Her circuit will consist of a thermistor, an LED and a variable voltage supply V_s as shown in Figure 1.

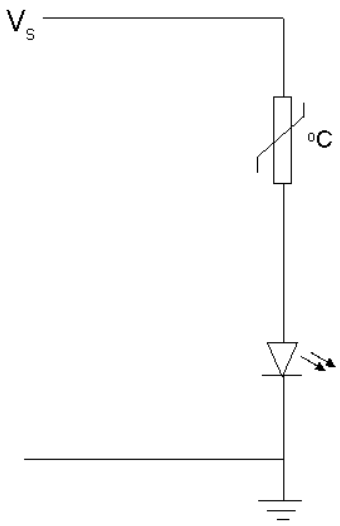


Figure 1

The characteristic curves for the thermistor and the LED are shown in Figures 2 and 3 respectively.

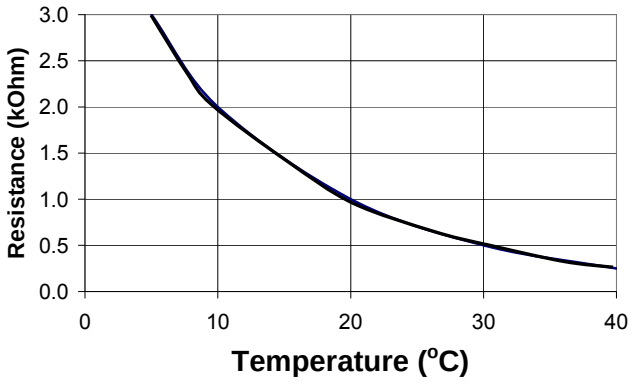


Figure 2

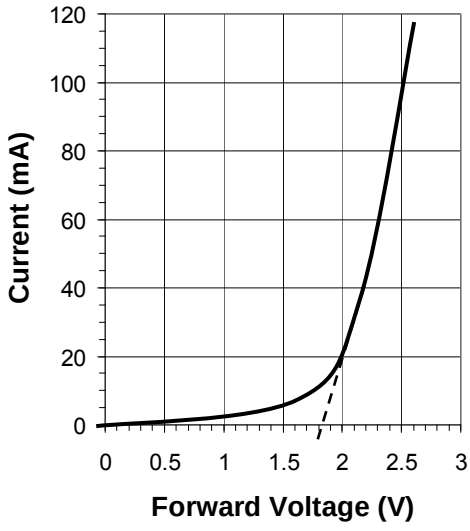


Figure 3

QUESTION 5

Determine the resistance of the thermistor (in kΩ) when the temperature is 10°C.

kΩ

1 mark

QUESTION 6
Determine the threshold voltage for the LED.

V

1 mark

Emily sets the supply voltage at 25.8 V.

QUESTION 7
Determine the current in the LED when the temperature is 10^{o}C.

mA

2 marks

The current needs to be at least 10 mA to ensure the LED is visible and it should be visible when the temperature rises above 10^{o}C.

QUESTION 8
Will Emily's circuit work as she intends? Provide reasons for your answer.

3 marks

QUESTION 9
Which of the following is most likely to be referred to as an "ohmic device"?

A. A diode.
B. A resistor.
C. A thermistor.
D. A light dependent resistor.

1 mark

QUESTION 10
Which of the following is most likely to respond as an "ohmic device" when all variables other than voltage and current are kept constant?

A. A diode.
B. An incandescent light globe.
C. A light emitting diode.
D. A light dependent resistor.

2 marks

Questions 11 and 12 refer to the following information:

A security system includes a 15 V battery, an alarm (resistance: R_A) and a photodiode as shown in Figure 4. The current–voltage characteristics for the photodiode are shown in Figure 5. The intensity of the incident light (units: W/m^2) can be varied and the resulting photodiode current is found to be proportional to the intensity of incident light. The alarm requires a potential difference of at least 6.0 V across it before it is considered adequately audible.

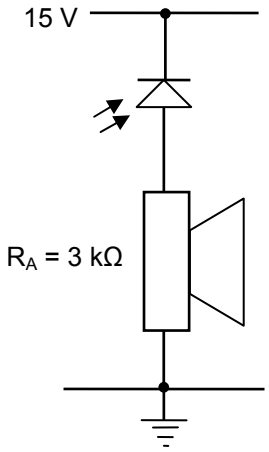


Figure 4

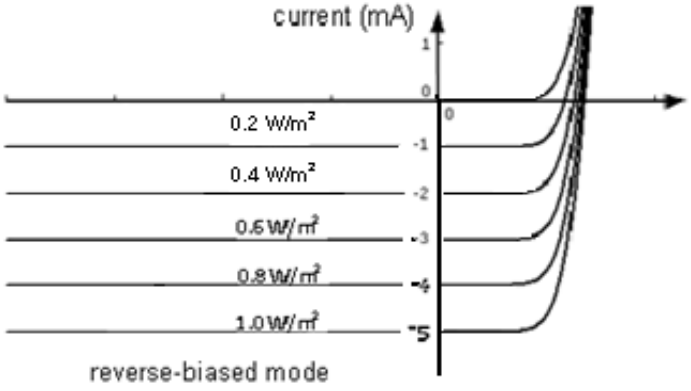


Figure 5

QUESTION 11
Estimate the light intensity required to make the alarm adequately audible.

W/m^2

2 marks

QUESTION 12
Over time, the voltage of the battery reduces to 11 V. At this time, what will be the minimum light intensity that the alarm can adequately respond to?

	W/m^2

1 mark

Questions 13 and 14 refer to the following information:

The input voltage signal shown in Figure 6 is passed through an amplifier and the resultant output signal is shown in Figure 7.

Figure 6

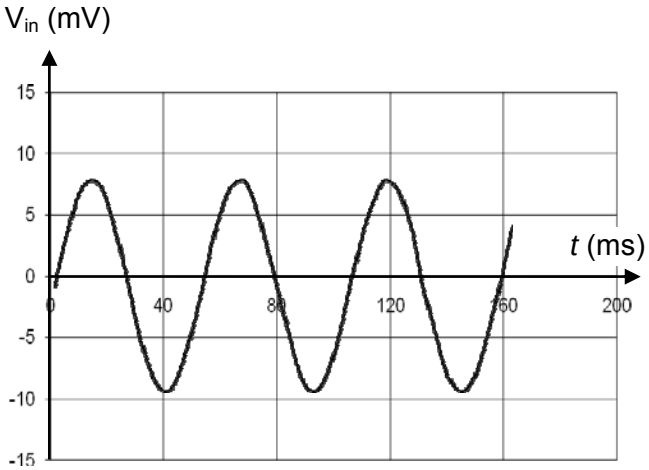
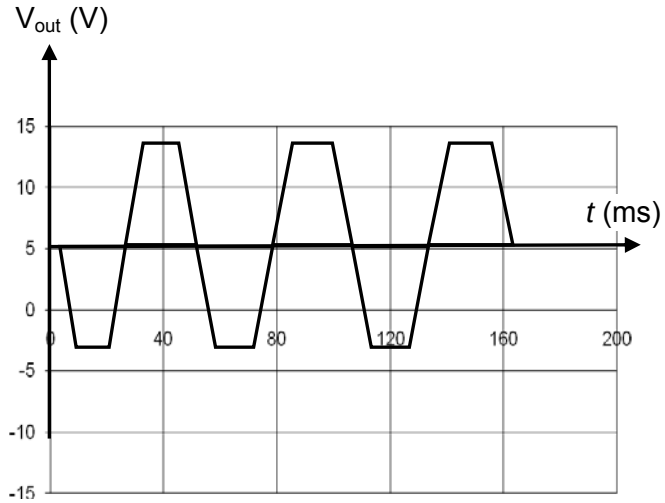


Figure 7



QUESTION 13
Estimate the frequency of the input signal as in Figure 6.

	Hz

2 marks

QUESTION 14
In describing the characteristics of this amplifier, circle one of the most appropriate of the two options for **each** of the **three** underlined characteristics.

Nature of amplifier	Linear Voltage Gain	Clipped at...
Inverting	***1.4***	***± 8.5 V***
or	or	or
Non-inverting	***1400***	***± 17 V***

3 marks

Figure 8 shows simplified sections of an optical-electrical system designed to transfer a telephone signal.

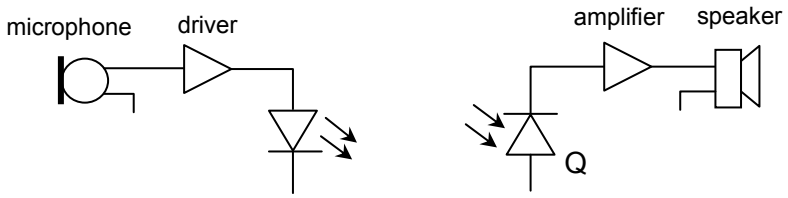


Figure 8

QUESTION 15
Which of the following sequences best describes the transfer of energy through this process?

A. sound → electrical → light → electrical → sound
B. sound → light → electrical → light → sound
C. sound → light →electrical → sound
D. light → electrical → sound

1 mark

QUESTION 16
In the system shown in Figure 8 the detecting input transducer (Q) is a photodiode. Name two other devices that could serve this purpose.

2 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 results from Maxwell's equations with respect to the speed of light?

A. Nothing can travel faster than the speed of light.
B. The speed of light only depends on the electrical and magnetic properties of the medium through which light is passing.
C. The speed of light depends on the speed of the medium through which the light is passing.
D. The speed of light depends on the speed of the source of the light.

2 marks

QUESTION 2
Which of the following best describes the classical principle of relativity?

A. There is a reference point in the universe at zero velocity.
B. There is no reference point in the universe at zero velocity.
C. Nothing can travel faster than the speed of light.
D. Physics is the same in all inertial reference frames.

2 marks

QUESTION 3
Which of the following describes Einstein's two postulates for special relativity?

A. Physics is the same in all reference frames and speed of light is constant for all observers.
B. Physics is the same in all reference frames and speed of light is constant for all inertial observers.
C. Physics is the same in all inertial reference frames and speed of light is constant for all observers.
D. Physics is the same in all inertial reference frames and speed of light is constant for all inertial observers.

2 marks

QUESTION 4
The aim of the Michelson-Morley experiment was to observe the change in interference pattern due to

A. The change in seasons.
B. Rotating the apparatus.
C. The ether wind.
D. The speed of the Earth.

2 marks

QUESTION 5
The length contraction of an object occurs when travelling close to the speed of light because

A. Time slows down when travelling close to the speed of light.
B. Length only contracts in the direction of motion.
C. The length only appears to get smaller but really stays the same.
D. The speed of light is constant for all observers.

2 marks

The following information refers to Questions 6 to 9:

Harry is stationed on a space station in deep space. Sally is on a spaceship travelling at 90% of the speed of light. Sally sends a 10 second radio message to Harry.

QUESTION 6
Which of the following is the proper time of the radio signal?

A. Time measured by Sally.
B. Time measured by Harry.
C. 90% of the time measured by Sally.
D. 90% of the time measured by Harry.

2 marks

QUESTION 7
Which of the following best estimates the time the radio message takes according to Harry?

A. 2.3 seconds.
B. 19.0 seconds.
C. 22.9 seconds.
D. 31.6 seconds.

2 marks

QUESTION 8
Which of the following is the proper length of Sally's spaceship?

A. Length measured by Harry.
B. Length measured by Sally.
C. 90% of the length measured by Harry.
D. 90% of the length measured by Sally.

2 marks

QUESTION 9
If Harry measures Sally's spaceship to be 200 m long, which of the following best estimates the length of the ship according to Sally?

A. 63 m
B. 87 m
C. 145 m
D. 458 m

2 marks

The following information refers to Questions 10 to 12:

1 GeV muons are being used in a high energy particle experiment. The rest mass of a single muon is 105.7 MeV ($e = 1.6\times10^{-16}$, $c = 3\times10^{8}$).

QUESTION 10
What is the rest mass of the muon in kilograms?

A. 5.6×10^{-20} kg
B. 1.9×10^{-28} kg
C. 1.9×10^{-35} kg
D. 5.9×10^{-43} kg

2 marks

QUESTION 11
What is the kinetic energy of the high energy muons?

A. 6 MeV
B. 105 MeV
C. 890 MeV
D. 1000 MeV

2 marks

QUESTION 12
What is the speed of the muons in multiples of c?

A. 0.82 c
B. 0.94 c
C. 0.99 c
D. 9 c

2 marks

QUESTION 13
Which of the following best describes why matter does not travel at the speed of light?

A. The speed of light is constant for all observers.
B. Time dilation.
C. Length contraction.
D. Inertia becomes infinite.

2 marks

End of Einstein's Special Relativity Section

DETAILED STUDY 2 – FURTHER ELECTRONICS

Questions 1 and 2 refer to the following information:

A circuit uses a $5V_{RMS}$ AC source, a silicon diode (switch-on voltage = 0.7 V) and a multimeter to measure (and graph) the potential difference across a resistor, as in Figure 1.

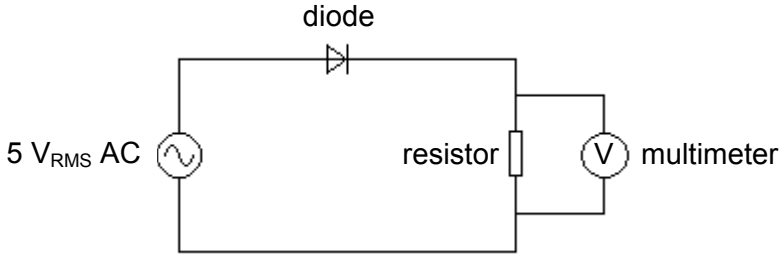
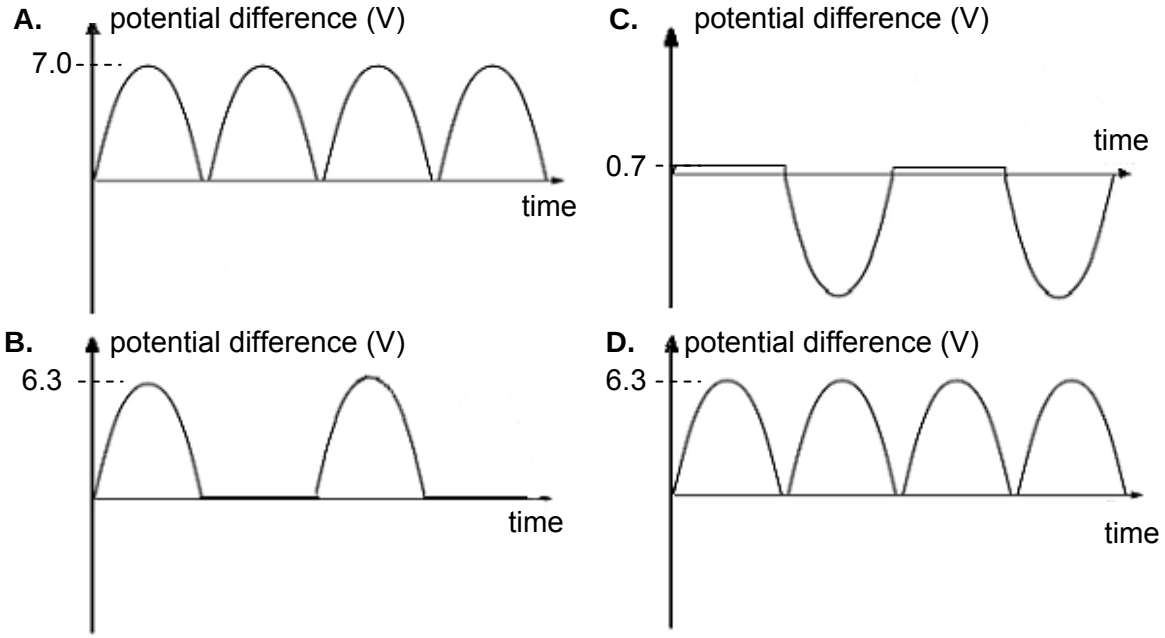


Figure 1

QUESTION 1
Which of the following graphs (**A** – **D**) best represents the resulting variation in potential difference across the resistor?



2 marks

QUESTION 2
The action of the circuit in Figure 1 would be best described as:

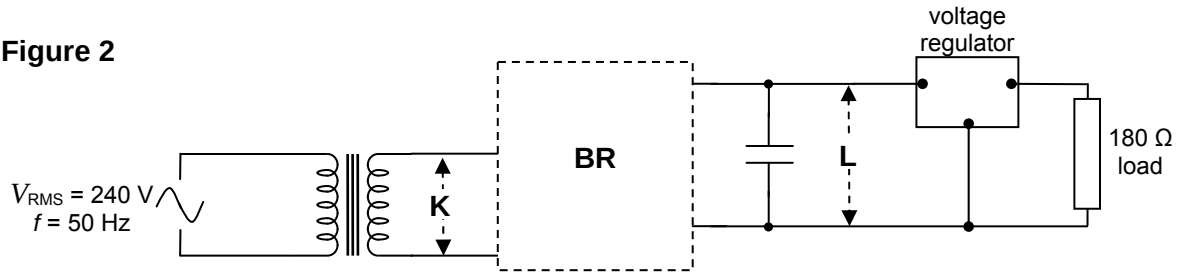
A. Half-wave rectifying.
B. Half-wave regulating.
C. Full wave rectifying.
D. Full wave regulating.

2 marks

Questions 3 to 10 refer to the following information:

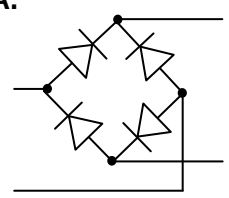
Figure 2 shows a correctly set up and operating rectified, smoothed and regulated 12 V DC power supply other than the bridge rectifier which can be placed in position **BR**. Testing devices such as a multimeter or a Cathode Ray Oscilloscope (CRO) can be connected in positions **K** and **L** as required.

Figure 2

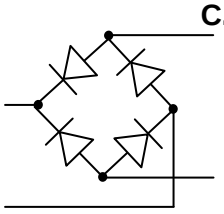


QUESTION 3
Which of the following arrangement of diodes (as a bridge rectifier) correctly completes the circuit in Figure 2 to serve the purpose intended?

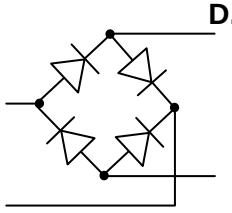
A.



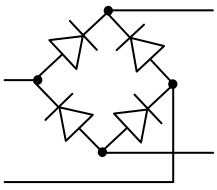
B.



C.



D.



2 marks

QUESTION 4
How much power is dissipated in the load if its resistance is 180 Ω?

A. 0.8 W
B. 8.0 W
C. 32 W
D. 320 W

2 marks

A multimeter (set on AC volts) connected at **K** reads 16 V_{RMS}. The secondary winding of the transformer has 200 turns and the transformer can be considered to be ideal.

QUESTION 5
How many turns are in the primary winding of the transformer?

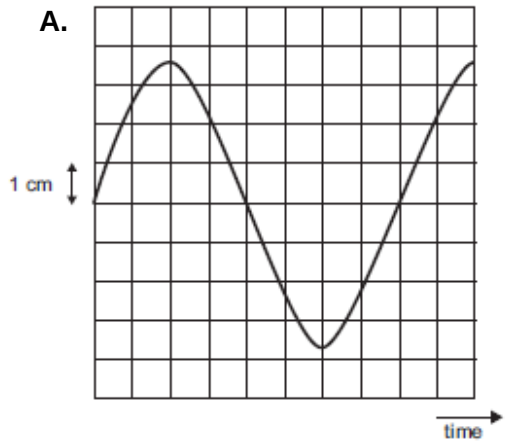
A. 1000
B. 2000
C. 3000
D. 4000

2 marks

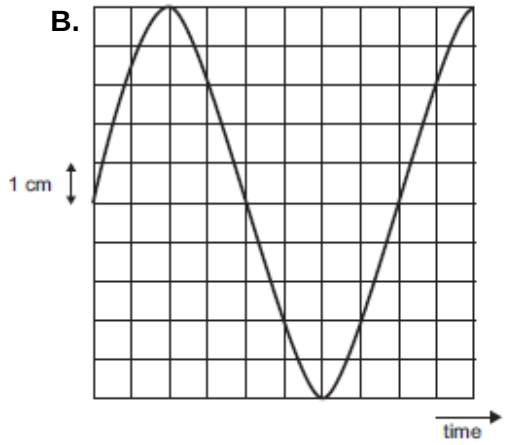
The circuit is tested using a CRO connected in position **K**. The screen has a grid of 1 cm^2 squares. The vertical scale is set to 4.5 V/cm and the horizontal scale is set to 2.5 ms/cm.

QUESTION 6
Which of the following sketches **(A-D)** is most likely to be the display seen on the screen of the CRO?

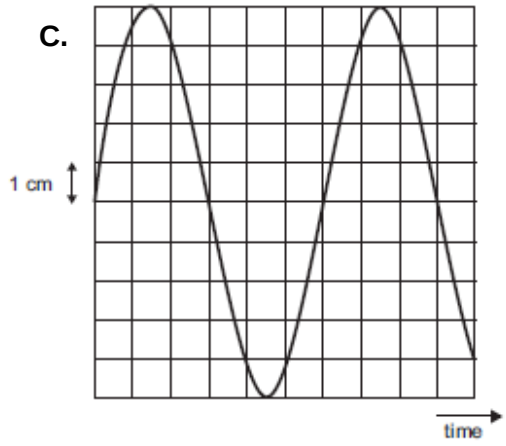
A.



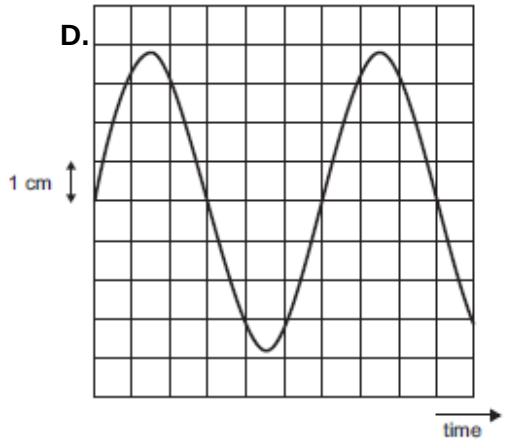
B.



C.



D.



2 marks

An accident causes a brief power surge during which the AC power supply raises to 390 V_{RMS} instead of the usual 240 V_{RMS}.

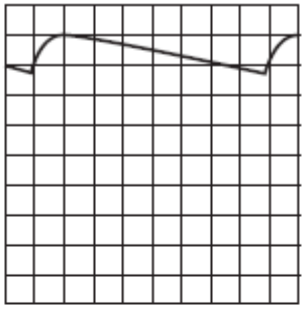
QUESTION 7
During this time, what would be the DC output voltage supplied across the 180 Ω resistor?

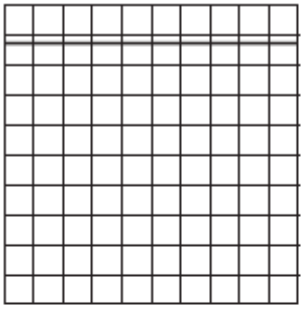
A. 12.0 V
B. 14.5 V
C. 17.0 V
D. 19.5 V

2 marks

With the AC supply returned to 240 V_{RMS}, the CRO is connected at position **L** with the same scale settings as before.

QUESTION 8
Which of the following **(A-D)** is most likely to be the display on the screen of the CRO?

A.


B.


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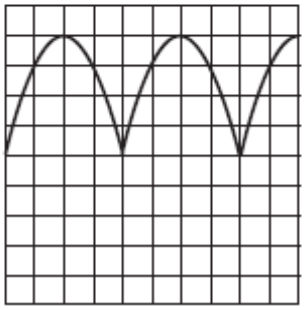
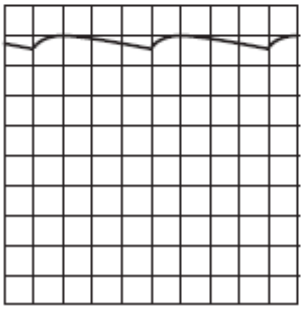


D.


2 marks

QUESTION 9
Which of the following measuring devices **(A-D)** below should be placed in position **L** to study the voltage at this point in the circuit?

A. A CRO.
B. A DC voltmeter.
C. An AC ammeter.
D. A DC ammeter.

2 marks

The 180 Ω load resistor (across the DC power supply circuit) is replaced by a 470 Ω resistor.

QUESTION 10
Which of the following best describes the resulting effects on the output voltage across the load resistor and the output current in the load resistor?

	Output Voltage	**Output Current**
A.	Increases	Increases
B.	Increases	Remains the same
C.	Remains the same	Decreases
D.	Decreases	Decreases

2 marks

QUESTION 11
Along with a "smooth" voltage signal which of the following is also desired?

A. Maximum resistance in the circuit.
B. A signal voltage of minimum average amplitude.
C. Minimum capacitance in the circuit.
D. A ripple voltage of minimum amplitude.

2 marks

The following information applies to Questions 12 and 13:

A student trials various combinations of a resistor (**R**) and a capacitor **(C)** to find the longest time constant (τ) for a circuit they are constructing.

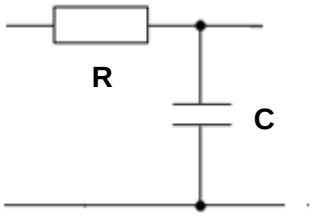


Figure 3

QUESTION 12
Which of the following combinations will result in the longest time constant?

	Resistance (kΩ)	Capacitance (μF)
A.	2	400
B.	3	300
C.	4	200
D.	5	100

2 marks

It's decided that the time constant should be 1.5 seconds but only a 250 μF capacitor is available.

QUESTION 13
What should be the resistance of the subsequent resistor to be used?

A. $1.67 \times 10^{-4}\ \Omega$
B. $3.75 \times 10^{-4}\ \Omega$
C. $1.67 \times 10^{3}\ \Omega$
D. $6.00 \times 10^{3}\ \Omega$

2 marks

End of Further Electronics Section

DETAILED STUDY 3: MATERIALS AND STRUCTURES

Questions 1 to 4 refer to the following information:

A Year 12 Physics student is testing the forces acting on a 3 m plank of wood which is resting on two supports at either end, A and B. The student stands a distance $x\ m$ from support A on the plank and their mass of 60 kg is held, as in Figure 1. We can assume the plank of wood has negligible mass.

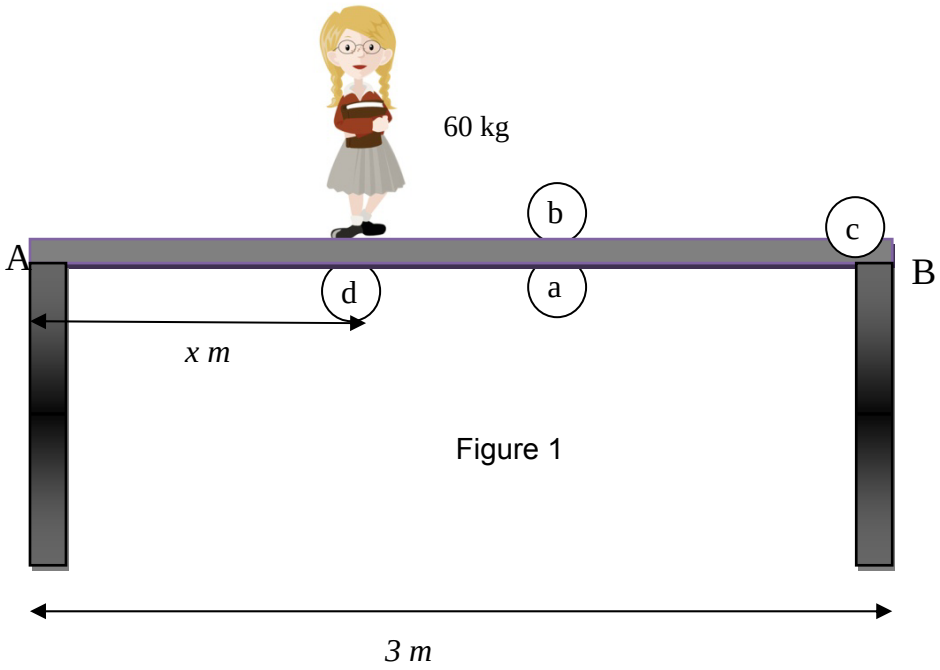


Figure 1

QUESTION 1
Which of the following best describes the forces acting **on** the plank?

	Tension	Compression	Weight
A	c	b	d
B	a	b	d
C	b	a	c
D	a	b	c

2 marks

QUESTION 2
Which of the following best estimates the distance for x such that the supporting force from A is **twice** the supporting force from B?

A. 0.5 m
B. 1 m
C. 1.5 m
D. 2 m

2 marks

QUESTION 3
Which of the following is the normal force acting on the plank at B?

A. 20 N
B. 200 N
C. 300 N
D. 600 N

2 marks

QUESTION 4
What is the maximum force that support A will experience with the student standing anywhere on the plank?

A. 100 N
B. 300 N
C. 600 N
D. 1200 N

2 marks

Questions 5 to 7 refer to the following information:

Figure 2 shows the stress-strain graph to fracture for 4 materials.

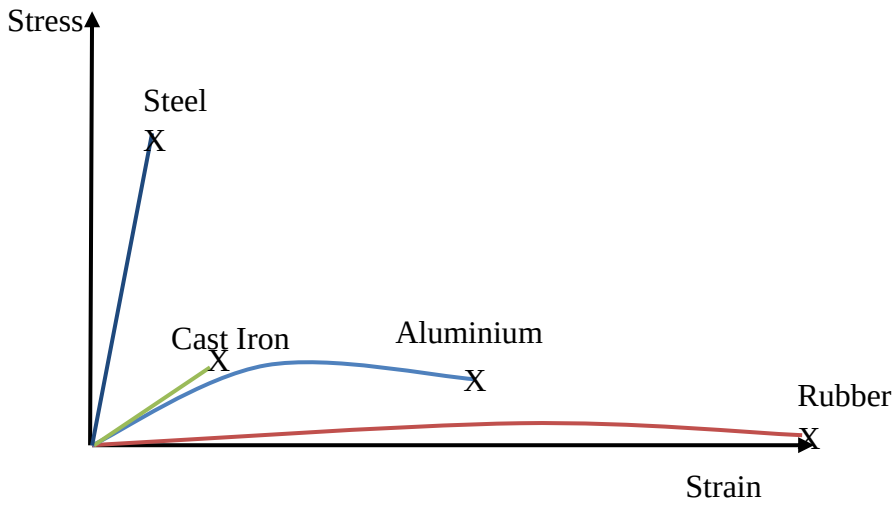


Figure 2

QUESTION 5
Which of the following materials has the largest strain energy per unit volume of material?

A. Cast Iron
B. Steel
C. Aluminium
D. Rubber

2 marks

QUESTION 6
Which of the following materials is the most ductile?

A. Cast Iron
B. Steel
C. Aluminium
D. Rubber

2 marks

QUESTION 7
Which of the following materials has the largest Young's Modulus?

A. Cast Iron
B. Steel
C. Aluminium
D. Rubber

2 marks

QUESTION 8
A steel pylon is used to support a large structure. The pylon has a surface area of 35 mm^2 and a length of 3 m. The pylon supports a force of 3×10^3 N. The Young's modulus for steel is 205 GPa. Which of the following best estimates the length that the pylon is compressed?

A. 0.125 mm
B. 1.25 mm
C. 12.5 mm
D. 125 mm

2 marks

Questions 9 and 10 refer to the following information:

Figure 3 is a stress-strain graph of Al.

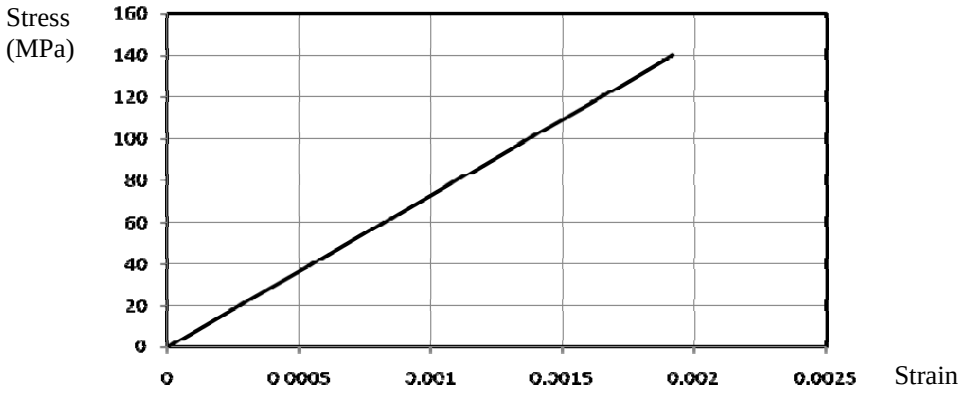


Figure 3

QUESTION 9
Which of the following best estimates the strain energy per unit volume of the Al under a stress of 120 MPa?

A. 0.1 J
B. 0.2 J
C. 100000 J
D. 200000 J

QUESTION 10
Which of the following best estimates the Young's modulus for Al?

A. 70 Pa
B. 70 kPa
C. 70 MPa
D. 70 GPa

2 marks

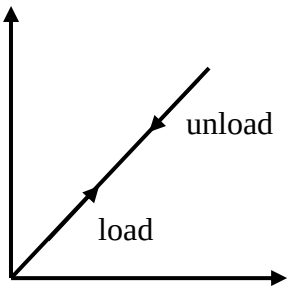
QUESTION 11
Which of the following best describes when a material is **brittle**?

A. Fractures.
B. Deforms plastically before fracture.
C. Suffers elastic deformation.
D. Little or no plastic deformation before fracture.

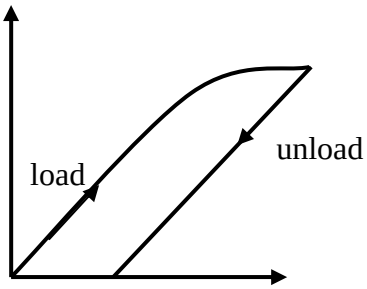
2 marks

QUESTION 12
Which of the following stress-strain graphs demonstrates the absorption of energy during loading within the elastic range?

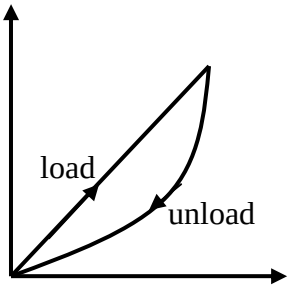
A.



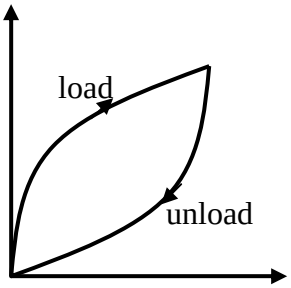
B.



C.



D.



2 marks

QUESTION 13
Composite materials are often used in building because

A. There are improvements in strength and toughness.
B. They are easier to produce.
C. They are easier to use.
D. They are more elastic.

2 marks

End of Structures and Materials Section