THE SCHOOL FOR EXCELLENCE (TSFX)

UNIT 3 PHYSICS 2009

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	15	15	36
	Electronics and Photonics	14	14	28
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 volleyball (mass = 0.225 kg) is hit very high in the air such that it returns vertically to earth and has reached a terminal velocity of 28.0 m/s downwards.

QUESTION 1
What is the magnitude and direction of the force of air resistance against the volleyball at this time?

N	**direction:**

3 marks

The volleyball is struck by a person with an impulse on the ball of 13.5 Ns upwards.

QUESTION 2
If the duration of the impact was 0.25 s, what was the average force of the person on the ball?

N	**direction:**

3 marks

QUESTION 3
With what velocity does the ball leave the person?

m/s	**direction:**

3 marks

QUESTION 4
Which one of the following is the **worst** representation of Newton's First Law; the Law of inertia?

A. An object maintains its state of motion unless acted on by an unbalanced force.

B. An object maintains its velocity unless acted on by an unbalanced force.

C. An object maintains its speed unless acted on by an unbalanced force.

D. An object maintains its momentum unless acted on by an unbalanced force.

E. An object maintains its inertia unless acted on by an unbalanced force.

2 marks

Questions 5 and 6 refer to the following information:

A small 24 g stone is placed on a fast moving circular turntable at a point 8 cm from the centre, as illustrated in Figure 1. It is moving with a speed of 50 m/s.

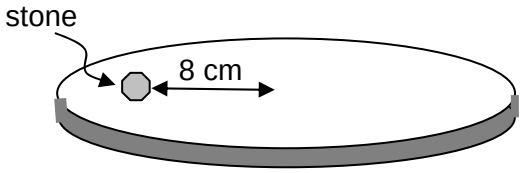


Figure 1

QUESTION 5
What is the magnitude of the frictional force holding the stone in its motion?

N

2 marks

QUESTION 6
The speed of the turntable is increased fairly rapidly and the stone (st) leaves its circular path. Which of the arrows **A - D** in Figure 2 indicates the most likely path of the stone as it leaves the turntable, as viewed from above?

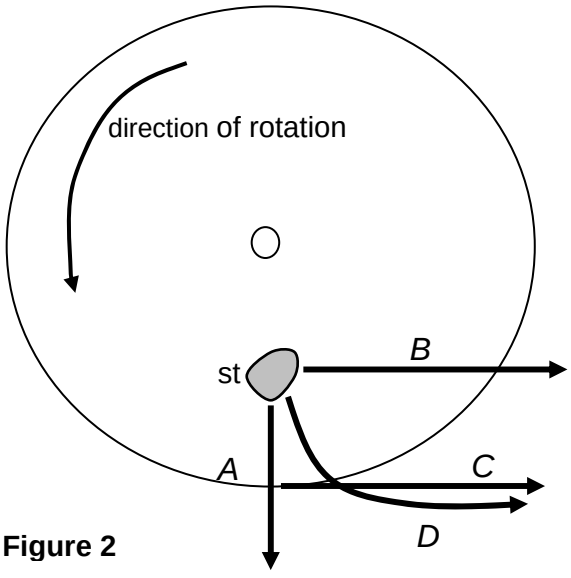


Figure 2

2 marks

QUESTION 7

Andrew, Betty and Charles are discussing the size of the earth's gravitational field at an **altitude** equal to the earth's radius (R_E), as illustrated in Figure 3.

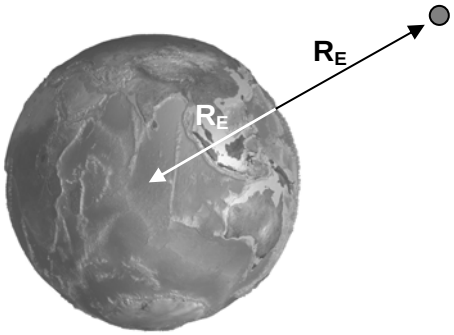


Figure 3

Andrew says that the gravitational field strength due to the Earth at this point will be 2.45 N/kg. Betty argues that it will be 4.9 N/kg and Charles is very confident that g = 9.8 N/kg at this altitude.

Explain who is correct and why?

_____

_____

_____

_____

_____

2 marks

Questions 8 to 10 refer to the following information:

In attempting to jump from one ramp to another a skater moving at 4.8 m/s attempts to clear a gap of 2.0 metres. The take-off angle is of 28° elevation. For questions 8 & 9 assume air resistance is negligible.

Figure 4

QUESTION 8
After leaving the first ramp, what time does it take for the skater to reach the highest point in his flight?

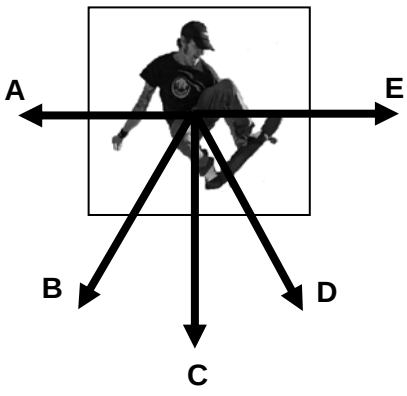
s

3 marks

QUESTION 9
Does the skater land on the other ramp? Show your calculations and reasoning.

3 marks

QUESTION 10
When positioned as in Figure 4, which of the vectors (**A – D**) represents the direction of the net force acting on the skater at this time? (Air resistance must be included for consideration).



2 marks

Questions 11 to 13 refer to the following information:

The Asteroid Research Spacecraft (ARS) has been launched and will orbit the asteroid Skradgit whose mass is very much less than that of earth.

QUESTION 11
Which one of the statements A to D best describes how the period of the spacecraft in orbit around Skradgit would compare with the period of an Earth satellite with the same orbital radius?

A. The period around the asteroid would be greater than for the Earth satellite.
B. The period around the asteroid would be less than for the Earth satellite.
C. The period would be the same.
D. There is insufficient information to decide.

2 marks

QUESTION 12
Explain your answer to Question 11.

_____

_____

_____

_____

_____

2 marks

The mass of the asteroid Skradgit is found to be 1.2×10^{21} kg and the ARS spacecraft has an orbital radius of only 3.5×10^{5} m.

QUESTION 13
Calculate the speed of the ARS spacecraft.

m/s

3 marks

Questions 14 to 15 refer to the following information:

A dog (mass = 14 kg) runs in a northerly direction across a beach with a speed of 3.0 m/s and turns to run to the west at 3.0 m/s.

QUESTION 14
What is the magnitude and direction of the change of velocity of the dog?

m/s	**direction:**

2 marks

QUESTION 15
What is the magnitude and direction of the impulse on the dog due to the sand?

kgm/s	**direction:**

2 marks

End of Section on Motion in One and Two Dimensions

AREA OF STUDY 2: ELECTRONICS AND PHOTONICS

Questions 1 to 5 refer to the following information:

Four identical globes with resistance 30 Ω are connected to a 12 V battery as shown in Figure 1 below.

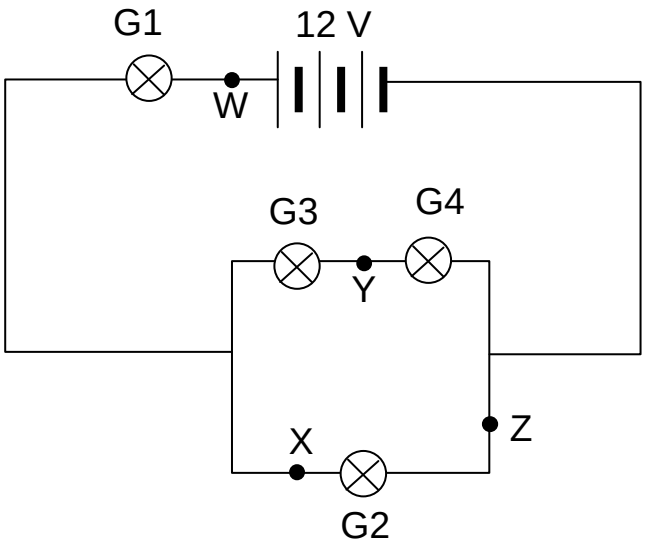


Figure 1

QUESTION 1
Determine the total resistance for the circuit in Figure 1.

Ω

3 marks

QUESTION 2
Determine the current produced by the battery.

A

2 marks

QUESTION 3
Which globe(s) will glow the brightest? Explain your answer.

Globe:

3 marks

QUESTION 4
At which point (W, X, Y, Z) would you place an *open* switch to increase the brightness of globe G_2?

A. W
B. X
C. Y
D. Z

2 marks

QUESTION 5
At which point (W, X, Y, Z) would you place an *ammeter* to confirm your answer to Question 2?

A. W
B. X
C. Y
D. Z

2 marks

Questions 6 to 9 refer to the following information:

Jo and Peter are designing a circuit to function as a thermostat. Their circuit will consist of a thermistor, an LED and a variable voltage supply, V_s, as shown in Figure 2.

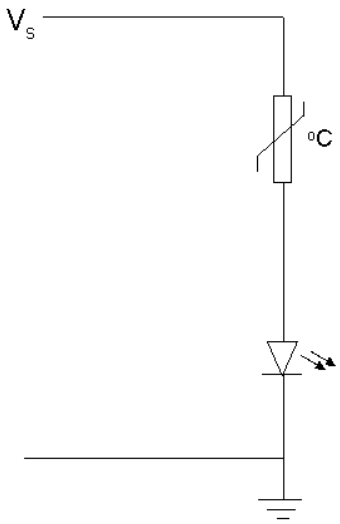


Figure 2

The characteristic curves for the thermistor and the LED are shown in Figures 3 and 4 respectively.

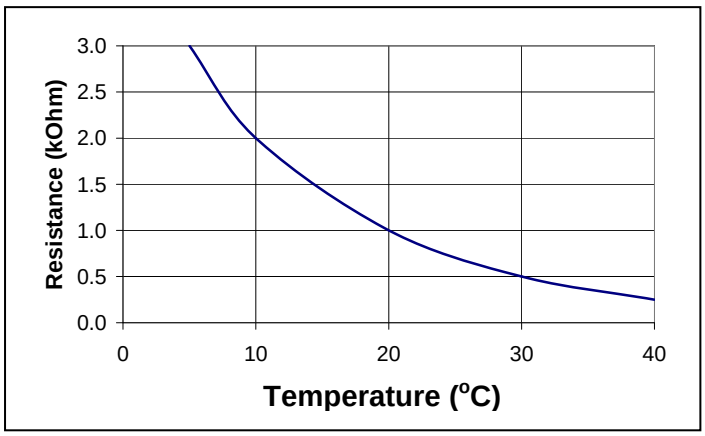


Figure 3

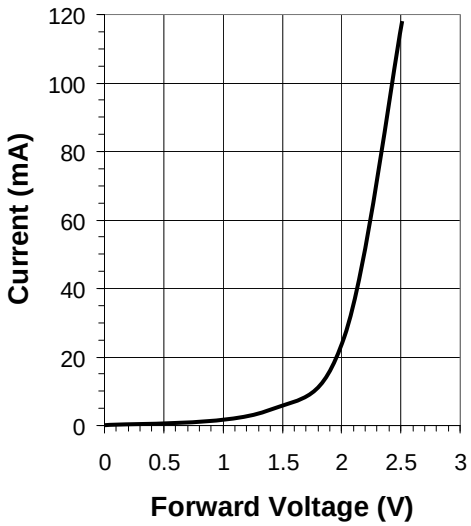


Figure 4

QUESTION 6
Determine the resistance of the thermistor in Ω when the temperature is 20°C.

Ω

1 mark

QUESTION 7
Determine the threshold voltage for the LED.

V

1 mark

Jo and Peter would like the LED to produce enough light for a photodiode to switch on a heater when the temperature is below 20°C. The LED will glow brightly enough when the current is 10mA.

QUESTION 8
Determine the supply voltage required for the LED to indicate when the temperature is 20°C.

V

2 marks

QUESTION 9
Will Jo and Peter's circuit work as they intended? *Provide reasons for your answer.*

3 marks

Questions 10 to 13 refer to the following information:

A state of the art audio system is to be set up in the music classroom. The system will be wired using optical cabling. The block diagram in Figure 5 shows the arrangement of the devices and the electrical components enabling the signal from a microphone to be sent to and amplified for a set of speakers.

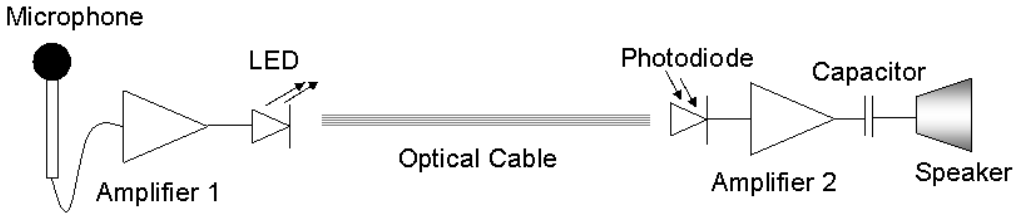


Figure 5

QUESTION 10
Which of the following components (A-D) shows where light intensity modulation occurs in the system described in Figure 5?

Modulation

A. Microphone
B. LED
C. Photodiode
D. Amplifier 1

2 marks

Amplifier 2 has the following transfer characteristics shown in Figure 6.

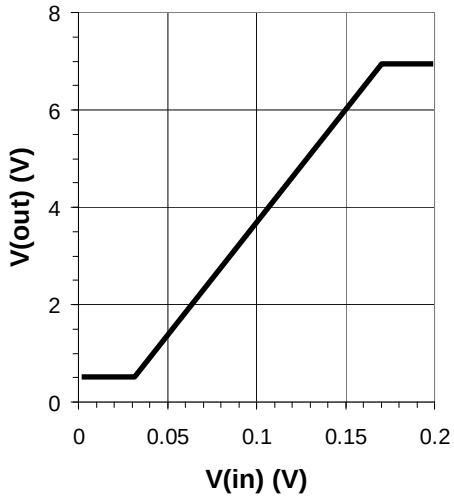


Figure 6

QUESTION 11
Is Amplifier 2 an inverting or non-inverting amplifier?

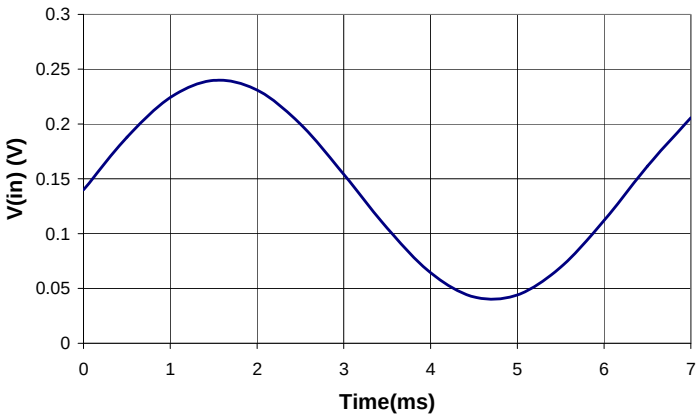
1 mark

QUESTION 12
Determine the voltage gain of Amplifier 2.

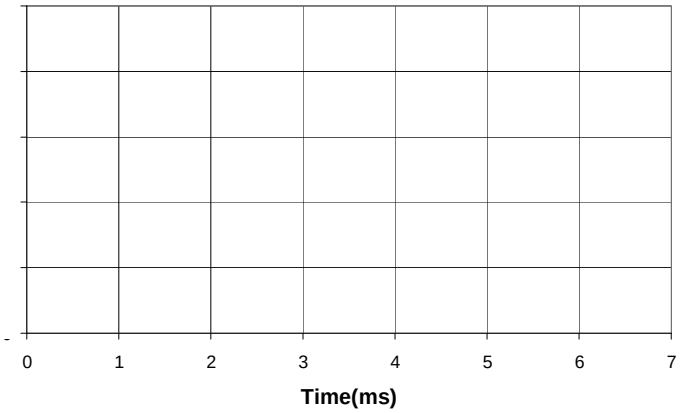
2 marks

The following input signal enters amplifier 2.

Figure 7



QUESTION 13
On the axes below, sketch the corresponding output voltage of amplifier 2. Clearly label the vertical axis.



3 marks

QUESTION 14
The photodiode receiving the light signal from the optical fibres has the following I-V curve.

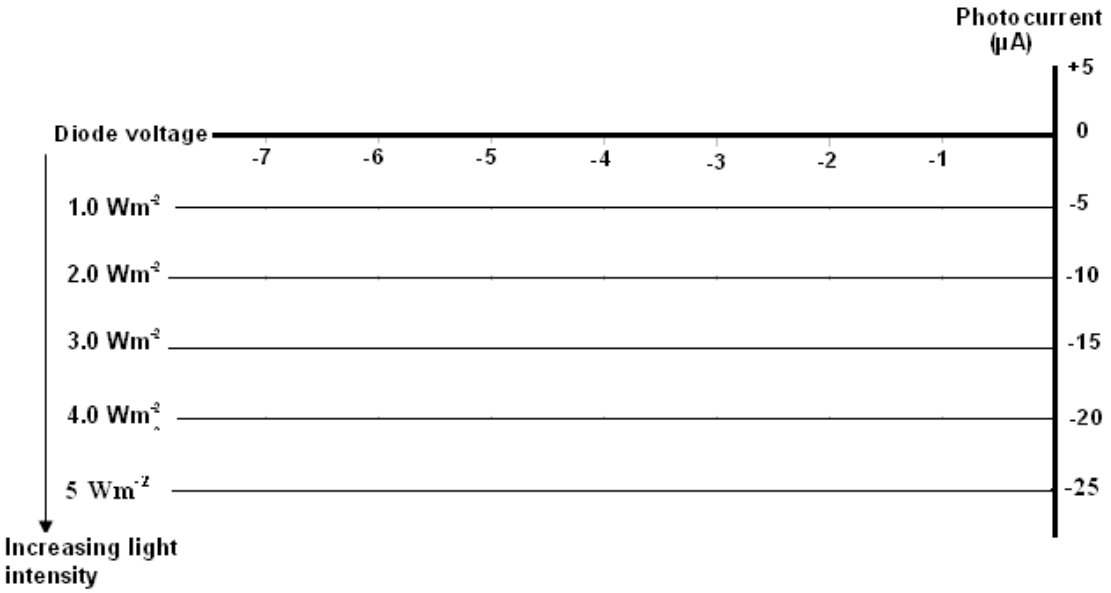


Figure 8

What is the photocurrent produced by the photodiode when a light intensity of 4.0 Wm^{-2} is produced by the optical cables?

	μA

1 mark

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

A frame of reference described as 'an inertial reference frame' is one that

A. must always be stationary.
B. is not accelerating.
C. is undergoing constant non-zero acceleration.
D. is moving with a known velocity.

2 marks

QUESTION 2

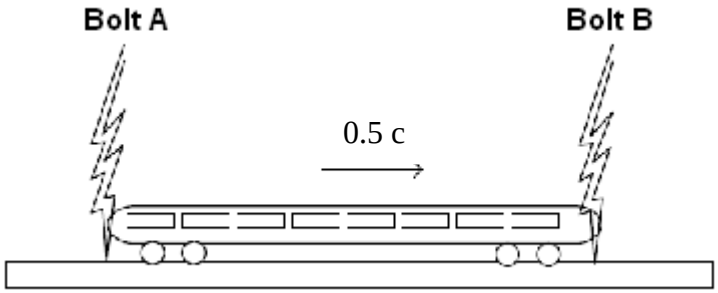
Galileo's postulate implies that:

A. a stationary observer will observe all inertial frames the same.
B. all inertial frames of reference are unique.
C. all velocities are relative to the observer.
D. time passes at different rates that depend on the speed of the observer.

2 marks

The following information refers to Questions 3 to 5:

Imagine a train of proper length 100 m passing through a station at half the speed of light. There are two lightning strikes, one at the front and one at the rear of the train, **leaving scorch marks on both the train and the station platform**. Observer X is standing on the station platform midway between the two strikes, while observer Y is sitting in the middle of the train. Light from each strike travels to both observers.



QUESTION 3
If observer X on the station concludes from his observations that the two lightning strikes occurred simultaneously, what would observer Y on the train see?

A. Observer Y would observe Bolt A first.
B. Observer Y would observe both Bolts at the same time.
C. Observer Y would observe Bolt B first.
D. Observer Y is going so fast no bolts of lightning will be observed.

2 marks

QUESTION 4
What will be the distance between the scorch marks on the *train*, according to X?

A. 76
B. 87m
C. 100m
D. 115m

2 marks

QUESTION 5
What will be the distance between the scorch marks on the *platform*, according to Y?

A. 76
B. 87m
C. 100m
D. 115m

2 marks

QUESTION 6
George is moving with uniform velocity of 0.9c relative to Wendy. They are each wearing a wristwatch with a second hand that takes one minute to make one complete revolution. When George observes the second hand on his watch to have made one complete revolution, how many revolutions will Wendy observe the second hand of her watch to have made?

A. 0.43
B. 0.9
C. 1.0
D. 2.3

2 marks

QUESTION 7
Muons have a half-life of 3.1×10^{-6} s as measured in a reference frame in which the muons are at rest. Suppose an accelerator creates a pulse of muons moving with a speed of 0.9c. How far will the pulse have travelled as measured by a laboratory observer when half the muons in the pulse will have decayed?
($c = 3.0 \times 10^{8}$ ms^{-1})

A. 835
B. 930
C. 1920
D. 2130

2 marks

The following information refers to Questions 8 and 9:

When electrons are accelerated through a potential difference of 1.50×10^6 V, they attain a speed of 0.97*c* relative to the laboratory. The rest mass of an electron is 9.1×10^{-31} kg.

QUESTION 8
Determine the mass of the electron at this speed.

A. 9.1×10^{-31} kg
B. 9.4×10^{-30} kg
C. 3.7×10^{-30} kg
D. 3.9×10^{-30} kg

2 marks

QUESTION 9
Determine its kinetic energy at this speed.

A. 1.02×10^{-13}J
B. 1.56×10^{-13}J
C. 2.51×10^{-13}J
D. 3.36×10^{-13}J

2 marks

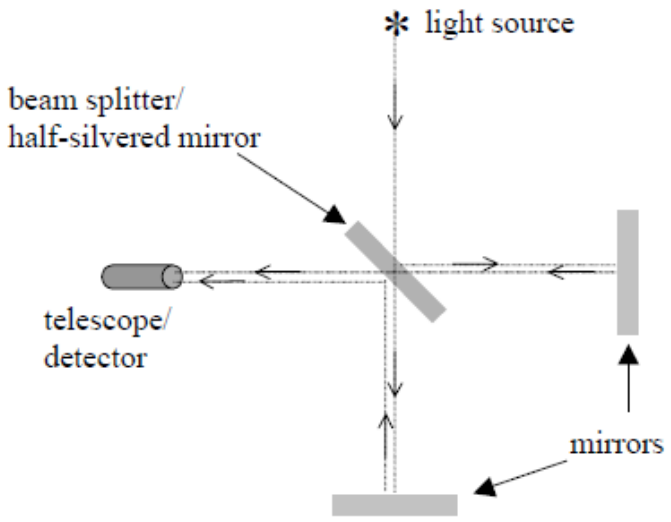
QUESTION 10

Relativistic momentum is:

A. equal to the internal change in an object's motion.
B. dependent on the relativistic mass and velocity of the object.
C. dependent only to an object's relative mass.
D. a fixed quantity related to the rest conditions of the object.

2 marks

QUESTION 11
In the Michelson-Morley experiment an interferometer is used in which a beam of light is split into two beams. These travel along different paths and are then recombined and interfere and so form interference fringes. The diagram below shows the main features of such an interferometer.



What did the results of the experiment indicate?

A. No detectable velocity difference from light reflecting off each mirror.
B. Speed of light is affected by the speed of the light source.
C. A changing interference fringe pattern was observed when the interferometer is rotated.
D. At difference times of the year the Earth travels in different directions.

2 marks

The following information refers to Questions 12 and 13:

Suppose that some time in the future it will be possible for astronauts to travel to a distant star system 8.4 light years away, at a constant speed of 0.95*c*.

QUESTION 12
How many years would it take for the astronauts to get there as measured by observers in the Earth's frame of reference?

A. 8.84 years
B. 8.4 years
C. 2.8 years
D. 1.4 years

2 marks

QUESTION 13
On arrival at the star system they immediately set out on the return journey, at the same speed. On their arrival back on Earth how many years have passed, since the astronauts first left Earth, **as measured by the astronauts**?

A. 2.8 years
B. 5.6 years
C. 16.8 years
D. 17.7 years

2 marks

End of Einstein's Special Relativity Section

DETAILED STUDY 2 – FURTHER ELECTRONICS

The circuit in Figure 1 has a capacitor whose state of charge can be determined by the position of switches S1 and S2.

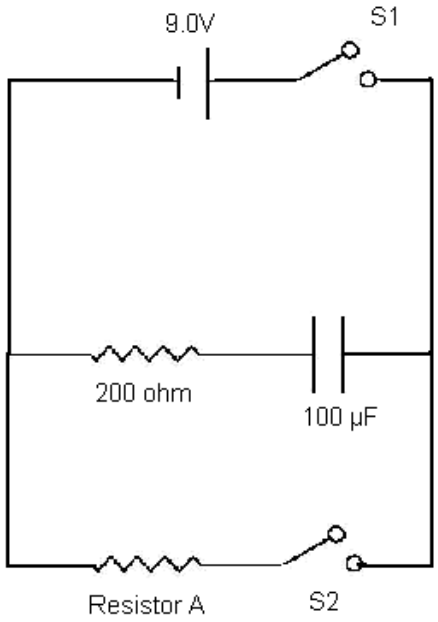


Figure 1

When switch S1 closes the 100µF capacitor charges. After a period of time in which the capacitor has fully charged, S1 opens and S2 closes causing the capacitor to discharge through resistor A.

QUESTION 1
What is the time constant for the charging of the capacitor?

A. 10 ms
B. 20 ms
C. 100 ms
D. 200ms

2 marks

The graph in Figure 2 represents the discharge characteristics of the capacitor when switch S2 closes.

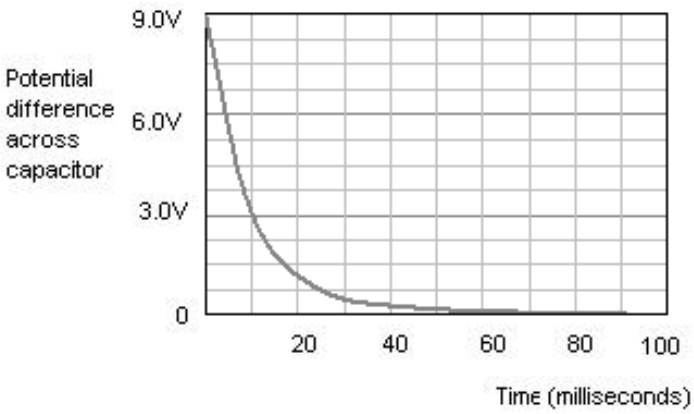


Figure 2

QUESTION 2
The value of resistor A is best represented by:

A. 100Ω
B. 200Ω
C. 500Ω
D. 1000Ω

2 marks

The following information applies to Questions 3 and 4:

In the circuit in Figure 3, a resistor is connected to an AC power supply through a single power diode. Leads of a cathode ray oscilloscope are connected to each side of the resistor at points A and B.

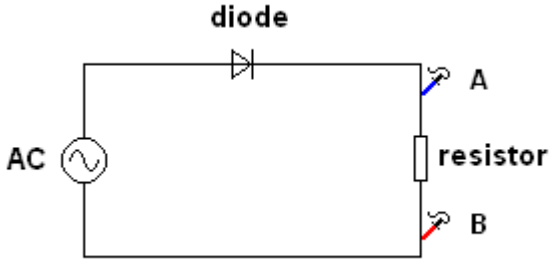


Figure 3

The following graphs in Figure 4 represent a range of possible displays on the screen of the cathode ray oscilloscope.

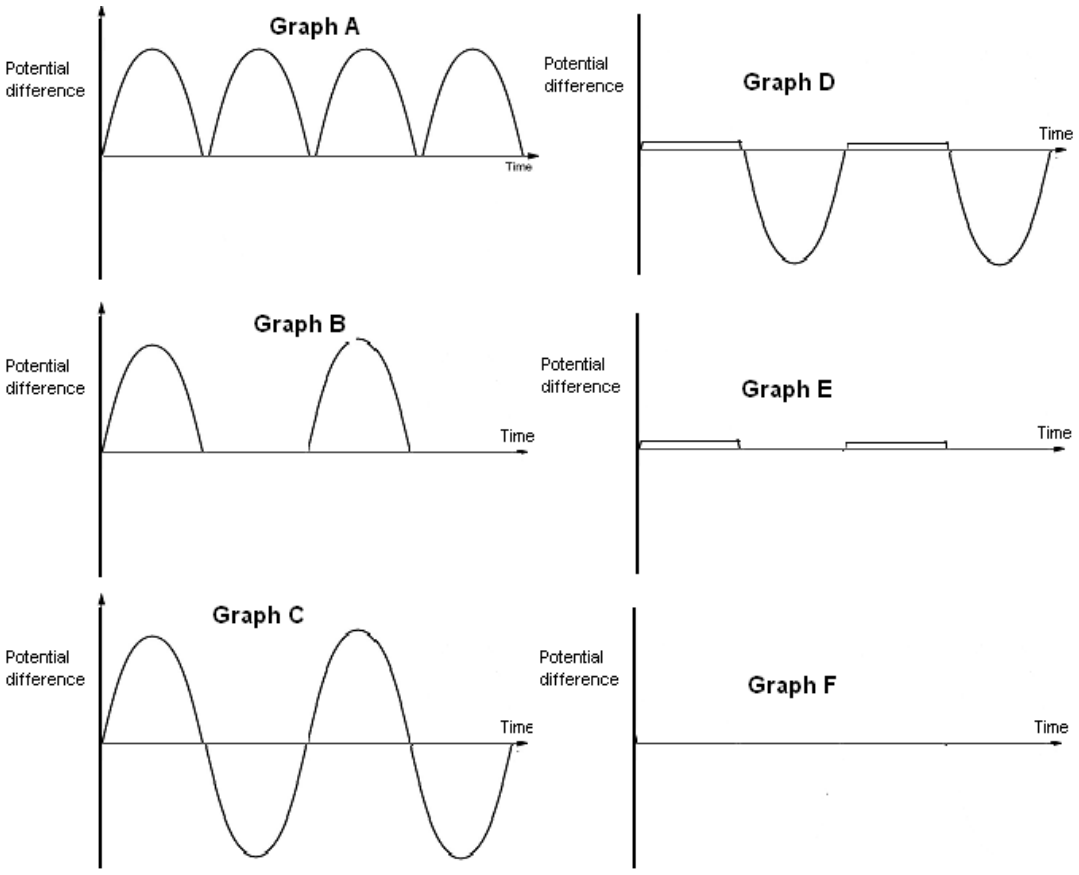


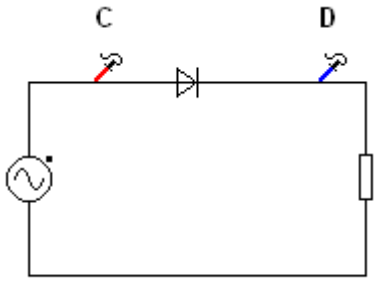
Figure 4

QUESTION 3
Which graph best represents the display on the cathode ray oscilloscope?

A. Graph A
B. Graph B
C. Graph C
D. Graph D
E. Graph E
F. Graph F

2 marks

QUESTION 4
The connections to the cathode ray oscilloscope are now moved to positions C and D.



Which graph best represents the time varying voltage that is likely to be viewed on the screen?

A. Graph A
B. Graph B
C. Graph C
D. Graph D
E. Graph E
F. Graph F

2 marks

QUESTION 5
The circuit in Figure 5 is a voltage divider power supply that can be used to provide a DC voltage (V OUT) to a LOAD.

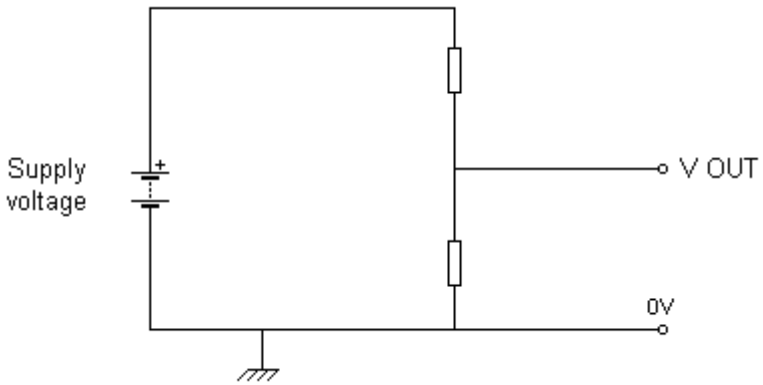


Figure 5

Select the alternative which best describes this circuit.

A. A regulated power supply because it can provide a DC voltage to the load at a value less than the supply voltage.

B. A regulated power supply because it can provide a constant DC voltage to a load.

C. An unregulated power supply because if the load resistance changes the value of V OUT also changes.

D. An unregulated power supply because the supply to the voltage divider is DC.

2 marks

QUESTION 6
The circuits in Figure 6 are attempts by a student to develop a full-wave rectified voltage supply to a resistor.

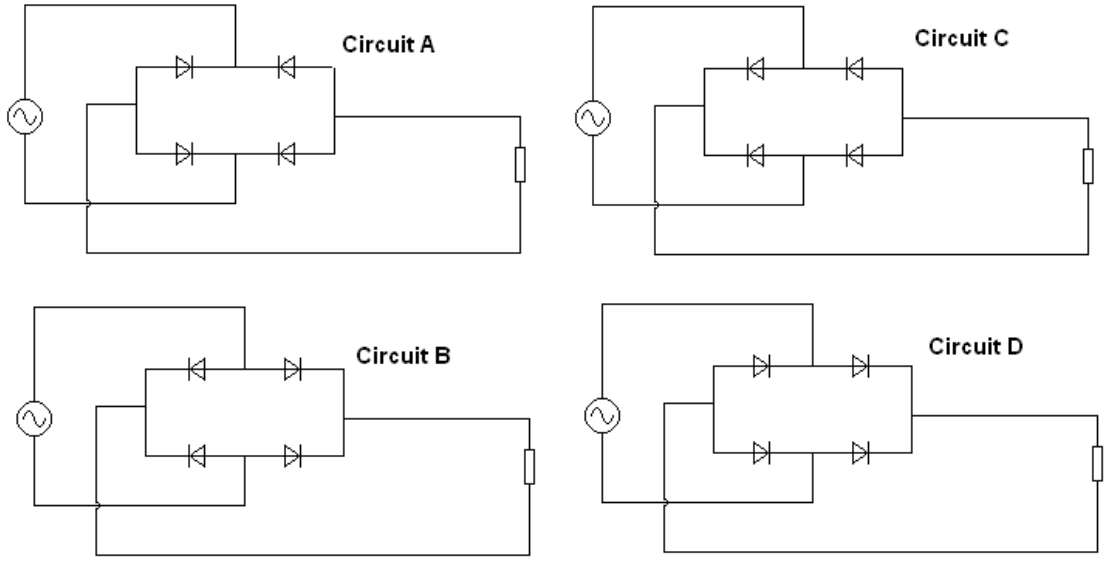


Figure 6

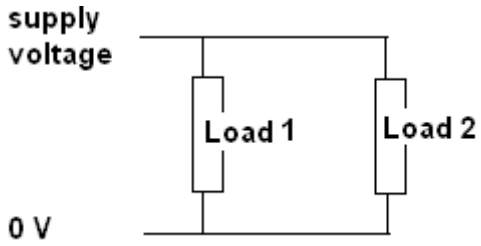
Choose the alternative that best indicates the full selection of successful circuits.

A. Circuit A only
B. Circuit B only
C. Circuit C only
D. Circuit D only
E. Circuits B and D
F. Circuits A and C
G. Circuits C and D
H. All of the above circuits

2 marks

QUESTION 7
A 100μF smoothing capacitor is used to reduce the ripple voltage in a full-wave rectified power supply to an ohmic load.

It was decided to operate a second identical load from the power supply as follows:

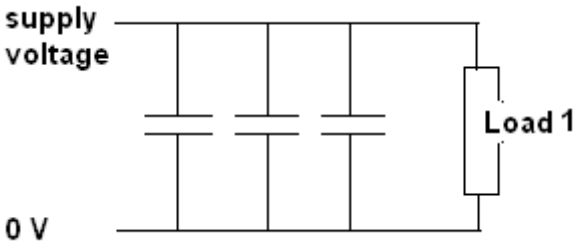


The ripple voltage with the second LOAD installed is likely to be about

A. Half the original value.
B. The same as the original value.
C. Twice the original.
D. No ripple voltage.

2 marks

QUESTION 8
The second LOAD was removed AND <u>an additional two capacitors</u> of the same value were added in parallel to the original:



Compared to the original peak-to-peak ripple voltage, it is now approximately

A. A third of the original ripple.
B. Two thirds of the original ripple.
C. The same as the original ripple.
D. Three times the original ripple.

2 marks

The following information refers to Questions 9 and 10:

The smoothed full-wave rectified voltage supplied to the input of a 6V IC voltage regulator (7806) is shown below in Figure 7. The voltage regulator has a 3.0V dropout zone requiring it to receive a minimum input of 9.0V. The smoothed voltage supply has a peak-to-peak variation of 2.0 volts and a peak of 12V. The LOAD has a resistance of 120 ohms.

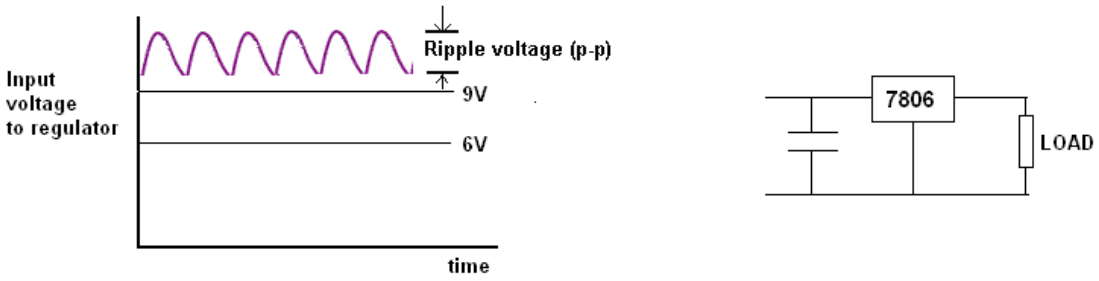


Figure 7

QUESTION 9
Which of the following best represents the power dissipated across the 7806 voltage regulator?

A. 0.25W
B. 0.30W
C. 0.50W
D. 0.60W

2 marks

QUESTION 10
The LOAD is changed for another resulting in the peak-to-peak ripple voltage increasing to 4.0V. The peak voltage remains at 12V.

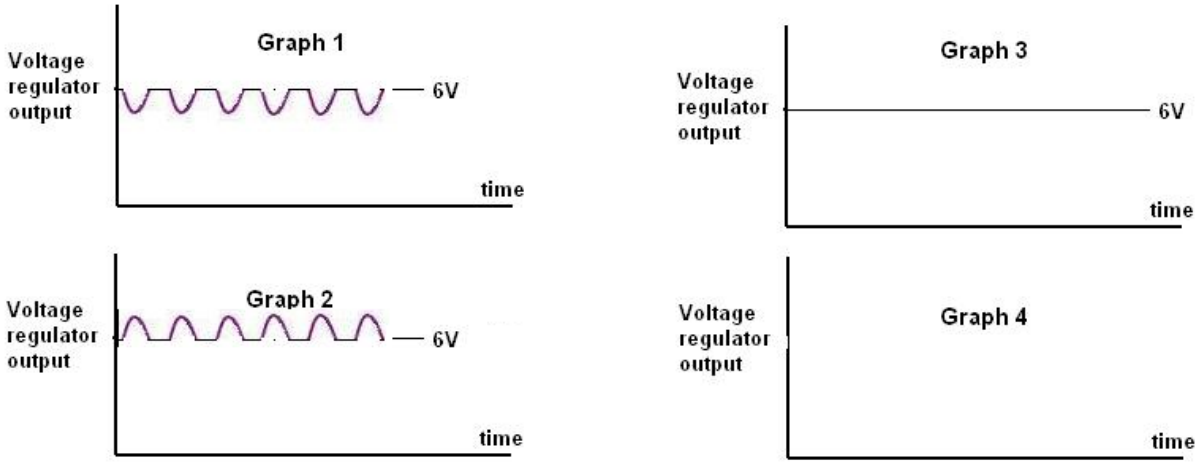


Figure 8

Which of the graphs shown in Figure 8 best represents the output of the voltage regulator now?

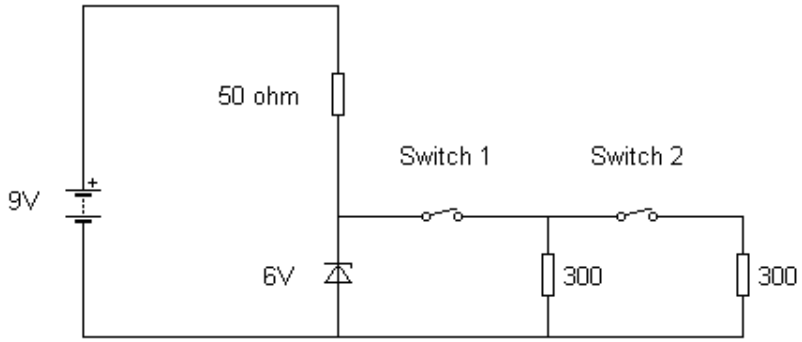
A. Graph 1
B. Graph 2
C. Graph 3
D. Graph 4

2 marks

The following information applies to Questions 11 to 13:

The circuit in Figure 9 uses a 6.0V zener diode to maintain a constant potential difference across a number of 300 ohm resistors. Switches 1 and 2 control current to the resistors. The zener has a power rating of 0.3W.

Figure 9



QUESTION 11
When switch 1 is closed and switch 2 open, what current flows through the zener diode?

A. 0.06A
B. 0.04A
C. 0.02A
D. zero

2 marks

QUESTION 12
Closing switch 2 so that both 300Ω resistors are connected causes current through the zener diode to:

A. Increase
B. Decrease
C. Remain the same

2 marks

QUESTION 13
Select the best alternative from the options below. When switch 1 opens,

A. The zener diode burns out.
B. The current through the 50 ohm resistor reduces.
C. The current through the 50 ohm resistor increases.
D. The zener diode switches off.

2 marks

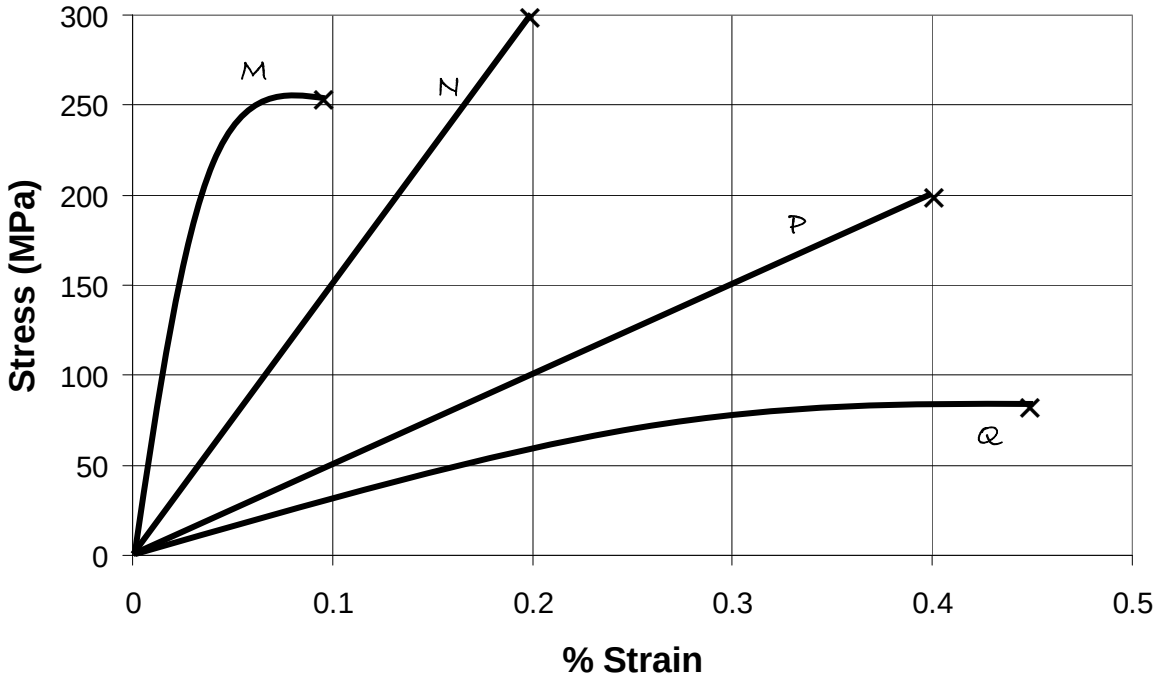
End of Further Electronics Section

DETAILED STUDY 3: MATERIALS AND STRUCTURES

Questions 1 to 5 refer to the following information:

The stress-strain graph in Figure 1 shows the properties of four materials.

Figure 1



QUESTION 1
Which of the four materials (A-D) has the greatest strength?

A. M
B. N
C. P
D. Q

2 marks

QUESTION 2
Which of the following properties (A-D) is true for material M?

A. stiffest
B. strongest
C. largest strain energy
D. toughest

2 marks

QUESTION 3
Which of the following quantities (A-D) best represents the energy per unit volume to fracture for material N?

A. 30 J/m^3
B. 300 J/m^3
C. 300 kJ/m^3
D. 30 MJ/m^3

2 marks

QUESTION 4
Which of the four materials (A-D) is the most brittle?

A. M
B. N
C. P
D. Q

2 marks

QUESTION 5
Which of the four quantities (A-D) best estimates the value of Young's Modulus for Material P?

A. 500 Pa
B. 500 kPa
C. 500 MPa
D. 50 GPa

2 marks

Questions 6 to 9 refer to the following information:

A balcony floor made of concrete is supported at the wall and by a support pillar 2 m from the wall. The balcony floor is 3 m wide as shown in Figure 2. Jeff is standing at the centre of the balcony floor. Jeff has a mass of 65 kg and the concrete floor has a mass of 200 kg.

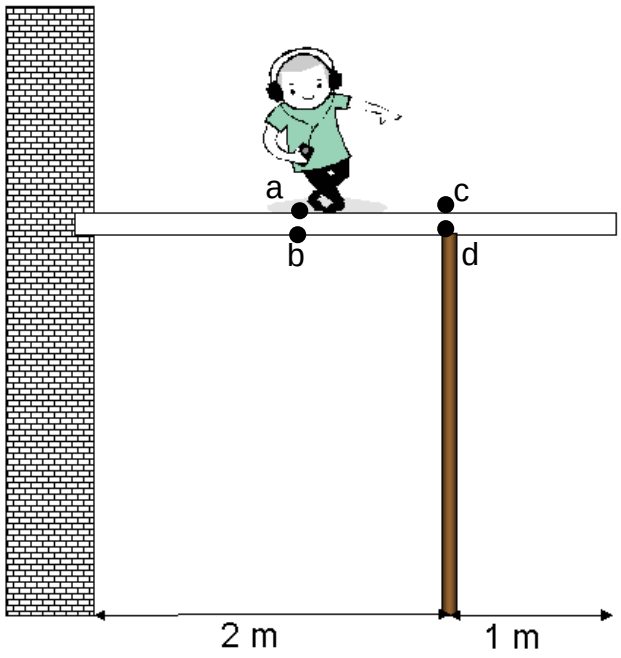


Figure 2

QUESTION 6
Which one or more of the following positions indicated by the dots in Figure 2, (A-D) would be the best place to reinforce the balcony floor with steel mesh?

A. a
B. b
C. c
D. d

2 marks

Jeff now walks to the end of the balcony. The balcony is in static equilibrium.

QUESTION 7
Which of the following types of forces (A-D) best describes the force at point d?

A. shear
B. compression
C. tensile
D. gravitational

2 marks

QUESTION 8
Which of the following quantities (A-D) best estimates the force from the supporting pillar on the balcony floor?

A. 248 N
B. 265 N
C. 2475 N
D. 2650 N

2 marks

QUESTION 9
Which of the following quantities (A-D) best estimates the force acting on the balcony from the wall?

A. 0 N
B. 175 N
C. 1750 N
D. 2650 N

2 marks

Questions 10 to 13 refer to the following information:

A steel cable has a Young's Modulus of 200 GPa. The cable has a cross-sectional area of 100 mm^2 and is 50 m long. The cable is then stretched such that its length is now 50.05 m.

QUESTION 10
Which of the following quantities (A-D) best estimates the % strain of the cable?

A. 0.0001
B. 0.001
C. 0.099
D. 0.1

2 marks

The cable is now stretched further and experiences a stress of 500 MPa.

QUESTION 11
Which of the following quantities (A-D) best estimates the net force on the cable?

A. 50 N
B. 50×10^{3} N
C. 50×10^{6} N
D. 50×10^{9} N

2 marks

QUESTION 12
Which of the following quantities (A-D) represents the new strain experienced by the steel cable?

A. 0.0025
B. 0.25
C. 2.5
D. 1×10^{5}

2 marks

QUESTION 13
Which of the following statements (A-D) best describes why steel is used for cabling rather than aluminium which has a Young's modulus of 70 GPa?

A. Steel is not a composite material
B. Steel is more elastic
C. Steel is less brittle
D. Steel is stiffer

2 marks

End of Structures and Materials Section

THE SCHOOL FOR EXCELLENCE
UNIT 3 PHYSICS 2009
COMPLIMENTARY WRITTEN EXAMINATION 1

SECTION A – CORE STUDIES

AREA OF STUDY 1 - MOTION IN ONE AND TWO DIMENSIONS

QUESTION 1

At terminal velocity the force of air resistance (up) is equal in magnitude to the weight force down. Therefore the force of air resistance is 2.25 N up (or 2.21 N up if using g= 9.8).

[1 mark] for recognising $|mg| = |F_{air}|$
[1 mark] for 2.25 N
[1 mark] for direction = up

QUESTION 2

$\Delta p = F\Delta t$ $\quad F_{ave} = \frac{\Delta p}{\Delta t} = \frac{13.5}{0.25}$ = 54 N

[1 mark] for correct substitution into formula
[1 mark] for 54 N
[1 mark] for direction = up

QUESTION 3

$\Delta p = m\Delta v$
$\Delta p = m(v-u)$

Take upward as positive: $13.5 = 0.225 (v - -28)$

$$\frac{13.5}{0.225} = v + 28$$

$$60 = v + 28$$

$v = 60 - 28$ = 32 m/s upward

[1 mark] for correct substitution into formula
[1 mark] for 32 m/s
[1 mark] for direction = upward

QUESTION 4

C is the correct option. Speed does not take direction into account.
The other 4 statements are essentially correct.

QUESTION 5

Friction is providing the centripetal force.

$$F_c = \frac{mv^2}{r} = \frac{0.024 \times 50^2}{0.08} = 750\ N$$

[1 mark] for correct substitution into formula
[1 mark] for 750 N

QUESTION 6

B is the correct option.
The stone moves off tangential to its circular path.

QUESTION 7

Andrew is correct (g = 2.45 N/kg). [1 mark]
The gravitational field strength is inversely proportional to the square of the radial distance according to the equation:

$$g = \frac{GM}{r^2}$$ [1 mark]

When the radial distance is doubled, the gravitational field strength will be a quarter of its value at the surface of the Earth.

QUESTION 8

The skater's initial vertical velocity is given by $u_y = 4.8\sin 28° = 2.25$ m/s. [1 mark]

Using this and the formula v = u + at gives: 0 = 2.25 – 10t [1 mark]

t = 0.23 s [1 mark] for the time to reach the highest point.

QUESTION 9

Total time of flight = 2 x 0.23 = 0.46 s

Horizontal velocity = $u_x = v_x = 4.8\cos 28° = 4.238$ m/s [1 mark]

Therefore the attained range will be 0.46 x 4.238 = 1.95 m [1 mark] and given that the ramps are 2.0 m apart, he doesn't make it. [1 mark]

QUESTION 10

Gravity acts down and air resistance acts to the left (opposing his motion) so the best answer is B. Air resistance is significant in comparison with the weight force.

QUESTION 11

The correct answer is A.

QUESTION 12

According to the equation: $T = \sqrt{\frac{4\pi^2 R^3}{GM}}$ [1 mark] if the orbital radius is the same for both objects then the period will be greater for the lighter central mass (M).

[1 mark] for explanation.

QUESTION 13

According to: $v = \sqrt{\frac{GM}{R}}$

$v = \sqrt{\frac{6.67\times10^{-11}\times1.2\times10^{21}}{3.5\times10^{5}}}$ [2 marks] = 478 m/s [1 mark]

QUESTION 14

Using Pythagoras yields Δv = 4.24 m/s [1 mark] in the south-westerly [1 mark] direction.

QUESTION 15

$\Delta p = m\Delta v$ = 14 x 4.24 = 59.4 kgm/s [1 mark] south-west. [1 mark]

AREA OF STUDY 2 - ELECTRONICS AND PHOTONICS

QUESTION 1

$$\frac{1}{R_p} = \frac{1}{30} + \frac{1}{(30+30)} = \frac{3}{60}$$

$$R_p = 20\Omega$$

$$R_{tot} = 30 + 20 = 50\Omega$$

QUESTION 2

$$I = \frac{V}{R} = \frac{12}{50} = 0.24A$$

QUESTION 3

G1 has the greatest potential difference and current of all globes. As P=IV, G1 has the largest power and therefore the greatest brightness.

QUESTION 4

Answer is C. An open switch at point Y will redirect all the current through G2 and increase the brightness.

QUESTION 5

Answer is A. As all the current from the battery passes through point W, an ammeter at this point would measure the current from the battery.

QUESTION 6

1000 Ω

QUESTION 7

1.8 – 1.9 V

QUESTION 8

At 10mA, LED has a PD of 1.7 V, the thermistor has a PD of $V = IR = 10 \times 10^{-3} \times 1000 = 10V$
Supply Voltage = 10+1.7 = 11.7V

QUESTION 9

No as temp decreases, R increases and I decreases. Therefore LED turns off.

QUESTION 10

Answer is B.

QUESTION 11

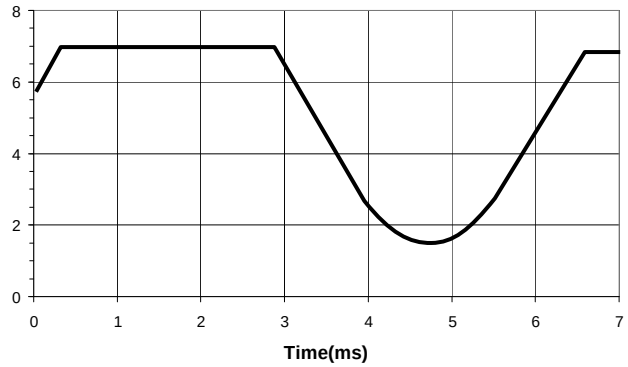
Non-inverting – as the gradient is positive.

QUESTION 12

Gradient of graph: $\frac{rise}{run} = \frac{6.5}{0.14} = 46$

QUESTION 13

Axes labelled to 7V, clipping at 7V corresponding over the time intervals of 0.3-2.8 ms and 6.5-7 ms. Minimum at 1.3 V. Also show the output signal as non-inverted.



QUESTION 14

20μA

SECTION B – CORE STUDIES

DETAILED STUDY 1 - EINSTEIN'S SPECIAL RELATIVITY

QUESTION 1 Answer is B

An inertial frame of reference is one which is not accelerating

QUESTION 2 Answer is C

Galileo postulated that all velocities are relative to the observer.

QUESTION 3 Answer is C

Given that X sees flashes travelling toward him with speed of light, as simultaneous. Observer Y, moving relative to X, will be in a different position from X when flashes arrive, so for Y they will *not* arrive simultaneously. The one coming from the front of the train will arrive first.

QUESTION 4 Answer is B

For X: $\frac{100}{\gamma} = \frac{100}{1.15} = 87\,m$

QUESTION 5 Answer is A

According to X the scorch marks on the station will be equal to the length of the observed train which is 87m. According to Y these marks will be length contracted.

$$\frac{100}{\gamma} = \frac{87}{1.15} = 76m$$

QUESTION 6 Answer is D

$t = \gamma t_o$; $\gamma = 2.3,$ therefore 2.3 revolutions

QUESTION 7 Answer is C

The half-life as measured by the laboratory observer = 3.1 x 10^{-6} x 2.3 = 7.1 x 10^{-6}s, Therefore distance travelled = speed x time = 0.9c x 7.1 x 10^{-6} = 1920m

QUESTION 8 Answer is C

$$\gamma = \frac{1}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}} = \frac{1}{\sqrt{1-0.97}} = 4.1$$

$$m = \gamma m_o = 4.1 \times 9.1 \times 10^{-31} = 3.7 \times 10^{-30}\ kg$$

QUESTION 9 Answer is C

$KE = (\gamma - 1)m_o c^2$ = (4.1 – 1) 9.1 x 10^{-31} x (3 x 10^8)^2 = 2.51 x 10^{-13}J

QUESTION 10 **Answer is B**

Dependent on the relativistic mass and velocity of the object.

QUESTION 11 **Answer is A**

No detectable velocity difference from light reflecting off each mirror

QUESTION 12 **Answer is A**

Travel time to the star system in Earth's reference frame = $\frac{8.4}{0.95} = 8.84 \, years$

QUESTION 13 **Answer is B**

$$\gamma = \frac{1}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}} = 3.2$$

Time in earth's reference frame would be 2 x 8.84 = 17.7 years

$T_{astronaut} = \frac{17.7}{\gamma} = \frac{17.7}{3.2} = 5.6 \, years$

DETAILED STUDY 2 - FURTHER ELECTRONICS

QUESTION 1 **Answer is B**

Time constant = R C =200 x 100 x 10^{-6} = 0.02s = 20ms

QUESTION 2 **Answer is A**

From the graph the time constant is found to be about 10ms.
Resistance = time constant / capacitance = 10 x 10^{-3} / 100 x 10^{-6} = 100 ohm

QUESTION 3 **Answer is B**

The supply to the resistor is half-wave rectified.

QUESTION 4 **Answer is D**

When the diode is forward biased there will be a small constant forward potential across it. In the other half of the cycle when the diode is reverse biased, it will have the full supply potential (as though it was an open switch).

QUESTION 5 **Answer is C**

To be deemed regulated it must provide constant output voltage over a range of load and supply voltages. In a voltage divider V OUT is dependent on the total resistance across it.

QUESTION 6 **Answer is G**

Both C and D result in current passing the same direction through the load

QUESTION 7 **Answer is C**

Adding a second LOAD doubles the current. Since $V_{RIPPLE} \propto I_{LOAD}$,
then ripple becomes double.

QUESTION 8 **Answer is A**

Since $V_{RIPPLE} \propto \frac{1}{C}$, then tripling capacitance by adding two additional capacitors would reduce ripple to one third of the original.

QUESTION 9 **Answer is A**

The current through the LOAD can be determined from $I_{LOAD} = \frac{V}{R} = \frac{6}{120} = 0.05A$

The average voltage supplied to the regulator is approximately 11V ($\frac{V_{MAX} + V_{MIN}}{2} \approx 11V$

The potential drop across the regulator is 11 – 6 = 5.0V
P_{LOSS} = V x I = 5.0 x 0.05 = 0.25W

QUESTION 10 **Answer is A**

The trough of the ripple voltage crosses into the dropout zone of the voltage regulator resulting in a reduced output voltage from the IC regulator.

QUESTION 11 **Answer is B**

$I_{50\Omega} = \frac{V}{R} = \frac{3}{50} = 0.06\,A$ and $I_{300\Omega} = \frac{V}{R} = \frac{6}{300} = 0.02A$

$I_{ZENER} = I_{50\Omega} - I_{300\Omega} = 0.06 - 0.02 = 0.04A$

QUESTION 12 **Answer is B**

The total current is unchanged at 0.06A, and with the switches closed each resistor draws 0.02A, resulting in only 0.02A flowing through the zener diode.

QUESTION 13 **Answer is A**

With switch 1 open all current is directed through the zener diode.

$P_{ZENER} = 6.0 \times 0.06 = 0.36W$ which exceeds the diode power rating.

DETAILED STUDY 3 - STRUCTURES AND MATERIALS

QUESTION 1 **Answer is B**

Greatest stress.

QUESTION 2 **Answer is A**

Largest gradient = stiffest

QUESTION 3 **Answer is C**

Area under graph: $\frac{1}{2}300\times10^{6}\times\frac{0.2}{100}=300\times10^{3}\,J/m^{3}$

QUESTION 4 **Answer is B**

QUESTION 5 **Answer is D**

Gradient : $\frac{rise}{run}=\frac{200\times10^{6}}{0.4\times10^{-2}}=50\times10^{9}\,Pa$

QUESTION 6 **Answer is B and C**

Concrete is weaker under tension and needs to be reinforced at points b and c.

QUESTION 7 **Answer is B**

QUESTION 8 **Answer is C**

Take torques at the wall.

$\Sigma\tau=0$

$2000\times1.5+650\times3=F\times2$

$F=2475N$

QUESTION 9 **Answer is B**

$\sum F=0$

$F_{w}+2475-2000-650=0$

$F_{w}=175$

QUESTION 10 **Answer is D**

$\%strain=\frac{\Delta l}{l}\times100=\frac{0.05}{50}\times100=0.1$

QUESTION 11 **Answer is B**

$F=\sigma A=500\times10^{6}\times100\times10^{-6}=50\times10^{3}\,N$

QUESTION 12 **Answer is A**

$$\varepsilon = \frac{\sigma}{E} = \frac{500 \times 10^6}{200 \times 10^9} = 0.0025$$

QUESTION 13 **Answer is D**

Steel is stiffer, having the larger Young's modulus.