

Physics

Trial Examination

HSC Course

2010

SOLUTIONS

General Instructions

Reading time - *5 minutes*

Working time - *135 minutes*

Board-approved calculators may be used.

Write using blue or black pen.

Draw diagrams using pencil.

Formulae sheets and a Periodic Table are provided with this question paper.

Answer all questions in the spaces provided.

This paper has two sections:

Total marks (75)

Part A

15 marks – attempt questions 1 -15

Part B

60 marks – attempt questions 16 - 28

Part A

Multiple Choice Answers

For questions 1 - 15 place a cross (X) in the column which matches your choice.

Question	A	B	C	D
1		X		
2	X			
3				X
4		X		
5			X	
6				X
7			X	
8			X	
9		X		
10				X
11		X		
12				X
13		X		
14			X	
15	X			

Marking Summary

Space 1 – 5 / 5

16 – 20 / 20

Space Total / 25

Motors 6 – 10 / 5

21 – 24 / 20

Motors Total / 25

Ideas 11 – 15 / 5

25 – 28 / 20

Ideas Total / 25

Final Mark / 75

Part B

Total Marks (60)

Attempt questions 16 – 28

Allow about 1 hour and 50 minutes for this part

Question 16 (4 marks)

- (a) Define Newton's *universal law of gravitation*. 2

The gravitational force between two objects is proportional to the product of the masses and inversely proportional to the square of the distance between them.

- (b) The average distance from the Earth to the Sun is 1.5×10^{11} m. The acceleration due to the Sun's gravitational field at the Earth is $6.0 \times 10^{-3} \text{ ms}^{-2}$.

Calculate the approximate mass of the Sun. 2

Use $g = GM/r^2$ make M the subject and then solve gives $M = 2.0 \times 10^{30} \text{ kg}$

Question 17 (3 marks)

- (a) Assume that you are in a closed container with no windows.

Identify whether it is possible to determine if the container is moving at a constant velocity or if it is stationary.

State the relevant principle in Physics that justifies your answer. 2

According to the principle of relativity, no experiment can be done to determine the state of constant motion of the container without reference to some point of object outside the container.

- (b) Identify the name that is given to the frame of reference referred to in part (a). 1

Inertial frame of reference

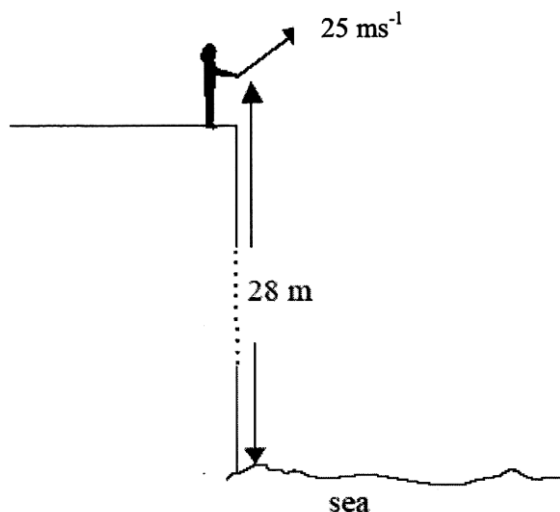
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A stone is thrown from the top of a cliff at a height of 28 m above the sea.

The stone is thrown at a speed of 25 ms^{-1} at an angle of 30° above the horizontal. (Ignore air resistance.)

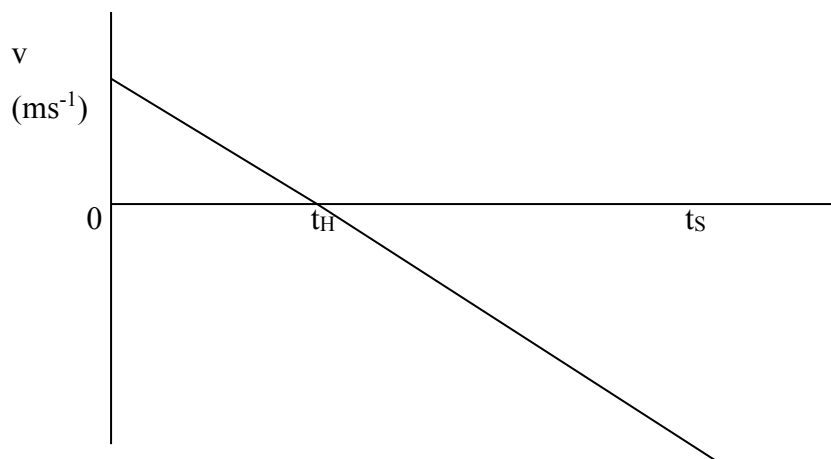
The maximum height reached by the stone from the point at which it is thrown is 8.0 m.

The stone leaves the cliff at time $t = 0$. It reaches its maximum height at $t = t_H$ and strikes the sea at $t = t_S$.



- (a) On the axes below sketch a graph to show how the magnitude of the vertical velocity of the stone varies with time, from $t = 0$ to $t = t_S$.

3



- (b) Calculate the total time (t_S) it will take for the stone to hit the water.

2

Calculate time to reach maximum height i.e. $t = v \sin \phi / g = 1.3 \text{ s}$

Calculate time to return to sea i.e. $t = \sqrt{2h / g} = 2.7 \text{ s}$

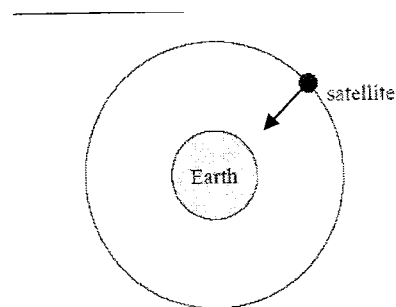
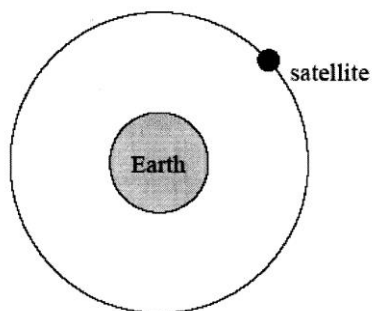
Therefore total time = $1.3 + 2.7 = 4.0 \text{ s}$

Question 19 (3 marks)

The diagram below shows a satellite in orbit around the Earth.

The diameter of the Earth is 12 560 km.

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- (a) State the name of the force causing the satellite's acceleration and show the direction in which it acts by drawing a vector to represent it on the above diagram. 1

Centripetal force or gravitational force

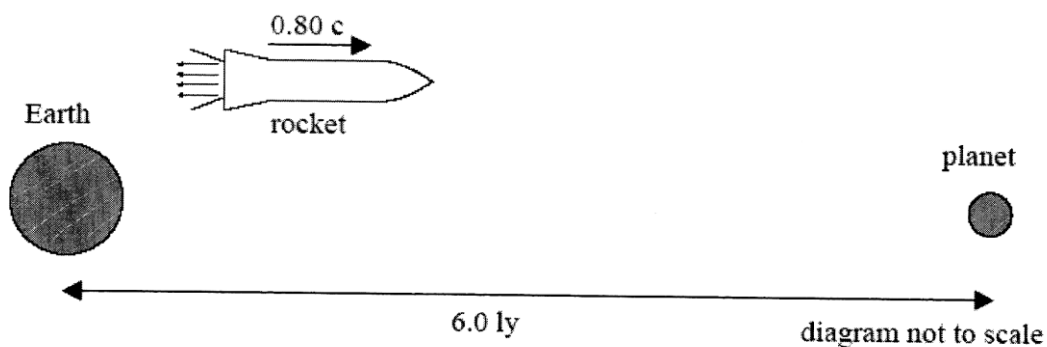
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Use $a = GM/r^2$ where r includes Earth's radius plus altitude of satellite and is in metres.

Gives $a = 0.58 \text{ ms}^{-2}$

Question 20 (5 marks)

A rocket moving at $0.80c$ relative to the Earth passes the Earth on its way to a distant planet. The distance between the Earth and the planet is 6.0 light years (ly) as measured by an observer on Earth.



- (a) Calculate the time taken for the journey from the Earth to the planet, according to an observer on Earth.

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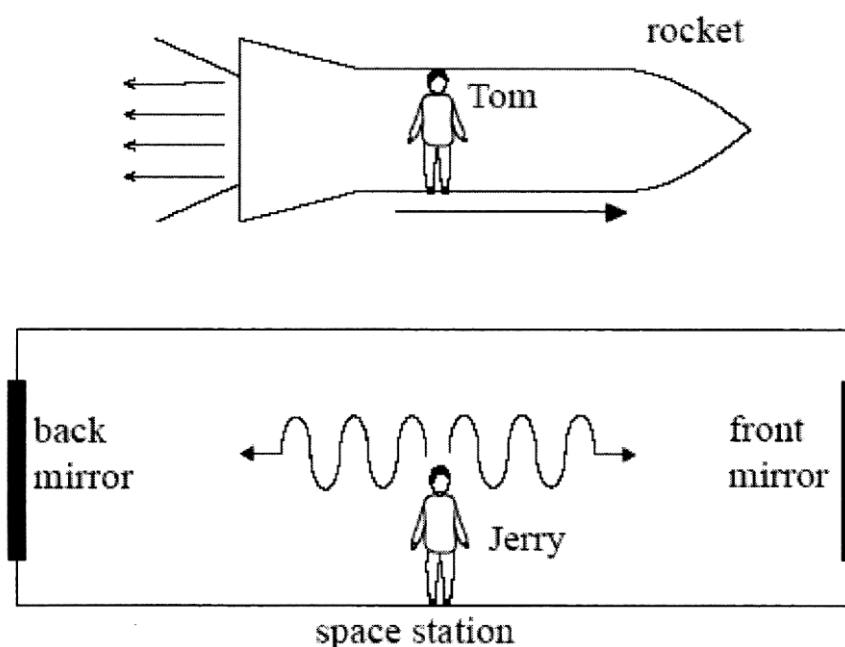
Use time = distance / speed = 6 / 0.8 = 7.5 years

- (b) Calculate the time taken for the journey from the Earth to the planet, according to an observer in the space ship.

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Use time dilation formula with $t_o = 7.5$, $v = 0.8c$ gives $t_v = 4.5$ years

- (c) Tom is an observer in a rocket that moves past a space station. Jerry is an observer in the middle of the space station. Jerry sends two light signals towards mirrors at the front and back of the space station. The signals are emitted simultaneously according to both Tom and Jerry. The signals are reflected off the mirrors and travel back to Jerry.



From Tom's frame of reference, determine whether the front or the back of the space station receives the signal first, or whether the signals arrive simultaneously. Justify your answer.

2

From Tom's point of view both signals travel at the same speed (and have been transmitted simultaneously); so since the front of the station moves towards the signal (relative to Tom), Jerry receives the reflected signal from the front mirror first.

Question 21 (4 marks)

- (a) A transformer connected to a 240 V mains supply has a primary coil with 100 turns and a secondary coil with 720 turns.

Calculate the output voltage.

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Use $V_s / V_p = n_s / n_p$ rearrange and solve for V_s gives $V_s = 1728 \text{ V}$

- (b) Describe the impact of the development of transformers on society.

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Step-up transformers allow the transmission of electrical energy while minimising energy losses and are needed in cathode ray type TVs. Step down transformers are used to provide safe local power supply and various voltages in domestic and industrial devices. Combined with rectifying circuitry, transformers are increasingly used to charge rechargeable batteries of many devices such as cordless drills, mobile phones and iPods.

Efficient transmission of energy using transformers has allowed the development of large cities and factory locations away from power stations and the development of affordable electronic and household appliances without dependence on battery power.

Question 22 (6 marks)

- (a) Outline the basic principle of induction motors.

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In induction motors, a squirrel cage is surrounded by a rotating magnetic field that induces an emf in the rods of the squirrel cage. As a result of this induced emf a current flows creating a magnetic field. This magnetic field interacts with the rotating magnetic field and torque results.

- (b) Galvanometers and loudspeakers are both applications of the motor effect and a moveable coil is a central part of each device.

Analyse how the motor effect is used to produce rotation of the coil in one device and vibration in the other.

4

In galvanometers the coil is flat and rectangular and on an axis parallel to the plane of the coil. It is surrounded by a radial magnetic field of constant strength which acts perpendicular to the axis of the coil, exerting opposing forces on 2 opposite sides of the coil which creates a torque and subsequent rotation.

In speakers, the coil is circular and elongated. The surrounding magnetic field is radial and parallel to the plane of each turn in the coil. The motor effect results in forces perpendicular to the plane of the coil but in the same direction for each part of the circular turns of the coil. The coil then moves in the direction of the force and changes direction with changes in current direction.

Question 23 (5 marks)

- (a) Justify the use of very high voltages for the transmission of electricity.

2

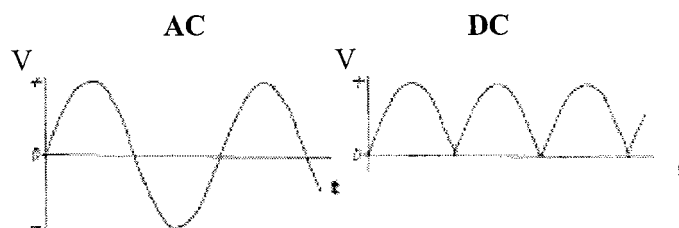
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- (b) Outline the reason for the limit on magnitude of the voltage used for transmission.

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The voltage is limited as extreme voltages (above 500 kV) ionise the air and insulators are unable to prevent conduction to the ground at the supporting towers. (Anything can be made to conduct if the potential difference is high enough!)

- (c) In the space below, sketch two graphs showing the output of simple AC and DC generators.

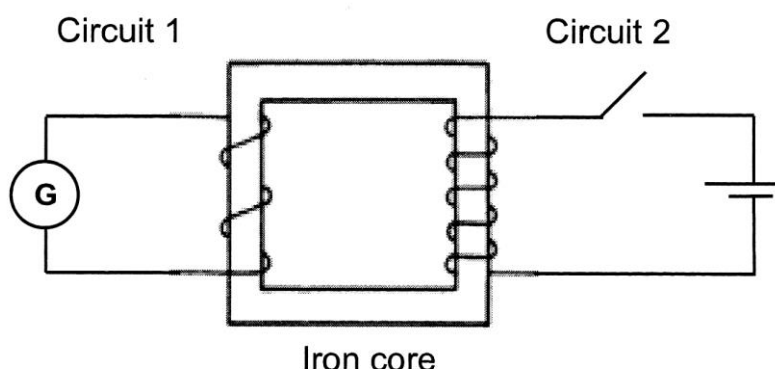
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Question 24 (5 marks)

Two coils are wrapped around the opposite sides of an iron core as shown in the diagram.

Circuit 1 has a galvanometer and circuit 2 has a switch and a battery.

When the switch is first closed, the galvanometer needle moves, then returns to zero.



- (a) Explain the cause of the current flow in circuit 1.

2

The closing of the switch in circuit 2 allows a current to flow. In the (very small) interval of time that it takes the current to reach a maximum value, there is a changing magnetic field in the vicinity of the coil. This induces an emf in circuit 1 which drives a current for a very small time. Once the current in circuit 2 has reached a maximum value and is steady, there is no longer a variable magnetic field so there is no emf produced and the current in circuit 1 drops to zero again.

- (b) Describe **TWO** changes to the apparatus that would increase the magnitude of the momentary current flow.

2

Increase the supply emf in circuit 2 AND / OR increase the ratio of turns in coil 2 compared to coil 1.

- (c) Propose ONE change to the apparatus that would produce a continuous current in circuit 1 while the switch is held closed.

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If AC is used in circuit 2 the fluctuations of the current will produced a continually fluctuating magnetic field and hence a continuous emf in circuit 1.

Question 25 (5 marks)

A certain substance has a work function of 2.2 eV. It is lit with two separate beams of light i.e. blue light with wavelength 450 nm and orange light with wavelength 650 nm.

- (a) Explain the concept of a “threshold frequency” as it applies to the photoelectric effect. 2
The threshold frequency refers to the frequency of the incident radiation. If the incident radiation has a frequency above the threshold frequency, electrons will be ejected from the metal surface. If the incident radiation has a frequency below the threshold frequency, no electrons will be emitted, regardless of the intensity of the incident beam.
- (b) By making appropriate calculations, verify the fact that blue light is more likely to cause the emission of electrons than orange light for the substance mentioned above. 3

Use $f = c/\lambda$ to turn the incident wavelengths into frequencies.

Use $E = hf$ where $E = 2.2 \times 1.6 \times 10^{-19} = 3.52 \times 10^{-19} \text{ J}$ to calculate the threshold frequency

i.e. $f = E/h = 5.31 \times 10^{14} \text{ Hz}$

Compare frequencies of orange light ($4.61 \times 10^{14} \text{ Hz}$) and blue light ($6.67 \times 10^{14} \text{ Hz}$) with the threshold frequency. As the frequency of the blue light exceeds the threshold frequency blue light is more likely to cause a photocurrent.

Question 26 (5 marks)

- (a) Describe how p-type semiconductors are produced. 1
P-type semiconductors are produced by adding small amounts of group III atoms to the pure semiconductor
- (b) Explain the electrical properties of p-type semiconductors compared to the electrical properties of pure semiconductors. 2

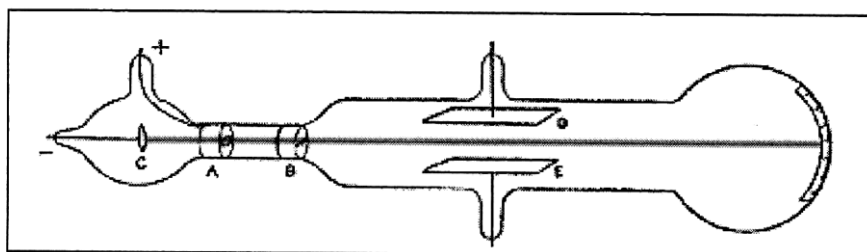
Doping a semiconductor increases its conductivity. This is achieved because the doping atoms contain only three bonding electrons in their outer shells, whereas the bonding requirements of the semiconductor call for 4 bonding electrons. The lack of electrons creates “holes” and these become the positive charge carriers that respond to the application of an external potential difference.

In insulators the valence band is full and there is a large energy gap between the valence and conduction bands. This prevents many electrons from moving into the conduction band. In conductors the conduction and valence bands blend into one band with many unfilled levels for electrons to occupy. This mobility of electrons results in the excellent conductivity of conductors.

Question 27 (4 marks)

At the end of the nineteenth century the inconsistent behaviour of cathode rays caused much debate among physicists.

The following diagram shows Thomson's original sketch of the apparatus he used to research cathode rays.



Explain how Thomson, using his apparatus, was able to settle the scientific debate about the nature of cathode rays.

4

The debate concerned whether cathode rays were negatively charged particles or electromagnetic radiation with a very short wavelength. Thomson reasoned that if the rays were charged particles they could be deflected by both electric and magnetic fields. His experiment used both fields with the forces balanced allowing him to find a value for the speed of the particles. He then used only the magnetic field and measured the radius of curvature of the path of the charged particles. From this data he was able to establish that the rays had the same properties no matter which metal formed the cathode and he established a charge to mass ratio for the charged particles.

Question 28 (6 marks)

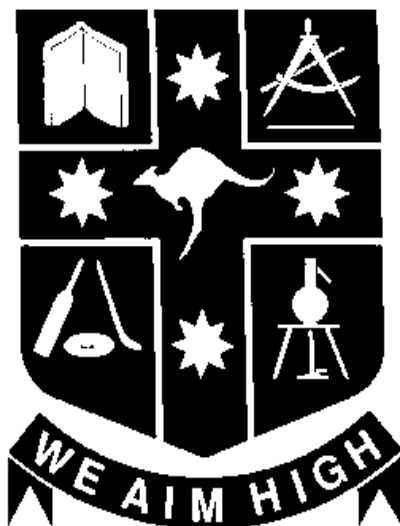
Samuel Johnson (mid-eighteenth century), when asked “What is poetry?” replied: “Why, sir, it is much easier to say what it is not. We all *know* what light is; but it is not easy to *tell* what it is.”

William Bragg (late nineteenth, early twentieth century), when asked to explain what light is, replied that physicists used the wave theory on Mondays, Wednesdays and Fridays, and the particle theory on Tuesdays, Thursdays and Saturdays.

Analyse the experimental AND theoretical contributions made by various scientists that resulted in the “model of light” referred to by William Bragg.

6

James Maxwell’s theory of electromagnetic radiation established the wave nature of light. Hertz produced such waves and measured their velocity confirming Maxwell’s theory. Explanations of the photoelectric effect were impossible with wave theory and theoretical explanations of black body radiation failed. Max Planck’s concept of quanta produced a successful black body radiation theory. Einstein used Planck’s concept of quantisation to explain the photoelectric effect. Since a quantum of energy is equivalent to a particle, electromagnetic radiation is considered to be both particle and wave as referred to by Bragg.



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 16 – 20 / 20

Space Total / 25

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Motors Total / 25

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Final Mark / 75

Part B

Total Marks (60)

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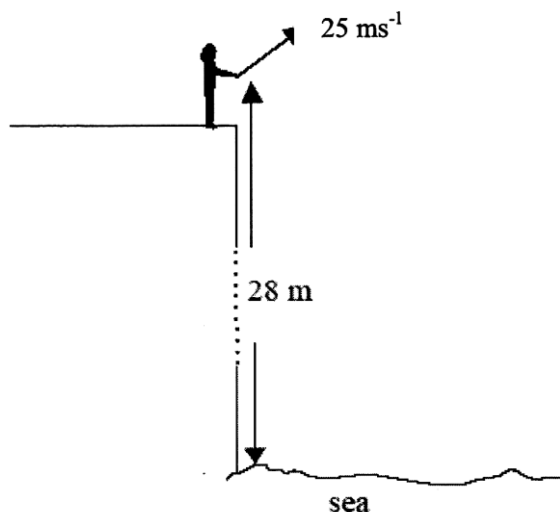
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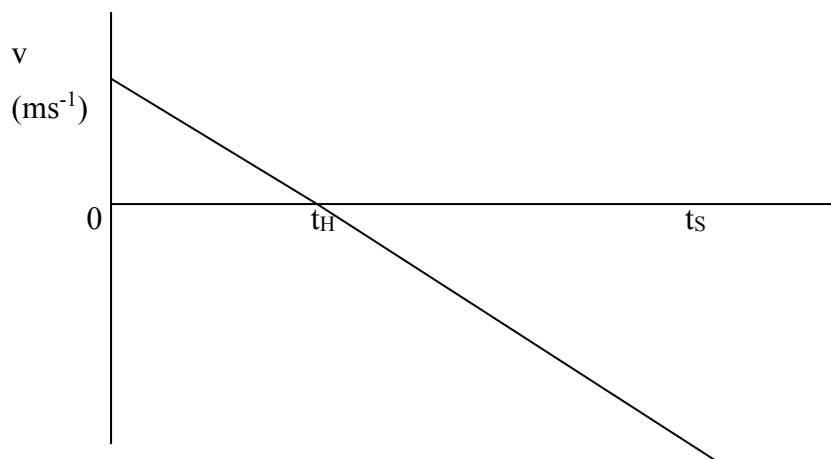
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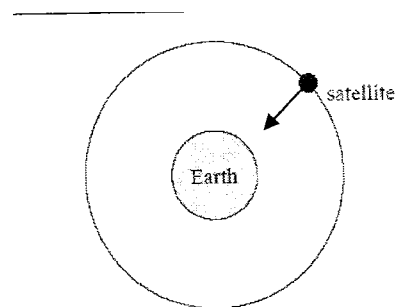
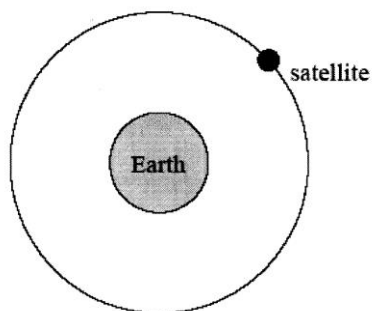
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The diagram below shows a satellite in orbit around the Earth.

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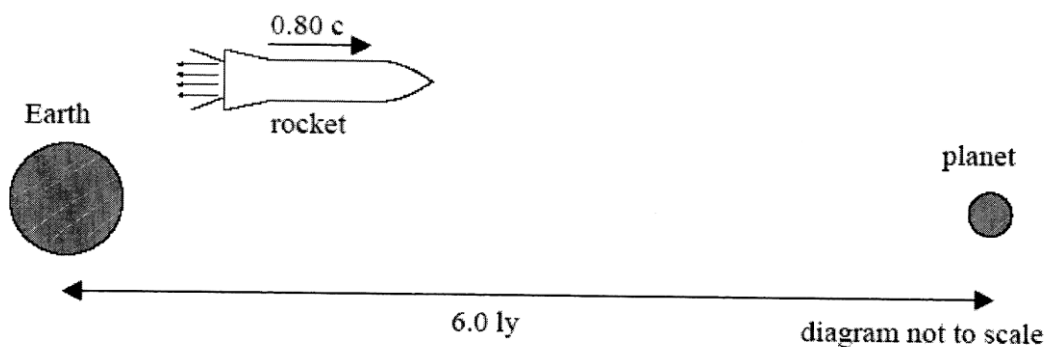
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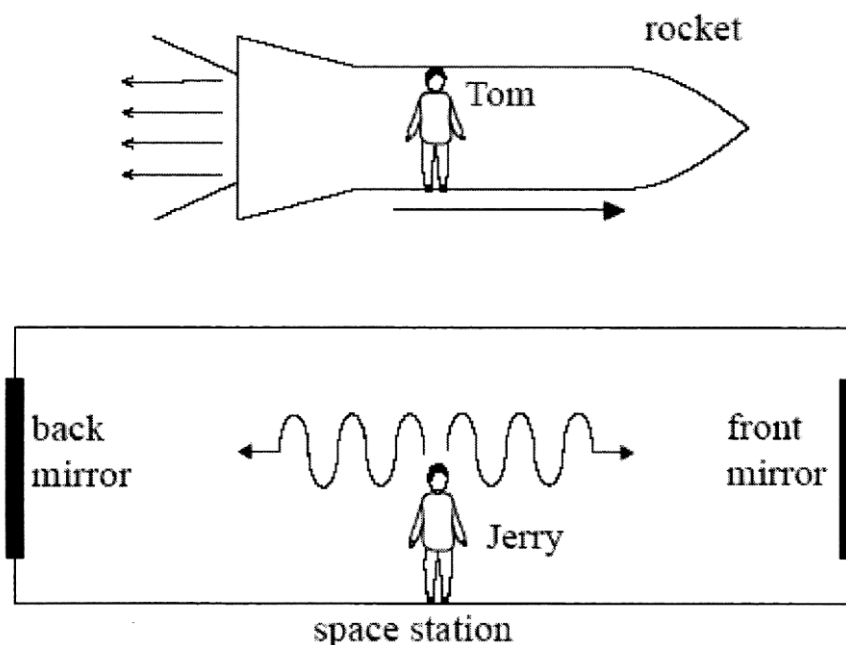
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- (a) Outline the basic principle of induction motors.

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Question 23 (5 marks)

- (a) Justify the use of very high voltages for the transmission of electricity.

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Electricity is transmitted at high voltages to reduce energy losses in transmission lines. Energy lost is dependent on I^2 ($P = I^2 R$) where I is current flowing and R is the resistance of the wires. Resistance increases proportionally with length. So energy loss increases with distance and with the square of the current. Therefore it is best to transmit electrical energy at low current by using the highest possible voltage. A high power transmission is still achieved as $P = VI$.

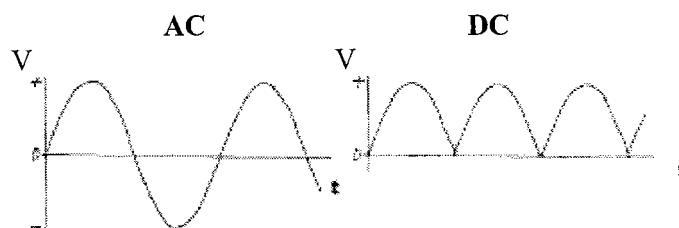
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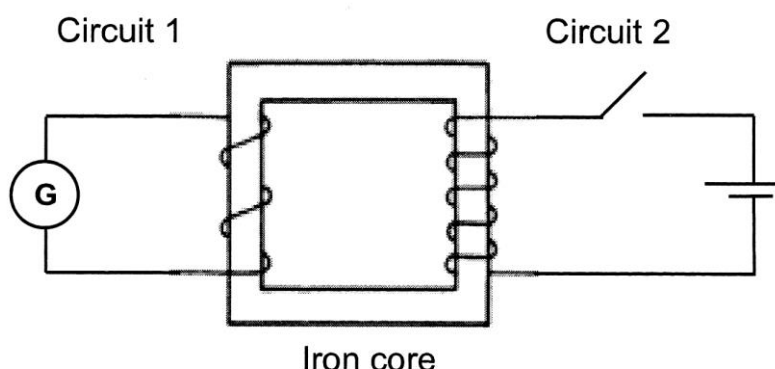


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Two coils are wrapped around the opposite sides of an iron core as shown in the diagram.

Circuit 1 has a galvanometer and circuit 2 has a switch and a battery.

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- (a) Explain the cause of the current flow in circuit 1.

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The closing of the switch in circuit 2 allows a current to flow. In the (very small) interval of time that it takes the current to reach a maximum value, there is a changing magnetic field in the vicinity of the coil. This induces an emf in circuit 1 which drives a current for a very small time. Once the current in circuit 2 has reached a maximum value and is steady, there is no longer a variable magnetic field so there is no emf produced and the current in circuit 1 drops to zero again.

- (b) Describe **TWO** changes to the apparatus that would increase the magnitude of the momentary current flow.

2

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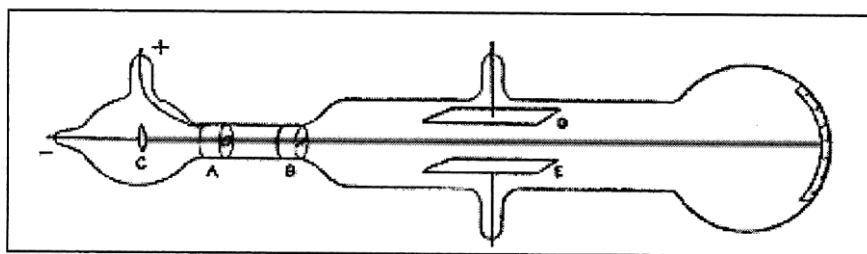
Doping a semiconductor increases its conductivity. This is achieved because the doping atoms contain only three bonding electrons in their outer shells, whereas the bonding requirements of the semiconductor call for 4 bonding electrons. The lack of electrons creates “holes” and these become the positive charge carriers that respond to the application of an external potential difference.

In insulators the valence band is full and there is a large energy gap between the valence and conduction bands. This prevents many electrons from moving into the conduction band. In conductors the conduction and valence bands blend into one band with many unfilled levels for electrons to occupy. This mobility of electrons results in the excellent conductivity of conductors.

Question 27 (4 marks)

At the end of the nineteenth century the inconsistent behaviour of cathode rays caused much debate among physicists.

The following diagram shows Thomson's original sketch of the apparatus he used to research cathode rays.



Explain how Thomson, using his apparatus, was able to settle the scientific debate about the nature of cathode rays.

4

The debate concerned whether cathode rays were negatively charged particles or electromagnetic radiation with a very short wavelength. Thomson reasoned that if the rays were charged particles they could be deflected by both electric and magnetic fields. His experiment used both fields with the forces balanced allowing him to find a value for the speed of the particles. He then used only the magnetic field and measured the radius of curvature of the path of the charged particles. From this data he was able to establish that the rays had the same properties no matter which metal formed the cathode and he established a charge to mass ratio for the charged particles.

Question 28 (6 marks)

Samuel Johnson (mid-eighteenth century), when asked “What is poetry?” replied: “Why, sir, it is much easier to say what it is not. We all *know* what light is; but it is not easy to *tell* what it is.”

William Bragg (late nineteenth, early twentieth century), when asked to explain what light is, replied that physicists used the wave theory on Mondays, Wednesdays and Fridays, and the particle theory on Tuesdays, Thursdays and Saturdays.

Analyse the experimental AND theoretical contributions made by various scientists that resulted in the “model of light” referred to by William Bragg.

6

James Maxwell’s theory of electromagnetic radiation established the wave nature of light. Hertz produced such waves and measured their velocity confirming Maxwell’s theory. Explanations of the photoelectric effect were impossible with wave theory and theoretical explanations of black body radiation failed. Max Planck’s concept of quanta produced a successful black body radiation theory. Einstein used Planck’s concept of quantisation to explain the photoelectric effect. Since a quantum of energy is equivalent to a particle, electromagnetic radiation is considered to be both particle and wave as referred to by Bragg.