BOARD OF STUDIES
NEW SOUTH WALES

2004

HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- A data sheet, formulae sheets and Periodic Table are provided at the back of this paper
- Write your Centre Number and Student Number at the top of pages 13, 17, 21 and 23

Total marks – 100

Section I Pages 2–26

75 marks

This section has two parts, Part A and Part B

Part A – 15 marks

- Attempt Questions 1–15
- Allow about 30 minutes for this part

Part B – 60 marks

- Attempt Questions 16–27
- Allow about 1 hour and 45 minutes for this part

Section II Pages 27–38

25 marks

- Attempt ONE question from Questions 28–32
- Allow about 45 minutes for this section

Section I
75 marks

Part A – 15 marks
Attempt Questions 1–15
Allow about 30 minutes for this part

Use the multiple-choice answer sheet.

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

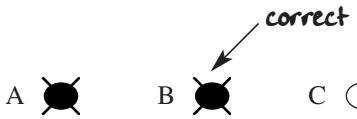
Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

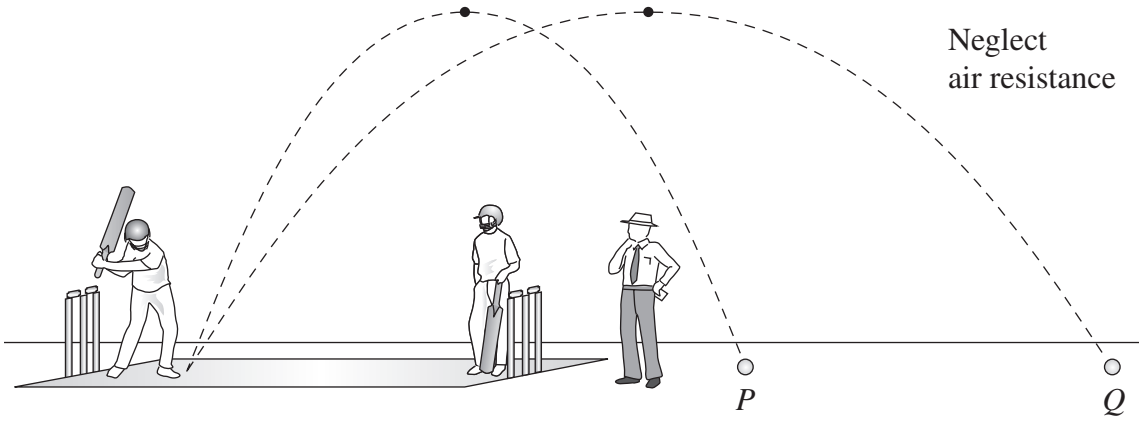
A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.



A ⊗ B ⊗ C ○ D ○

1 The picture shows a game of cricket.



The picture shows two consecutive shots by the batsman. Both balls reach the same maximum height above the ground but ball *Q* travels twice as far as ball *P*.

Which of the following is DIFFERENT for balls *P* and *Q*?

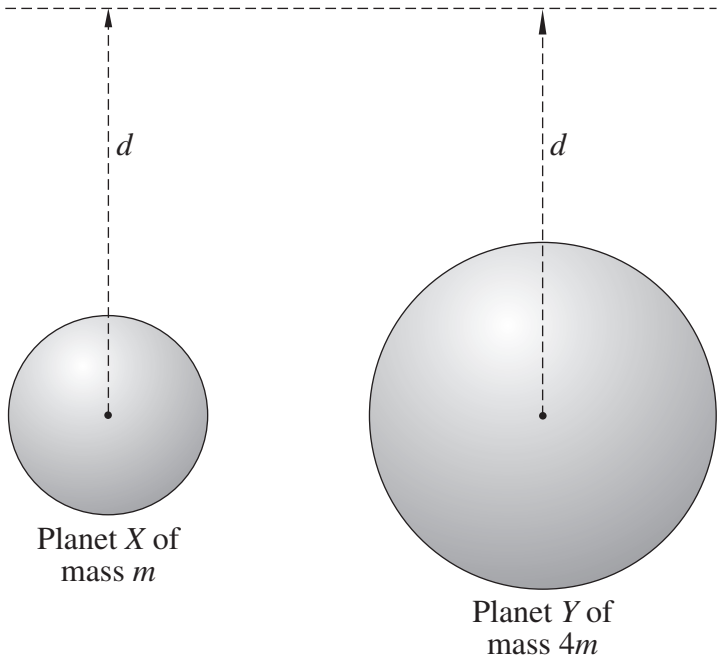
(A) Time of flight

(B) Initial velocity

(C) Gravitational force

(D) Gravitational acceleration

2 The diagram shows two planets X and Y of mass m and $4m$ respectively.



At the distance d from the centre of planet Y the acceleration due to gravity is $4.0\ \text{m s}^{-2}$.

What is the acceleration due to gravity at distance d from the centre of planet X?

(A) $1.0\ \text{m s}^{-2}$

(B) $2.0\ \text{m s}^{-2}$

(C) $2.8\ \text{m s}^{-2}$

(D) $4.0\ \text{m s}^{-2}$

3 A spaceship at a distance r metres from the centre of a star experiences a gravitational force of x newtons. The spaceship moves a distance $\frac{r}{2}$ towards the star.

What is the gravitational force acting on the spaceship when it is at this new location?

(A) $\frac{x}{2}$ newtons

(B) x newtons

(C) $2x$ newtons

(D) $4x$ newtons

4 An object of rest mass 8.0 kg moves at a speed of 0.6c relative to an observer.

What is the observed mass of the object?

(A) 6.4 kg

(B) 10.0 kg

(C) 12.5 kg

(D) 13.4 kg

5 Two spaceships are both travelling at relativistic speeds. Spaceship Beta shines a light beam forward as shown.

What is the speed of the light beam according to an observer on spaceship Alpha?

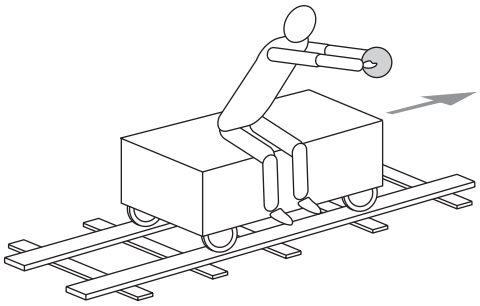
(A) The speed of the light beam is equal to c.

(B) The speed of the light beam is less than c.

(C) The speed of the light beam is greater than c.

(D) More information is required about the relative speed of the spaceships.

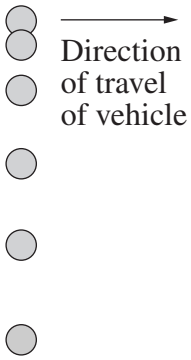
6 A ball is dropped by a person sitting on a vehicle that is accelerating uniformly to the right, as shown by the arrow.



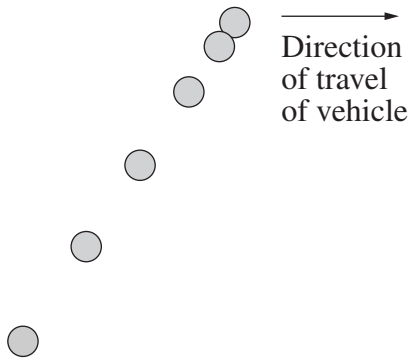
Ignore air resistance

Which of the following represents the path of the ball, shown at equal time intervals, observed from the frame of reference of the vehicle?

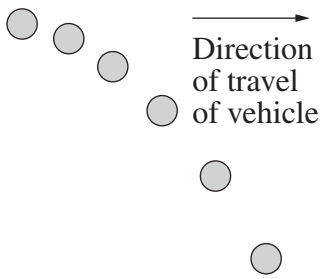
(A)



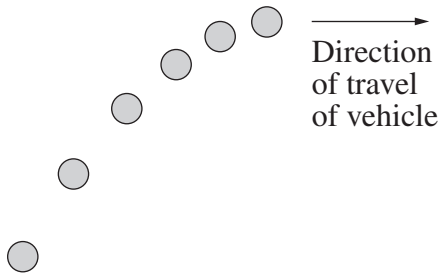
(B)



(C)



(D)



7 Why do some electrical appliances in the home need a transformer instead of operating directly from mains power?

(A) They require a voltage lower than the mains voltage.

(B) They require a source of energy that is DC rather than AC.

(C) They require an alternating current at a frequency other than 50 Hz.

(D) They consume less energy than a similar device without a transformer.

8 A transformer which has 60 turns in the primary coil is used to convert an input of 3 V into an output of 12 V.

Which description best fits this transformer?

	Type of transformer	*Number of turns in secondary coil*
(A)	Step up	15
(B)	Step down	240
(C)	Step up	240
(D)	Step down	15

9 An electric DC motor consists of 500 turns of wire formed into a rectangular coil of dimensions $0.2\text{ m} \times 0.1\text{ m}$. The coil is in a magnetic field of 1.0×10^{-3} T. A current of 4.0 A flows through the coil.

What is the magnitude of the maximum torque, and the orientation of the plane of the coil relative to the magnetic field when this occurs?

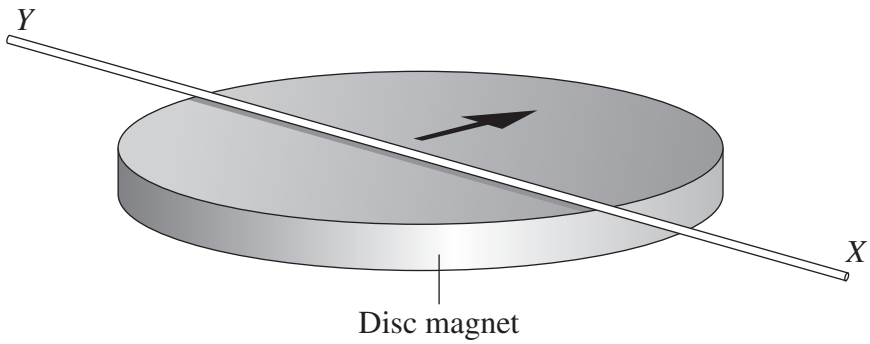
(A) 0.04 N m, parallel to the field

(B) 0.04 N m, perpendicular to the field

(C) 0.4 N m, parallel to the field

(D) 0.4 N m, perpendicular to the field

10 A disc magnet has its poles on its opposing flat surfaces. An insulated copper wire was placed on the disc magnet as shown in the diagram.



The instant the wire was connected to a DC battery, the wire was observed to move in the direction of the arrow.

Which statement describes the direction of the magnet's field and the direction of the current in the wire, consistent with this observation?

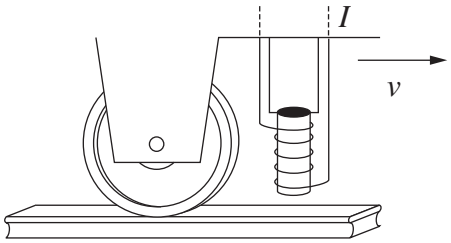
(A) The field was vertically upward and the current was from *X* to *Y*.

(B) The field was vertically upward and the current was from *Y* to *X*.

(C) The field was in the direction of the arrow and the current was from *X* to *Y*.

(D) The field was in the direction of the arrow and the current was from *Y* to *X*.

11 An electromagnet is attached to the bottom of a light train which is travelling from left to right, as shown.



When a large current is passed through the coils of the electromagnet, the train slows down as a direct result of the law of conservation of energy.

In which of the following devices is the law of conservation of energy applied in the same way?

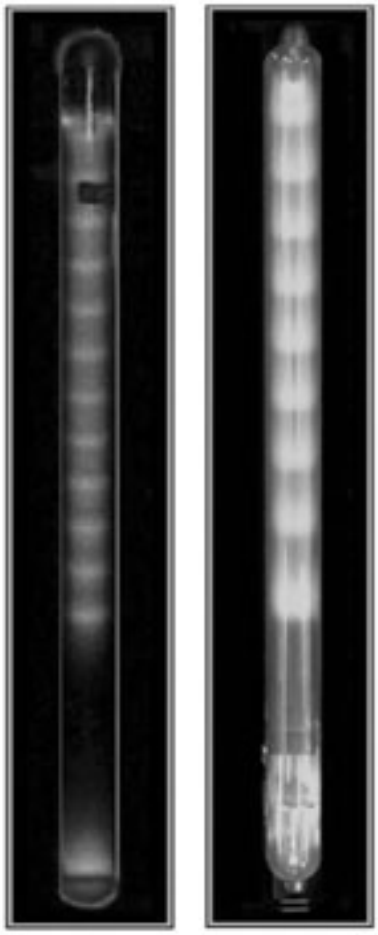
(A) DC motor

(B) Loudspeaker

(C) Induction motor

(D) Induction cooktop

12 Photographs of two gas discharge tubes are shown.



What causes the variations of the pattern of striations in the gas discharge tubes?

(A) Different gases in the tubes

(B) Different gas pressures in the tubes

(C) Different voltages applied to the tubes

(D) Different electrode materials used in the tubes

13 Compared to silicon atoms, phosphorus atoms have one more electron in their outer shell. Boron atoms have one less electron than silicon atoms in their outer shell.

Which of the following is the correct statement?

(A) An *n*-type semiconductor is produced when silicon is doped with phosphorus, and a *p*-type semiconductor when silicon is doped with boron.

(B) A *p*-type semiconductor is produced when silicon is doped with phosphorus, and an *n*-type semiconductor when silicon is doped with boron.

(C) The addition of phosphorus atoms turns silicon into a conductor but the addition of boron atoms turns silicon into an insulator.

(D) The addition of boron atoms turns silicon into a conductor but the addition of phosphorus atoms turns silicon into an insulator.

14 The minimum amount of energy needed to eject an electron from a clean aluminium surface is 6.72×10^{-19} J.

What is the maximum wavelength of incident light that can be shone on this aluminium surface in order to eject electrons?

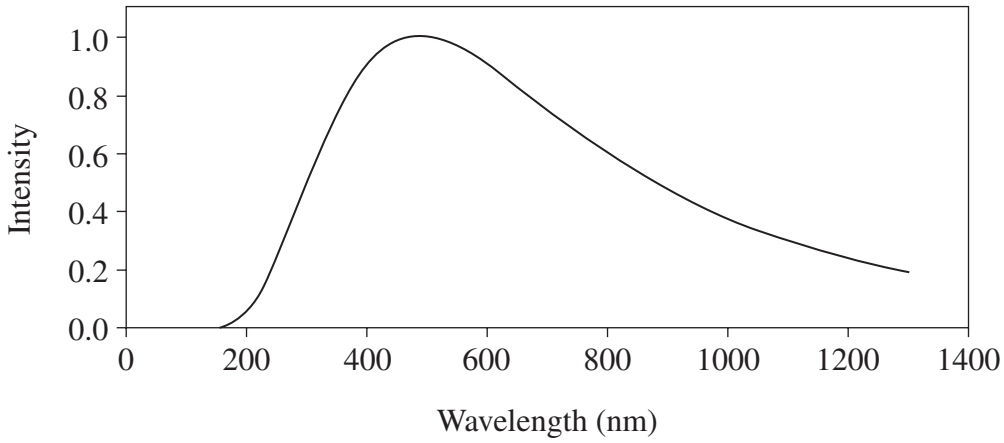
(A) 9.86×10^{-16} m

(B) 2.96×10^{-7} m

(C) 3.38×10^{6} m

(D) 1.02×10^{15} m

15 The graph shows the intensity–wavelength relationship of electromagnetic radiation emitted from a black body cavity.



In 1900, Planck proposed a mathematical formula that predicted an intensity–wavelength relationship consistent with the experimental data.

The success of this formula depended on which of the following hypotheses?

(A) The intensity of light is dependent on the wavelength.

(B) Light is quantised, with the energy of light quanta depending on the frequency.

(C) Light is a wave whose intensity is readily expressed using mathematical formulae.

(D) Light is quantised, with the energy of the light quanta depending on the size of the cavity from which it is emitted.

BLANK PAGE

Centre Number

Student Number

Section I (continued)

Part B – 60 marks
Attempt Questions 16–27
Allow about 1 hour and 45 minutes for this part

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Marks

Question 16 (4 marks)

A projectile is fired at a velocity of 50 m s^{-1} at an angle of 30° to the horizontal. **4**

Determine the range of the projectile.

.....

.....

.....

.....

.....

.....

.....

.....

Marks

Question 17 (6 marks)

In July 1969 the Apollo 11 Command Module with Michael Collins on board orbited the Moon waiting for the Ascent Module to return from the Moon's surface. The mass of the Command Module was 9.98×10^3 kg, its period was 119 minutes, and the radius of its orbit from the Moon's centre was 1.85×10^6 metres.

(a) Assuming the Command Module was in circular orbit, calculate

(i) the mass of the Moon; **2**

.....

.....

.....

.....

.....

.....

(ii) the magnitude of the orbital velocity of the Command Module. **2**

.....

.....

.....

.....

.....

.....

(b) The docking of the Ascent Module with the Command Module resulted in an increase in mass of the orbiting spacecraft. The spacecraft remained at the same altitude. **2**

This docking procedure made no difference to the orbital speed. Justify this statement.

.....

.....

.....

.....

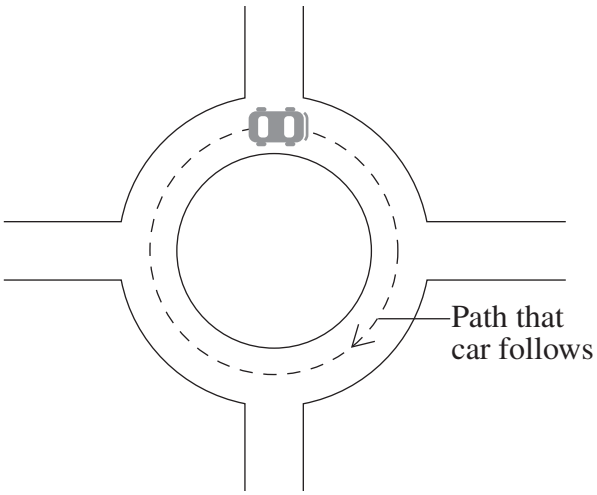
.....

.....

Marks

Question 18 (4 marks)

A car with a mass of 800 kg travels at a constant speed of 7.5 m s^{-1} on a roundabout so that it follows a circular path with a radius of 16 m. **4**



A person observing this situation makes the following statement.

> 'There is no net force acting on the car because the speed is constant and the friction between the tyres and the road balances the centripetal force acting on the car.'

Assess this statement. Support your answer with an analysis of the horizontal forces acting on the car, using the numerical data provided above.

.....

.....

.....

.....

.....

.....

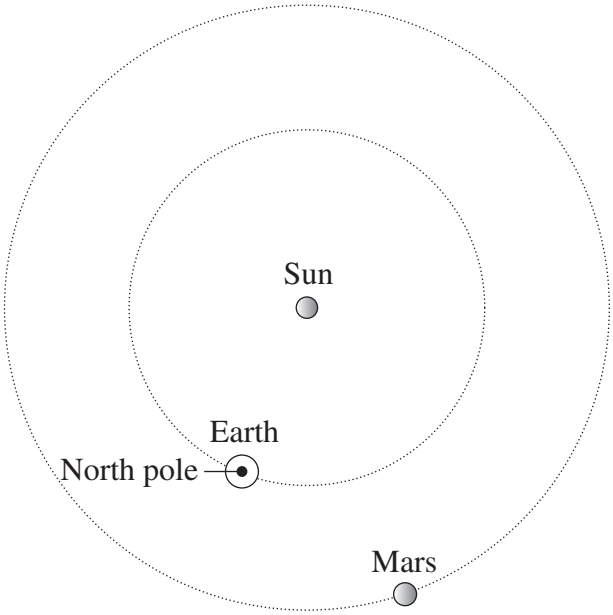
.....

.....

Marks

Question 19 (6 marks)

On 11 June 2003 the Mars Rover called Spirit was launched on a satellite from Earth when the planets were in the positions shown in the diagram below. The satellite arrived at Mars on 3 December 2003.



(a) Indicate on the diagram the approximate positions of Earth and Mars on 3 December 2003 and show the satellite's trajectory to Mars. **3**

(b) Discuss the effect of Earth's motion on the launch and trajectory to Mars of this satellite. **3**

.....

.....

.....

.....

.....

.....

Physics

Centre Number

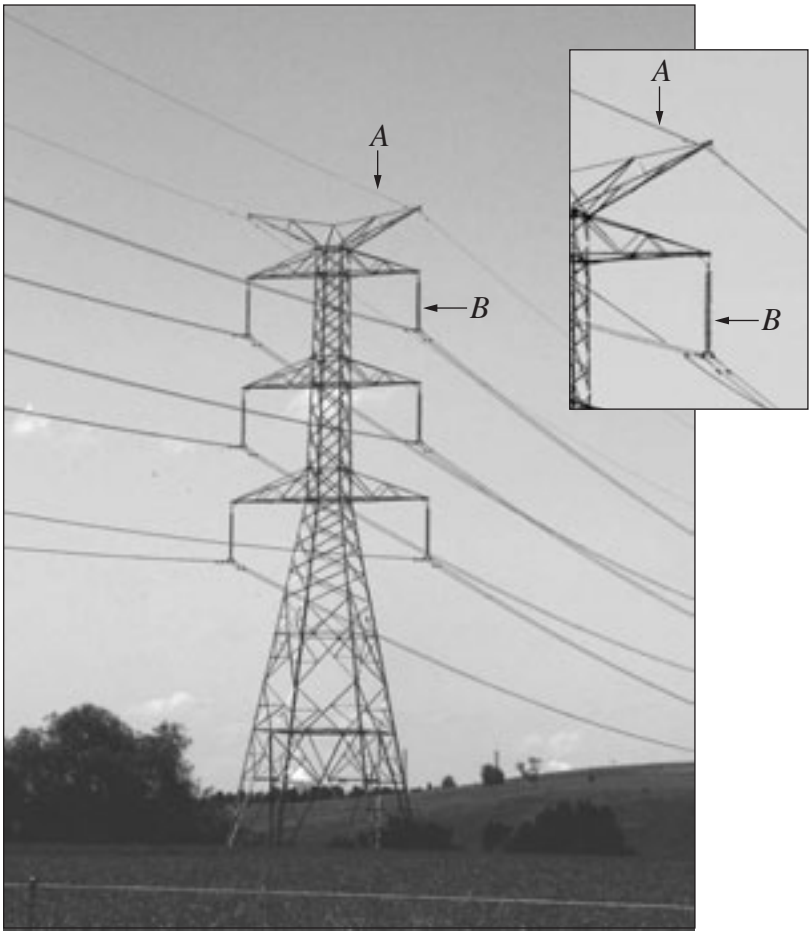
Section I – Part B (continued)

Student Number

Marks

Question 20 (2 marks)

The photograph below shows a transmission line support tower. The inset shows details of the top section of the tower. **2**



Describe the role of each of the parts labelled *A* and *B* in the photograph.

.....

.....

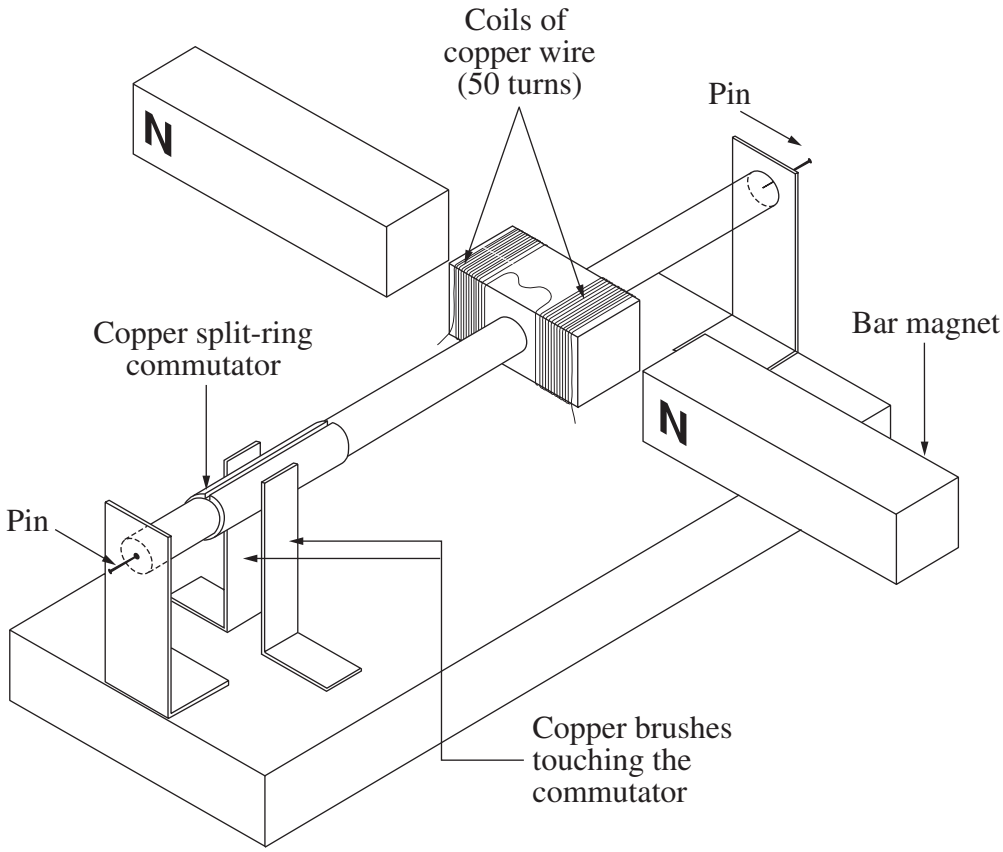
.....

.....

Marks

Question 21 (6 marks)

(a) The diagram shows a two-pole DC motor as constructed by a student. **3**



Identify THREE mistakes in the construction of this DC motor as shown in the diagram.

.....

.....

.....

.....

.....

.....

Question 21 continues on page 19

Question 21 (continued)

(b) An ammeter was used to measure the current through a small DC motor. While it was running freely, a current of 2.09 A was recorded. While the motor was running, the axle of the motor was held firmly, preventing it from rotating, and the current was then recorded as 2.54 A. **3**

Explain this observation.

.....

.....

.....

.....

.....

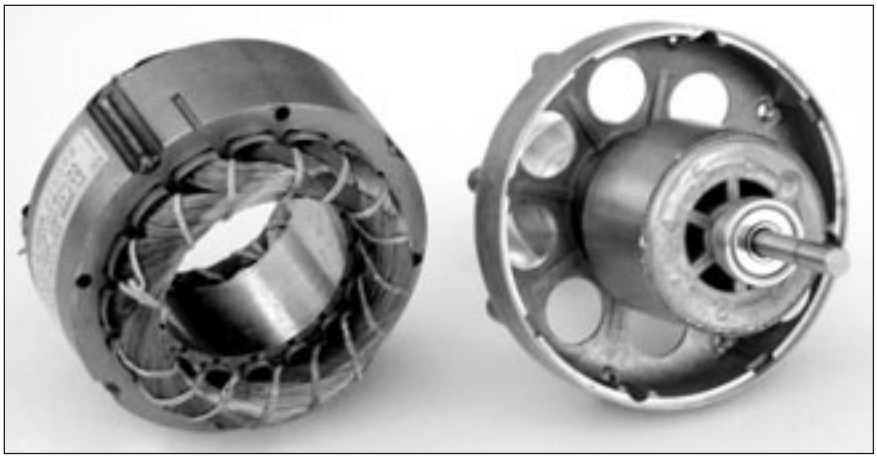
.....

End of Question 21

Marks

Question 22 (3 marks)

The photograph below shows parts of an AC electric motor. **3**



Describe the main features of this type of motor and its operation.

.....

.....

.....

.....

.....

.....

Marks

Question 23 (6 marks)

In the past 50 years electrical technology has developed from the widespread use of thermionic devices to the use of solid state devices and superconductors.

(a) List THREE disadvantages of thermionic devices that led to their replacement. **3**

.....

.....

.....

.....

.....

.....

(b) Outline ONE advantage of using superconductors, with reference to TWO applications. **3**

.....

.....

.....

.....

.....

.....

.....

.....

.....

Marks

Question 24 (6 marks)

In the late nineteenth century Westinghouse and Edison were in competition to supply electricity to cities. This competition led to Edison holding public demonstrations to promote his system of DC generation over Westinghouse's system of AC generation. **6**

Propose arguments that Westinghouse could have used to convince authorities of the advantages of his AC system of generation and distribution of electrical energy over Edison's DC supply.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

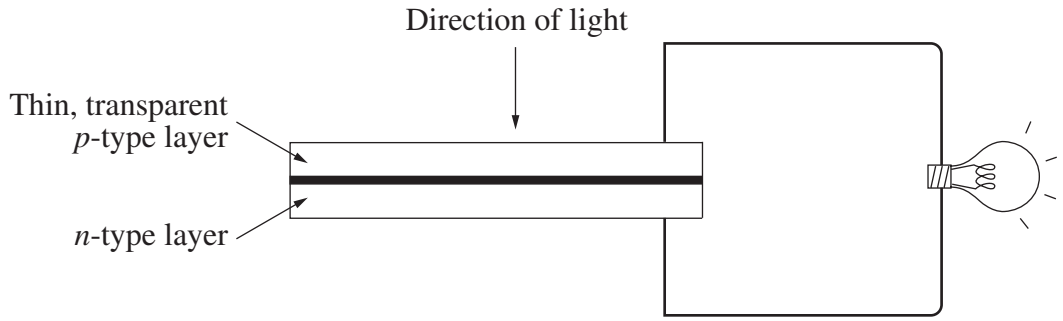
.....

.....

Marks

Question 25 (6 marks)

An example of a solar cell is shown below. **6**



The solar cell is able to produce a current due to the photoelectric effect and the electrical properties of the *n*-type and *p*-type layers.

Use this information to outline the process by which light shining on the solar cell produces an electric current that can light up a light globe.

.....

.....

.....

.....

.....

.....

.....

.....

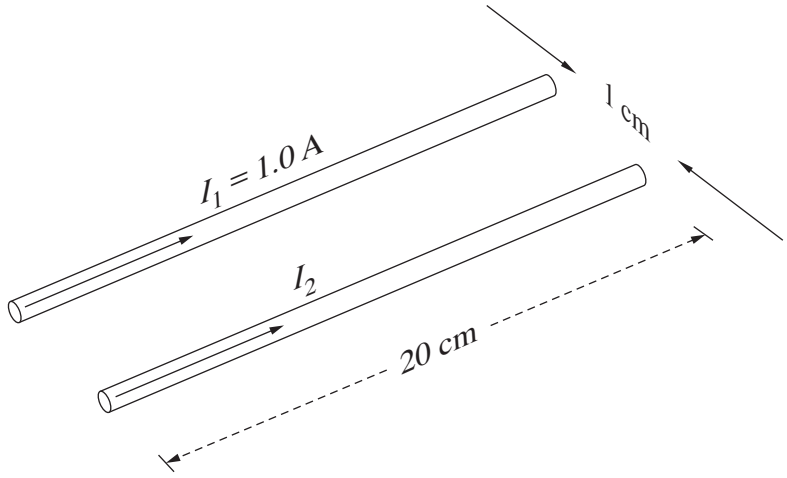
.....

.....

.....

Question 26 (7 marks)

The diagram shows part of an experiment designed to measure the force between two parallel current-carrying conductors.



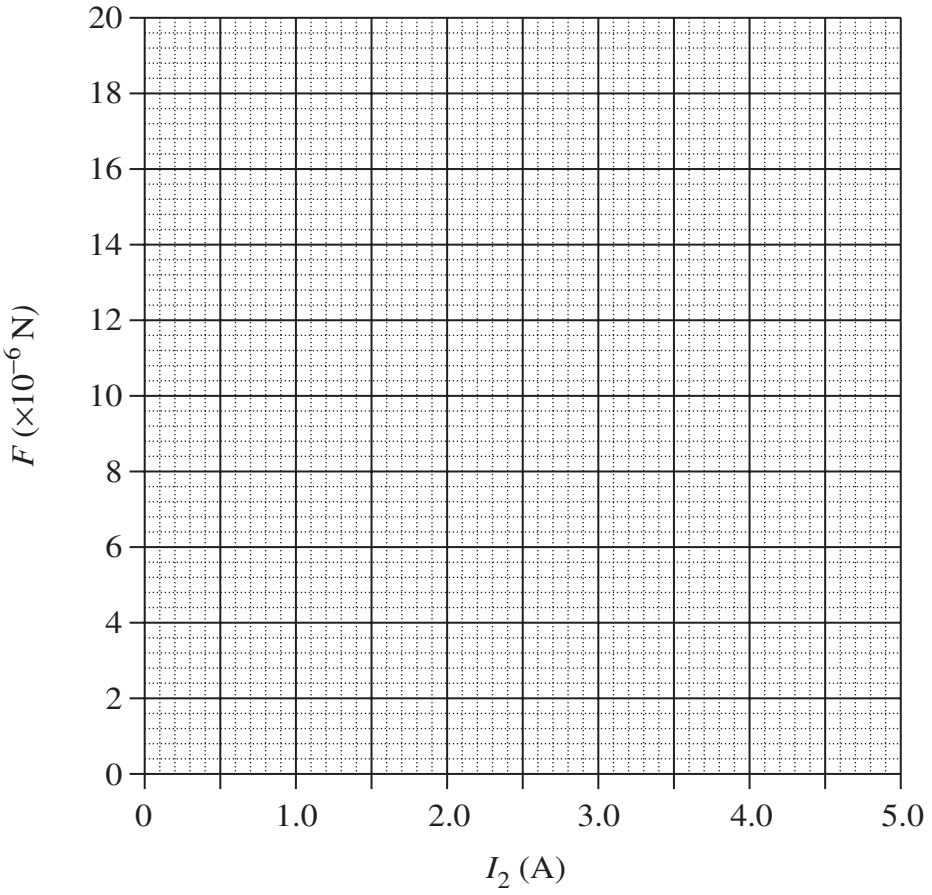
The experimental results are tabulated below.

I_2 (A)	Force ($\times 10^{-6}$ N)
0	0
2.0	7
3.0	11
4.0	14
5.0	18

Question 26 continues on page 25

Question 26 (continued)

(a) Plot the data and draw the line of best fit. **3**



(b) Calculate the gradient of the line of best fit from the graph. **1**

.....

.....

(c) Write an expression for the magnetic force constant k in terms of the gradient and other variables. **2**

.....

.....

(d) Use this expression and the gradient calculated in part (b) to determine the value of the magnetic force constant k. **1**

.....

.....

End of Question 26

Marks

Question 27 (4 marks)

A sports magazine commenting on the athletic ability of Michael Jordan, the famous basketball player said: **4**

> 'Being an athlete takes more brains than brawn. It takes time and effort. It takes endurance and commitment. It takes an athlete who can stay in the air for 2.5 seconds while shooting a goal; an athlete who knows which laws of physics keep him there.'

Assess the information presented in this magazine, using appropriate calculations to support your argument.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Physics

Section II

25 marks
Attempt ONE question from Questions 28–32
Allow about 45 minutes for this section

Answer the question in a writing booklet. Extra writing booklets are available.

Show all relevant working in questions involving calculations.

Marks

Question 28 — Geophysics (25 marks)

(a) (i) The magnetic properties of rocks (Earth materials) are useful in the study of geophysics. **1**

Recall TWO other properties of Earth materials that are studied in geophysics.

(ii) Describe the magnetic properties of Earth materials and outline how these properties have led to an understanding of the variation in Earth's magnetic field over time. **3**

(b) (i) The period of a simple pendulum can be used to calculate a value for g, using the relationship **4**

$$T = 2\pi\sqrt{\frac{l}{g}}$$

where l = length of the pendulum string in metres.

An experiment was performed in which a pendulum 40.0 cm long had a period of 1.268 s.

Use these data to calculate a value for g and hence calculate the radius of Earth at this location.

(ii) The pendulum was moved to a new location on the surface of Earth at the same latitude and same distance from the centre of Earth. At this new location the pendulum had a longer period. **2**

Account for its longer period with reference to Earth's gravitational field and propose a physical basis for this variation.

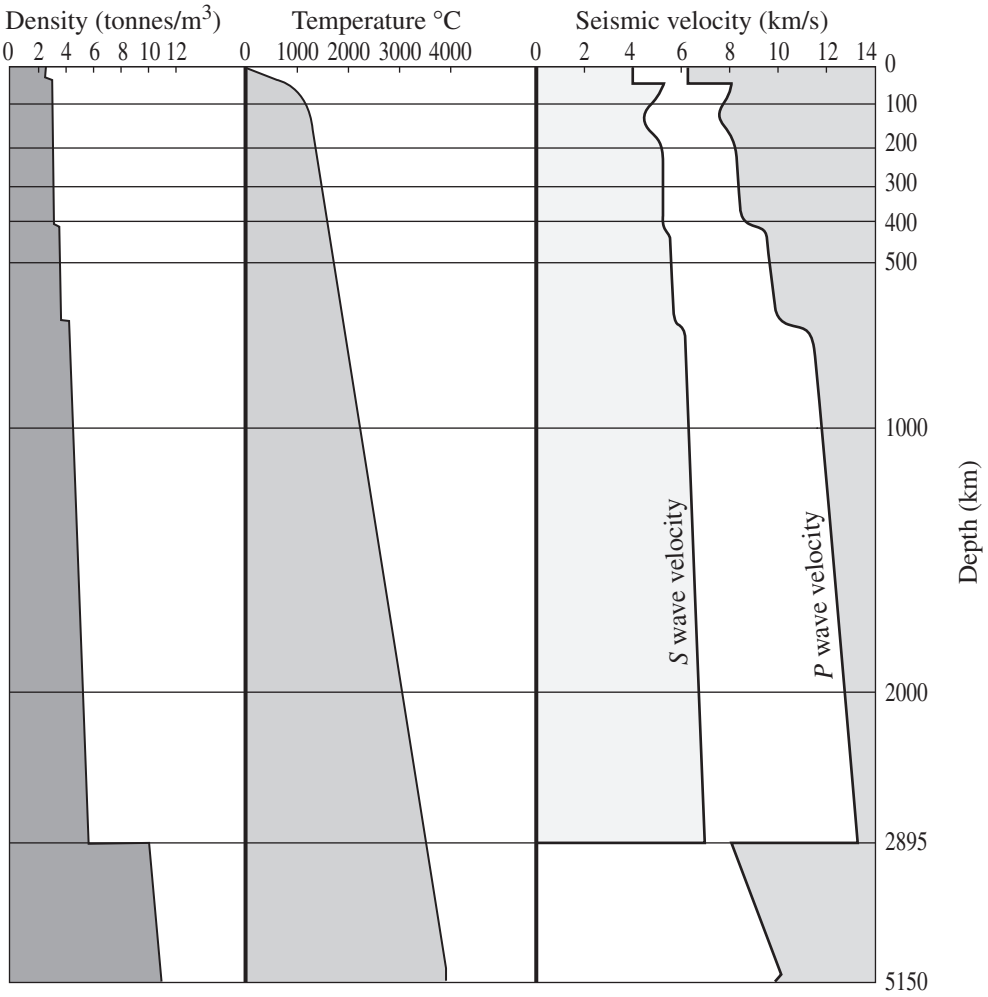
(c) Explain the uses of satellites in providing information about Earth. Include in your answer a comparison of geostationary and low Earth orbits, proposing which would be preferred for remote sensing. **7**

Question 28 continues on page 29

Marks

Question 28 (continued)

(d) The diagram below summarises the changes of properties with depth in Earth.



(i) During your study of geophysics you carried out a first-hand investigation to analyse the variation in density of different rock types. **3**

Describe how your investigation was carried out to ensure that the densities you determined were reliable.

(ii) Referring to the density graph above, account for the discontinuities (abrupt changes) at 50 km and 2895 km. **2**

(iii) The right-hand section of the diagram shows the velocity of *P* waves and *S* waves. **3**

Account for the changes in velocity shown, including an explanation for the effects at 50 km and 2895 km for both *P* and *S* waves.

End of Question 28

Marks

Question 29 — Medical Physics (25 marks)

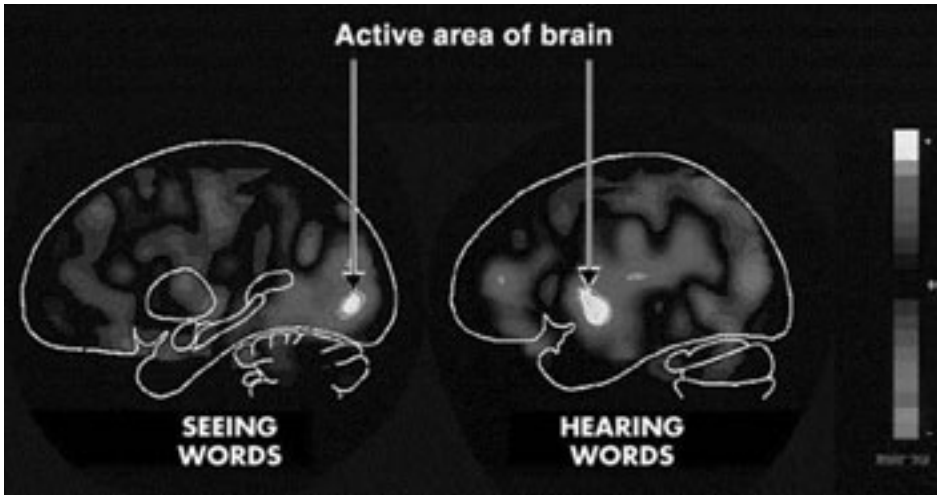
(a) (i) Describe how the piezoelectric material used in an ultrasound transducer can be made to vibrate to produce compressions and rarefactions in body tissues. **1**

(ii) Examine the following image showing the heads of unborn twins. **3**

Describe how the image of the heads of the twins was produced.

(b) Different medical imaging technologies are used to enhance the information available to scientists and doctors.

(i) The following PET images of the brain show the active areas when the same words were seen on a video screen (left image) and heard through earphones (right image). To produce these images, glucose tagged with the radioisotope F-18 was first injected into the person's body. **3**



With reference to these images and the role of the tagged glucose, evaluate how PET imaging technology is changing our understanding of the way the brain functions.

Question 29 continues on page 31

Question 29 (continued)

(ii) Identify the imaging technology used to obtain blood flow characteristics of blood moving through the heart, and describe the principle that enables information about the movement of blood to be measured. **3**

(c) Nobel Prizes are awarded annually 'to those who . . . have conferred the greatest benefit to mankind' (quote from Alfred Nobel's will). The following table shows information about some people who have received Nobel Prizes, and the reasons for their award. **7**

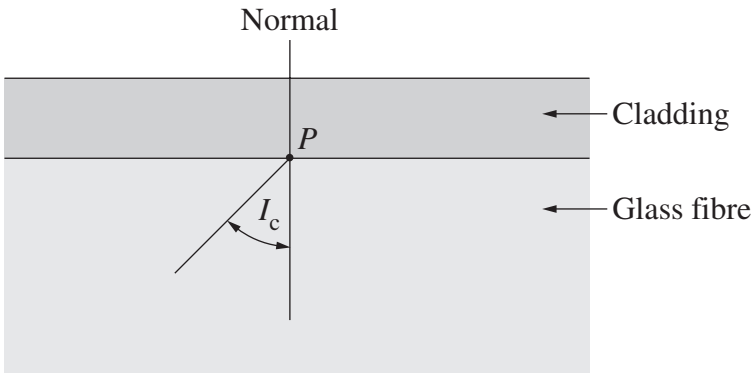
Award	*Recipients*	*Citation (reasons for award)*
1956 Nobel Prize for Physics	William Bradford Shockley Walter Houser Brattain John Bardeen	'for their researches on semiconductors and their discovery of the transistor effect'
1972 Nobel Prize for Physics	John Bardeen Leon Neil Cooper John Robert Schrieffer	'for their jointly developed theory of superconductivity, usually called the BSC-theory'
2003 Nobel Prize for Physics	Alexei Abrikosov Vitaly Ginzburg Anthony Leggett	'for their pioneering contributions to the theory of superconductors and superfluids'
2003 Prize for Medicine	Peter Mansfield Paul Lauterbur	'for their discoveries concerning magnetic resonance imaging'

With reference to the physical processes upon which MRI depends, assess the impact of advances in knowledge about semiconductors and superconductors on the development of magnetic resonance imaging.

Question 29 continues on page 32

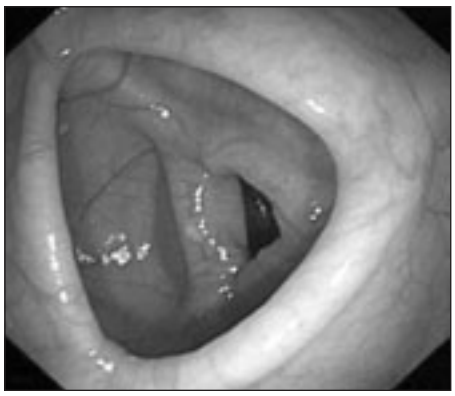
Question 29 (continued)

(d) (i) During your study of medical physics you carried out a first-hand investigation of the transfer of light by optical fibres. The diagram below shows part of the cross-section of an optical fibre, with the critical angle labelled. **2**



Sketch the diagram in your answer booklet and show a ray of light that is totally internally reflected at the point *P* in the fibre.

(ii) The photograph shows a normal endoscopic image of the transverse part of the large intestine. **3**



www.gastrolab.net

Describe how the optical fibres in an endoscope are used to produce an image such as the one shown.

(iii) Describe how an endoscope could be used to obtain tissue samples from inside the large intestine, and outline why the endoscope is of particular use in this procedure. **3**

End of Question 29

Marks

Question 30 — Astrophysics (25 marks)

(a) (i) Identify the initial and final elements of the principal sequence of nuclear reactions for a star on the Main Sequence. **2**

(ii) Identify the type of star that the Sun will initially turn into after it completes its Main Sequence evolution. State the main source of energy in the core at this stage. **2**

(b) The apparent magnitudes of three stars are measured with a telescope equipped with a camera, first with a red filter placed in front of the detector, and then with a blue filter placed in front of it. The absolute magnitudes of the three stars can be determined from their spectra, and are listed in the fourth column of the table for the red filter.

The results are shown in the table.

Star	*Apparent magnitude red filter*	*Apparent magnitude blue filter*	*Absolute magnitude red filter*
Betelgeuse	–0.89	+0.41	–6.47
Rigel	+0.18	+0.14	–6.69
Sirius	–1.46	–1.46	+1.46

(i) Use the data in the table to determine which is the bluest of these three stars. **3**

(ii) Calculate the distance to Rigel in parsecs. **3**

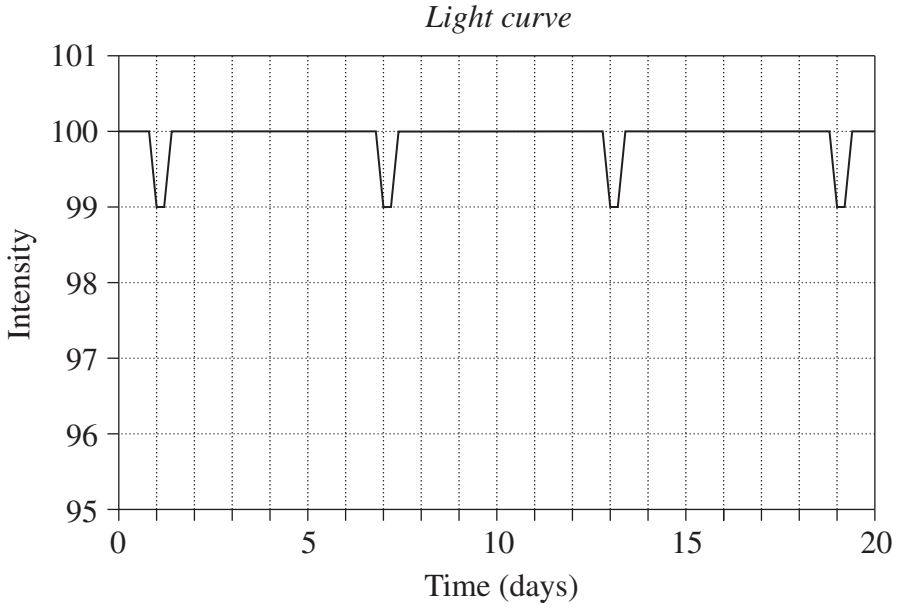
(c) Describe how the spectrum of a star can be used to determine its temperature, chemical composition and aspects of its motion. **7**

Question 30 continues on page 34

Marks

Question 30 (continued)

(d) An astronomer made regular measurements of the intensity of a star over the course of several days and obtained the light curve shown below.



(i) Describe the features of this light curve that suggest that the astronomer is observing an eclipsing binary system. **2**

(ii) If both stars have equal masses of 2×10^{30} kg, determine the separation of the two stars. **3**

(iii) The astronomer concludes that the system is a white dwarf eclipsing the other star. The intensity of light from the star is proportional to its cross-sectional area. **3**

That is, $I \propto \pi r^2$.

Using the data and diagram, calculate the radius of the white dwarf as a fraction of the radius of the other star. Assume that the white dwarf has negligible luminosity.

End of Question 30

Marks

Question 31 — From Quanta to Quarks (25 marks)

(a) (i) Identify TWO features of the strong nuclear force that binds the nucleons together within the nucleus of an atom. **2**

(ii) When Chadwick discovered the neutron he estimated its mass as 1.15 times the mass of the proton, quite close to its true value. **2**

State the TWO laws of physics he used to make this estimate.

(b) (i) The table below lists the first generation of quarks and antiquarks. **2**

Quarks			*Antiquarks*		
Name	*Symbol*	*Charge*	*Name*	*Symbol*	*Charge*
Up	u	$+\frac{2}{3}e$	Antiup	$\bar{u}$	$-\frac{2}{3}e$
Down	d	$-\frac{1}{3}e$	Antidown	$\bar{d}$	$+\frac{1}{3}e$

The Standard Model of matter states that baryons, like protons and neutrons, are comprised of three quarks, while mesons, like the pions π^+ and π^-, are comprised of one quark and one antiquark.

Using the table above, state the quark composition of the neutron and the negative pion.

(ii) The first atomic bomb was a simple uranium-235 fission device. One mode of fission for uranium-235 is given below. **4**

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{139}_{54}\text{Xe} + {}^{94}_{38}\text{Sr} + 3\,{}^{1}_{0}\text{n}$$

Calculate the mass defect and the energy released per ^{235}U atom, given the following nuclear masses and other data:

$^{235}_{92}\text{U} = 234.9934$ u $\qquad$ $^{139}_{54}\text{Xe} = 138.8883$ u

$^{94}_{38}\text{Sr} = 93.8945$ u $\qquad$ $^{1}_{0}\text{n} = 1.00867$ u

$1\text{ u} = 1.66 \times 10^{-27}$ kg $\qquad$ $c = 3.00 \times 10^{8}$ m s^{-1}

u = atomic mass unit

Question 31 continues on page 36

Question 31 (continued)

(c) **7**

> One cannot understand the [particle] physics of the past several decades without understanding the nature of the accelerator . . . the dominant tool in the field for the past forty years. By understanding the accelerator, one also learns much of the physics principles that physicists have laboured centuries to perfect.
>
> Leon Lederman and Dick Teresi, *The God Particle*, 1993

Describe how the key features and components of the standard model of matter have been developed using accelerators as a probe.

(d) (i) During your study of From Quanta to Quarks you carried out a first-hand investigation to observe the visible components of the hydrogen spectrum. **2**

Identify the equipment you used to observe this spectrum.

(ii) During your physics course you examined first hand the emission spectrum of atomic hydrogen. The four coloured lines are listed in the table below. **4**

Colour of the emission line	*Name of the emission line*	*Electron transition*
Red	H_α	$n = 3$ to $n = 2$
Green	H_β	$n = 4$ to $n = 2$
Blue	H_γ	$n = 5$ to $n = 2$
Violet	H_δ	$n = 6$ to $n = 2$

Calculate the wavelength of the H_β spectral line, and hence determine the energy of the emitted photon.

(iii) Describe TWO limitations of Bohr's model of the hydrogen atom. **2**

End of Question 31

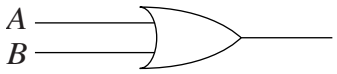
Marks

Question 32 — The Age of Silicon (25 marks)

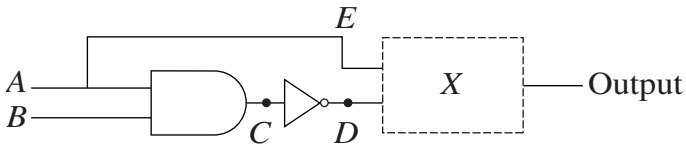
(a) (i) Outline the role of the electromagnet and switch contacts in a relay. **2**

(ii) Explain how a relay works. **2**

(b) (i) Identify the gate shown below and predict the output if the input at *A* is 1 and at *B* is 0. **2**



(ii) The diagram below shows a logic circuit. Determine the gate *X* which gives an output of 1 if the input *A* is 1 and *B* is 1. Justify your answer by using a truth table. **4**



(c) SILIAC, the first computer owned and operated by the University of Sydney, built in the 1950s, was constructed using thermionic devices. Its successor, the KDF9, was built in the late 1960s using solid state devices (transistors). Today's supercomputers are built using integrated circuits. **7**

Assess the impact on computers of each succeeding device, with reference to the differences between each device.

Question 32 continues on page 38

Question 32 (continued)

(d) The diagrams below show two different inverting amplifiers.

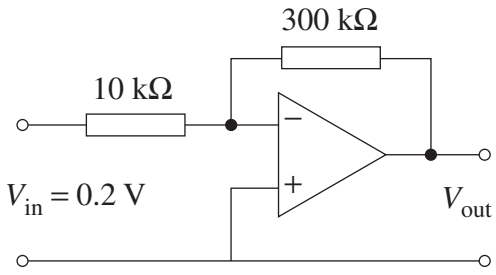


Diagram 1

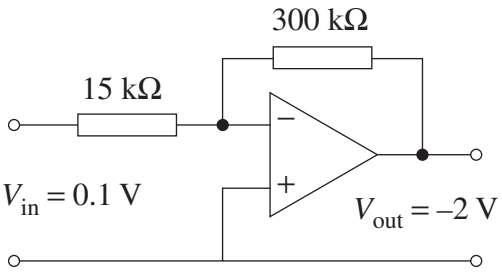


Diagram 2

(i) Calculate V_{out} in Diagram 1. **2**

The two circuits are now combined to produce a summing amplifier as shown below.

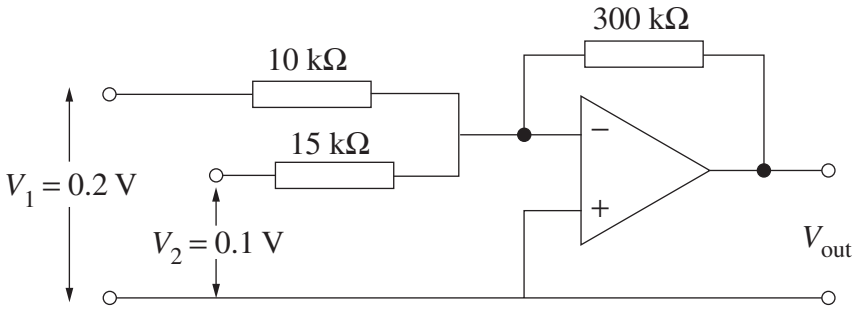


Diagram 3

(ii) Calculate V_{out} in Diagram 3 using your results in part (i) and the data in Diagram 2, and verify your value at V_{out} using the following formula for the output voltage for a summing amplifier. **3**

$$V_{out} = -R_3\left(\frac{V_1}{R_1} + \frac{V_2}{R_2}\right).$$

(iii) Explain the use of the three resistors in the summing amplifier shown in Diagram 3. **3**

End of paper

DATA SHEET

Charge on electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	340 m s^{-1}
Earth's gravitational acceleration, g	9.8 m s^{-2}
Speed of light, c	3.00×10^8 m s^{-1}
Magnetic force constant, $\left(k \equiv \frac{\mu_0}{2\pi}\right)$	2.0×10^{-7} N A^{-2}
Universal gravitational constant, G	6.67×10^{-11} N m^2 kg^{-2}
Mass of Earth	6.0×10^{24} kg
Planck constant, h	6.626×10^{-34} J s
Rydberg constant, R (hydrogen)	1.097×10^7 m^{-1}
Atomic mass unit, u	1.661×10^{-27} kg 931.5 MeV/c^2
1 eV	1.602×10^{-19} J
Density of water, ρ	1.00×10^3 kg m^{-3}
Specific heat capacity of water	4.18×10^3 J kg^{-1} K^{-1}

FORMULAE SHEET

$$v = f\lambda$$

$$I \propto \frac{1}{d^2}$$

$$\frac{v_1}{v_2} = \frac{\sin\ i}{\sin\ r}$$

$$E = \frac{F}{q}$$

$$R = \frac{V}{I}$$

$$P = VI$$

$$\text{Energy} = VIt$$

$$v_{\text{av}} = \frac{\Delta r}{\Delta t}$$

$$a_{\text{av}} = \frac{\Delta v}{\Delta t} \text{ therefore } a_{\text{av}} = \frac{v-u}{t}$$

$$\Sigma F = ma$$

$$F = \frac{mv^2}{r}$$

$$E_k = \frac{1}{2}mv^2$$

$$W = Fs$$

$$p = mv$$

$$\text{Impulse} = Ft$$

$$E_p = -G\frac{m_1 m_2}{r}$$

$$F = mg$$

$$v_x^{\,2} = u_x^{\,2}$$

$$v = u + at$$

$$v_y^{\,2} = u_y^{\,2} + 2a_y\Delta y$$

$$\Delta x = u_x t$$

$$\Delta y = u_y t + \frac{1}{2}a_y t^2$$

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$F = \frac{Gm_1 m_2}{d^2}$$

$$E = mc^2$$

$$l_v = l_0\sqrt{1-\frac{v^2}{c^2}}$$

$$t_v = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$m_v = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

FORMULAE SHEET

$$\frac{F}{l} = k\frac{I_1 I_2}{d}$$

$$F = BIl\sin\theta$$

$$\tau = Fd$$

$$\tau = nBIA\cos\theta$$

$$\frac{V_p}{V_s} = \frac{n_p}{n_s}$$

$$d = \frac{1}{p}$$

$$M = m - 5\log\left(\frac{d}{10}\right)$$

$$\frac{I_A}{I_B} = 100^{\left(m_B - m_A\right)/5}$$

$$m_1 + m_2 = \frac{4\pi^2 r^3}{GT^2}$$

$$F = qvB\sin\theta$$

$$E = \frac{V}{d}$$

$$E = hf$$

$$c = f\lambda$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\lambda = \frac{h}{mv}$$

$$Z = \rho v$$

$$\frac{I_r}{I_0} = \frac{\left[Z_2 - Z_1\right]^2}{\left[Z_2 + Z_1\right]^2}$$

$$A_0 = \frac{V_{\text{out}}}{V_{\text{in}}}$$

$$\frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{R_{\text{f}}}{R_{\text{i}}}$$

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	Symbol of element	Name of element
79	Au	Gold
Atomic Weight	197.0	

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.39 Zinc	31 Ga 69.72 Gallium	32 Ge 72.61 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [98.91] Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanides	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po [210.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223.0] Francium	88 Ra [226.0] Radium	89–103 Actinides	104 Rf [261.1] Rutherfordium	105 Db [262.1] Dubnium	106 Sg [263.1] Seaborgium	107 Bh [264.1] Bohrium	108 Hs [265.1] Hassium	109 Mt [268] Meitnerium	110 Uun — Ununnilium	111 Uuu — Unununium	112 Uub — Ununbium	113	114 Uuq — Ununquadium	115	116 Uuh — Ununhexium	117	118 Uuo — Ununoctium

Lanthanides

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm [146.9] Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.0 Ytterbium	71 Lu 175.0 Lutetium

Actinides

89 Ac [227.0] Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np [237.0] Neptunium	94 Pu [239.1] Plutonium	95 Am [241.1] Americium	96 Cm [244.1] Curium	97 Bk [249.1] Berkelium	98 Cf [252.1] Californium	99 Es [252.1] Einsteinium	100 Fm [257.1] Fermium	101 Md [258.1] Mendelevium	102 No [259.1] Nobelium	103 Lr [262.1] Lawrencium

Where the atomic weight is not known, the relative atomic mass of the most common radioactive isotope is shown in brackets.
The atomic weights of Np and Tc are given for the isotopes ^{237}Np and ^{99}Tc.