BOARD OF STUDIES
NEW SOUTH WALES

2012

HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
  Black pen is preferred
- 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, 19, 23, 25 and 27

Total marks – 100

Section I Pages 2–28

75 marks

This section has two parts, Part A and Part B

Part A – 20 marks

- Attempt Questions 1–20
- Allow about 35 minutes for this part

Part B – 55 marks

- Attempt Questions 21–30
- Allow about 1 hour and 40 minutes for this part

Section II Pages 29–39

25 marks

- Attempt ONE question from Questions 31–35
- Allow about 45 minutes for this section

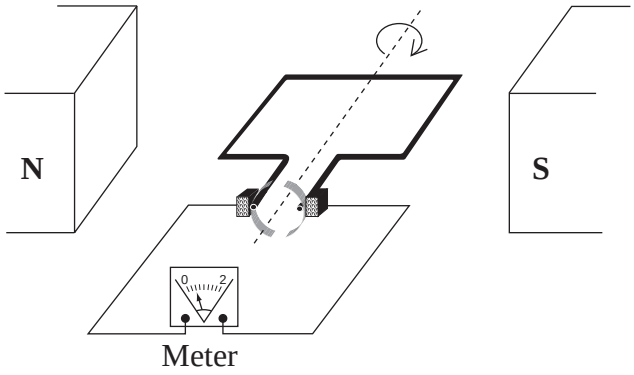
Section I
75 marks

Part A – 20 marks
Attempt Questions 1–20
Allow about 35 minutes for this part

Use the multiple-choice answer sheet for Questions 1–20.

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1 The diagram shows a device connected to a meter.



What device is shown in the diagram?

(A) AC motor

(B) DC motor

(C) AC generator

(D) DC generator

2 What is currently used to define the standard metre?

(A) The speed of light

(B) The signals from GPS satellites

(C) The wavelength of light from a krypton lamp

(D) The distance between two lines on a platinum iridium bar

3 What part of a cathode ray tube allows a person to observe the position of an electron beam?

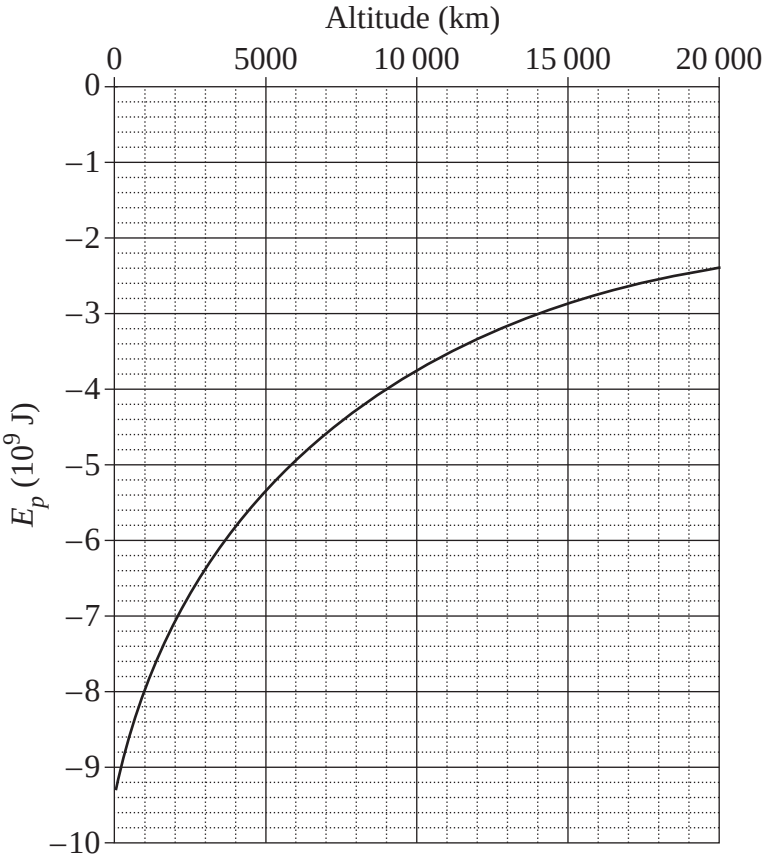
(A) A maltese cross

(B) A heated filament

(C) A fluorescent screen

(D) A uniform magnetic field

4 The graph shows how the gravitational potential energy (E_p) of a satellite changes with its altitude.



What is the change in gravitational potential energy of the satellite when its altitude is reduced from 14 000 km to 4000 km?

(A) -8.8×10^9 J

(B) -2.8×10^9 J

(C) 2.8×10^9 J

(D) 8.8×10^9 J

5 Which of the following could be added to a crystal of silicon to create a p-type semiconductor?

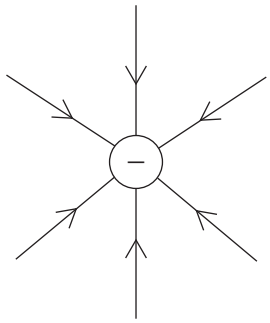
(A) Carbon

(B) Copper

(C) Gallium

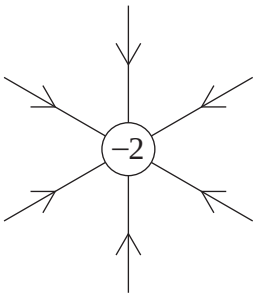
(D) Phosphorus

6 The diagram represents the electric field around a negative charge.

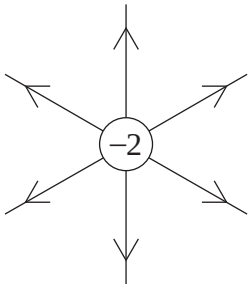


If the magnitude of the charge were doubled, which diagram would best represent the new electric field?

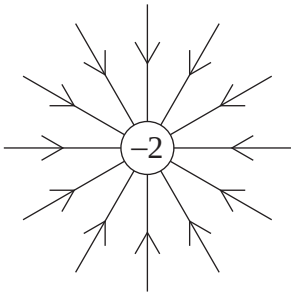
(A)



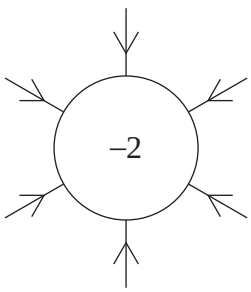
(B)



(C)



(D)



7 In moving-coil galvanometers, the coil experiences a torque because of the current flowing through it.

What ensures that this torque is directly proportional to the current flowing through the coil?

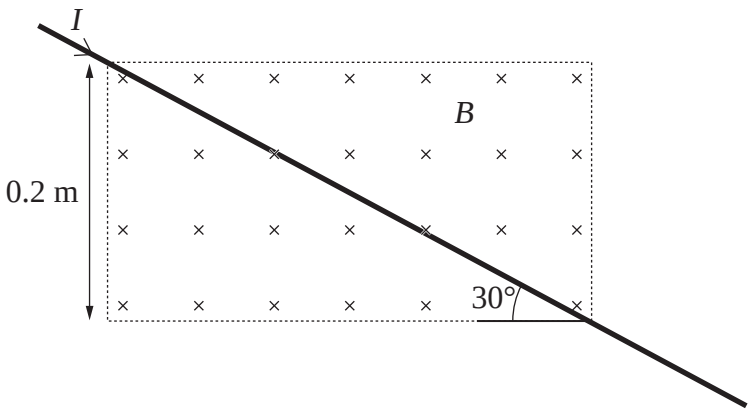
(A) A return spring

(B) A radial magnetic field

(C) A laminated soft iron core

(D) A constant cross-sectional area of the coil

8 A current-carrying wire passes through a region of uniform magnetic field, magnitude 0.05 T, and as a result experiences a force of magnitude 0.03 N.



What is the current I?

(A) 1.5 A

(B) 1.7 A

(C) 3.0 A

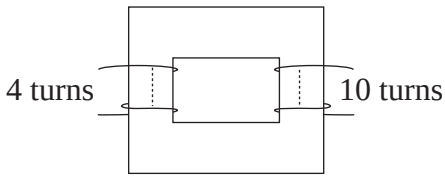
(D) 6.0 A

9 Compared to a geostationary orbit, which row of the table correctly describes the relative properties of a low Earth orbit?

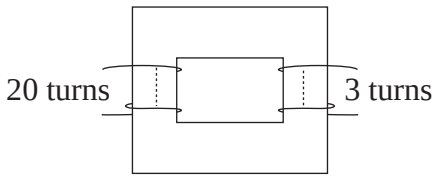
	Orbital velocity	*Orbital period*
(A)	Higher	Higher
(B)	Higher	Lower
(C)	Lower	Higher
(D)	Lower	Lower

10 Which of the following ideal transformers could be used to convert an input voltage of 20 volts AC to an output voltage of 2 volts AC?

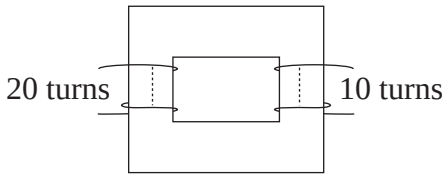
(A)



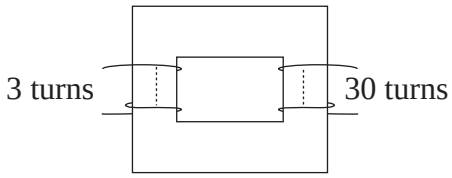
(B)



(C)



(D)



11 Which of the following is correct about the forces acting during a rocket launch?

(A) Equal and opposite forces act on the rocket. This enables it to continue to accelerate even in the vacuum of space.

(B) The engines exert an upward thrust on the rocket. This thrust exceeds the downward force of the engines on the air.

(C) The rocket engines exert a downward force on the gases being expelled. These gases exert an upward force on the engines.

(D) The expelled gases exert a force against the launch pad. The launch pad then exerts an equal and opposite force on the rocket causing it to accelerate.

Use the data below to answer Questions 12 and 13.

Orbital period of the Moon around Earth	2.36×10^6 s
Mean orbital radius of the Moon	3.83×10^8 m
Mass of Earth	6.0×10^{24} kg
Mass of the Moon	7.35×10^{22} kg

12 What is the centripetal force experienced by the Moon due to Earth's influence?

(A) 2.0×10^{20} N

(B) 1.6×10^{22} N

(C) 4.7×10^{26} N

(D) 7.6×10^{28} N

13 What is the orbital period of an Earth satellite having an orbital radius half that of the Moon?

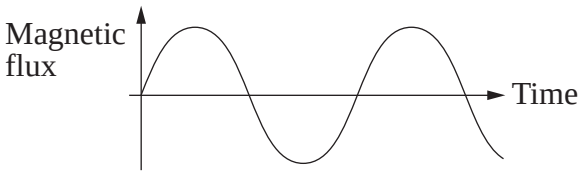
(A) 5.9×10^5 s

(B) 8.3×10^5 s

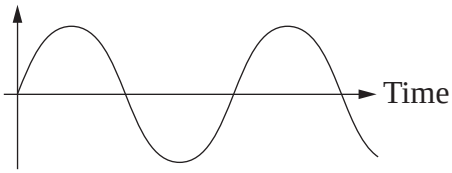
(C) 1.2×10^6 s

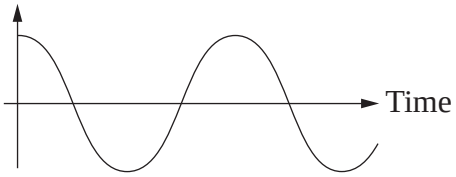
(D) 7.5×10^6 s

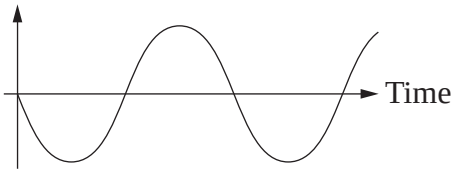
14 The graph shows variation in magnetic flux through a coil with time.

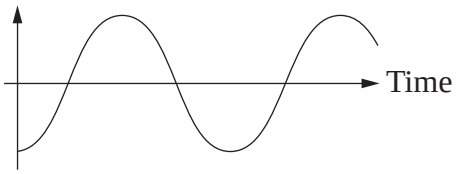


Which graph best represents the corresponding induced emf in the coil?

(A)


(B)


(C)


(D)


15 A magnet can be levitated above a superconductor, when the superconductor is below its critical temperature.

Which statement best describes how this occurs?

(A) All of the magnet's field is absorbed by the superconductor.

(B) The superconductor creates currents in the magnet, resulting in a repulsive force.

(C) Cooper pairs are exchanged between the superconductor and the magnet through its field.

(D) Some of the magnet's field is excluded by the superconductor, resulting in a repulsive force.

16 An ideal electric motor connected to a DC voltage source rotates at a constant rate of 200 revolutions per minute. There is no load on the motor.

Which of the following is a correct statement about the operation of the motor?

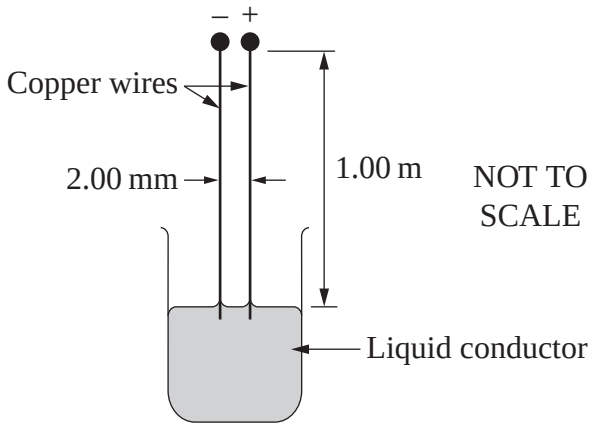
(A) The applied voltage must exceed the back emf in order to keep the motor running.

(B) There is no back emf because it is only produced in AC motors due to the changing flux.

(C) The back emf is equal to the applied voltage because no work is being done by the motor.

(D) The back emf must exceed the applied voltage to prevent the motor's speed from increasing.

17 The following equipment is attached to a DC power supply.



What current must be flowing through the wires to result in a force of 2.50×10^{-3} N between them?

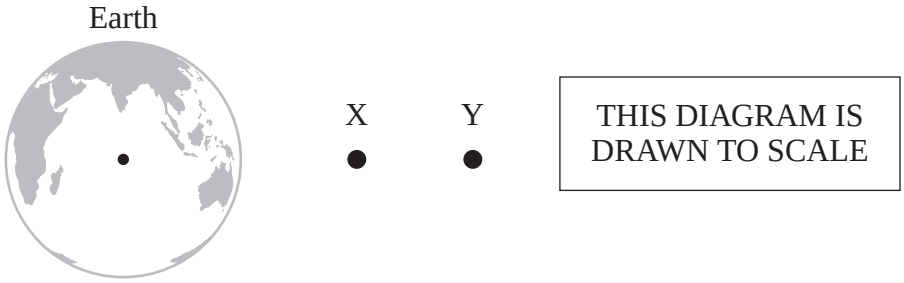
(A) 0.224 A

(B) 5.00 A

(C) 12.5 A

(D) 25.0 A

18 The gravitational force, due to Earth, on a mass positioned at X is F_x and on the same mass positioned at Y is F_y. The diagram is drawn to scale.



What is the value of $\frac{F_x}{F_y}$?

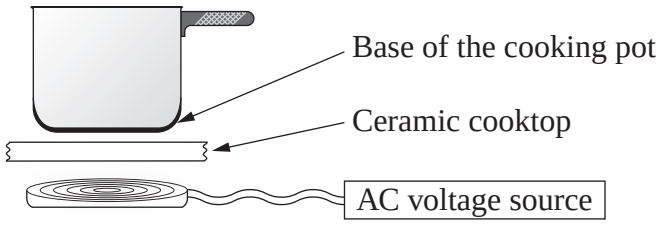
(A) 1.5

(B) 2.0

(C) 2.25

(D) 4.0

19 The diagram represents an induction cooking system.

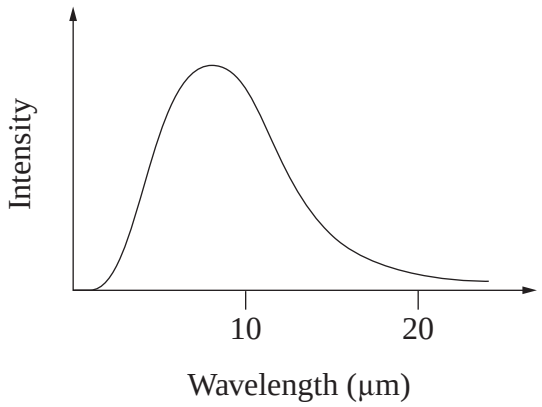


Which row in the following table shows the set of conditions that would result in the most rapid heating of the base of the cooking pot?

	AC voltage frequency	*Electrical resistance of pot base*
(A)	Low	Low
(B)	Low	High
(C)	High	Low
(D)	High	High

20 A company wishes to develop a semiconductor sensor to detect thermal radiation from people. The sensor will work on the same principle as a solar cell.

Typical Human Blackbody Radiation Curve



Semiconductor	*Band gap* (eV)
HgCdTe	0.03
InSb	0.17
Si	1.1
GaN	3.4

Using the information provided, which semiconductor would be most suitable for this purpose?

(A) HgCdTe

(B) InSb

(C) Si

(D) GaN

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Physics

Centre Number

Student Number

Section I (continued)

Part B – 55 marks
Attempt Questions 21–30
Allow about 1 hour and 40 minutes for this part

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

Question 21 (6 marks)

(a) Outline a first-hand investigation that could be performed to measure a value for acceleration due to gravity. **3**

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(b) How would you assess the accuracy of the result of the investigation? **1**

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(c) How would you increase the reliability of the data collected? **1**

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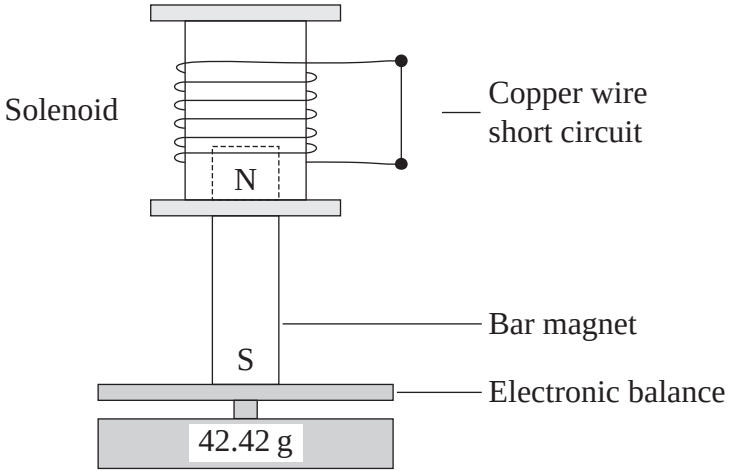
(d) How would you assess the reliability of the data collected? **1**

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Question 22 (6 marks)

A bar magnet is placed on a sensitive electronic balance as shown in the diagram. A hollow solenoid is held stationary, such that the magnet is partly within the solenoid.



The solenoid is then lifted straight up without touching the magnet. The reading on the balance is observed to change briefly.

(a) Why does a current flow in the solenoid? **2**

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(b) Explain the reason for changes in the reading on the electronic balance as the solenoid is removed. **4**

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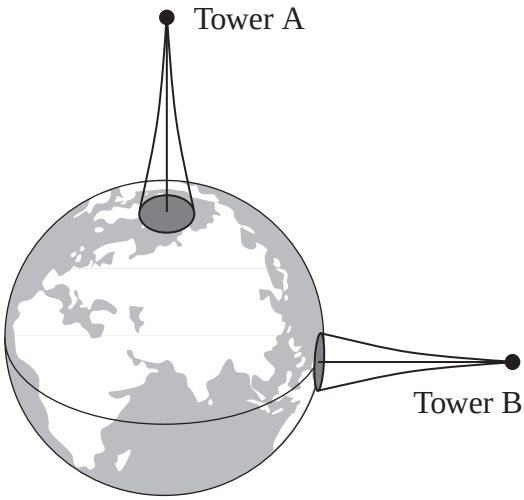
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Question 23 (4 marks)

Consider the following thought experiment. **4**

Two towers are built on Earth's surface. The height of each of the towers is equal to the altitude of a satellite in geostationary orbit about Earth. Tower A is built at Earth's North Pole and Tower B is built at the equator.



NOT TO SCALE

Identical masses are simultaneously released from rest from the top of each tower. Explain the motion of each of the masses after their release.

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Question 24 (5 marks)

(a) Using a labelled diagram, outline the differences in the energy bands of conductors, semiconductors and insulators. **2**

(b) Explain why a current is able to flow in a pure semiconductor when an electric field is applied across it. **3**

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Centre Number

Student Number

Section I – Part B (continued)

Question 25 (7 marks)

(a) Why have transistor circuits largely replaced thermionic devices? **2**

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(b) Assess the impact of the use of transistors on society. **5**

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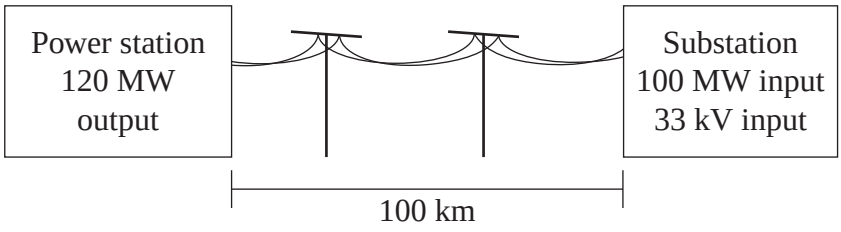
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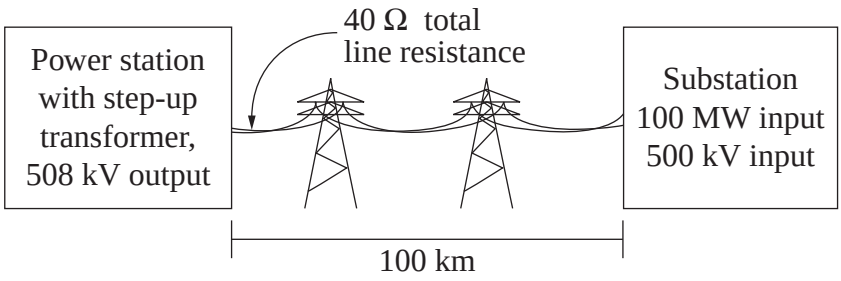
Question 26 (6 marks)

A transmission line is to be used to supply 100 MW of power from a power station to a substation 100 km away. Three possible designs are shown below.

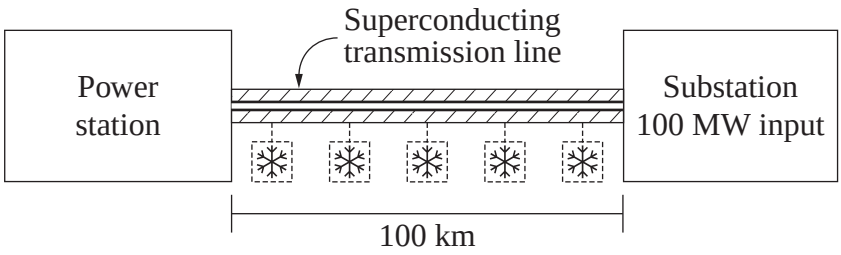
Design A – Low voltage



Design B – High voltage



Design C – Superconducting



The cooling requirements for the superconducting transmission line consume 30 kW per km of line

Question 26 continues on page 21

Using physics principles and appropriate calculations, evaluate each design to determine the best way of transmitting power from the power station to the substation. **6**

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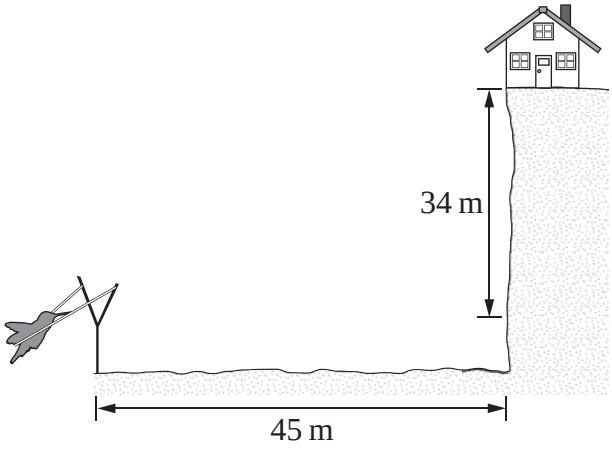
End of Question 26

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Question 27 (4 marks)

A toy bird is launched at 60° to the horizontal, from a point 45 m away from the base of a cliff. **4**



NOT TO SCALE

Calculate the magnitude of the required launch velocity such that the toy bird strikes the base of the wooden building at the top of the cliff, 34 m above the launch height.

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Question 28 (7 marks)

(a) Outline ONE piece of evidence supporting Einstein's theory of relativity. **2**

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(b) What criteria are used to test and validate a theory? **3**

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(c) The distance between the cathode and screen in a cathode ray tube is 40 cm. **2**

If an electron travels through the tube at 3.0×10^7 m s^{-1}, what is the apparent distance from the cathode to the screen in the electron's frame of reference?

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Question 29 (5 marks)

How is the motor effect used to produce different sounds in a loudspeaker? Include a labelled diagram. **5**

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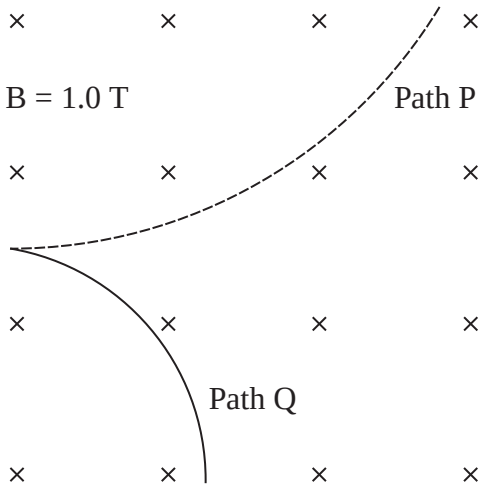
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Question 30 (5 marks)

The diagram shows the paths taken by two moving charged particles when they enter a region of uniform magnetic field.



(a) Why do the paths curve in different directions? **1**

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(b) Why are the paths circular? **2**

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(c) How do the properties of a particle affect the radius of curvature of its path in a uniform magnetic field? **2**

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Physics

Section II

25 marks
Attempt ONE question from Questions 31–35
Allow about 45 minutes for this section

For Questions 31–34
- answer parts (a)–(c) of the question in Section II Answer Booklet 1.
- answer parts (d)–(e) of the question in Section II Answer Booklet 2.

Extra writing booklets are available.

For Question 35
- answer parts (a)–(b) of the question in Section II Answer Booklet 1.
- answer parts (c)–(d) of the question in Section II Answer Booklet 2.

Extra writing booklets are available.

Show all relevant working in questions involving calculations.

Pages

Question 31 Geophysics 31–33

Question 32 Medical Physics 34

Question 33 Astrophysics 35–36

Question 34 From Quanta to Quarks 37

Question 35 The Age of Silicon 38–39

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Question 31 — Geophysics (25 marks)

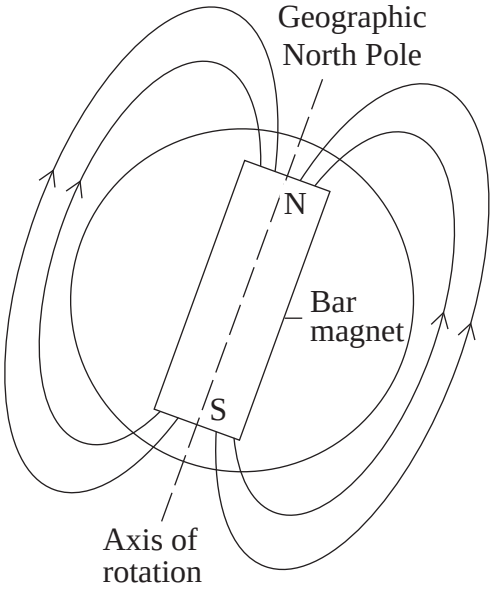
Answer parts (a)–(c) in Section II Answer Booklet 1.

(a) Jean Richer observed that a pendulum clock, which was accurately calibrated in Paris, lost about 150 seconds per day when it was used on the equatorial island of Cayenne. **3**

Outline the effects of TWO variables that changed the behaviour of the clock.

(b) (i) Why does Earth's magnetic field change over time? **2**

(ii) A website used the following model to explain Earth's magnetic field. **3**

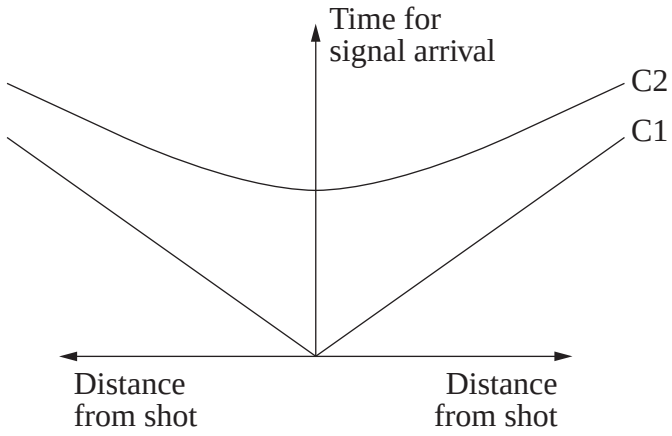


Analyse the validity of this model.

Question 31 continues on page 32

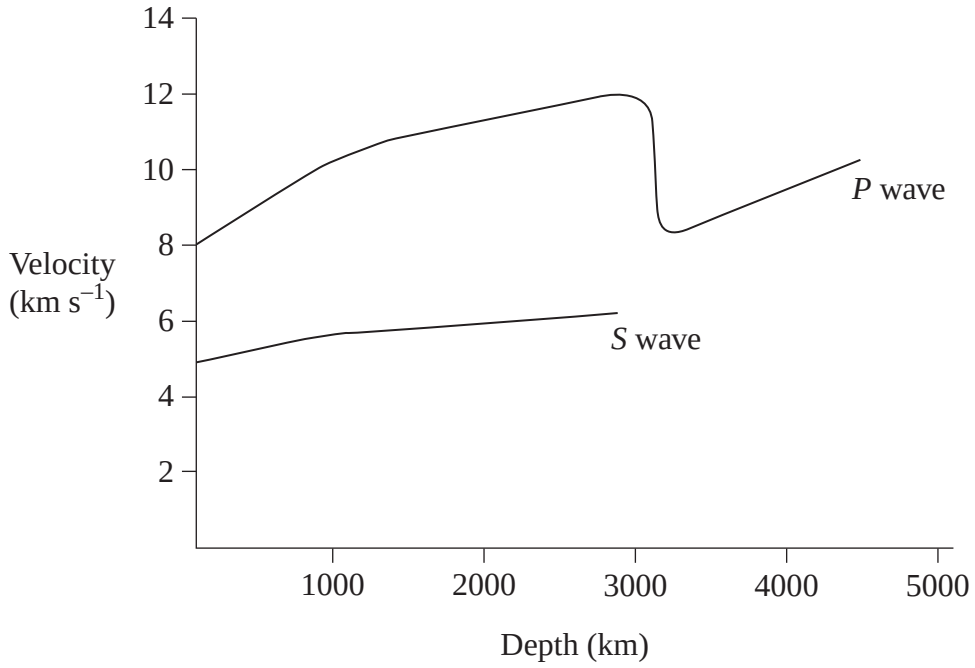
Question 31 (continued)

(c) (i) Data obtained from a shot-geophone analysis is shown on the following graph. **2**



Outline what the lines C1 and C2 on this graph represent.

(ii) Account for the behaviour of *P* waves and *S* waves represented by the following graph. **4**



Question 31 continues on page 33

Question 31 (continued)

Answer parts (d)–(e) in Section II Answer Booklet 2.

(d) (i) What is the significance of the magnetic anomalies associated with rocks adjacent to mid-ocean ridges? **3**

(ii) Other than the geometric fit of continents or magnetic evidence, what evidence supports the theory of plate tectonics? **2**

(e) How is remote sensing used to obtain information about Earth? **6**

End of Question 31

Question 32 — Medical Physics (25 marks)

Answer parts (a)–(c) in Section II Answer Booklet 1.

(a) (i) The first X-ray image of a human was made in 1895 but it was not until 1972 that CAT scan imaging was developed. **2**

Account for the time interval between the development of these two related technologies.

(ii) Contrast the information provided by PET scans and CAT scans. **2**

(iii) Contrast the production of radiation used for PET scans and CAT scans. **3**

(b) (i) What effects do the pulses of radio waves have on hydrogen nuclei in the body of a person having a magnetic resonance image scan? **3**

(ii) Outline how advances in physics in the 20th century contributed to the development of magnetic resonance imaging. **3**

(c) Describe the properties that make a radioactive isotope useful for medical imaging. Include a specific example of a radioactive isotope in your answer. **3**

Answer parts (d)–(e) in Section II Answer Booklet 2.

(d) Explain how endoscopes obtain images of internal organs. **3**

(e) Discuss the range of information obtained from, and the limitations of, ultrasound medical imaging technology. **6**

Question 33 — Astrophysics (25 marks)

Answer parts (a)–(c) in Section II Answer Booklet 1.

(a) (i) Why do astronomers use both apparent and absolute measurements in photometry? **1**

(ii) Compare how astronomers obtain photometric and spectroscopic data. **4**

(b) (i) Describe the problems associated with ground-based optical astronomy in terms of resolution. **3**

(ii) How can the resolution of ground-based optical telescopes be improved? **2**

(c) (i) Draw a flow diagram for stellar evolution using the following celestial objects: **2**

- Black hole
- Main sequence star
- Neutron star/pulsar
- Planetary nebula
- Red giant
- Supernova
- White dwarf.

(ii) All naturally occurring elements have been synthesised within stars. Explain how this occurs. **3**

Answer parts (d)–(e) in Section II Answer Booklet 2.

(d) (i) Explain how trigonometric parallax is used to determine the distances to stars. **3**

(ii) Outline ONE limitation of using trigonometric parallax to determine distances to stars. **1**

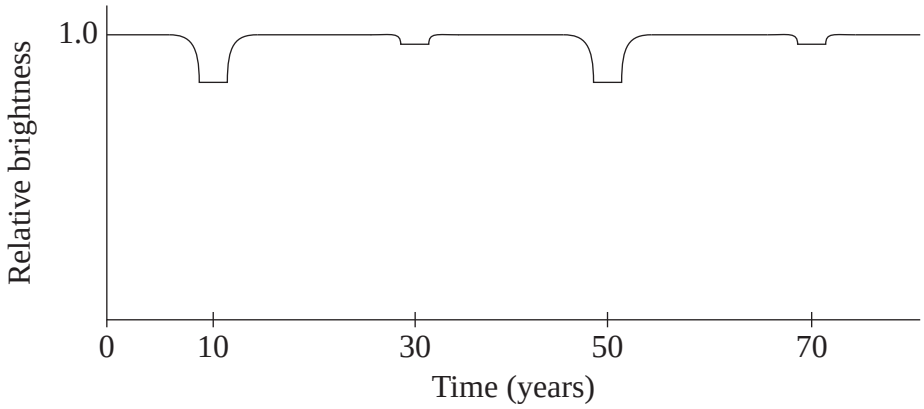
Question 33 continues on page 36

Question 33 (continued)

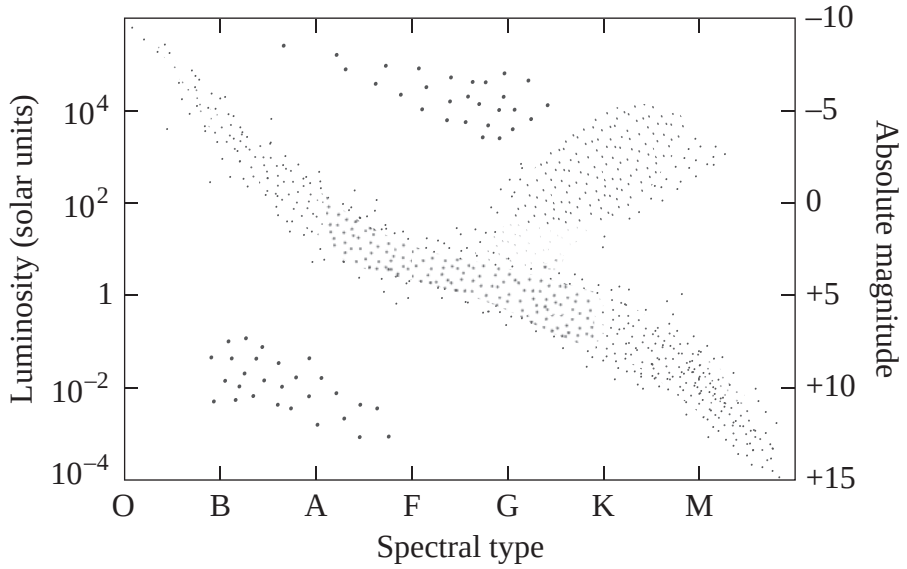
(e) Astronomers have obtained the following data about stars in a binary system. **6**

	Star A	*Star B*
Apparent magnitude	0.34	13.16
Spectral class	F5	A4
Luminosity (relative to Sun)	7.3	0.0063
Average separation	2.2×10^9 km	

Light Curve for the Binary System



Herzsprung-Russell Diagram



Analyse the above data to write a detailed description of this binary system.

End of Question 33

Question 34 — From Quanta to Quarks (25 marks)

Answer parts (a)–(c) in Section II Answer Booklet 1.

(a) (i) Using diagrams and text, outline Bohr's explanation of the Balmer series. **3**

(ii) Outline TWO observations from atomic emission spectra that could not be fully explained by the Rutherford-Bohr model. **2**

(b) (i) What are the requirements for an uncontrolled nuclear chain reaction? **3**

(ii) How does the equivalence between mass and energy relate to what occurs during the natural radioactivity process? **2**

(c) How can neutrons be used to probe the positions of nuclei within the structure of a metal crystal? Make reference to the work of Louis de Broglie in your answer. **4**

Answer parts (d)–(e) in Section II Answer Booklet 2.

(d) (i) Explain how the internal structures of the proton and neutron determine their properties. **3**

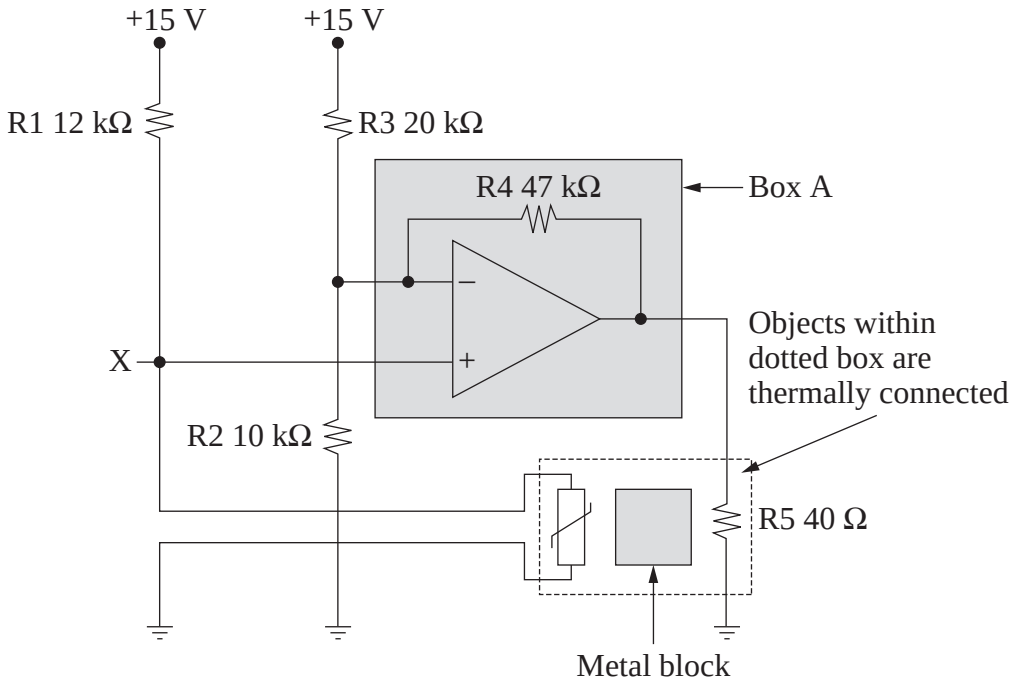
(ii) How are accelerators used to investigate the structure of matter? **2**

(e) Describe the role of conservation laws in the development of atomic physics. **6**

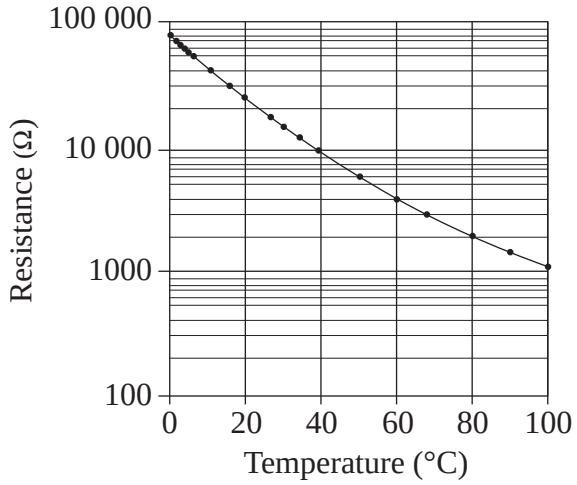
Question 35 — The Age of Silicon (25 marks)

Answer parts (a)–(b) in Section II Answer Booklet 1.

(a) A circuit and a graph of the thermistor characteristic curve are shown. In the circuit the thermistor and R5 are firmly attached to a metal block, and all three are at the same temperature.



Thermistor characteristic curve



Question 35 continues on page 39

Question 35 (continued)

(i) Classify the circuit on the opposite page as an electric circuit or an electronic circuit and justify your choice. **2**

(ii) Identify the functions of the TWO transducers in this circuit. **2**

(iii) Draw a set of axes in your booklet and sketch how the voltage at point X varies with temperature. **3**

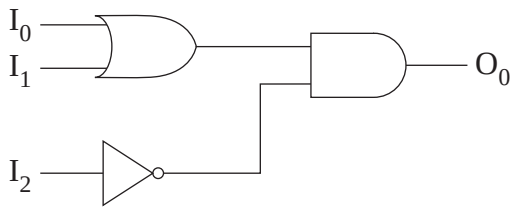
(iv) Describe the function of the circuit in Box A. **4**

(v) Calculate the equilibrium temperature achieved by the metal block in this circuit, assuming that the block is thermally connected to the thermistor and R5. **3**

(b) Explain the use of relays, rather than transistors, to switch large currents in circuits. **2**

Answer parts (c)–(d) in Section II Answer Booklet 2.

(c) For the logic circuit shown, construct a truth table. **3**



(d) Analyse how the development of modern electronics has been influenced by our increased understanding of the properties of materials and the development of complex manufacturing techniques. **6**

End of paper

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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

$$v = f\lambda$$

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

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

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

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

$$P = VI$$

$$\text{Energy} = VIt$$

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

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

$$\Sigma F = ma$$

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

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

$$W = Fs$$

$$p = mv$$

$$\text{Impulse} = Ft$$

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

$$F = mg$$

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

$$v = u + at$$

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

$$\Delta x = u_x t$$

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

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

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

$$E = mc^2$$

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

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

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

FORMULAE SHEET

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

$$F = BIl\sin\theta$$

$$\tau = Fd$$

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

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

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

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

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

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

$$F = qvB\sin\theta$$

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

$$E = hf$$

$$c = f\lambda$$

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

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

$$Z = \rho v$$

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

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

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

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

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 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 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 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc 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 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 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 Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium						

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm 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 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Elements with atomic numbers 113 and above have been reported but not fully authenticated.

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of data. Some data may have been modified.