
Student Number

Sydney Girls High School

2020

TRIAL
HSC
EXAMINATION

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A data sheet, formulae sheet and Periodic Table are provided at the back of this paper
- For questions in Section II, show all relevant working in questions involving calculations

Total Marks: 100

Section I – 20 marks (pages 2-12)

- Attempt Questions 1-20
- Allow about 35 minutes for this section

Section II – 80 marks (pages 13-31)

- Attempt Questions 21-34
- Allow about 2 hours and 25 minutes for this section

Section I

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 How does the charge and mass of Beta particles compare with Alpha particles?

A. beta particles have more mass and more charge than alpha particles.

B. beta particles have less mass and less charge than alpha particles.

C. beta particles have more mass and less charge than alpha particles.

D. beta particles have less mass and more charge than alpha particles.

2 Carbon-14 undergoes spontaneous radioactive decay by releasing a beta-minus particle.

Identify the daughter nuclide formed after the decay.

A. Boron-10

B. Carbon-12

C. Nitrogen-14

D. Oxygen-16

3 A neodymium laser emits light with a wavelength of 1064 nm.

What is the energy of each photon emitted by the laser?

A. 1.87×10^{-19} J

B. 7.05×10^{-23} J

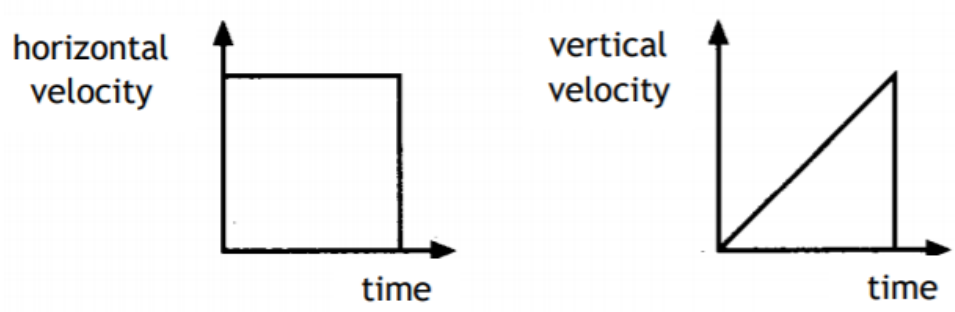
C. 1.87×10^{-26} J

D. 7.05×10^{-19} J

4 A ball is kicked horizontally from the edge of the cliff and lands in the sea.

Assuming negligible air resistance, which pair of graphs show the horizontal and vertical velocity-time graphs for the ball during its flight?

A.



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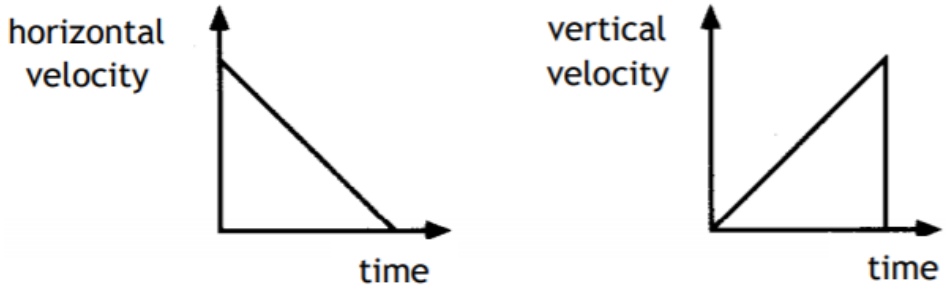

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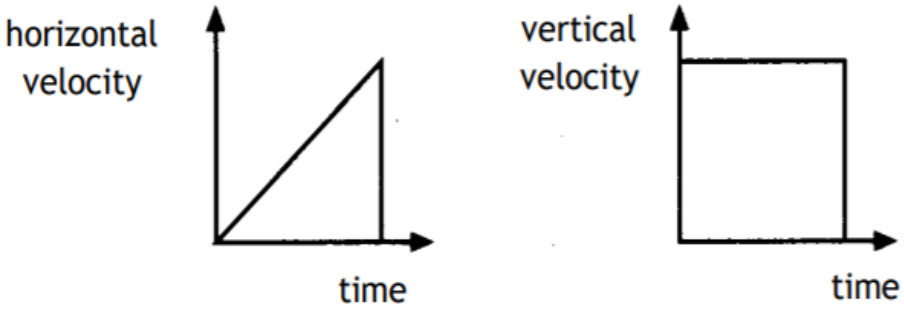
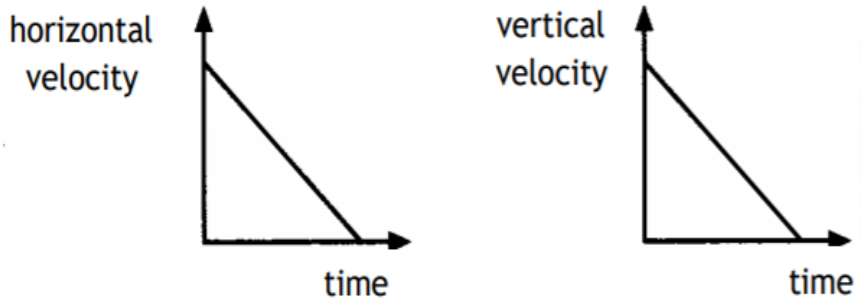


D.



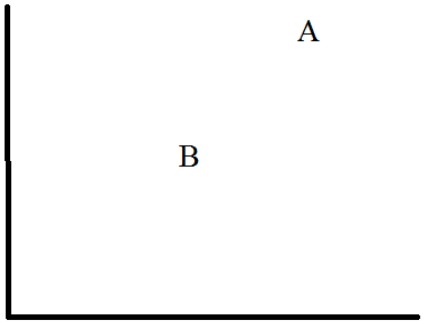
5 A motor is connected in series with an ammeter 2.0 A current was recorded in the ammeter when no load was attached to it. The current reading in the ammeter increased to 3.2 A when a load was attached to the motor whilst the supply EMF remains the same.

What conclusion can be drawn about the number of rotations per minute (RPM) and the back EMF in the coil after the load is attached to the motor?

	Speed of rotation (RPM)	*Back EMF*
A.	Increased	Increased
B.	Decreased	Decreased
C.	Decreased	Increased
D.	Increased	Decreased

6 The HR diagram given below shows the position of two stars A, which is a supergiant; and B which is a main sequence star.

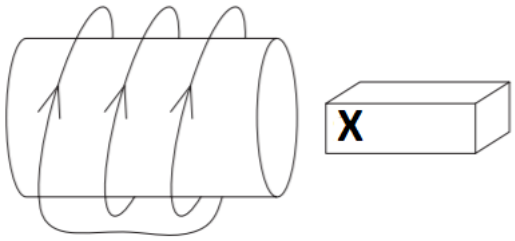
What can be concluded about the luminosity and temperature of star A as compared that of star B.



	Luminosity of Star B	*Temperature of Star B*
A.	Higher than A	Higher than A
B.	Lower than A	Lower than A
C.	Lower than A	Higher than A
D.	Higher than A	Lower than A

7 A bar magnet is moved relative to a coil which results in an induced current in the coil as shown in the diagram below.

What conclusion can be drawn about the polarity of the X end of the bar magnet and direction of its relative motion?



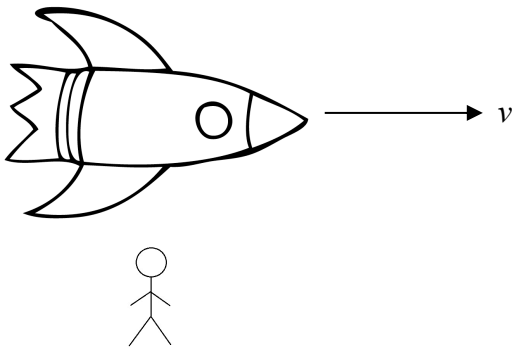
A. X is the north pole, the coil is stationary and the bar magnet is moved to the right.

B. X is the north pole, the coil is stationary and the bar magnet is moved to the left.

C. X is the south pole, the coil is moved to the left and the bar magnet is stationary.

D. X is the south pole and the bar magnet and the coil are moved away from each other.

8 An observer watches as a spacecraft passes by at relativistic speed, perpendicular to her line of sight.



The astronauts inside the spacecraft have measured the spacecraft to be 45 m long and 15 m wide.
How long and wide is the spacecraft according to the observer?

A. Exactly 45 m long and less than 15 m wide.

B. Less than 45 m long and exactly 15 m wide.

C. Less than 45 m long and less than 15 m wide.

D. More than 45 m long and more than 15 m wide

9 A satellite in a circular orbit of radius R has a orbital period T. If this satellite is moved to a higher orbit of orbital radius 4R, what will be the orbital period of the satellite in the higher orbit?

A. 2T

B. 4T

C. 8T

D. 16T

10 The Earth has a radius of 6378 km.

What would be the escape velocity if a spacecraft is in orbit at a height of 25480 km above the surface of the Earth?

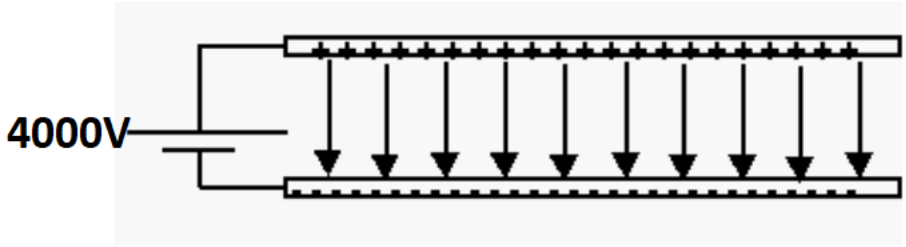
A. 3.5 km/s

B. 5.0 km/s

C. 5.6 km/s

D. 11.2 km/s

11 Consider a parallel plate separated by a distance of 1.0 mm and connected to a power supply as shown in the diagram below.



What would the magnitude of the acceleration experienced by an electron be when placed between the parallel plates?

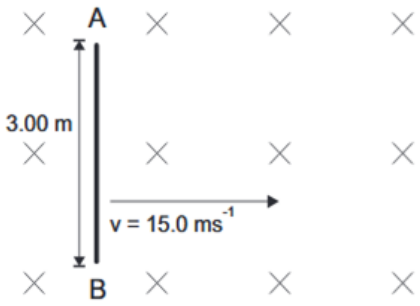
A. 6.4×10^{15} ms^{-2}

B. 7.0×10^{15} ms^{-2}

C. 6.4×10^{17} ms^{-2}

D. 7.0×10^{17} ms^{-2}

12 A length of wire is pulled with constant velocity through a magnetic field, as shown in the diagram below.



What is the strength of the magnetic field if the wire develops an EMF of 40V?

A. 0.89 T

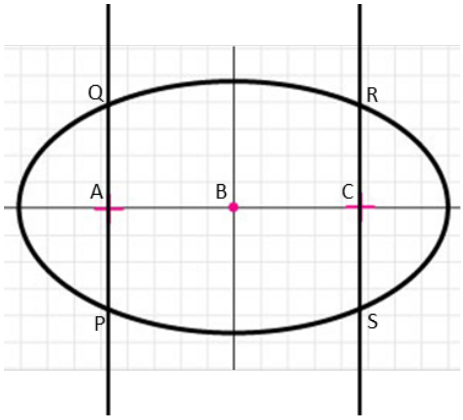
B. 1.13 T

C. 45 T

D. 1800 T

13 The image below represents the elliptical path of a planet around a star.

Which of the following statements is most correct?



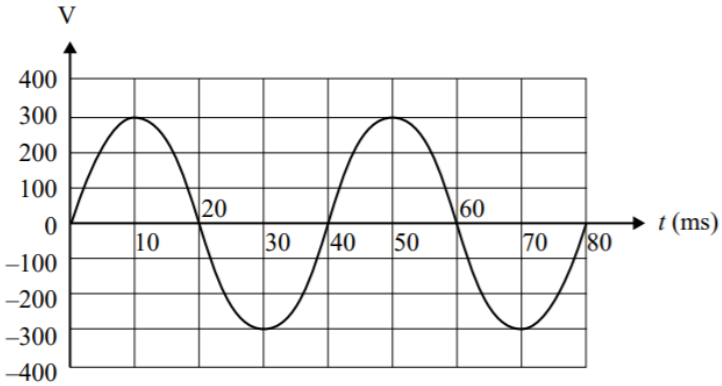
A. The star is located at C and the planet takes less time to travel P to Q than it does for R to S.

B. The star is located at C and the planet takes more time to travel P to Q than it does for R to S.

C. The star is located at A and the planet takes the same time to travel P to Q as it does for R to S.

D. The star is located at B and the planet takes the same time to travel P to Q as it does for R to S.

14 Following signal was obtained from an AC generator.



What is the frequency of rotation of the coil in the generator?

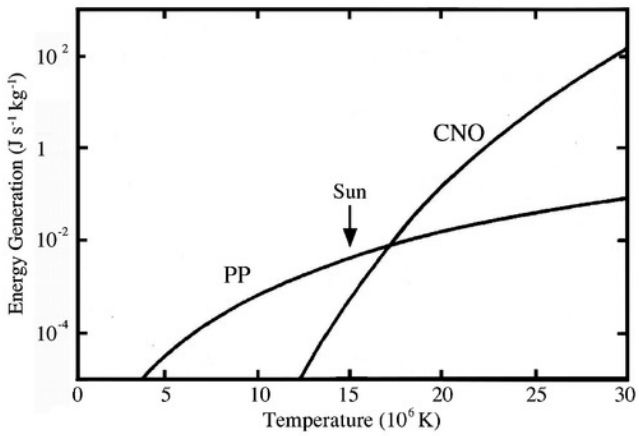
A. 0.025 Hz

B. 0.04 Hz

C. 25 Hz

D. 40 Hz

15 Following graph shows the relative rate of two main types of hydrogen fusion reactions.



Based on your knowledge of the data presented in the HR diagram and the information in the above graph what conclusion can be made regarding hydrogen fusion in stars.

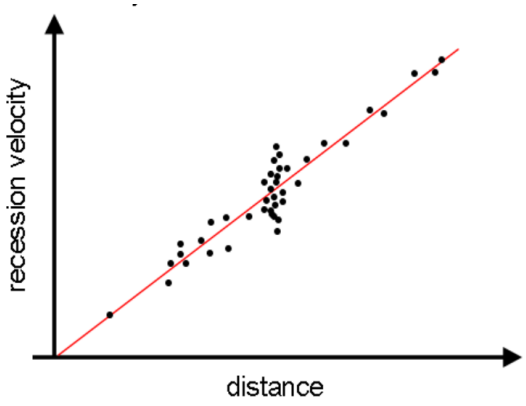
A. The CNO cycle only occurs in red giants.

B. The Sun does not use CNO cycle for energy production.

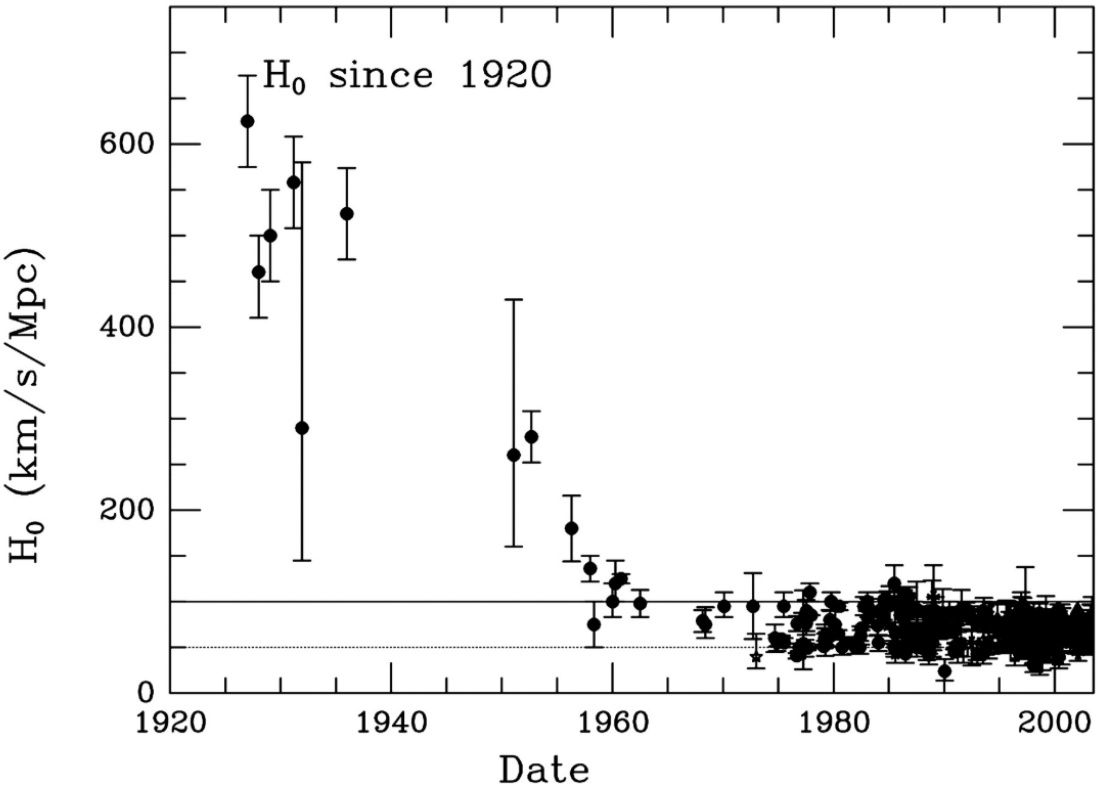
C. PP chain is the main energy source in cooler main sequence stars.

D. More luminous stars generate most of their energy using the PP chain.

16 In the graph below, the gradient of the line is known as Hubble's constant H_0.



Hubble's constant has been revised over time. In the graph below, the vertical line for each data point represents the uncertainty in these measurements.



What is a possible reason for the change in measurements over time?

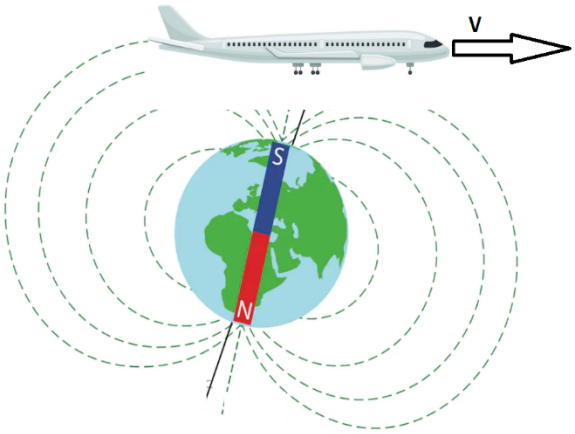
A. The value of H_0 has decreased.

B. Knowledge of stellar evolution has improved.

C. Better technology allowed more measurements to be made.

D. The rate of expansion has increased during this time period.

17 Consider an aeroplane flying over the north pole in Earth's magnetic field as shown the diagram below.



What would be the polarity of the EMF induced in the plane?

A. Front of the plane would have a higher potential

B. Back of the plane would have a higher potential

C. Wing tip pointing into the page would have a higher potential

D. Wing tip pointing out of the page would have a higher potential

18 Threshold frequency of sodium is 5.8×10^{14} Hz and for zinc 8.8×10^{14} Hz.

What can be concluded about the kinetic energy of electrons emitted from zinc as compared to the electrons emitted from sodium due to the photoelectric effect?

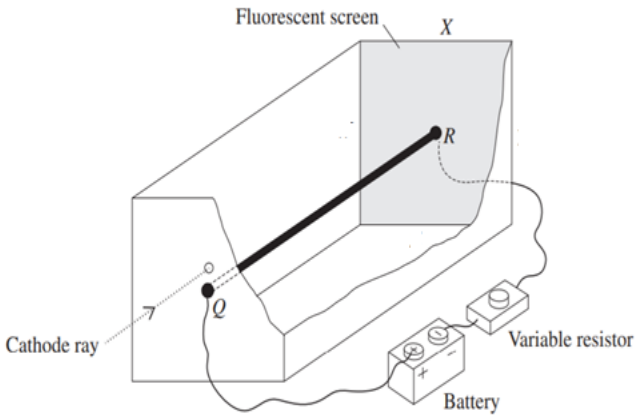
A. Kinetic energy of electrons emitted from zinc can never be higher than the electrons emitted from sodium.

B. Kinetic energy of electrons emitted from zinc will always be higher than the electrons emitted from sodium.

C. Kinetic energy of electrons emitted from zinc can be higher than the electrons emitted from sodium if relatively higher frequency of light is used with zinc.

D. Kinetic energy of electrons emitted from zinc can be higher than the electrons emitted from sodium if relatively higher intensity of light is used with zinc.

19 A straight current-carrying conductor, QR, is connected to a battery and a variable resistor. QR is enclosed in an evacuated chamber with a fluorescent screen at one end as shown in the diagram below.



A cathode ray which is made up of a beam of electrons enters the chamber directly above Q, initially travelling parallel to QR. It passes through the chamber and strikes the fluorescent screen causing a bright spot.

What can be done to move the bright spot closest to the position X on the screen?

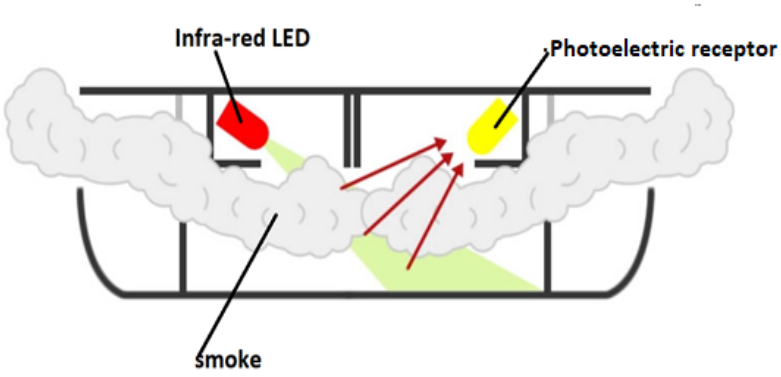
A. Increase the current in QR.

B. Increase the resistance of the variable resistor.

C. Decrease the voltage in power supply.

D. Reverse the direction of current in QR.

20 An optical smoke alarm (also called photo-electric smoke alarm) works using the light scatter principle as shown in the diagram below.



As the smoke enters the smoke detector, particles in the smoke cause the Infra-red light to be scattered onto the photoelectric receptor. Once the scattered light hits the photoelectric receptor, a signal is sent to the integrated circuit due to release of electrons from the receptor. This causes the alarm to sound alerting the occupants to the fire.

What requirement needs to be met for the optical smoke alarm to function properly?

A. Smoke entering the smoke alarm should reach the photoelectric receptor.

B. Smoke entering the smoke alarm should not scatter the infra-red light.

C. Work function of the photoelectric receptor should be greater than the energy of infra-red photons.

D. Threshold frequency of the photoelectric receptor should be less than the frequency of infra-red light.

2020

TRIAL
HSC
EXAMINATION

Student Number

Physics

Section II
Answer Booklet

80 marks
Attempt Questions 21-35
Allow about 2 hours and 25 minutes for this section

Instructions

- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of the response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

Question 21 (5 marks)

A tennis ball bounces off the ground at an angle of 40° to the horizontal, with an initial velocity of 25 ms^{-1}. The tennis court fence is six metres away, and is 4 m high.

(a) Calculate the time needed for the ball to travel a horizontal distance of 6 m. **3K**

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(b) Determine whether the ball will go over the fence. Support your answer with calculations. 2A

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Question 22 (4 Marks)

Explain how astronomers use starlight to calculate the surface temperature of a star. 4K

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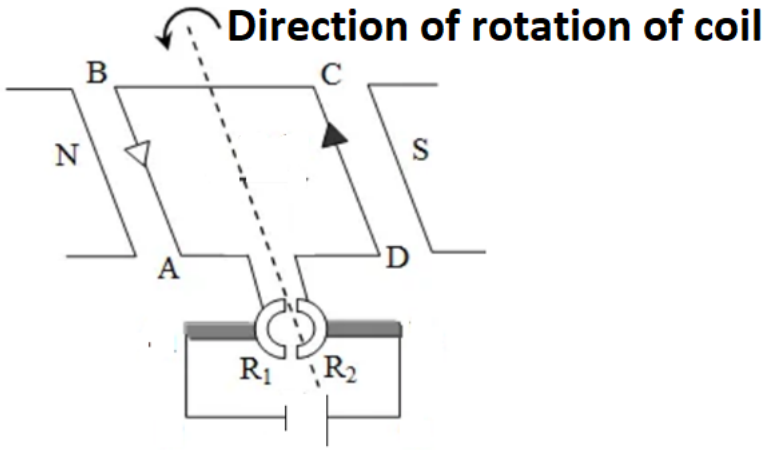
Question 23 (4 Marks)

The schematic diagram given below shows how a DC motor works. The coil ABCD in the diagram is connected to the split rings (R_1 and R_2) of the commutator.

Use the diagram to explain the role of split ring commutator in a DC motor. 4K



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Question 24 (6 marks)

An object dropped vertically downwards experiences gravitational force and acceleration.

Ashley conducted an experiment to determine the value of acceleration due to gravity by dropping a ball from different heights. Her results are outlined in the table below.

Height from which ball is dropped (m)	Time taken by the ball to reach the ground (s)	
0.5	0.32	
0.7	0.38	
0.9	0.43	
1.1	0.47	
1.3	0.52	
1.5	0.55	

(a) Use Ashley's data to produce a linear graph which can be analysed to calculate acceleration due to gravity. Include any calculations in the table above. 3A

(Question 24 continues on next page)

(b) Use the graph to calculate the value of acceleration due to gravity. 2A

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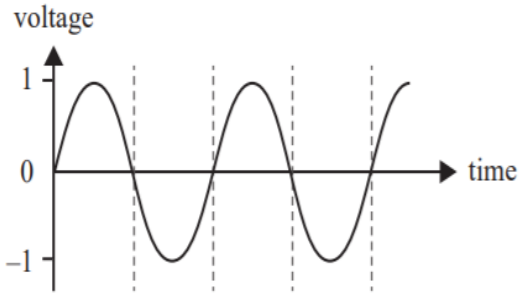
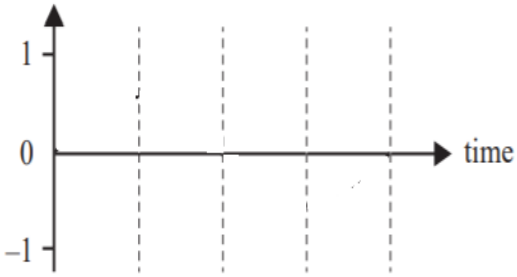
Question 25 (6 Marks)

A graph of output voltage versus time of an AC generator is shown below.



(a) Sketch the output signal of the AC generator on the scale provided below if the rate of revolutions of the generator is reduced to half. 3K



(b) Describe energy conversions in electric power generation and transmission. 3K

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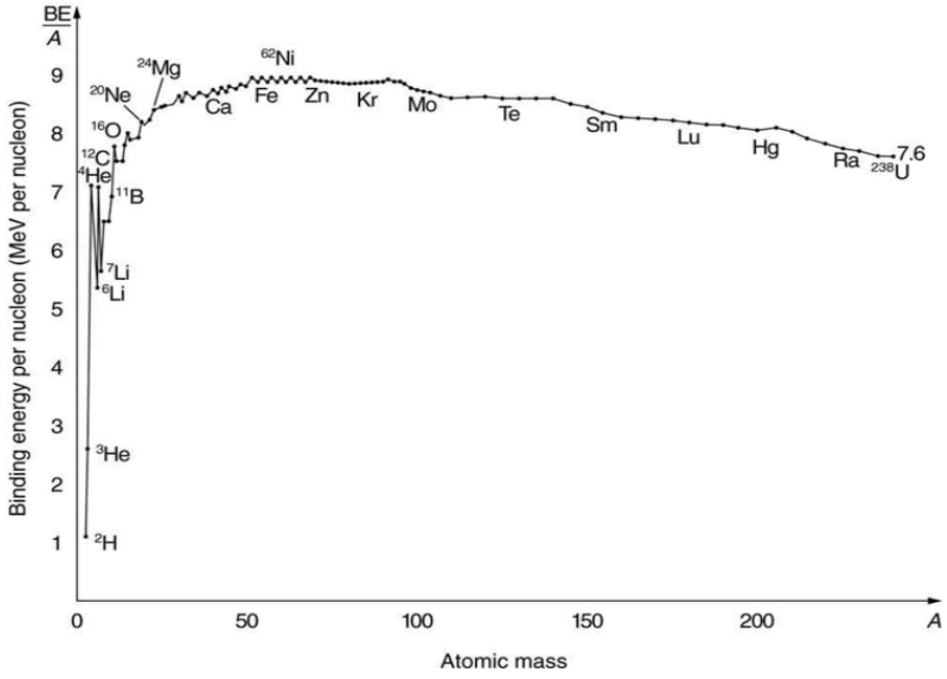
Question 26 (5 marks)

With reference to the graph below explain the process of fusion in stars. 5K



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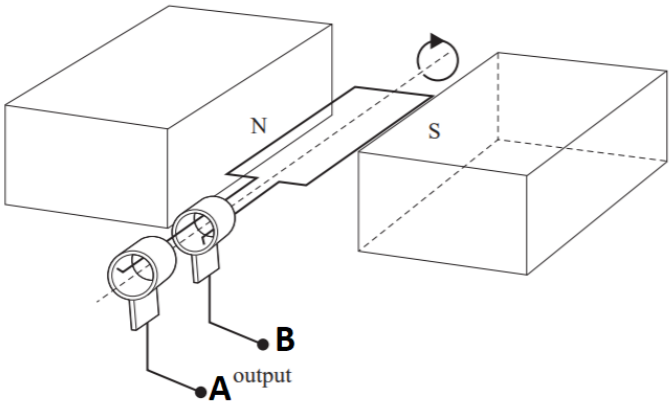
Question 27 (5 marks)

Consider the diagram of a generator provided below



(a) Deduce the polarity of terminals A and B at the point in time shown in the diagram. Use Lenz's law to justify your answer. 3K

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(b) The loop in the diagram has a dimension of 0.50 m × 0.25 m and the strength of the magnetic field is 0.4T. Calculate maximum magnetic flux through the coil. 2A

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Question 28 (6 marks)

Student Number

Uranium-238 undergoes spontaneous radioactive decay by releasing one alpha particle

Masses of all relevant nuclides involved have been provided below.

Uranium-238	238.05079 u
Daughter nuclide	234.04363 u
Helium-4	4.00260 u

(a) Write the balanced nuclear equation for the decay process. 2A

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(b) Calculate the amount of energy released during the decay and account for the release of energy. 4K

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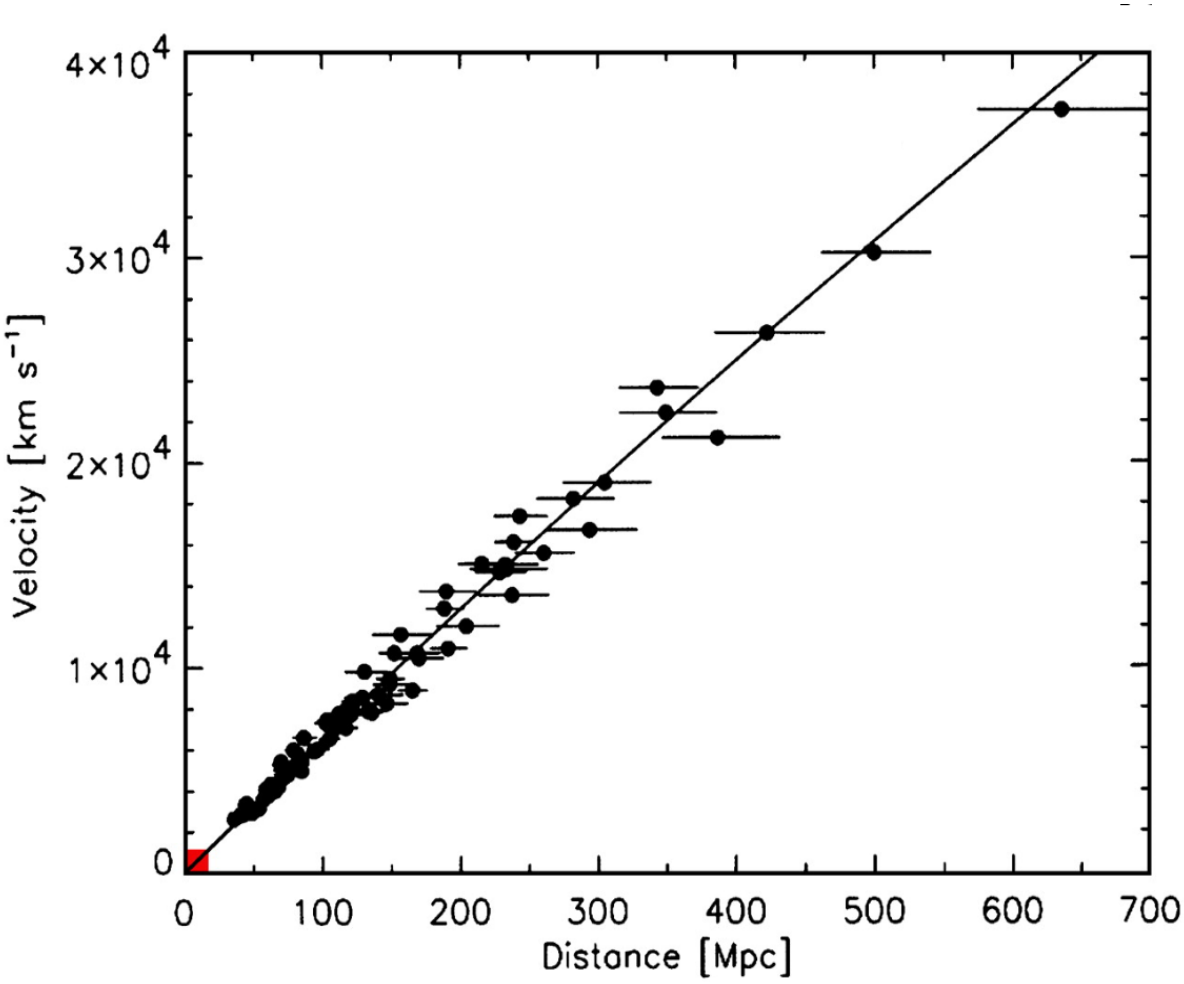
Question 29 (9 marks)

The Hubble diagram, based on well observed supernovae has been provided in the graph below.



(a) Explain how spectroscopy can be used to determine the velocity of the observed supernovae. 3K

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(Question 29 continues on next page)

(b) The reciprocal of the gradient of the trend line is the age of the universe. Use the graph to calculate the age of the universe in years. (1 megaparsec = 3.086×10^{19} km) 3A

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(c) Explain how the data presented in the graph provides evidence for the Big Bang theory. 3K

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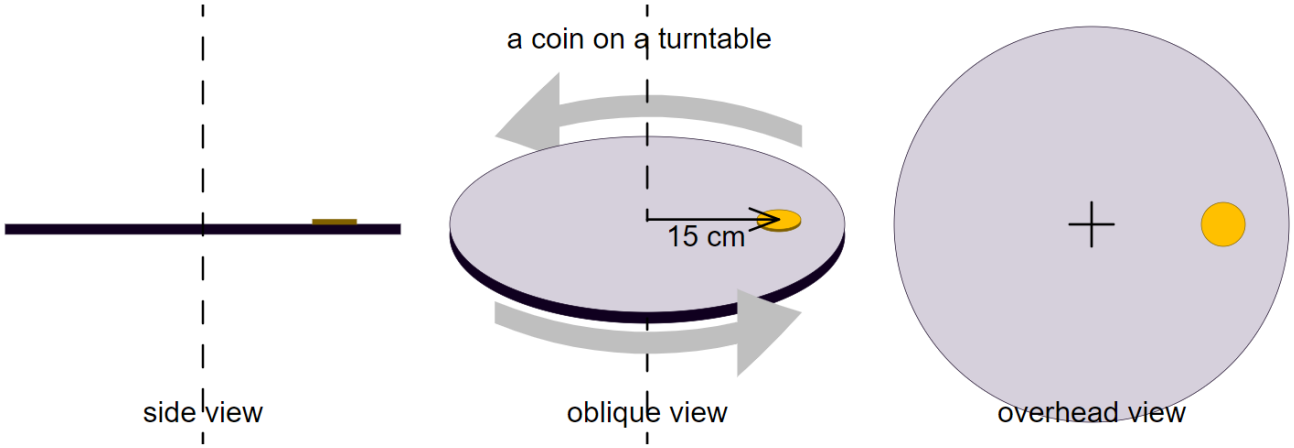
Question 30 (6 marks)

A 55g coin is placed on a horizontal turntable 15 cm from its centre as shown in the diagrams below. The turntable rotates at a constant rate in a counter clockwise direction as seen from above. The coin does not slip and the turntable completes one rotation every 500 ms.



(Question 30 continues on next page)

(a) On the figure labelled **"side view",** draw free body diagram to represent the forces acting on the coin. (You do not need to draw the arrows to scale.) 3A

(b) Calculate the centripetal force on the coin and the frictional force between the coin and turntable. 3A

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Question 31 (4 marks)

The earth has a radius of 6378 km.

Data for three different satellites orbiting earth has been outlined in the table provided below.

Satellite System	Orbital Height (Km)	Orbital Velocity (Km/Sec)	Orbital Period (H M S)
Intelsat (GEO)	35,786	3.0747	23 56 4.1
New ICO (MEO)	10,255	4.8954	5 55 48.4
Iridium (LEO)	1,469	7.1272	1 55 17.8

Account for the difference in the orbital velocities of the satellites. 4K

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Question 32 (4 marks)

Operational specifications for a small DC motor has been provided in the table below.

PARAMETER	CONDITIONS	SPECIFICATION
Rated Operating Voltage		3 V
Rated Load	Maximum continuous torque	0.05 mNm
Rated Load Speed	At rated voltage under fixed torque at rated load	14,000 rpm
N/L Speed	Measured at rated voltage	23,000 rpm [+/- 2,500]
Max. Start Voltage	Measured at no load	0.5 V
Max. N/L Current	Measured at rated voltage	20 mA
Max. Operating Voltage		3.6 V
Max. Start Current	At rated voltage	180 mA
Min. Insulation Resistance	At 50V DC between motor terminal and case	1 MOhm
Max. Rated Load Current	At rated voltage under fixed torque at rated load	70 mA

Use relevant data from the table provided to explain how back EMF affects functioning of DC motors. 4K

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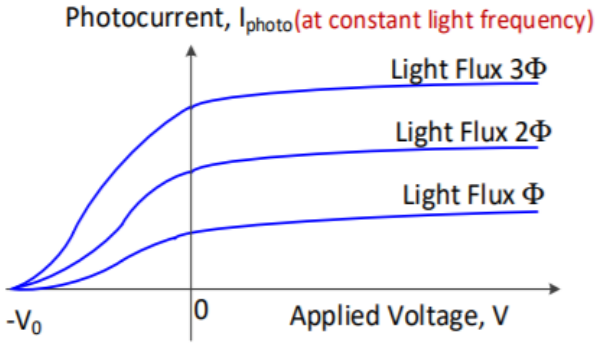
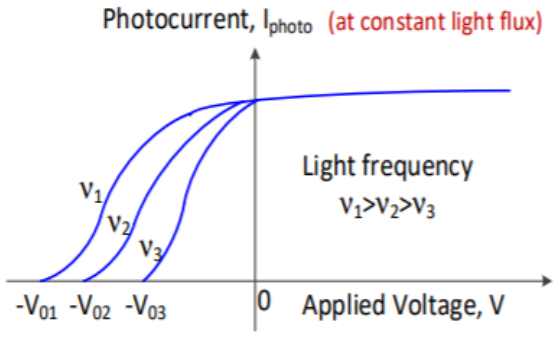
Question 33 (7 marks)

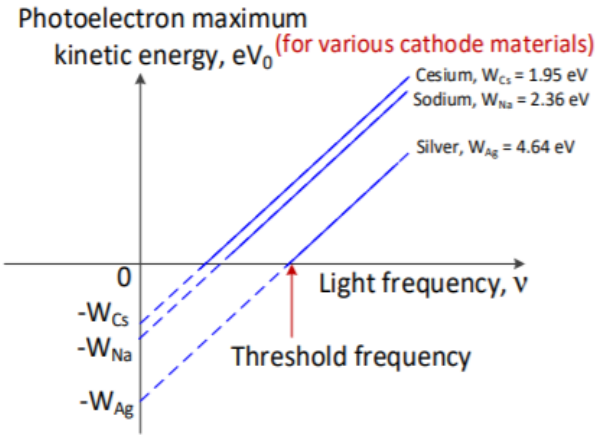
The main aspects observed in the early experiments regarding the photoelectric effect have been summarised in the graphs below.



(a)



(b)



(c)

Physicists realised that a new theory for light was required to explain these results. Justify this statement. 7K

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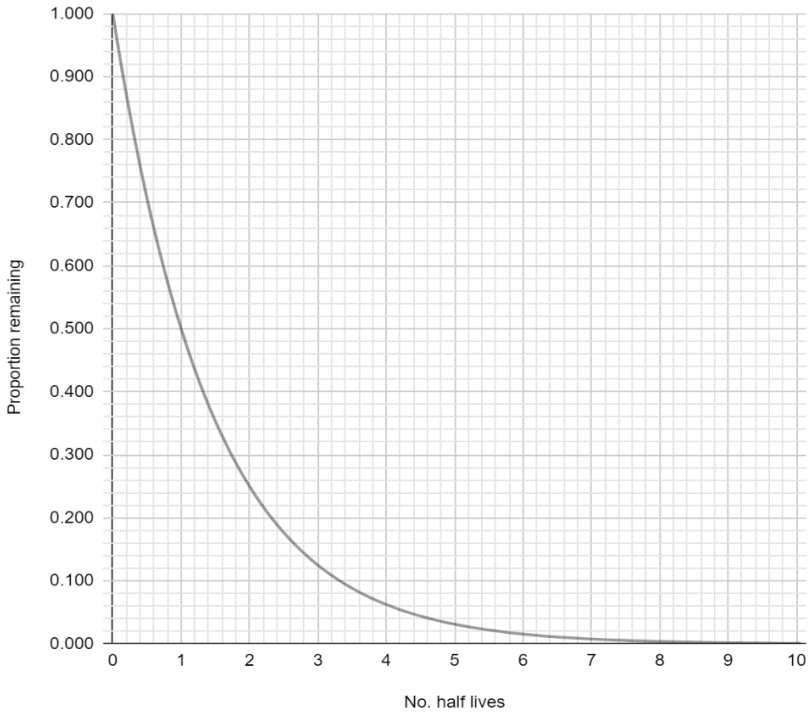
Question 34 (9 marks)

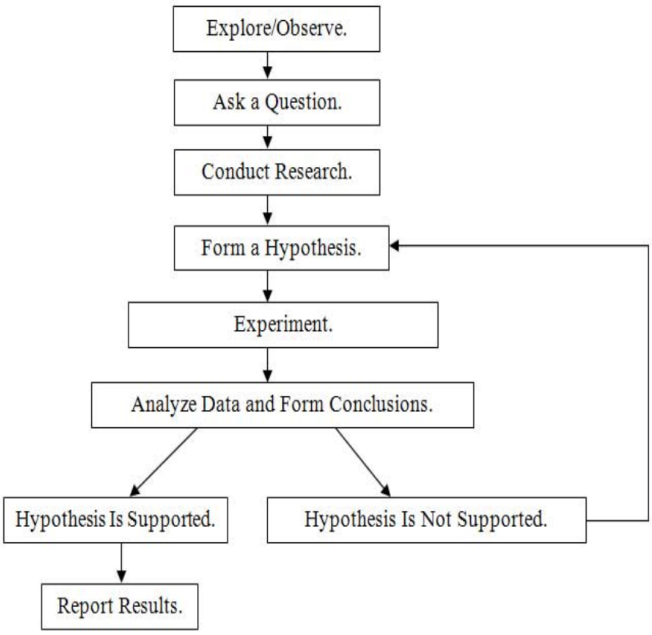
Cosmic rays hitting the upper atmosphere produces muons, travelling at 0.98 *c*.

Scientists found that 49000 muons were able to reach Earth's surface for every million muon measured at 10 km above the surface of the Earth. This was much higher considering the half-life of muon was known to be 1.56 μs.

Graphical model of exponential decay of particles has been provided below.



Using the observations of muons as an example to analyse how the scientific method as shown below is used to advance scientific knowledge. 9K



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Section II extra writing space

If you use this space, clearly indicate which question you are answering.

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DATA SHEET

Charge on the 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 ms^{-1}
Earth's gravitational acceleration, g	9.8 ms^{-2}
Speed of light, c	3.00×10^8 m s^{-1}
Electric permittivity constant, ε_0	8.854×10^{-12} A^2 s^4 kg^{-1} m^{-3}
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7}$ 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's 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}
Wien's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$\Delta U = mg\Delta h$$

$$P = \frac{\Delta E}{\Delta t}$$

$$\sum \frac{1}{2}mv^2_{\text{before}} = \sum \frac{1}{2}mv^2_{\text{after}}$$

$$\Delta \vec{p} = \vec{F}_{\text{net}}\Delta t$$

$$\omega = \frac{\Delta \theta}{t}$$

$$\tau = r_{\perp}F = rF\sin\theta$$

$$v = \frac{2\pi r}{T}$$

$$U = -\frac{GMm}{r}$$

$$v = u + at$$

$$\vec{F}_{\text{net}} = m\vec{a}$$

$$W = F_{||}s = Fs\cos\theta$$

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

$$P = F_{||}v = Fv\cos\theta$$

$$\sum m\vec{v}_{\text{before}} = \sum m\vec{v}_{\text{after}}$$

$$a_c = \frac{v^2}{r}$$

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

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

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

Waves and thermodynamics

$$v = f\lambda$$

$$f = \frac{1}{T}$$

$$d\sin\theta = m\lambda$$

$$n_x = \frac{c}{v_x}$$

$$I = I_{\max}\cos^2\theta$$

$$Q = mc\Delta T$$

$$f_{\text{beat}} = \left| f_2 - f_1 \right|$$

$$f' = f\frac{\left(v_{\text{wave}} + v_{\text{observer}}\right)}{\left(v_{\text{wave}} - v_{\text{source}}\right)}$$

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$\sin\theta_c = \frac{n_2}{n_1}$$

$$I_1r_1^2 = I_2r_2^2$$

$$\frac{Q}{t} = \frac{kA\Delta T}{d}$$

Electricity and magnetism

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

$$V = \frac{\Delta U}{q}$$

$$W = qV$$

$$W = qEd$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$B = \frac{\mu_0 NI}{L}$$

$$\Phi = B_{||}A = BA\cos\theta$$

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

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

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$I = \frac{q}{t}$$

$$V = IR$$

$$P = VI$$

$$F = qv_{\perp}B = qvB\sin\theta$$

$$F = lI_{\perp}B = lIB\sin\theta$$

$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$$

$$\tau = nIA_{\perp}B = nIAB\sin\theta$$

$$V_p I_p = V_s I_s$$

Quantum, special relativity and nuclear

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

$$K_{max} = hf - \phi$$

$$\lambda_{max} = \frac{b}{T}$$

$$E = mc^2$$

$$E = hf$$

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

$$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)}$$

$$p_v = \frac{m_0 v}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$N_t = N_0 e^{-\lambda t}$$

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

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	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

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

Standard atomic weights are abridged to four significant figures.

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

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

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

Student Number

Sydney Girls High School

2020

TRIAL
HSC
EXAMINATION

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A data sheet, formulae sheet and Periodic Table are provided at the back of this paper
- For questions in Section II, show all relevant working in questions involving calculations

Total Marks: 100

Section I – 20 marks (pages 2-12)

- Attempt Questions 1-20
- Allow about 35 minutes for this section

Section II – 80 marks (pages 13-31)

- Attempt Questions 21-34
- Allow about 2 hours and 25 minutes for this section

Section I

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

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

Question	Answer
1	B
2	C
3	A
4	A
5	B
6	C
7	A
8	B
9	C
10	B
11	D
12	A
13	B
14	C
15	C
16	C
17	C
18	C
19	A
20	D

1 How does the charge and mass of Beta particles compare with Alpha particles?

A. beta particles have more mass and more charge than alpha particles.

B. beta particles have less mass and less charge than alpha particles.

C. beta particles have more mass and less charge than alpha particles.

D. beta particles have less mass and more charge than alpha particles.

2 Carbon-14 undergoes spontaneous radioactive decay by releasing a beta-minus particle.

Identify the daughter nuclide formed after the decay.

A. Boron-10

B. Carbon-12

C. Nitrogen-14

D. Oxygen-16

3 A neodymium laser emits light with a wavelength of 1064 nm.

What is the energy of each photon emitted by the laser?

A. 1.87×10^{-19} J

B. 7.05×10^{-23} J

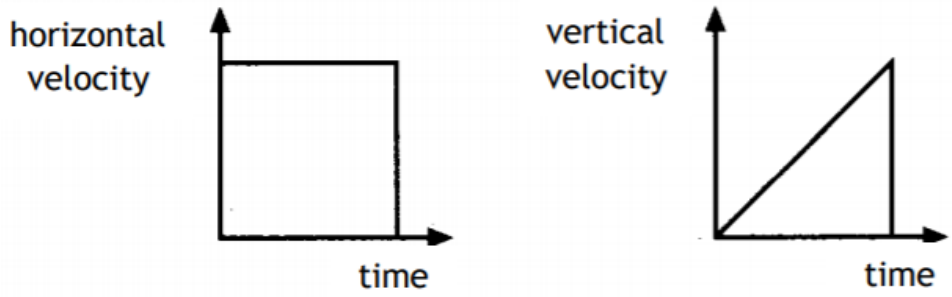
C. 1.87×10^{-26} J

D. 7.05×10^{-19} J

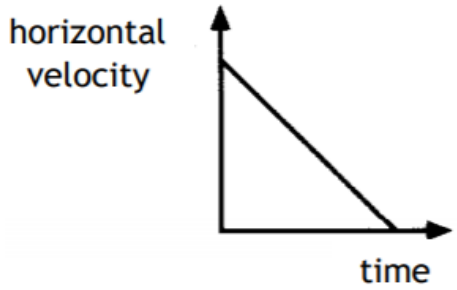
4 A ball is kicked horizontally from the edge of the cliff and lands in the sea.

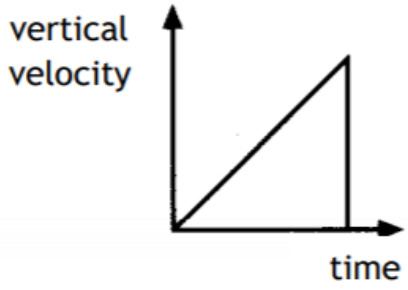
Assuming negligible air resistance, which pair of graphs show the horizontal and vertical velocity-time graphs for the ball during its flight?

A.

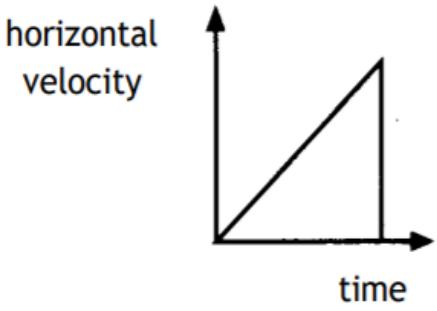


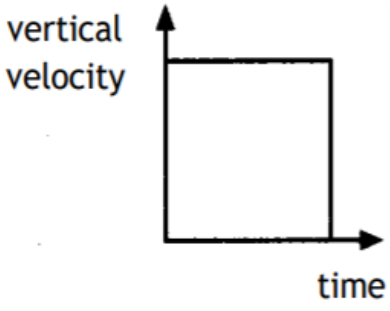
B.



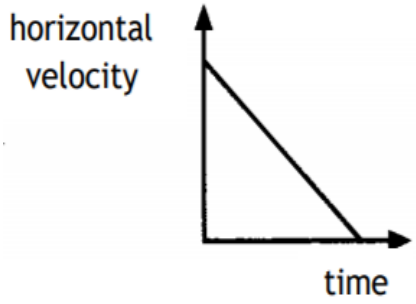


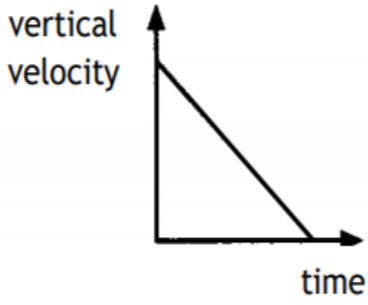
C.





D.





5 A motor is connected in series with an ammeter 2.0 A current was recorded in the ammeter when no load was attached to it. The current reading in the ammeter increased to 3.2 A when a load was attached to the motor whilst the supply EMF remains the same.

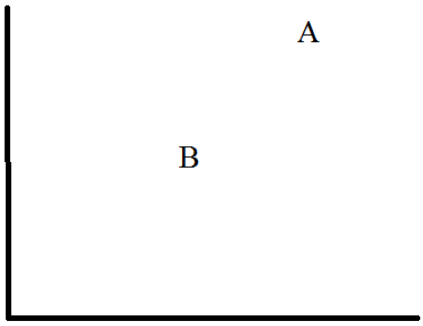
What conclusion can be drawn about the number of rotations per minute (RPM) and the back EMF in the coil after the load is attached to the motor?

Speed of rotation (RPM)	*Back EMF*

A.	Increased	Increased
B.	Decreased	Decreased
C.	Decreased	Increased
D.	Increased	Decreased

6 The HR diagram given below shows the position of two stars A, which is a supergiant; and B which is a main sequence star.

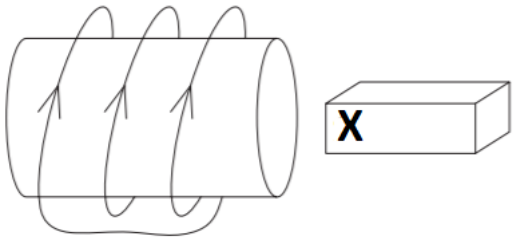
What can be concluded about the luminosity and temperature of star A as compared that of star B.



	Luminosity of Star B	*Temperature of Star B*
A.	Higher than A	Higher than A
B.	Lower than A	Lower than A
C.	Lower than A	Higher than A
D.	Higher than A	Lower than A

7 A bar magnet is moved relative to a coil which results in an induced current in the coil as shown in the diagram below.

What conclusion can be drawn about the polarity of the X end of the bar magnet and direction of its relative motion?



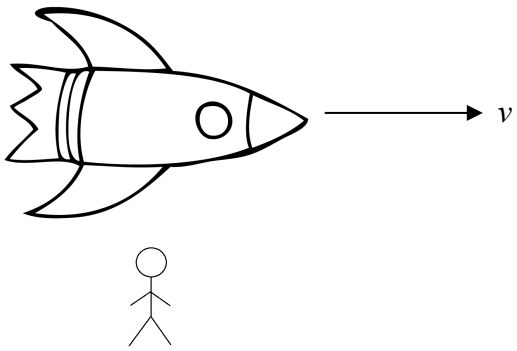
A. X is the north pole, the coil is stationary and the bar magnet is moved to the right.

B. X is the north pole, the coil is stationary and the bar magnet is moved to the left.

C. X is the south pole, the coil is moved to the left and the bar magnet is stationary.

D. X is the south pole and the bar magnet and the coil are moved away from each other.

8 An observer watches as a spacecraft passes by at relativistic speed, perpendicular to her line of sight.



The astronauts inside the spacecraft have measured the spacecraft to be 45 m long and 15 m wide.
How long and wide is the spacecraft according to the observer?

A. Exactly 45 m long and less than 15 m wide.

B. Less than 45 m long and exactly 15 m wide.

C. Less than 45 m long and less than 15 m wide.

D. More than 45 m long and more than 15 m wide

9 A satellite in a circular orbit of radius R has a orbital period T. If this satellite is moved to a higher orbit of orbital radius 4R, what will be the orbital period of the satellite in the higher orbit?

A. 2T

B. 4T

C. 8T

D. 16T

10 The Earth has a radius of 6378 km.

What would be the escape velocity if a spacecraft is in orbit at a height of 25480 km above the surface of the Earth?

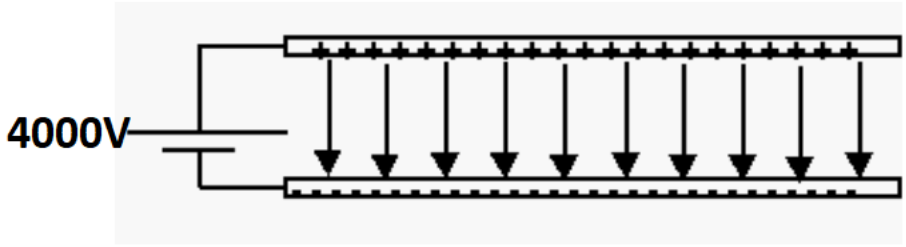
A. 3.5 km/s

B. 5.0 km/s

C. 5.6 km/s

D. 11.2 km/s

11 Consider a parallel plate separated by a distance of 1.0 mm and connected to a power supply as shown in the diagram below.



What would the magnitude of the acceleration experienced by an electron be when placed between the parallel plates?

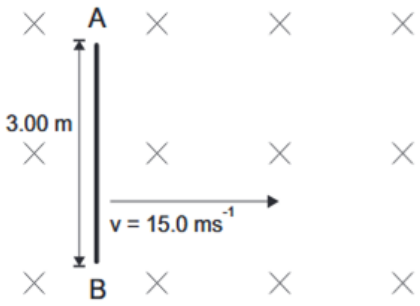
A. 6.4×10^{15} ms^{-2}

B. 7.0×10^{15} ms^{-2}

C. 6.4×10^{17} ms^{-2}

D. 7.0×10^{17} ms^{-2}

12 A length of wire is pulled with constant velocity through a magnetic field, as shown in the diagram below.



What is the strength of the magnetic field if the wire develops an EMF of 40V?

A. 0.89 T

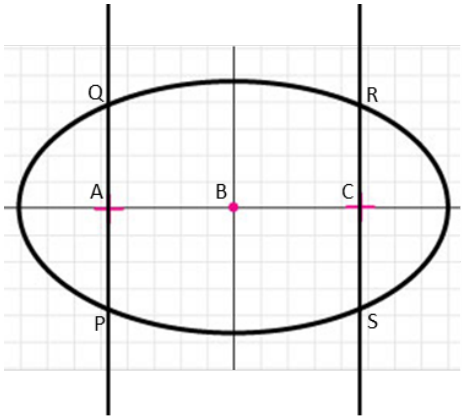
B. 1.13 T

C. 45 T

D. 1800 T

13 The image below represents the elliptical path of a planet around a star.

Which of the following statements is most correct?



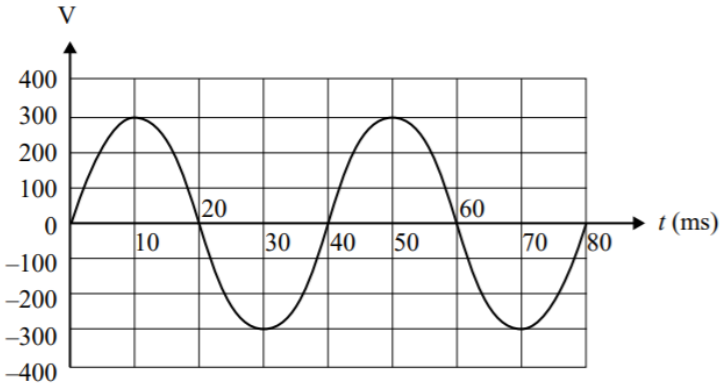
A. The star is located at C and the planet takes less time to travel P to Q than it does for R to S.

B. The star is located at C and the planet takes more time to travel P to Q than it does for R to S.

C. The star is located at A and the planet takes the same time to travel P to Q as it does for R to S.

D. The star is located at B and the planet takes the same time to travel P to Q as it does for R to S.

14 Following signal was obtained from an AC generator.



What is the frequency of rotation of the coil in the generator?

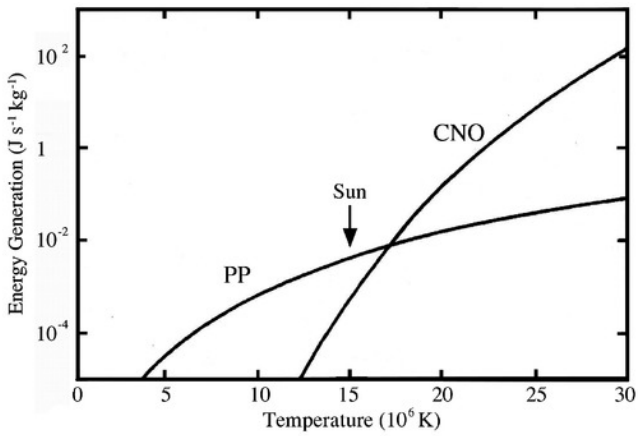
A. 0.025 Hz

B. 0.04 Hz

C. 25 Hz

D. 40 Hz

15 Following graph shows the relative rate of two main types of hydrogen fusion reactions.



Based on your knowledge of the data presented in the HR diagram and the information in the above graph what conclusion can be made regarding hydrogen fusion in stars.

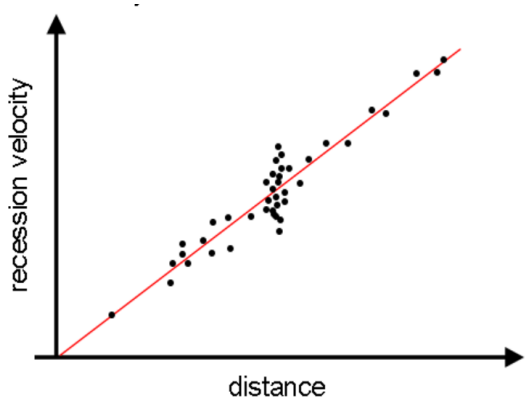
A. The CNO cycle only occurs in red giants.

B. The Sun does not use CNO cycle for energy production.

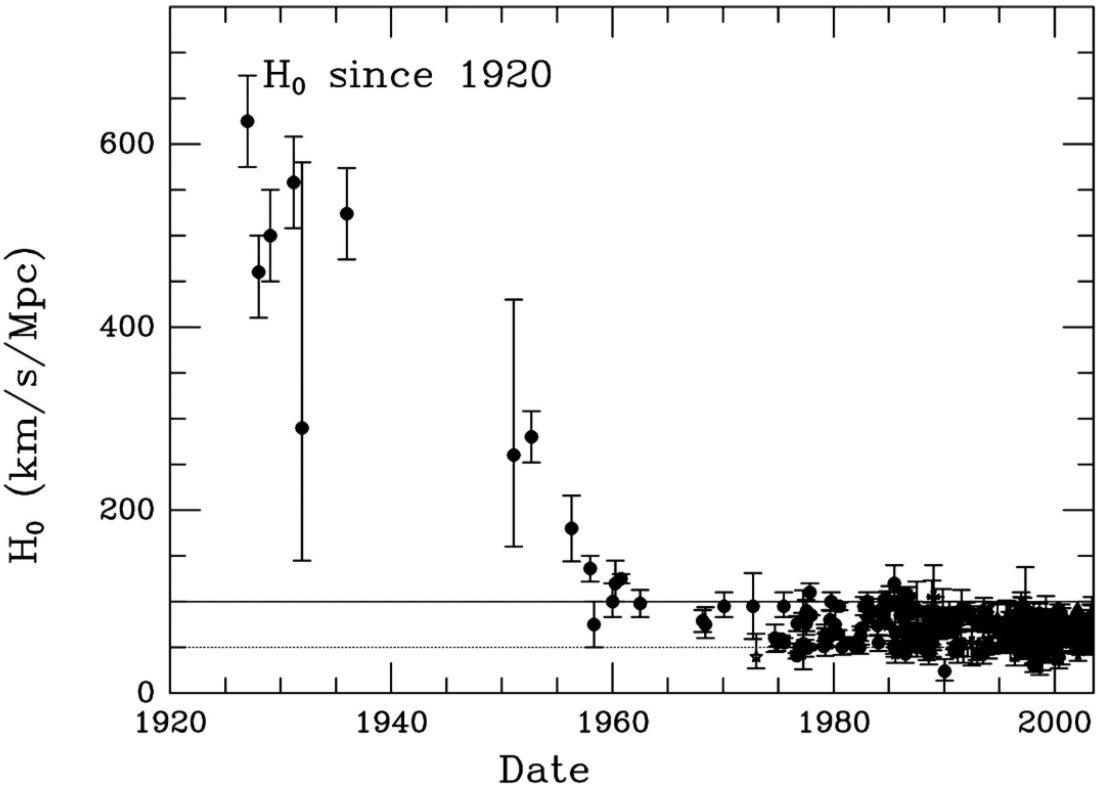
C. PP chain is the main energy source in cooler main sequence stars.

D. More luminous stars generate most of their energy using the PP chain.

16 In the graph below, the gradient of the line is known as Hubble's constant H_0.



Hubble's constant has been revised over time. In the graph below, the vertical line for each data point represents the uncertainty in these measurements.



What is a possible reason for the change in measurements over time?

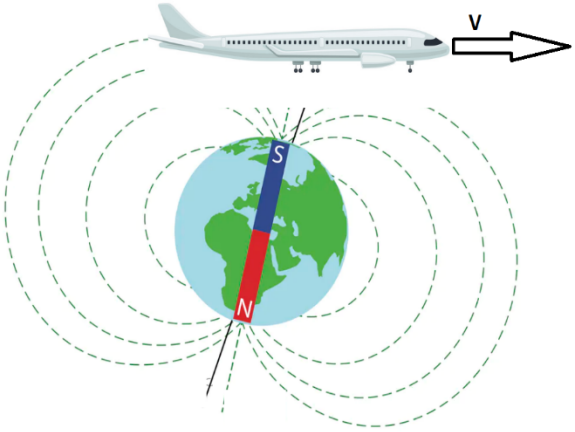
A. The value of H_0 has decreased.

B. Knowledge of stellar evolution has improved.

C. Better technology allowed more measurements to be made.

D. The rate of expansion has increased during this time period.

17 Consider an aeroplane flying over the north pole in Earth's magnetic field as shown the diagram below.



What would be the polarity of the EMF induced in the plane?

A. Front of the plane would have a higher potential

B. Back of the plane would have a higher potential

C. Wing tip pointing into the page would have a higher potential

D. Wing tip pointing out of the page would have a higher potential

18 Threshold frequency of sodium is 5.8×10^{14} Hz and for zinc 8.8×10^{14} Hz.

What can be concluded about the kinetic energy of electrons emitted from zinc as compared to the electrons emitted from sodium due to the photoelectric effect?

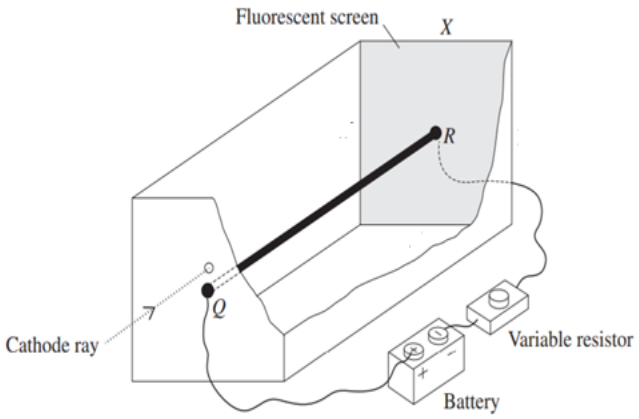
A. Kinetic energy of electrons emitted from zinc can never be higher than the electrons emitted from sodium.

B. Kinetic energy of electrons emitted from zinc will always be higher than the electrons emitted from sodium.

C. Kinetic energy of electrons emitted from zinc can be higher than the electrons emitted from sodium if relatively higher frequency of light is used with zinc.

D. Kinetic energy of electrons emitted from zinc can be higher than the electrons emitted from sodium if relatively higher intensity of light is used with zinc.

19 A straight current-carrying conductor, QR, is connected to a battery and a variable resistor. QR is enclosed in an evacuated chamber with a fluorescent screen at one end as shown in the diagram below.



A cathode ray which is made up of a beam of electrons enters the chamber directly above Q, initially travelling parallel to QR. It passes through the chamber and strikes the fluorescent screen causing a bright spot.

What can be done to move the bright spot closest to the position X on the screen?

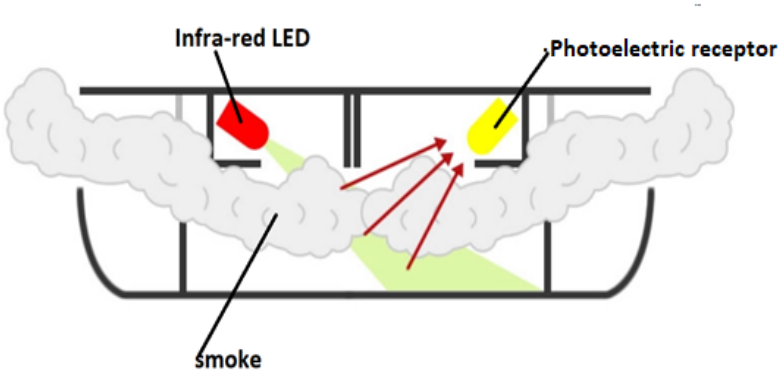
A. Increase the current in QR.

B. Increase the resistance of the variable resistor.

C. Decrease the voltage in power supply.

D. Reverse the direction of current in QR.

20 An optical smoke alarm (also called photo-electric smoke alarm) works using the light scatter principle as shown in the diagram below.



As the smoke enters the smoke detector, particles in the smoke cause the Infra-red light to be scattered onto the photoelectric receptor. Once the scattered light hits the photoelectric receptor, a signal is sent to the integrated circuit due to release of electrons from the receptor. This causes the alarm to sound alerting the occupants to the fire.

What requirement needs to be met for the optical smoke alarm to function properly?

A. Smoke entering the smoke alarm should reach the photoelectric receptor.

B. Smoke entering the smoke alarm should not scatter the infra-red light.

C. Work function of the photoelectric receptor should be greater than the energy of infra-red photons.

D. Threshold frequency of the photoelectric receptor should be less than the frequency of infra-red light.

2020

TRIAL
HSC
EXAMINATION

Student Number

Physics

Section II
Answer Booklet

80 marks
Attempt Questions 21-35
Allow about 2 hours and 25 minutes for this section

Instructions

- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of the response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

Question 21 (5 marks)

A tennis ball bounces off the ground at an angle of 40° to the horizontal, with an initial velocity of 25 ms^{-1}. The tennis court fence is six metres away, and is 4 m high.

(a) Calculate the time needed for the ball to travel a horizontal distance of 6 m. **2**

Criteria	Marks
• Provides relevant calculation	2
• Provides some relevant information	1

Sample answer:

- $u_x = u\cos\theta = 25 \cos 40 = 19.15$
- $\Delta x = u_x t$
  - $t = \Delta x / u_x = 0.31$ s

(b) Determine whether the ball will go over the fence. Support your answer with calculations. 3

Criteria	Marks
• Provides correct calculation to support statement of whether it will go over the fence.	3
• Provides relevant calculation	2
• Provides some relevant information	1

Sample answer:

- $s_y = u_y t + \frac{1}{2} a_y t^2 = 25 \sin 40\ 0.31 - 4.9 \times 0.31^2 = 4.6$ m
- At the time the ball reaches the fence its height above the ground (4.6 m) is higher than the fence (4 m) therefore it will go over.

Question 22 (4 Marks)

Explain how astronomers use starlight to calculate the surface temperature of a star. 4

Criteria	Marks
• Explains how astronomers would gather spectroscopic data from the star, use the spectrograph to find the peak wavelength of the blackbody curve, and then substitute into the relevant equation to find T.	4
• Describes that spectroscopy can be used to find wavelength to substitute into the equation.	3
• Outlines the relevant formula and states that it can be used to find T	2
• Provides some relevant information	1

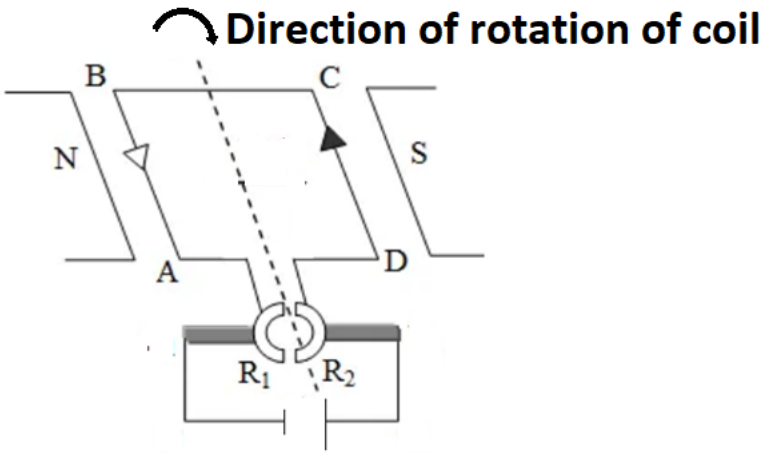
Sample answer:

Astronomers would analyse the starlight using spectroscopy. The spectrum would show a blackbody curve, from which the wavelength with the greatest intensity (peak wavelength) can be determined. This peak wavelength can then be substituted into the equation for Wien's displacement law, $\lambda_{max} = b/T$, to find the surface temperature, T.

Question 23 (4 Marks)

The schematic diagram given below shows how a DC motor works. The coil ABCD in the diagram is connected to the split rings (R_1 and R_2) of the commutator.

Use the diagram to explain the role of split ring commutator in a DC motor. 4



Criteria	Marks
• Uses annotations or references to the diagram to explain the role of the commutator, including clear and thorough descriptions of the forces and torques involved.	4
• Describes the role of the commutator in keeping the rotor turning, with explanation involving current and forces that would be produced.	3
• Identifies the role of commutator in changing the current direction with some explanation.	2
• Provides some relevant information	1

Sample answer:

The commutators role is to enable the rotor to turn continuously. At the instant shown in the diagram, the force on the wire AB would act up, generating a torque in the direction shown by the arrow. Once the rotor turns so that it is upright, the upwards force would generate no torque due to the relative directions of F and d. At this point, the commutator has also rotated and the current would briefly cut out due to the split. The rotor's inertia would cause it to continue moving. The connection is then re-established with the current in wire section AB reversed. It will then experience a downwards force. This allows the torque to maintain its clockwise direction.

Question 24 (6 marks)

An object dropped vertically downwards experiences gravitational force and acceleration.

Ashley conducted an experiment to determine the value of acceleration due to gravity by dropping a ball from different heights. Her results are outlined in the table below.

Height from which ball is dropped (m)	Time taken by the ball to reach the ground (s)	
0.5	0.32	
0.7	0.38	
0.9	0.43	
1.1	0.47	
1.3	0.52	
1.5	0.55	

(a) Use Ashley's data to produce a linear graph which can be analysed to calculate acceleration due to gravity. Include any calculations in the table above. 4

Criteria	Marks
• Includes all of the following features: suitable choice of variables to plot, independent or derivative on x-axis, all data plotted correctly, appropriate line of best fit, axes labelled and with units.	4
• Most features included (1-2 errors or omissions)	3
• Data plotted with axes labelled correctly (possibly without units)	2
• Some data plotted	1

Sample answer:

Graph should have Time^2 (s^2) vs height (m), with a linear line of best fit.

(b) Use the graph to calculate the value of acceleration due to gravity. 2

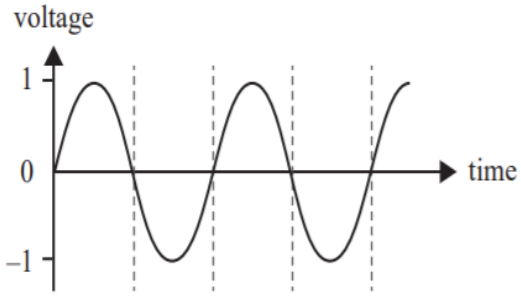
Criteria	Marks
• Gradient determined using two points on line, acceleration determined.	2
• Gradient determined	1

Sample answer:

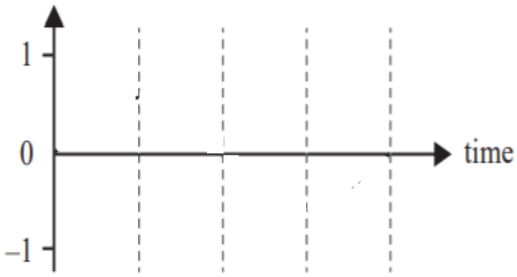
- Gradient = (0.3-0.1)/(1.5-0.5) = 0.2
- $s_y = + ½ a_y t^2$ (u = 0)
- Since graph is t^2 vs s_y, $t^2 = (2/a) s_y$
- a = 2/gradient = 2/0.2 = 10 ms^{-2}

Question 25 (6 Marks)

A graph of output voltage versus time of an AC generator is shown below.



(a) Sketch the output signal of the AC generator on the scale provided below if the rate of revolutions of the generator is reduced to half. 3



Criteria	Marks
• Sine curve with period doubled and amplitude approx. half.	3
• Sine curve with period doubled (amplitude the same as before)	2
• Any sine or cosine curve.	1

(b) Describe energy conversions in electric power generation and transmission. 3

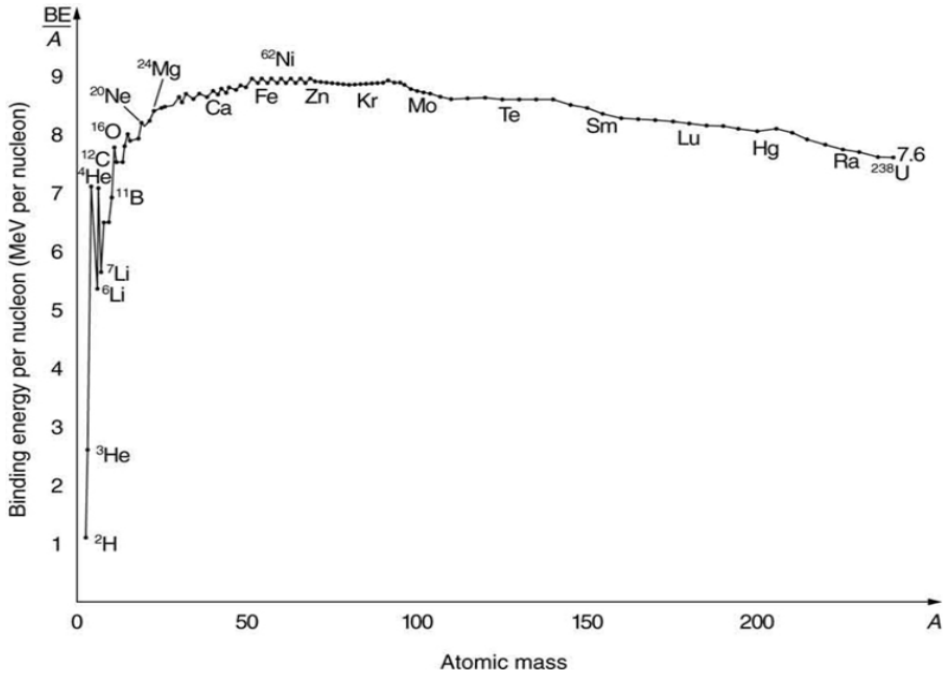
Criteria	Marks
• Describes two conversions (1 for generation and 1 for transmission)	3
• Identifies two conversions, related to generation, transmission or use.	2
• Identifies one conversion	1

Sample answer:

In a power station, kinetic energy (due to steam) is converted into electrical potential energy by the generator. During transmission to the consumer, some electrical energy is lost as heat energy due to joule heating of the wires.

Question 26 (5 marks)

With reference to the graph below explain the process of fusion in stars. 5



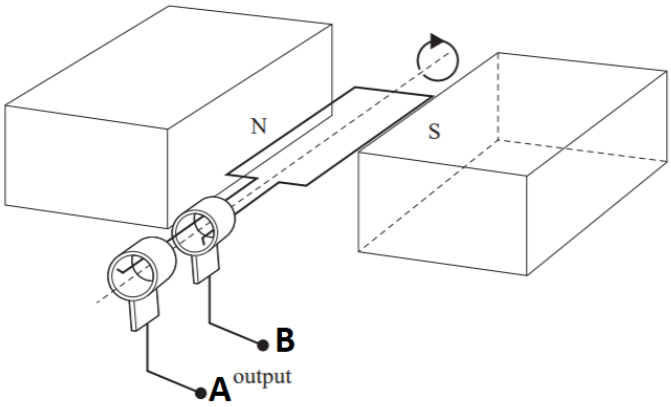
Criteria	Marks
• Full, coherent explanation including: Description of at least two fusion processes, use of the graph (with numeric quotes) to explain why energy is released during one fusion process, use of the trends or shape of the graph to show the limits of fusion.	5
• Logical explanation including most features, including a specific reference to graph	4
• Identifies a relevant feature of the graph, relates fusion to energy release, with one example of a fusion process	3
• Relates fusion to the release of energy and mentions graph	2
• Provides some relevant information	1

Sample answer:

Fusion involves the combination of two nuclei to form a larger one. The process of fusing hydrogen to form helium is the main source of energy in main sequence stars. The final reaction in the proton-proton chain involves the combination of two He-3 nuclei to form He-4 (and two free protons). According to the graph, He-3 has a binding energy per nucleon of approximately2.6 MeV, while He-4 is 7.1 MeV (and protons have zero binding energy). Therefore, the total binding energy has decreased in the process. This indicates that some of the mass of the reactants has been released as energy. The rising shape of the graph until Fe-56 shows that fusion processes of smaller nuclei will result in the release of energy, for example, the combination of Be-8 and He-4 as part of the triple alpha process. The falling trend after this point shows that energy would have to be added to allow fusion processes.

Question 27 (5 marks)

Consider the diagram of a generator provided below



(a) Deduce the polarity of terminals A and B at the point in time shown in the diagram. Use Lenz's law to justify your answer. 3

Criteria	Marks
• Identifies the correct polarities, by determining the current direction with well-explained use of Lenz's law.	3
• Use's Lenz's law to determine the correct current direction	2
• States Lenz's law OR determines the correct current.	1

Sample answer:

At the time shown, the wire segment near the north pole is moving upward. This motion creates a change in flux through the coil. Lenz's law states the current induced will be such that it will oppose this change. Therefore, the induced current will result in a downwards force on this wire segment, causing the speed of the motion to be reduced. Using the right-hand palm rule, this current would need to be into the page, causing the current to circulate clockwise around the coil. The conventional current would therefore exit the generator via B, making it positive terminal.

(b) The loop in the diagram has a dimension of 0.50 m × 0.25 m and the strength of the magnetic field is 0.4T. Calculate maximum magnetic flux through the coil. 2

Criteria	**Marks**
• Use the relevant equation to calculate the value, with units.	2
• Use the relevant equation to calculate the value	1

Sample answer:

$\Phi = BA = 0.4 \times 0.5 \times 0.25 = 0.05$ Wb (or Tm^2)

Student Number

Question 28 (6 marks)

Uranium-238 undergoes spontaneous radioactive decay by releasing one alpha particle

Masses of all relevant nuclides involved have been provided below.

Uranium-238	238.05079 u
Daughter nuclide	234.04363 u
Helium-4	4.00260 u

(a) Write the balanced nuclear equation for the decay process. 2

Criteria	Marks
Provides balanced nuclear reaction with appropriate symbols	2
Provides some relevant detail	1

Sample answer:

$^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He}$

(b) Calculate the amount of energy released during the decay and account for the release of energy.

4

Criteria	Marks
• Applies correct method to calculate energy in MeV or J • Accounts for energy release	4
• Applies correct method to calculate energy in MeV or J OR • Accounts for energy release	3
• Shows the main steps to calculate energy release	2
• Provides some relevant information	1

Sample answer:

Mass defect = 238.05079 – (234.04363 + 4.00260)

Mass defect = 238.05079 – 238.04623

Mass defect = 0.00456 u

Energy released = 0.00456 x 931.5

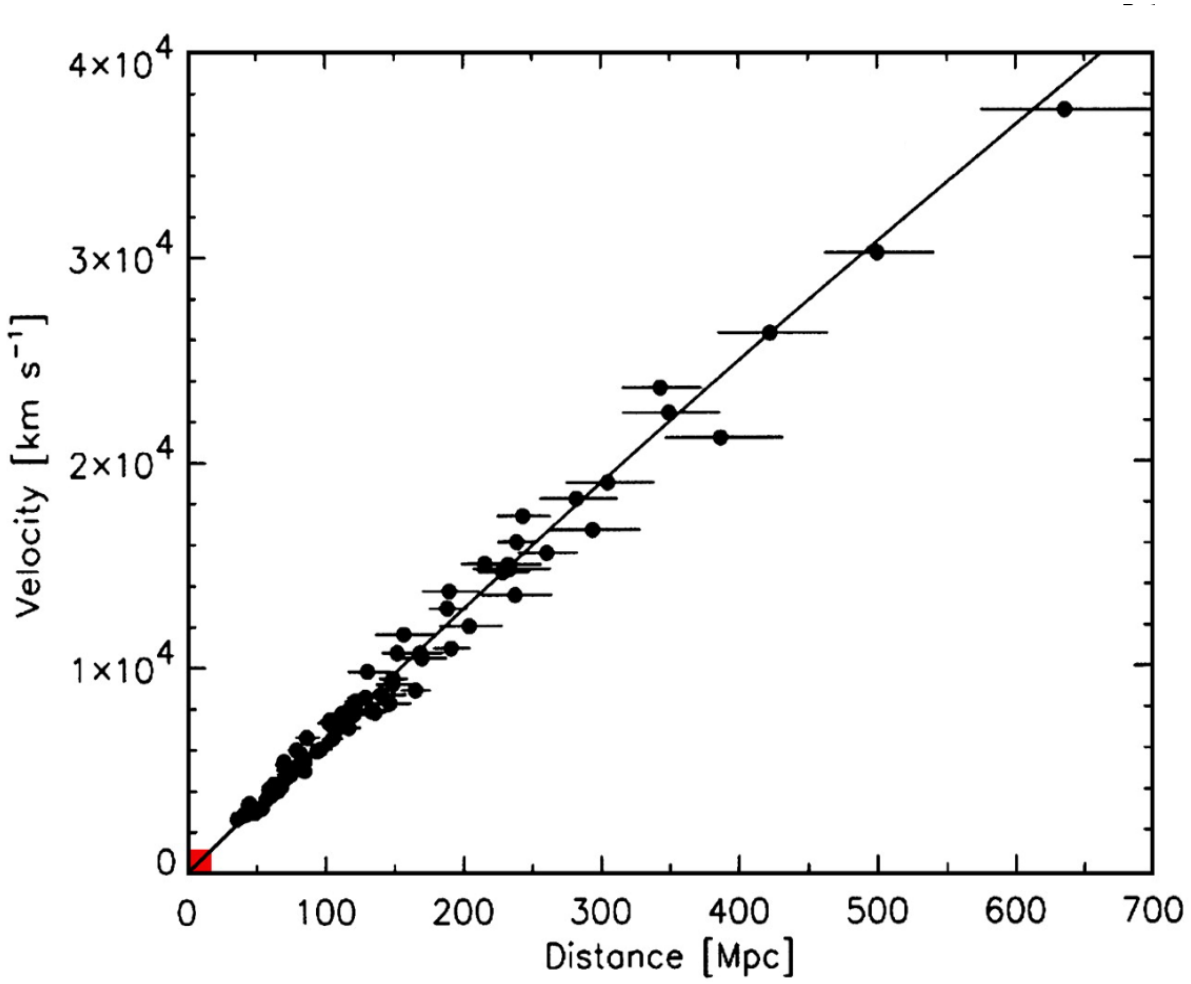
Energy released = 4.24764 MeV

(Energy released = 6.796×10^{-13} J)

Energy is obtained from the conversion of some mass to energy as described in the equation $E = mc^2$

Question 29 (9 marks)

The Hubble diagram, based on well observed supernovae has been provided in the graph below.



(a) Explain how spectroscopy can be used to determine the velocity of the observed supernovae.

3

Criteria	Marks
• Relates doppler shift of spectral lines to velocity	3
• Relates 'redshift' to velocity	2
• Provides some relevant information	1

Sample answer:

Stars have characteristic absorption (or emission) spectral lines located at specific frequencies according to their chemical composition. If these lines are shifted toward the longer wavelengths it indicates the star is moving away from us.

(Question 29 continues on next page)

(b) The reciprocal of the gradient of the trend line is the age of the universe. Use the graph to calculate the age of the universe in years. (1 megaparsec = 3.086×10^{19} km) 3

Criteria	Marks
• Correctly calculates the age in years	3
• Provides some relevant steps	2
• Provides one relevant step	1

Sample answer:

Gradient = (4×10^4) km/s ÷ 650 Mpc

Gradient = $(4 \times 10^4) \div (650 \times 3.086 \times 10^{19})$

Gradient = $61.538461 \div 3.086 \times 10^{19}$

Gradient = $1.99411735 \times 10^{-18}$

1/Gradient = 5.01475×10^{17} seconds

1/Gradient = $(5.01475 \times 10^{17}) \div (365.25 \times 24 \times 60 \times 60)$

1/Gradient = 1.58×10^{10} years

Age = 1.58×10^{10} years

Age = 15.8 billion years

(c) Explain how the data presented in the graph provides evidence for the Big Bang theory. 3

Criteria	Marks
• Describes the trend shown in the graph • Explains the trend in terms of expansion of the universe	3
• Describes the trend shown in the graph OR • Describes the expansion of the universe over time	2
• Provides some relevant information	1

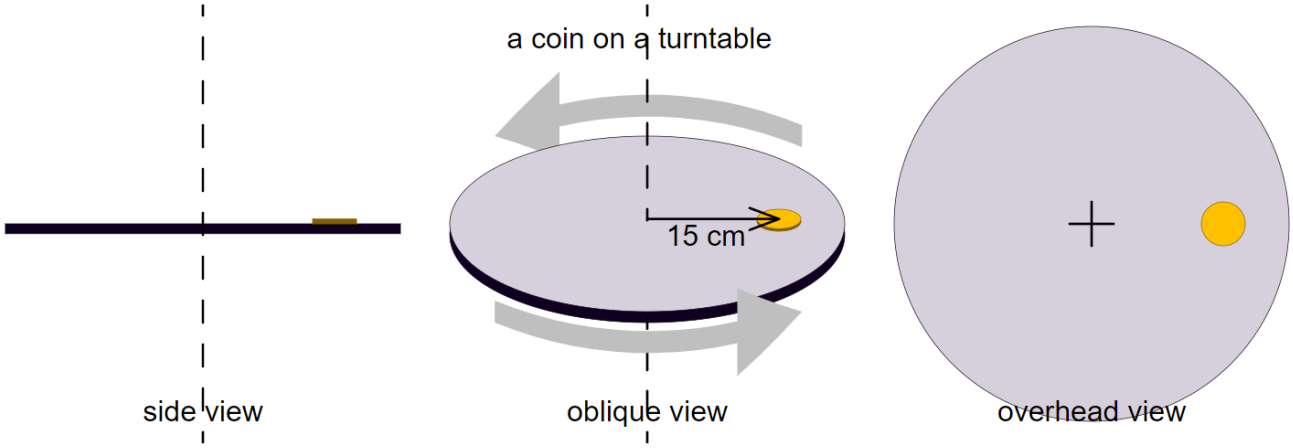
Sample answer:

The data in the graph shows that the further away an object is the greater its recessional velocity is.

This increase in velocity with distance can be explained using the Big Bang model that involves expansion of space over time.

Question 30 (6 marks)

A 55g coin is placed on a horizontal turntable 15 cm from its centre as shown in the diagrams below. The turntable rotates at a constant rate in a counter clockwise direction as seen from above. The coin does not slip and the turntable completes one rotation every 500 ms.

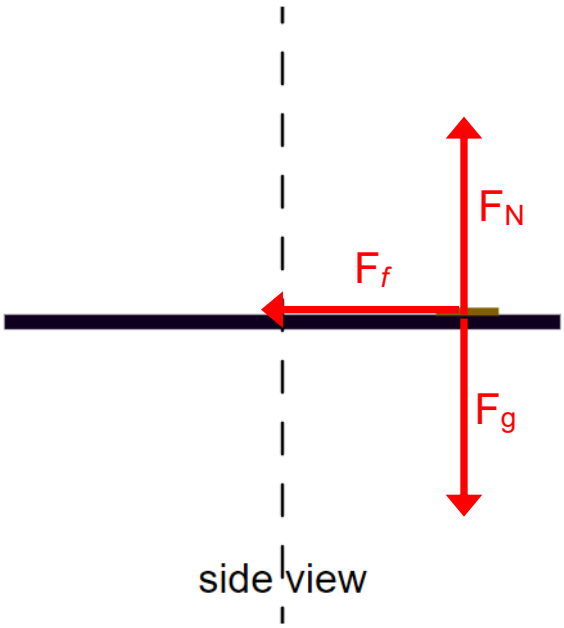


(Question 30 continues on next page)

(a) On the figure labelled **"side view",** draw free body diagram to represent the forces acting on the coin. (You do not need to draw the arrows to scale.) 3

Criteria	**Marks**
• Correctly labels forces acting on the coin	3
• Correctly labels the majority of forces acting on the coin	2
• Provides some relevant information	1

Sample answer:



(b) Calculate the centrip ween the coin and turntable. 3

Criteria	Marks
• Correctly calculates frictional and centripetal forces	3
• Performs some relevant steps	2
• Provides some relevant information	1

Sample answer:

$v = 2\pi r/T$

$v = 2\pi(15 \times 10^{-2}) / (500 \times 10^{-3})$

$v = 1.88$ m/s

$F_c = f = mv^2/r$

$F_c = f = (55 \times 10^{-3}) \times v^2 / (15 \times 10^{-2})$

$F_c = f = 1.3$ N

Question 31 (4 marks)

The earth has a radius of 6378 km.

Data for three different satellites orbiting earth has been outlined in the table provided below.

Satellite System	Orbital Height (Km)	Orbital Velocity (Km/Sec)	Orbital Period (H M S)
Intelsat (GEO)	35,786	3.0747	23 56 4.1
New ICO (MEO)	10,255	4.8954	5 55 48.4
Iridium (LEO)	1,469	7.1272	1 55 17.8

Account for the difference in the orbital velocities of the satellites. 4

Criteria	Marks
• Recognises that radius equates to height plus r_E • Uses relevant equations to determine relationship between v and r	4
• Uses relevant equations to determine relationship between v and r	3
• Outlines relationship between v and r	2
• Provides some relevant information	1

Sample answer:

By equating $F = GMm/r^2$ and $F = mv^2/r$ we obtain the equation

$v = \sqrt{GM/r}$

As the table identifies satellites orbiting the earth, the orbital radius for all three satellites will equate to their orbital height plus the radius of the earth. Therefore, as height increases so does orbital radius.

From the derived equation we can see that velocity will decrease as radius increases (height increases).

Question 32 (4 marks)

Operational specifications for a small DC motor has been provided in the table below.

PARAMETER	CONDITIONS	SPECIFICATION
Rated Operating Voltage		3 V
Rated Load	Maximum continuous torque	0.05 mNm
Rated Load Speed	At rated voltage under fixed torque at rated load	14,000 rpm
N/L Speed	Measured at rated voltage	23,000 rpm [+/- 2,500]
Max. Start Voltage	Measured at no load	0.5 V
Max. N/L Current	Measured at rated voltage	20 mA
Max. Operating Voltage		3.6 V
Max. Start Current	At rated voltage	180 mA
Min. Insulation Resistance	At 50V DC between motor terminal and case	1 MOhm
Max. Rated Load Current	At rated voltage under fixed torque at rated load	70 mA

Use relevant data from the table provided to explain how back EMF affects functioning of DC motors. 4

Criteria	**Marks**
• Explains how back emf affects function • Provides supporting data	4
• Explains how back emf affects function	3
• Describes induced emf	2
• Provides some relevant information	1

Sample answer:

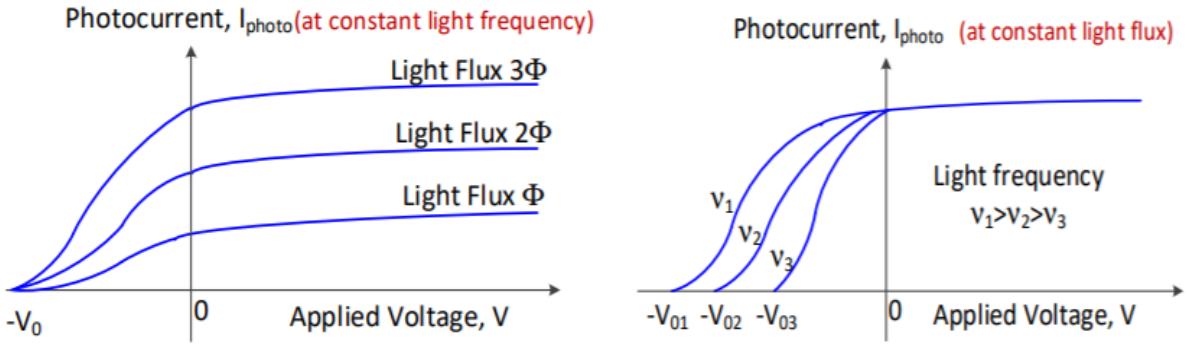
At start up the DC motor is not yet moving, hence there is no back emf. The operating voltage at that point will equal the supply voltage. Once the motor is in operation the motion of the coil will induce a back emf (in accordance with Lenz's law) that will in effect reduce the operating voltage since ($V_{operating} = V_{supply} - V_{backemf}$).

As the operating voltage is lower than the supply voltage and the resistance of the coil is fixed this means that the current through the motor is lower during operation (V =

IR). We can see this in the difference between the high start-up current 180mA as opposed to the lower operating current 20 – 70 mA. (The upper value of 70 mA is due to a load reducing rotation and hence reducing back emf)

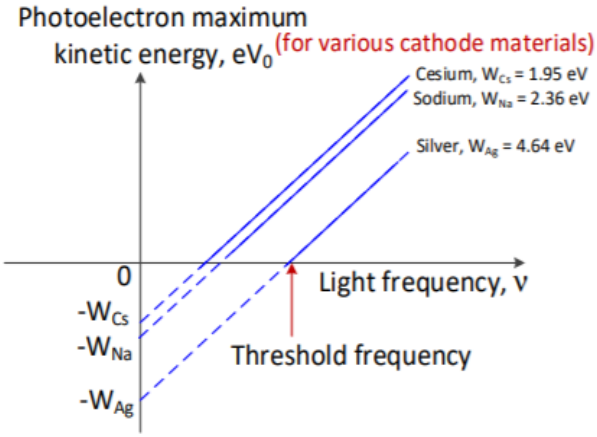
Question 33 (7 marks)

The main aspects observed in the early experiments regarding the photoelectric effect have been summarised in the graphs below.



(a)

(b)



(c)

Physicists realised that a new theory for light was required to explain these results. Justify this statement.

Criteria	Marks
• Explains results using new theory • Describes limitations of previous theory with respect to results	7
• Explains result(s) using new theory • Describes limitations of previous theory with respect to result(s)	6
• Explains result using new theory	5
• Describes new theory	4
• Describes limitations of previous theory with respect to result(s)	3
• Describes previous theory	2
• Provides some relevant information	1

Sample answer:

The information in the graphs could not be explained by the existing wave model of light.

Graph (a) shows that an increase in light intensity results in an increase in photocurrent but not an increase in kinetic energy of the electrons (indicated by same stopping voltage). This contradicted wave theory that linked increased intensity with increased kinetic energy of electrons. This is also seen in Graph (b) where an increase in frequency resulted in increased kinetic energy of electrons (different stopping voltage). Graph (c) also showed that the kinetic energy of the electrons was determined by the light frequency and not intensity as suggested by wave theory.

Einstein's photon model of light where photons had E = hf accounted for the relationship between frequency and kinetic energy acquired by photoelectrons. It also explained why more photons (intensity) would produce a larger photocurrent (graph a) and that the same number of photons (same intensity) at different frequencies would produce the same photocurrent but with higher kinetic energies (graph b).

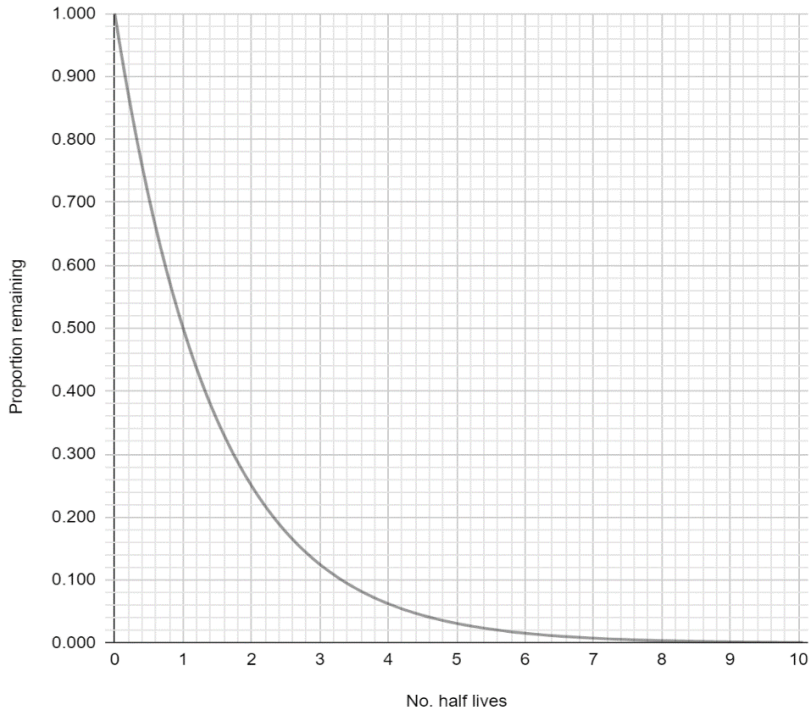
Finally, it explains why the minimum amount of energy required for a photocurrent from different metals was determined by light frequency and not intensity (graph c).

Question 34 (9 marks)

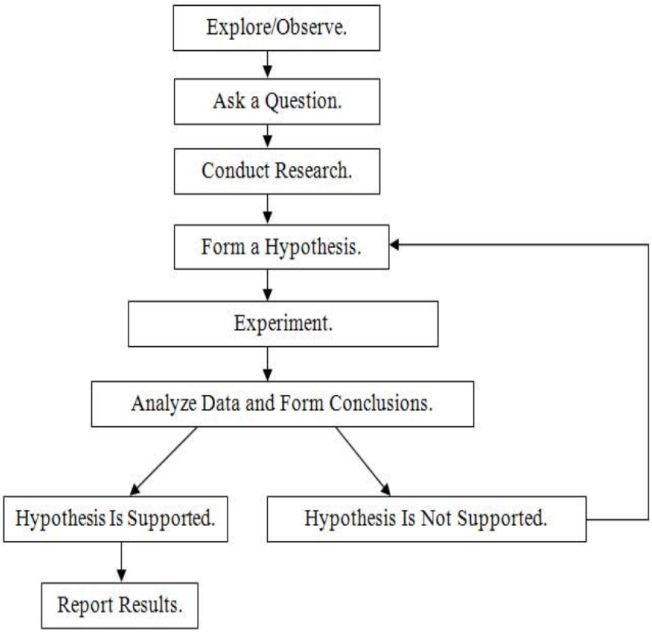
Cosmic rays hitting the upper atmosphere produces muons, travelling at 0.98 *c*.

Scientists found that 49000 muons were able to reach Earth's surface for every million muon measured at 10 km above the surface of the Earth. This was much higher considering the half-life of muon was known to be 1.56 μs.

Graphical model of exponential decay of particles has been provided below.



Using the observations of muons as an example to analyse how the scientific method as shown below is used to advance scientific knowledge. 9



Criteria	Marks
• Provides clear link between scientific method and detailed quantitative analysis of muon data	8-9
• Provides clear link between scientific method and quantitative analysis of muon data	6-7
• Establishes link between scientific method and aspects of quantitative analysis of muon data OR • Provides detailed qualitative explanation of muon data	4-5
• Provides relativistic calculated data OR • Provides qualitative explanation of muon data	3
• Provides relevant calculation	2
• Provides some relevant information	1

Sample answer:

Experimental proof was required to prove Einstein's theory of special relativity. The observation regarding muons in the atmosphere provided evidence that supported the associated concepts of time dilation and length contraction.

Newtonian physics predicts muons would take 3.4 x 10^{-5} s to travel 10 km

$$v = \frac{s}{t}$$

$$0.98 \times (3 \times 10^8) = \frac{10\,000}{t}$$

Time dilation predicts an observed time of 6.7 μs

$$3.4 \times 10^{-5} = \frac{t_0}{\sqrt{1 - {0.98c^2}/{c^2}}}$$

Length contraction predicts the distance travelled to be 2.2 km which would also correspond to a time of 6.7 μs

$$L_v = 10\,000\sqrt{1 - {0.98c^2}/{c^2}}$$

$$v = \frac{s}{t}$$

$$0.98 \times (3 \times 10^8) = \frac{2\,200}{t}$$

This equates to approx 4.3 half lives which according to the graph allows 5% of muons (~ 49 000) to reach the surface, supporting the hypothesis.

$$no.of\ half\ lives = \frac{6.67\ \mu s}{1.56\ \mu s}$$

Section II extra writing space

If you use this space, clearly indicate which question you are answering.

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DATA SHEET

Charge on the 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 ms^{-1}
Earth's gravitational acceleration, g	9.8 ms^{-2}
Speed of light, c	3.00×10^8 m s^{-1}
Electric permittivity constant, ε_0	8.854×10^{-12} A^2 s^4 kg^{-1} m^{-3}
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7}$ 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's 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}
Wien's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$\Delta U = mg\Delta h$$

$$P = \frac{\Delta E}{\Delta t}$$

$$\sum \frac{1}{2}mv^2_{\text{before}} = \sum \frac{1}{2}mv^2_{\text{after}}$$

$$\Delta \vec{p} = \vec{F}_{\text{net}}\Delta t$$

$$\omega = \frac{\Delta \theta}{t}$$

$$\tau = r_{\perp}F = rF\sin\theta$$

$$v = \frac{2\pi r}{T}$$

$$U = -\frac{GMm}{r}$$

$$v = u + at$$

$$\vec{F}_{\text{net}} = m\vec{a}$$

$$W = F_{||}s = Fs\cos\theta$$

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

$$P = F_{||}v = Fv\cos\theta$$

$$\sum m\vec{v}_{\text{before}} = \sum m\vec{v}_{\text{after}}$$

$$a_c = \frac{v^2}{r}$$

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

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

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

Waves and thermodynamics

$$v = f\lambda$$

$$f = \frac{1}{T}$$

$$d\sin\theta = m\lambda$$

$$n_x = \frac{c}{v_x}$$

$$I = I_{\max}\cos^2\theta$$

$$Q = mc\Delta T$$

$$f_{\text{beat}} = \left| f_2 - f_1 \right|$$

$$f' = f\frac{\left(v_{\text{wave}} + v_{\text{observer}}\right)}{\left(v_{\text{wave}} - v_{\text{source}}\right)}$$

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$\sin\theta_c = \frac{n_2}{n_1}$$

$$I_1r_1^2 = I_2r_2^2$$

$$\frac{Q}{t} = \frac{kA\Delta T}{d}$$

Electricity and magnetism

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

$$V = \frac{\Delta U}{q}$$

$$W = qV$$

$$W = qEd$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$B = \frac{\mu_0 NI}{L}$$

$$\Phi = B_{||}A = BA\cos\theta$$

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

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

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$I = \frac{q}{t}$$

$$V = IR$$

$$P = VI$$

$$F = qv_{\perp}B = qvB\sin\theta$$

$$F = lI_{\perp}B = lIB\sin\theta$$

$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$$

$$\tau = nIA_{\perp}B = nIAB\sin\theta$$

$$V_p I_p = V_s I_s$$

Quantum, special relativity and nuclear

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

$$K_{max} = hf - \phi$$

$$\lambda_{max} = \frac{b}{T}$$

$$E = mc^2$$

$$E = hf$$

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

$$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)}$$

$$p_v = \frac{m_0 v}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$N_t = N_0 e^{-\lambda t}$$

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

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	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

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

Standard atomic weights are abridged to four significant figures.

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

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

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