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CHAPTER 8

Sample
HSC Examination Paper
with 2018 HSC Questions

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 formulae sheet, data sheet and Periodic Table are provided at the back of this book (pp. 381–384)
- For questions in Section II, show all relevant working in questions involving calculations

Total marks: 100

Section I – 20 marks

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

Section II – 80 marks

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

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Section I

20 marks
Attempt Questions 1–20
Allow about 35 minutes for this section

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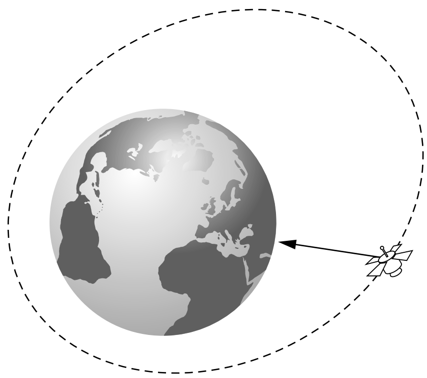
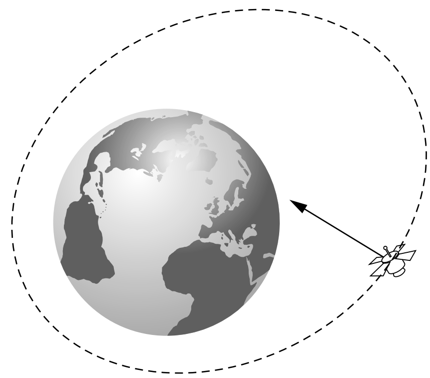
1 A satellite orbits Earth as shown.

Which diagram correctly shows the direction of the satellite's acceleration?

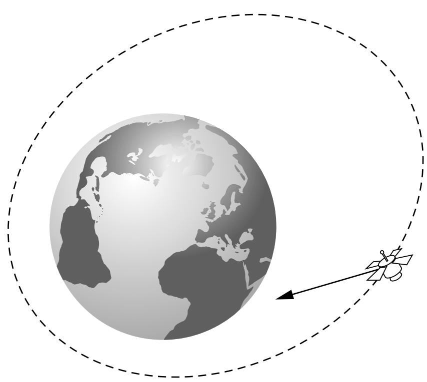
A.



B.



C.



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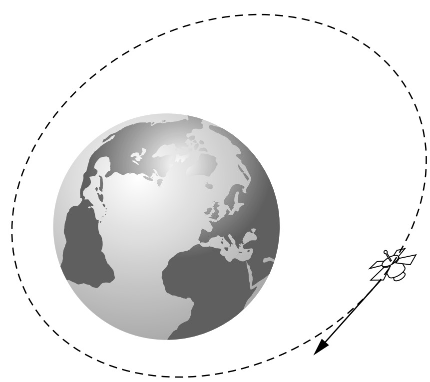

(2018 HSC)

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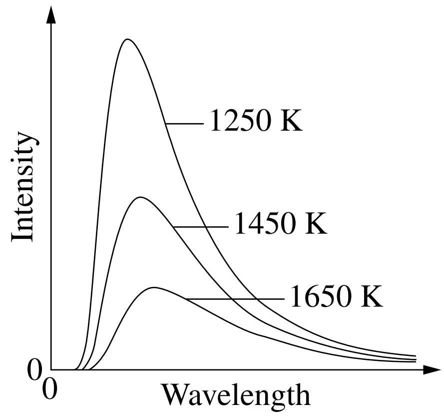
2 Which graph is consistent with predictions resulting from Planck's hypothesis regarding radiation from hot objects?

A.



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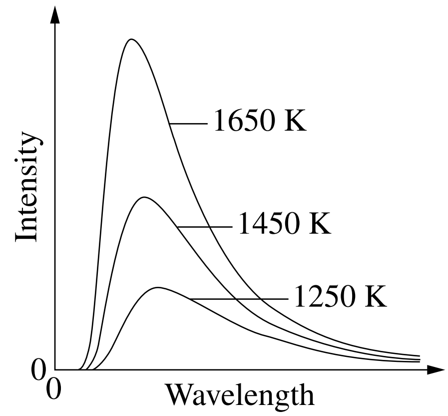

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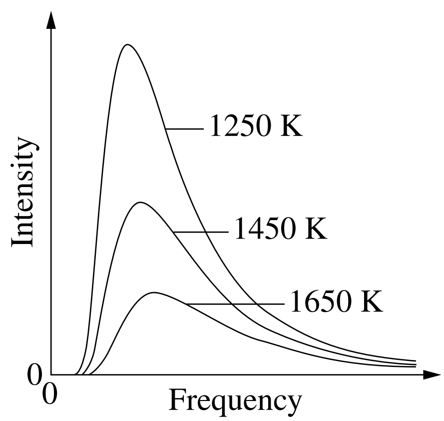

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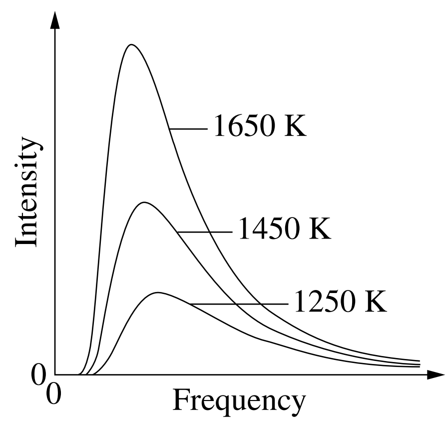
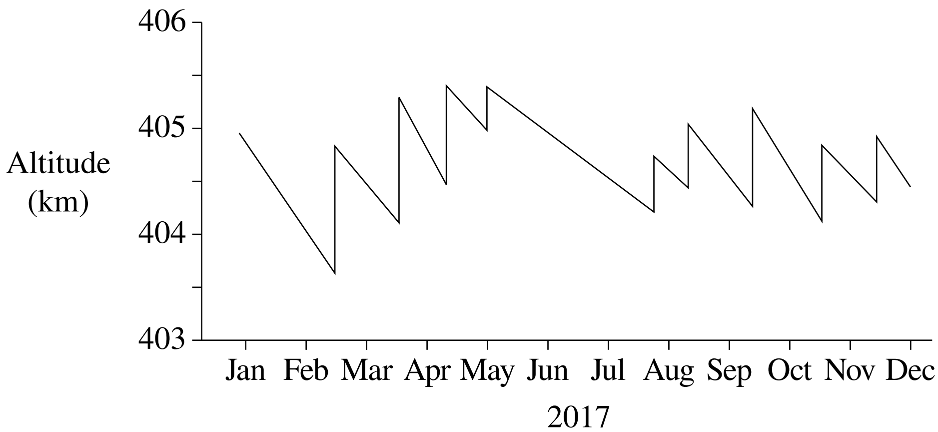


(2018 HSC)

3 The graph shows the altitude of the International Space Station (ISS) during 2017.



The altitude can only be boosted by supply craft visiting the ISS.

Why does the altitude decrease in the times between height boosts?

A. Momentum of the ISS is being transferred to air molecules.

B. The moon's gravity changes the net force on the ISS as it orbits Earth.

C. The decrease in altitude makes it possible for a supply craft to reach the ISS.

D. The total mass of the ISS changes with the deliveries from each supply craft.

(2018 HSC)

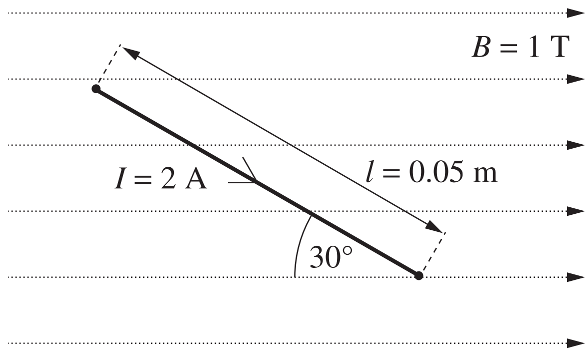
4 A motor, battery and ammeter are connected in series. When the motor is turning at full speed, the ammeter has a reading of 0.1 A. While the motor is spinning, a person holds the shaft of the motor to stop it.

Which row of the table correctly identifies the change in the ammeter reading and an explanation for the change?

	Reading on ammeter	*Explanation*
A.	Decreases	Decrease in back emf
B.	Increases	Increase in back emf
C.	Decreases	Increase in back emf
D.	Increases	Decrease in back emf

(2018 HSC)

5 The diagram shows a current-carrying conductor in a magnetic field.



What is the magnitude of the force on the conductor?

A. 0 N

B. 0.05 N

C. 0.09 N

D. 0.10 N

(2018 HSC)

6 Passing coherent, monochromatic light through a pair of closely spaced slits produces an interference pattern on a distant screen like the one shown in Figure E1. If 20 slits were used rather than two slits and the separation between each pair of slits remained constant, how would the interference pattern on the screen change?

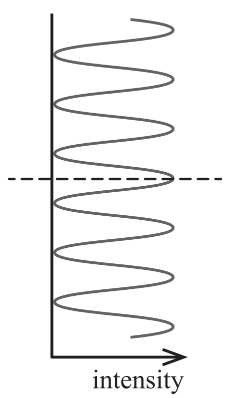


Figure E1. Double slit interference pattern

A. The maxima would become sharper and less intense but the separation between the maxima would not change.

B. The maxima would become sharper but the intensity of the maxima and the separation between the maxima would not change.

C. The maxima would become sharper and more intense but the separation between the maxima would not change.

D. The maxima would become sharper and less intense and the separation between the maxima would decrease.

(Sample question)

7 A planet X has twice the mass and twice the radius of Earth.

What is the magnitude of the gravitational acceleration close to the surface of planet X?

A. $\frac{1}{2}g$

B. $1\ g$

C. $2\ g$

D. $4\ g$

(2018 HSC)

8 How is energy produced in a red dwarf main sequence star?

A. By hydrogen fusing to helium in the core via the CNO cycle

B. By hydrogen fusing to helium in the core via the proton–proton (P–P) chain reaction

C. By helium fusing to carbon in the core via the triple alpha reaction

D. By the continual gravitational compression of the star causing gravitational potential energy to be converted to internal kinetic energy

(Sample question)

9 A hypothetical journey to a distant star might be accomplished in an astronaut's life span by travelling at relativistic speeds.

What is the key concept which underpins such a hypothetical journey?

A. From the frame of reference of the spacecraft making the journey, the distance to the star is less.

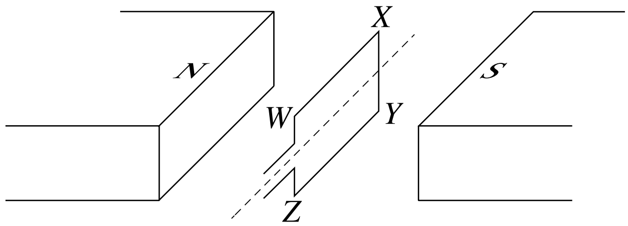
B. Clocks on the spacecraft run slower and hence the rate at which fuel is used for the journey is decreased.

C. Relativistic effects on the spacecraft reduce its mass, making it possible to accelerate to the speeds needed for such a journey.

D. The relativistic increase in the mass of the fuel on board makes it possible to complete a longer journey with less fuel.

(2018 HSC)

10 The diagram shows some parts of a simple DC motor.



Which row of the table correctly describes the direction of force acting on side *WX* and the direction of torque this produces on the coil?

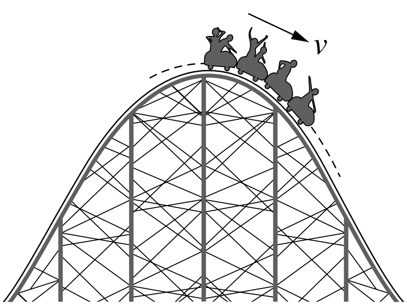
	Direction of force acting on WX	*Direction of torque produced on the coil by the force acting on WX*
A.	Remains constant	Remains constant
B.	Remains constant	Reverses every 180°
C.	Reverses every 180°	Remains constant
D.	Reverses every 180°	Reverses every 180°

(2018 HSC)

11 During the launch of a space vehicle from Earth, an astronaut feels an increased downward *g* force.

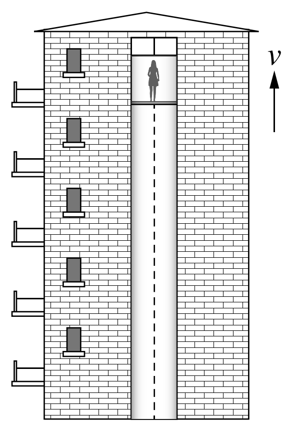
In which of the following situations would a person also feel an increased downward *g* force?

A.



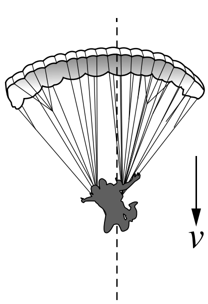
Roller-coaster speeding up

B.



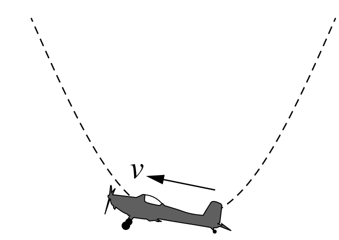
Lift slowing down

C.



Parachute falling at a constant velocity

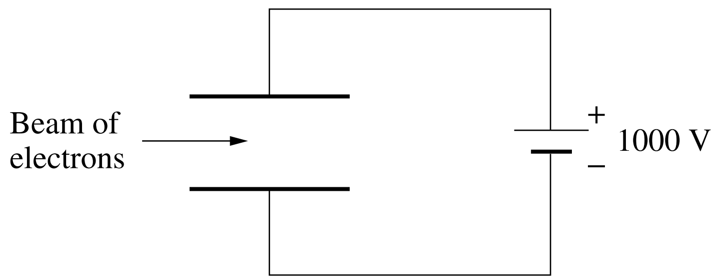
D.



Plane pulling out of a dive

(2018 HSC)

12 The diagram shows electrons travelling in a vacuum at 2×10^6 m s^{-1} between two charged metal plates 1×10^{-3} m apart.



A magnetic field is to be applied to make the electrons continue to travel in a straight line.

What is the magnitude and direction of the magnetic field that is to be applied?

A. 5×10^{-1} T into the page

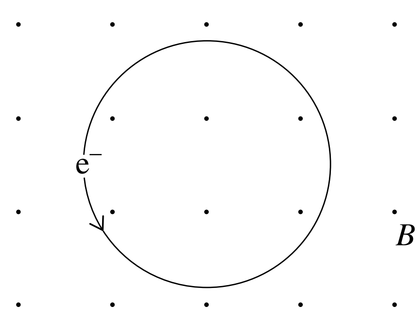
B. 5×10^{-1} T out of the page

C. 1×10^{6} T into the page

D. 1×10^{6} T out of the page

(2018 HSC)

13 An electron moves in a circular path with radius r in a magnetic field as shown.



If the speed of the electron is increased, which row of the table correctly shows the effects of this change?

	Force on electron	*Radius of path*
A.	Increases	Decreases
B.	Increases	Increases
C.	Decreases	Decreases
D.	Decreases	Increases

(2018 HSC)

14 Two stars X and Y were observed to have a similar pattern of absorption lines in their spectra. All the absorption lines in star Y's spectrum were, however, shifted to a slightly higher frequency and were broader than the absorption lines in the spectrum from star X. What could cause the difference in the observed spectra?

A. Star Y could be moving away from the Earth faster and rotating faster than star X.

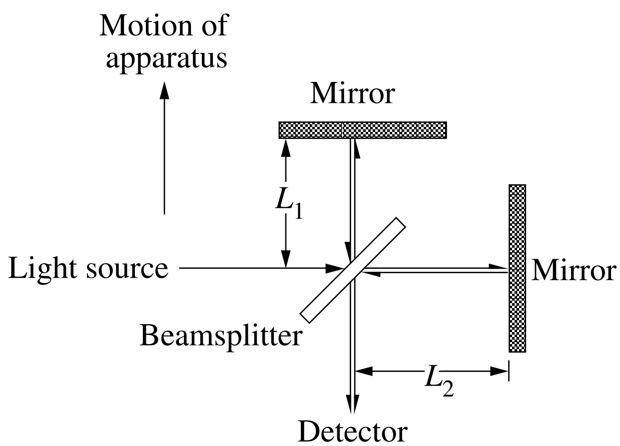
B. Star Y could be rotating faster but moving towards the Earth more slowly than star X.

C. Star Y could be rotating faster but moving away from the Earth more slowly than star X.

D. Star Y could be moving towards the Earth faster than star X and be less dense than star X.

(Sample question)

15 The diagram shows a simplified model of the Michelson–Morley experiment. It can be assumed that distances L_1 and L_2 are equal without affecting the outcome.



The times taken for the light to travel in both directions along the lengths L_1 and L_2 are t_1 and t_2 respectively.

What was Michelson attempting to demonstrate in this experiment?

A. The relativistic contraction of L_1 would cause t_1 to be less than t_2.

B. The ether is carried through space with Earth, which would cause t_1 to be equal to t_2.

C. The times t_1 and t_2 would be the same because the velocity of the apparatus was much less than the speed of light.

D. The motion of the apparatus resulting from Earth's orbital motion around the sun would cause t_1 to be greater than t_2.

(2018 HSC)

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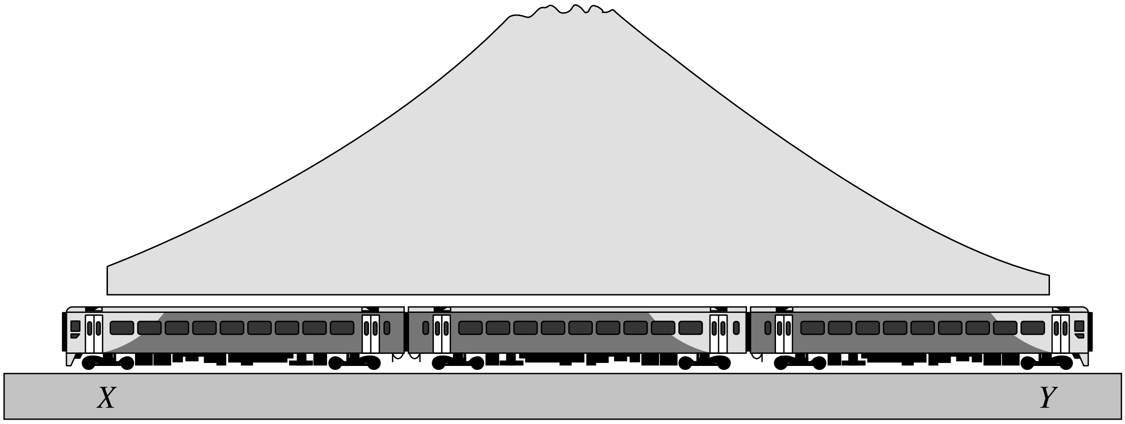
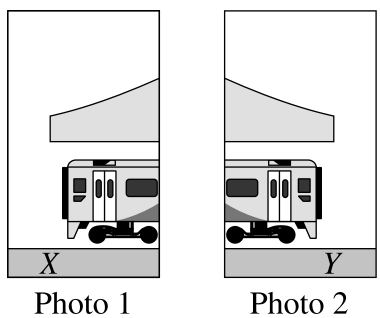
16 When a train is at rest in a tunnel, the train is slightly longer than the tunnel.



In a thought experiment, the train is travelling from left to right fast enough relative to the tunnel that its length contracts and it fits inside the tunnel.

An observer on the ground sets up two cameras, at *X* and *Y*, to take photos at exactly the same time. The photos show that both ends of the train are inside the tunnel.



A passenger travelling on the train at its centre can see both ends of the tunnel and is later shown the photos.

From the point of view of the passenger, what is observed and what can be deduced about the photos?

A. The tunnel's length contracts so the train does not fit, and photo 2 is taken before photo 1.

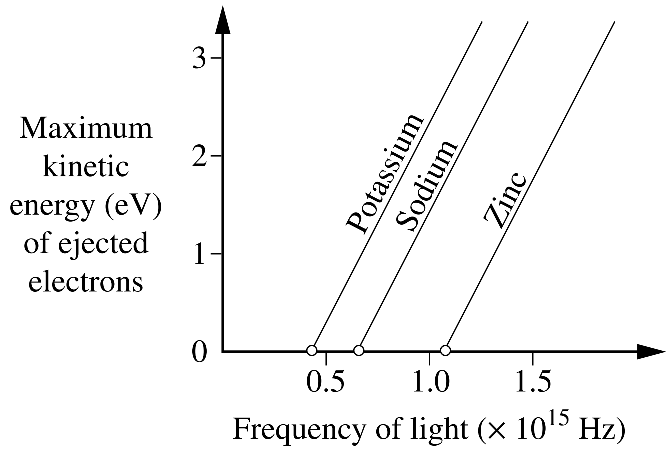
B. The tunnel's length contracts so the train does not fit, and photos 1 and 2 are taken at the same time.

C. The tunnel appears to expand due to length contraction of the train, allowing it to fit in the tunnel, and photo 1 is taken before photo 2.

D. The tunnel appears to expand due to length contraction of the train, allowing it to fit in the tunnel, and photos 1 and 2 are taken at the same time.

(2018 HSC)

17 The graph shows the maximum kinetic energy of electrons ejected from different metals as a function of the frequency of the incident light.



What can be deduced from this graph?

A. The maximum kinetic energy of ejected electrons is proportional to the number of photons incident on the metal surface.

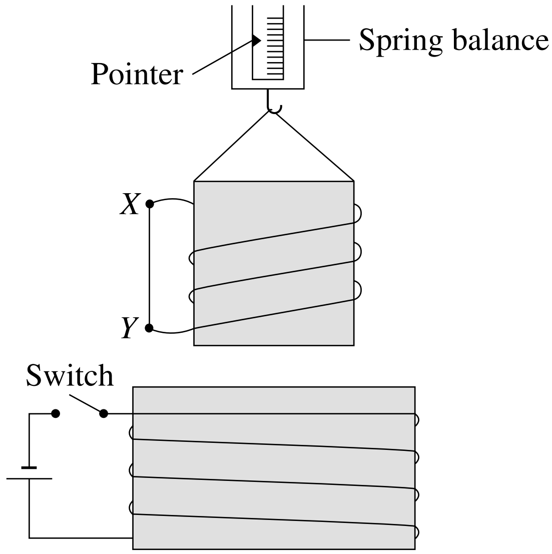
B. More photons are required to cause an electron to be ejected from zinc than from potassium.

C. Any photon that can eject an electron from the surface of zinc must also be able to cause an electron to be ejected from potassium.

D. For any given frequency that causes electrons to be ejected from all three metals, the number of electrons ejected is always greatest for potassium.

(2018 HSC)

18 An experiment is set up as shown.



When the switch is closed, the reading on the spring balance changes immediately, then returns to the initial reading.

Which row of the table correctly shows the direction of the current through the straight conductor *XY* and the direction in which the pointer on the spring balance initially moves?

	Direction of current through the straight conductor	*Direction in which the pointer initially moves*
A.	From *X* to *Y*	Down
B.	From *X* to *Y*	Up
C.	From *Y* to *X*	Down
D.	From *Y* to *X*	Up

(2018 HSC)

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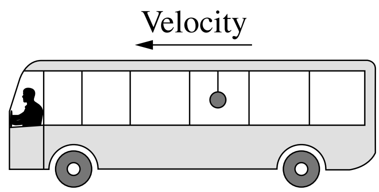
19 A mass was hanging from the roof of a bus that was travelling forward on a horizontal road at a constant velocity.



The string holding the mass was cut. At the same instant, the bus driver applied the brakes, causing the bus to slow down at a rate of 3 m s^{-2}.

To an observer outside the bus, the mass follows a parabolic trajectory.

Which statement correctly describes the resulting motion of the mass observed from within the frame of reference of the moving bus?

A. The mass travelled in a straight line vertically downwards.

B. The mass travelled in a straight line downwards and towards the front of the bus.

C. The mass travelled in a parabolic path downwards and towards the back of the bus.

D. The mass travelled in a parabolic path downwards and towards the front of the bus.

(2018 HSC)

20 How is Rydberg's constant (R) related to the longest wavelength (λ_α) emitted from the Balmer series of the hydrogen atom?

A. $R = 6\lambda_\alpha$

B. $R = 36\lambda_\alpha/5$

C. $R = 36/5\lambda_\alpha$

D. $R = 6/\lambda_\alpha$

(Sample question)

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 response.
- Show all relevant working in questions involving calculations.

Please turn over

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Question 21 (4 marks) **Marks**

(a) Compare the force of gravity exerted on the moon by Earth with the force of gravity exerted on Earth by the moon. **2**

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(b) The acceleration due to gravity on the moon is 1.6 m s^{-2} and on Earth it is 9.8 m s^{-2}. Quantitatively compare the mass and weight of a 70 kg person on the moon and on Earth. **2**

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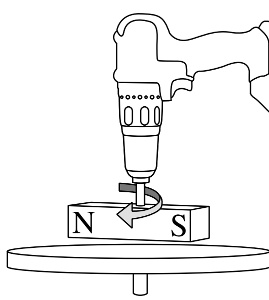
(2018 HSC)

Question 22 (6 marks)

(a) A drill spins a magnet above a non-magnetic metal disc which is free to rotate. **3**



Explain the effect of the rotating magnet on the disc.

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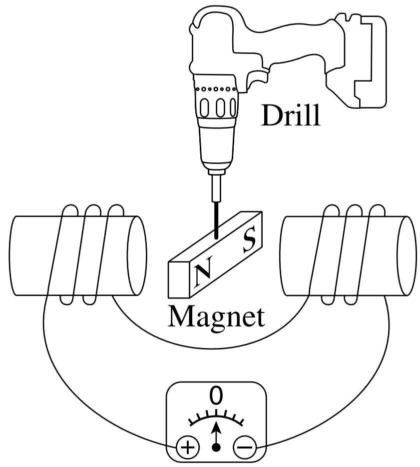
(2018 HSC)

Question 22 continues

Question 22 (continued) **Marks**

(b) The diagram shows a magnet attached to an electric drill so that it can be rotated between two coils connected to a voltmeter. **3**



The drill starts from rest and gradually speeds up, reaching its full speed after three revolutions.

Sketch a graph showing the induced emf across the coils during the time that it takes the magnet to reach its full speed.

(2018 HSC)

End of Question 22

Question 23 (5 marks) **Marks**

(a) A star X has a surface temperature of 30 000 K. Determine the wavelength at which star X would emit the most intense electromagnetic radiation. **1**

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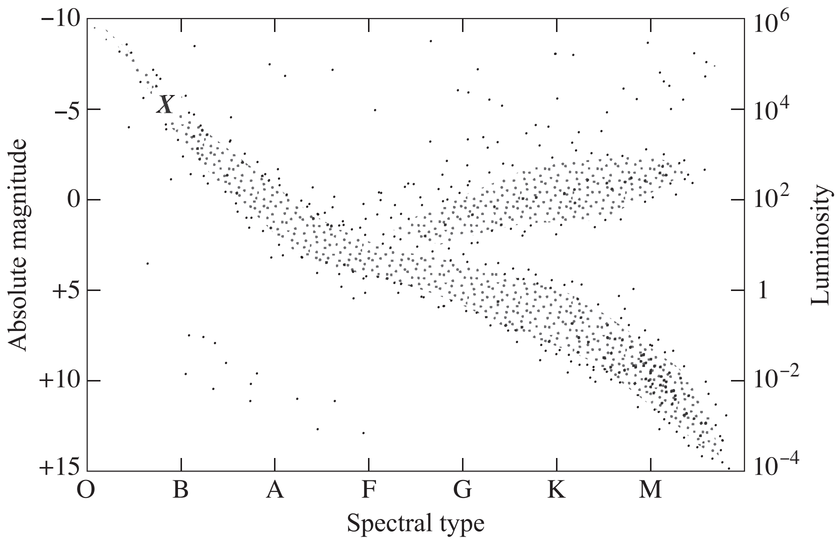
(b) A H–R diagram is shown. Star X is a main sequence star of 12 solar masses. **4**



Describe how star X will change physically and chemically as it continues to evolve.

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(2018 HSC)

Question 24 (5 marks) **Marks**

(a) Explain why the eddy currents in a transformer core reduce the voltage induced in the secondary coil. **2**

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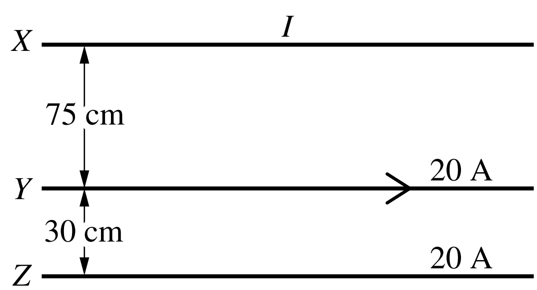
(Sample question)

(b) Three parallel wires *X*, *Y* and *Z* all carry electric currents. A force of attraction is produced between *Y* and *Z*. There is zero net force on *Y*. **3**



What is the magnitude and direction of the current in *X*?

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(2018 HSC)

Marks

Question 25 (6 marks)

(a) What is the missing isotope marked $^{?}_{?}X$ in the reaction shown below? **1**

$$^{234}_{90}Th \rightarrow \, ^{?}_{?}X + \, ^{0}_{-1}\beta + \, ^{0}_{0}\overline{\nu}$$

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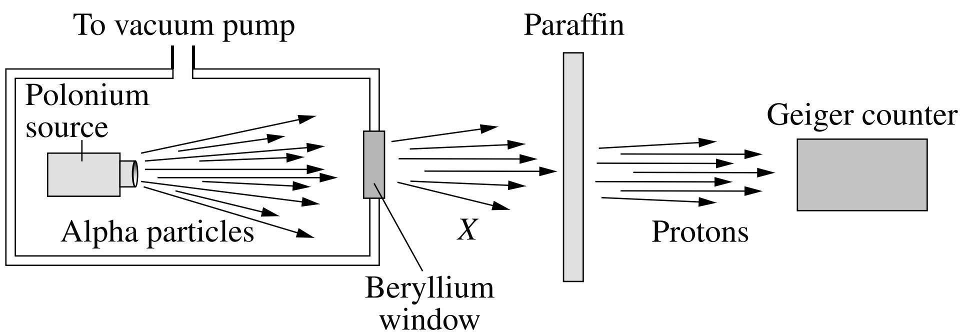
(b) The diagram shows apparatus used to investigate subatomic particles. **2**



How did Chadwick use a law of physics to identify a property of *X*?

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Question 25 continues

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Question 25 (continued) **Marks**

(c) The following is a nuclear reaction that produces a neutron. **3**

$$^{4}_{2}\alpha + ^{9}_{4}\text{Be} \rightarrow ^{12}_{6}\text{C} + ^{1}_{0}\text{n}$$

The table shows the masses of the particles in the reaction.

Particle	*Mass* (*u*)
$^{4}_{2}\alpha$	4.0012
$^{9}_{4}\text{Be}$	9.0122
$^{12}_{6}\text{C}$	12.0000
$^{1}_{0}\text{n}$	1.0087

Using the data from the table, calculate the energy released in this reaction. State your answer in joules.

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(2018 HSC)

End of Question 25

Question 26 (4 marks) **Marks**

Outline the similarities and differences between the effects of electric fields and gravitational fields on matter. In your answer, refer to the definitions of these fields. **4**

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(2018 HSC)

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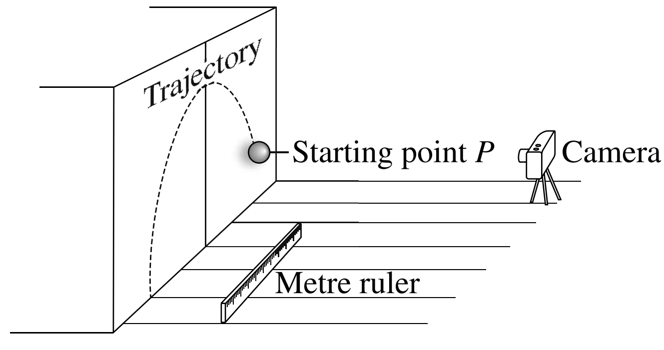
Question 27 (6 marks) **Marks**

(a) The diagram shows a camera and a ruler set up to obtain data about a projectile's motion along the trajectory shown. The entire trajectory is visible through the camera. **3**



Identify ONE of the errors in this set-up and describe the effect of this error on the results.

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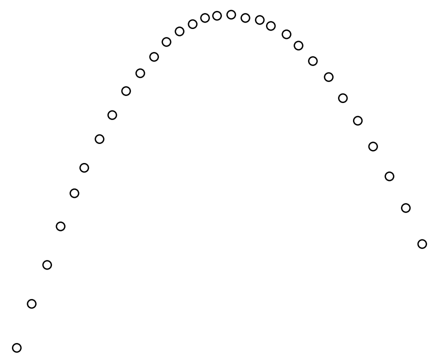
Question 27 continues

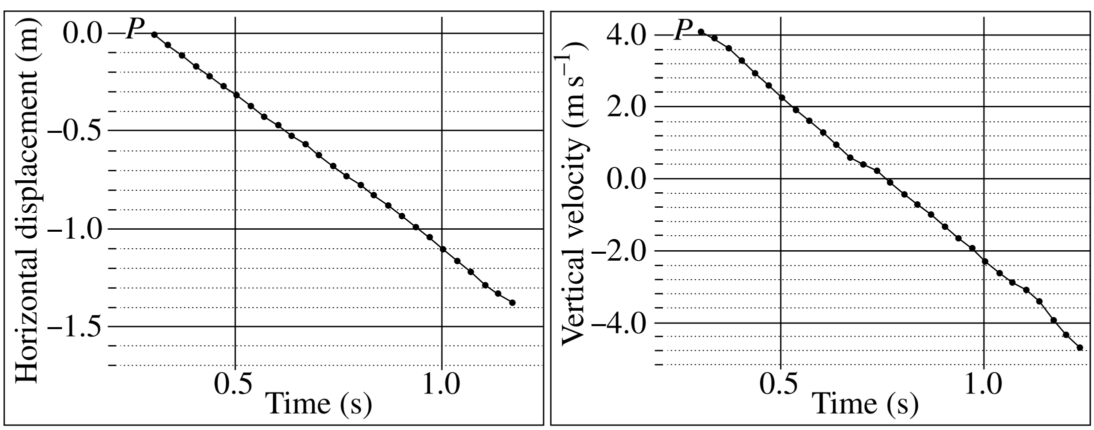
Question 27 (continued) **Marks**

(b) An experiment was set up based on the method described in part (a), but conducted so that the data obtained were valid. **3**

The image shows the trajectory of the ball.



The graphs show data from this experiment.



Using the graphs, describe the velocity and acceleration of the ball quantitatively and qualitatively.

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(2018 HSC)

End of Question 27

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Question 28 (5 marks) **Marks**

The radius of the moon is 1740 km. The moon's mass is 7.35×10^{22} kg. In this question, ignore the moon's rotational and orbital motion.

A 20 kg mass is launched vertically from the moon's surface at a velocity of 1200 m s^{-1}.

(a) Show that the change in potential energy of the mass in moving from the surface to an altitude of 500 km is 1.26×10^7 J. **2**

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(b) Calculate the velocity of the 20 kg mass at an altitude of 500 km. **3**

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(2018 HSC)

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Question 29 (8 marks) **Marks**

(a) Compare quarks and leptons and explain where each type of particle could be found in an atom. **4**

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(b) Compare a controlled and uncontrolled nuclear fission chain reaction and account for the energy released in such reactions. **4**

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(Sample question)

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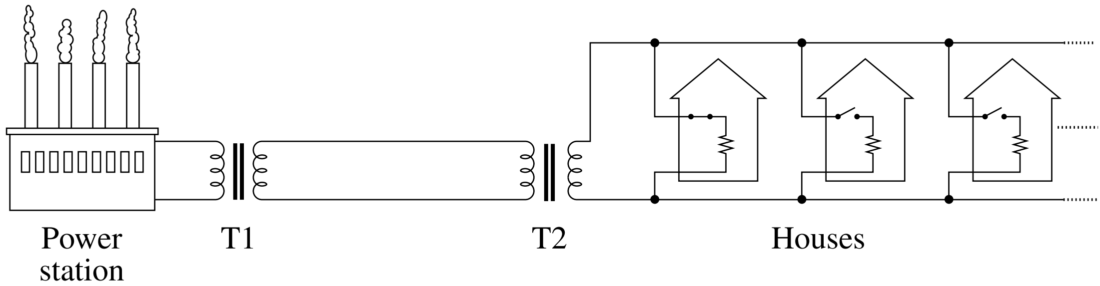
Question 30 (6 marks) **Marks**

The diagram shows a model of a system used to distribute energy from a power station through transmission lines and transformers to houses. **6**



During the evening peak period there is an increase in the number of electrical appliances being turned on in houses.

Explain the effects of this increased demand on the components of the system, with reference to voltage, current and energy.

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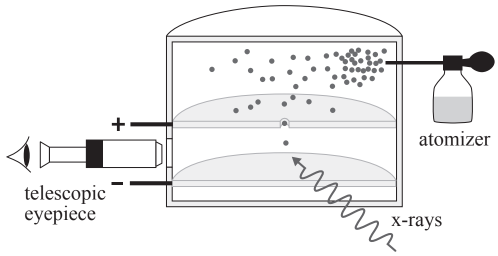
(2018 HSC)

Marks

Question 31 (7 marks)

In 1910 Robert Millikan conducted a famous experiment in which he used tiny oil droplets to find the charge on an electron. A schematic diagram of this experiment is shown below.



Consider an experiment in which the horizontally charged plates are 2 cm apart. An oil droplet of mass 5 mg is suspended between the plates when a potential difference of 250 V is placed across the charged plates. Note that the top plate is at the higher potential. The following questions refer to this experiment.

(a) What is the purpose of the X-rays in this experiment? **1**

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(b) Find the electric field between the charged horizontal plates. **2**

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(c) Calculate the charge on the suspended droplet. **2**

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(d) How was Millikan able to find the charge on a single electron when each oil droplet was multiply charged? **2**

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(Sample question)

Question 32 (5 marks) **Marks**

Bismuth-210 undergoes alpha decay and has a half-life of five days.

(a) Write a nuclear decay equation for $^{210}_{83}Bi$. **2**

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(b) What percentage of bismuth-210 would have undergone radioactive decay after three days? **3**

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(Sample question)

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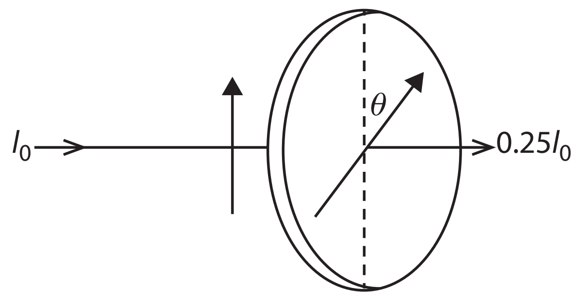
Question 33 (5 marks) **Marks**

In an experiment involving polarised light, a polarising filter was observed to reduce the intensity of a beam of polarised light to 25% of the incident intensity.



(a) With the aid of a diagram outline the difference between a polarised electromagnetic wave and an unpolarised electromagnetic wave. **3**

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(b) Find the angle θ between the direction of polarisation of the incident light and the polarising axis of the filter in the experiment illustrated above. **2**

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(Sample question)

Marks

Question 34 (3 marks)

Explain how the light that reaches the Earth from a star can be used to determine the chemical composition of the star's atmosphere. **3**

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(Sample question)

Question 35 (5 marks)

Outline de Broglie's hypothesis and explain how it was experimentally verified. **5**

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(Sample question)

Sample HSC Examination Paper with 2018 HSC Questions

Sample Answers

Section I

1 A As $F = ma$, the satellite will accelerate in the same direction as the net force on the satellite. Because the only force operating on the satellite is gravity, the satellite will experience an acceleration towards the centre of the Earth.

2 B The intensity of the radiation emitted from a black body increases with the temperature but the wavelength at which the greatest intensity of radiation is emitted decreases (by Wien's Law $\lambda = b/T$).

3 A The ISS is a low Earth satellite and, consequently, collisions with air molecules reduce the velocity of the space station, causing it to lose altitude.

4 D Back emf is an induced voltage that increases with the speed of rotation of the motor. If the motor is slowed down, the back emf decreases, which will increase net emf across the rotor coil and the current flowing in the coil. Hence holding the motor will decrease the back emf but increase the current flowing in the coil.

5 B The magnitude of the force on the coil is given by $F = lIB \sin\theta = 0.05 \times 2 \times 1 \times \sin 30^\circ = 0.05$ N.

6 C This is similar to replacing the double slits with a diffraction grating. Increasing the number of slits increases the number of minima between each maximum, which sharpens the maxima in the pattern. Because each maxima is made up of light from many slits, rather than from two slits, increasing the number of slits increases the intensity of each maxima. The distance between maxima is related to the slit separation and as the slit separation remains constant in this example the separation between maxima will not change.

7 A The gravitational acceleration for a planet is given by $g = \dfrac{GM}{r^2}$. If the mass and radius were doubled the new gravitational acceleration would be $g = \dfrac{2}{2^2} = \dfrac{1}{2}g$.

8 B Main sequence stars all fuse hydrogen to helium in the core and as this is a red dwarf star it is a very low mass star and hydrogen fusion will occur via the proton–proton (P–P) chain reaction. This is because the P–P chain requires a slightly lower ignition temperature than the CNO cycle.

9 A From the spacecraft's frame of reference, the stars are moving rapidly towards the ship and hence the distance between the stars is contracted in accordance with

$l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)}$. This means that an observer in the spacecraft measures the distance

to the star to be shorter than the distance measured by an observer on Earth.

10 C Because this is a DC motor its commutator will reverse the current direction on the side *WX* each half cycle, which will reverse the direction of the force on *WX* each half cycle. This change in the direction of the force ensures the torque on the coil remains in a constant direction.

11 D We can assume the plane turns in an approximately circular motion at the bottom of the dive. Now because the centripetal force and centripetal acceleration of the plane are upwards, the pilot would experience an increased apparent weight force (i.e. an increased *g* force).

12 A The electric field between the plates is $E = \frac{V}{d} = \frac{1000}{1 \times 10^{-3}} = 1 \times 10^6 \text{ Vm}^{-1}$.

To travel straight through, the net force must be zero and, hence,

$qvB = qE$ or $B = \frac{E}{v} = \frac{1 \times 10^6}{2 \times 10^6} = 0.5$ T.

By the right-hand palm rule, the magnetic field would have to be into the page to produce a downwards force on the negative electron. This downwards force would balance the upwards force on the electron produced by the electric field.

13 B As $F = qvB$, increasing the speed will increase the force on the electron. Now as the centripetal force is produced by the force on the charge due to its motion in the magnetic field we can write $qvB = \frac{mv^2}{r}$ or $r = \frac{mv}{qB}$. Hence increasing the speed will also increase the radius (r).

14 C The lines in star *Y*'s spectrum are blue shifted with respect to star *X*. If star *X* was moving away from the Earth more slowly than star *Y*, the spectra from star *X* would exhibit a greater red shift and hence the spectra of star *X* would be shifted to longer wavelengths than the spectra of star *Y*. The spectral lines of rapidly rotating stars are broadened due to the simultaneous red and blue shift produced by the motion of each side of the star. The broadened spectral lines in star *Y*'s spectrum could therefore be due to the star rotating rapidly.

15 D Michelson and Morley believed the speed of light would change if the source or observer moved with respect to the ether. They reasoned that light would take longer to move back and forth when travelling parallel to the ether wind than when moving back and forth across the ether wind. Their experiment produced a null result because the speed of light is an absolute constant that is independent of the speed of the source or observer.

16 A The tunnel is moving with respect to the observer in the train and hence an observer in the train sees the length of the tunnel contracted. Because the observer on the train is moving with respect to the outside observer, the observer in the train will not agree with the outside observer's observation that the photographs were taken simultaneously. The observer in the train will see photo 2 taken before photo 1 because the light from this event will reach them first because the train has moved to the right in the time it takes for the light from the event to reach the observer.

17 C As the threshold frequency to remove an electron from zinc is greater than the threshold frequency for the other two metals, a photon that can eject an electron from zinc will have enough energy to eject an electron from either of the other two metals.

18 B Switching the current on produces an increasing magnetic field downwards. By Lenz's law the induced current in the upper coil will oppose this change by producing an increasing magnetic field upwards. An upwards magnetic field would imply the current moves from *XY* by the right-hand grip rule. As the fields are in opposite directions, the coils will repel one another, decreasing the apparent weight of the top coil.

19 B The mass is initially at rest with respect to the bus driver. If the bus was moving at constant velocity the bus driver would see the mass fall straight downwards. However, as the bus was slowing down at 3 ms^{-2} the bus driver would see the mass falling downwards with an acceleration of 9.8 ms^{-2}, but the horizontal component of the motion would result in the object also accelerating forwards at 3 ms^{-2} with respect to the bus driver. The vertical distance moved in a time t would be $y = \frac{1}{2}gt^2$ and the horizontal distance would be $x = \frac{1}{2}3t^2$. Because the ratio of the horizontal distance

x to the vertical distance y is a constant (i.e. $\frac{x}{y} = \frac{\frac{3}{2}t^2}{\frac{1}{2}gt^2} = \frac{3}{g}$) the mass moves in a straight line downwards and towards the front of the bus with respect to the driver.

20 C Bohr suggested that the longest wavelength of the Balmer series would be produced when an electron moved from the $n = 3$ orbital to the $n = 2$ orbital and, hence, by applying Bohr's equation,

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

$$\frac{1}{\lambda_\alpha} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$= \frac{5R}{36}$$

and hence,

$$R = \frac{36}{(5\lambda_\alpha)}$$

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Section II

Question 21 (Total 4 marks)

(a) The force of gravity on each object is given by $F = \frac{GMm}{r^2}$, where G is the universal constant of gravity, M is the mass of the Earth, m is the mass of the Moon and r is the distance between their centres.

The force is one of attraction between the bodies. By Newton's 3rd law, the magnitude of the gravitational force on each body due to the other is equal but it operates in the opposite direction on each body, resulting in a force of attraction between the two bodies. Thus the force exerted by the Moon on the Earth is equal but in the opposite direction to the force exerted on the Earth by the Moon. *(2 marks)*

(b) Mass is a measure of the inertia of a body and will therefore be the same (i.e. 70 kg) on the Moon and the Earth.

Weight is a measure of the force of gravity on the body given by $w = mg$. Hence on Earth the person will have a weight of $w = mg = 70 \times 9.8 = 686$ N, while on the Moon the person's weight will be $w = mg = 70 \times 1.6 = 112$ N. *(2 marks)*

Question 22 (Total 6 marks)

(a) The conducting disc will experience a changing magnetic field which will induce eddy currents in the disc.

By Lenz's law the induced currents will be in a direction that will produce magnetic fields which will oppose the change that produced the currents.

Hence the eddy currents will produce magnetic fields that will exert a force on the magnet in the opposite direction to the magnet's motion. By Newton's 3rd law an equal and opposite force will be exerted on the disc in the same direction as the magnet's motion. This force will cause the disc to rotate in the same direction as the magnet is rotating. *(3 marks)*

(b) The magnitude of the induced emf will increase as the magnet spins faster as, by Faraday's law of electromagnetic induction, the emf is proportional to the rate of change of magnetic flux linking the coils (i.e. emf = $\frac{-n\Delta BA}{\Delta t}$).

The emf produced will be AC and the period of the first three cycles will decrease until the motor reaches operating speed.

At operating speed, the period will be constant and the peak magnitude of the induced voltage will remain constant. *(3 marks)*

The induced emf is shown in Figure E2.

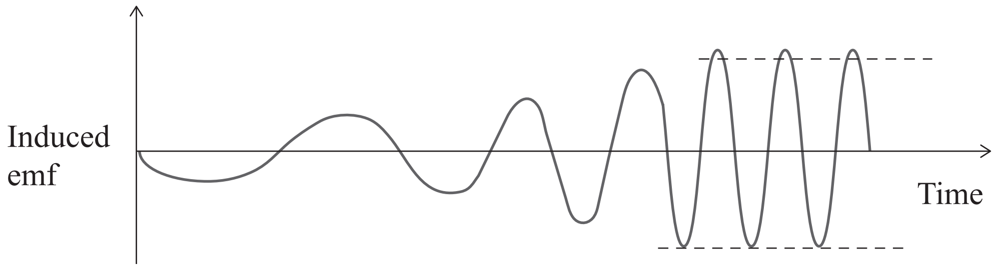

Figure E2. Induced emf as a function of time

Question 23 (Total 5 marks)

(a) Applying Wien's displacement law,

$$\lambda_{max} = \frac{b}{T} = \frac{2.898 \times 10^{-3}}{3 \times 10^{4}} = 9.66 \times 10^{-8}\text{ m} = 97\text{ nm}$$ *(1 mark)*

(b) From its position on the H–R diagram (and its mass) we see that star *X* is a hot, blue–white, B-class giant main sequence star fusing hydrogen to helium in its core via the CNO reaction. Star *X* will have a comparatively short life span on the main sequence and when it develops a large enough helium core it will collapse until the helium starts to fuse to carbon and the increased core temperature also starts hydrogen fusion in a shell around the core. This will cause the star to greatly expand and the outer layers to cool, forming a red supergiant star.

The star will progressively fuse heavier elements in the core and in shells around the core until an iron core forms. The star slowly loses mass while it is fusing elements because some mass is converting into energy in accordance with Einstein's mass–energy relationship $E = mc^2$. As the fusion of iron consumes rather than releases energy, the star will collapse and then explode in a supernova and spread much of its mass outwards into the surrounding space. If the remaining core is large enough it may collapse into a neutron star with a diameter of about 20 km.

Large stars have short life spans and hence must be second or higher generation stars. Chemically such stars are initially made up mostly of hydrogen with some helium and trace amounts of heavier elements.

As the star passes through its life span, fusing heavier and heavier elements, the percentage of heavier elements (up to iron) gradually increases. When it explodes in a supernova some elements heavier than iron will be produced by the huge amount of energy released. The core may then collapse to a neutron star, which is essentially nuclear material rather than atomic material. *(4 marks)*

Question 24 (Total 5 marks)

(a) The AC current on the primary coil produces a changing magnetic field in the transformer core that induces eddy currents in the core. The direction of these currents by Lenz's law will produce magnetic fields to oppose the change that created them.

Thus eddy currents reduce the magnetic field in the core. By Faraday's law the induced emf on the secondary coil is proportional to the rate of change of magnetic flux and as the eddy currents reduce the rate of change of magnetic flux, less emf will be induced on the secondary coil. *(2 marks)*

(b) If the net force on wire Y is zero, the force on wire Y due to the current in wire Z must be equal and opposite to the force on wire Y due to the current in wire X.

$$F_{xy} = F_{zy}$$

$$\frac{kI_xI_yl}{r_{xy}} = \frac{kI_zI_yl}{r_{zy}}$$

$$I_x = \frac{I_zr_{xy}}{r_{zy}}$$

$$= \frac{20 \times 0.75}{0.3} = 50\text{A}$$

in the same direction as the current in wire Y. *(3 marks)*

Question 25 (Total 6 marks)

(a) By balancing the charge and number of nucleons on each side of the equation we see that the missing isotope is ${}^{234}_{91}Pa$. *(1 mark)*

(b) Chadwick used kinematics to determine the speed of the particles labelled X and the recoil velocity of the protons and nitrogen nuclei after they had been hit by the particles labelled X in the diagram.

By using conservation of momentum and energy he was then able to calculate the mass of the particles labelled X.

He found that these neutral particles were slightly heavier than a proton and hence discovered that the unknown particles labelled X were the long sought-after 'neutrons'. *(2 marks)*

(c) The mass defect will be given by

$$\Delta m = \textit{mass of products} - \textit{mass of reactants}$$
$$= 12.0000 + 1.0087 - (4.0012 + 9.0122)$$
$$= -0.0047 \text{ u and hence } 0.0047 \text{ u must be converted into energy in this reaction.}$$

Energy released $= 0.0047 \times 931.5 = 4.378$ Mev
$= 4.378 \times 10^{6} \times 1.602 \times 10^{-19}$
$= 7.014 \times 10^{-13}$ J

OR students may convert the mass defect to kilograms and then use $E = mc^2$ as follows,

$$\Delta m = 0.0047 \times 1.661 \times 10^{-27}$$

$$= 7.8067 \times 10^{-30} \text{ kg}$$

$$E = mc^2 = 7.8067 \times 10^{-30} \times (3 \times 10^{8})^2 = 7.026 \times 10^{-13} \text{ J}$$

(Note that the answer differs slightly from the one above because the speed of light is $2.997\,924\,58 \times 10^{8}$ rather than 3×10^{8} as given in the data sheet.) *(3 marks)*

Question 26 (Total 4 marks)

Gravitational fields exert a force on all objects with mass. The gravitational field (g) at a point in space is defined as the gravitational force per unit mass placed at the point ($g = \frac{F}{m}$) and hence has units of N $kg^{-1} = ms^{-2}$. The gravitational field strength at a point is equal to the acceleration due to gravity at that point. The gravitational force on a body is always in the direction of the gravitational field at that point. The gravitational field a distance r from a planet of mass M would be given by $g = \frac{GM}{r^2}$.

Electric fields exert a force on charged objects. The electric field (E) at a point is defined as the force that would appear on a unit, with a positive test charge placed at the point ($E = \frac{F}{q}$). The units of the electric field are NC^{-1}. Positively charged objects experience a force in the direction of the electric field while negatively charged objects experience a force in the opposite direction to the charge. The electric field a distance r from a point charge q is given by $E = \frac{kq}{r^2}$.

Objects with mass are surrounded by gravitational fields, while charged objects are surrounded by electric fields.

The force on a charged particle in an electric field is given by $F = qE$, while the force on a charged object in an electric field is given by $F = mg$. Both electric and magnetic fields are vector fields as both have a magnitude and direction at each point in the field. Both types of fields can be represented by lines of force. Gravitational fields exert a force on all matter, while electric fields only exert a force on charged objects. In addition, the gravitational field exerts a force in the direction of the field only, while the force exerted by an electric field depends on the sign of the charge on the body.

OR Students could represent this information in a table of similarities and differences between the two types of fields. *(4 marks)*

Question 27 (Total 6 marks)

(a) The end of the metre rule is not placed at the start of the motion.

This will produce a zero error in measurements of the horizontal position using the ruler.

If the zero error was not taken into account, the measured horizontal position (x) of the ball from the starting point at each time would be less than the actual distance.

OR Because the camera is offset the gradations on the metre rule will not appear to be constantly spaced due to parallax error. This will result in incorrect values being measured for the horizontal position of the particle. *(3 marks)*

(b) The graphs show that the horizontal component of the velocity remains constant, while the vertical component changes due to the local acceleration due to gravity. Motion towards the left and downwards is called negative, while upwards motion is called positive.

The horizontal velocity of the ball is constant as the first graph of horizontal displacement against time is a straight line. The horizontal acceleration is therefore zero and the gradient of the first graph gives the horizontal velocity

$= v_x = \text{gradient} = \dfrac{(0.3 - 1.1)}{(1.0 - 0.5)} = -1.6\ \text{ms}^{-1}$ or $1.6\ \text{ms}^{-1}$ to the left.

The vertical velocity, as shown in the graph of vertical velocity against time, changes throughout the flight. The gradient of the line of best fit of this graph will be equal to the vertical acceleration, which is constant.

$= \text{gradient} = \dfrac{(-2.4 - 2.3)}{(1.0 - 0.5)} = \dfrac{-4.8}{0.5} = -9.4\ \text{ms}^{-2}$ or $9.4\ \text{ms}^{-2}$ downwards. *(3 marks)*

Question 28 (Total 5 marks)

(a) The change in gravitational potential energy is given by:

$$\begin{aligned}\Delta U &= U_{final} - U_{initial}\\ &= -\frac{GMm}{r_{final}} - \left(-\frac{GMm}{r_{initial}}\right)\\ &= GMm\left(\frac{1}{r_{initial}} - \frac{1}{r_{final}}\right)\\ &= 6.67 \times 10^{-11} \times 7.35 \times 10^{22} \times 20\left(\frac{1}{1740 \times 10^3} - \frac{1}{2240 \times 10^3}\right) = 1.26 \times 10^7\text{J}\end{aligned}$$

Thus moving the 20 kg mass from the surface to 500 km above the surface increases the gravitational potential energy by 1.26×10^7 J. *(2 marks)*

(b) Because the object is in free flight, the total energy of the object is conserved and the initial kinetic energy is gradually converted to gravitational potential energy as the object moves upwards.

The kinetic energy remaining at 500 km will be given by:

$$\begin{aligned}K_{\text{final}} &= K_{\text{initial}} - \Delta U\\ &= \frac{1}{2}mv^2 - \Delta U\\ &= \frac{1}{2}(20)(1200)^2 - 1.26 \times 10^7\\ &= 1.8 \times 10^6\ \text{J} = 1.8\ \text{MJ}\end{aligned}$$

Now the velocity can be calculated from the expression for kinetic energy:

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

and hence

$$\begin{aligned}v &= \sqrt{\frac{2K}{m}}\\ &= \sqrt{\frac{2 \times 1.8 \times 10^6}{20}}\\ &= 424.3\ \text{ms}^{-1}\end{aligned}$$

(3 marks)

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Question 29 (Total 8 marks)

(a) Quarks are comparatively massive fundamental particles with fractional charges.

Quarks are affected by all the fundamental forces and obey the Pauli exclusion principle. Quarks are bound tightly together by gluons to form mesons and baryons. Mesons consist of two quarks, while baryons are made up of three quarks. Protons and neutrons are baryons. Protons are made up of two up quarks each carrying a charge of $+\frac{2}{3}$ and one down quark which carries a charge of $-\frac{1}{3}$, giving a net charge of +1. Neutrons are made up of two down quarks and one up quark giving a net charge of zero. Thus quarks are found in the atomic nucleus.

Leptons are comparatively light fundamental particles that obey the Pauli exclusion principle but which are not affected by the strong (colour) force.

Leptons can be charged particles like the electron or uncharged particles like the electron neutrino. Electrons (leptons) surround the nucleus of the atom. *(4 marks)*

(b) Fission reactions are artificial nuclear reactions, which involve very large nuclei absorbing a neutron and splitting into two smaller nuclei. Fission of uranium-235 and some other very large isotopes are accompanied by the release of two or more neutrons. As these neutrons can be used to initiate further fission reactions, it is possible to set up a fission chain reaction in a suitable (critical) mass of fissionable material. When a large nucleus undergoes fission, the products are more stable than the reactants and hence some mass is converted into energy in the reaction.

An uncontrolled nuclear chain reaction will occur if the mass of fissionable material is greater than the critical mass for the material. Uncontrolled fission reactions run at an increasing rate because each fission reaction initiates more than one further fission reaction.

A fission bomb is an example of an uncontrolled fission reaction.

A controlled nuclear fission reaction is one that runs at a constant rate. That is, only one of the neutrons released in each fission reaction is used to initiate a further fission reaction.

This type of reaction is used in fission power stations where cadmium control rods are used to absorb the excess neutrons and hence control the rate at which the reaction occurs. *(4 marks)*

Question 30 (Total 6 marks)

First, in terms of energy, during peak electrical use periods, more power is used by consumers and hence more power is drawn from the system.

To supply the increased power being drawn from each transformer, more power must be put into the first transformer T1 by the generator.

Because energy is conserved, drawing more power from the system will mean more mechanical power must be supplied to the generator. As the load is increased, the generator will become harder to turn at the same rate of rotation and hence will require more mechanical power to be put into the generator to maintain the rate of rotation.

If the system was 100% efficient, the electrical power drawn from the system would be equal to the mechanical power used to turn the generator. In reality, some energy is lost to heat in the lines and in the transformers. The loss in the lines and the windings of the transformers increase when the current is increased as $P_{loss} = I^2R$. More current will also heat the wire, increasing the resistance and further increasing the power lost in the lines and transformer windings.

Now, in terms of voltage and current, more electrical power (current) is used when householders switch on more parallel circuits. This will increase the current drawn from the transformers T1 and T2 (as they operate at specific voltages) and from the generator.

This increased current in the generator will, by Lenz's law, make the generator harder to turn.

We can understand this by remembering that the induced current in the generator produces magnetic fields that will oppose the change that created the current. That is, the magnetic fields will oppose the generator being turned. If the mechanical input power was not increased when the load was increased, the speed of rotation of the generator would decrease and the AC frequency and peak voltage produced by the generator would decrease. This drop in voltage would prevent any extra power being drawn from the system. *(6 marks)*

Question 31 (Total 7 marks)

(a) The X-rays were used to charge the oil droplets.

(X-ray photons are energetic enough to ionise the air molecules between the charged plates and the free electrons tend to stick to the oil droplets.) *(1 mark)*

(b) $E = \frac{V}{d} = \frac{250}{0.2} = 12\,500 \text{ Vm}^{-1}$ downwards *(2 marks)*

(c) First note that 5 mg = 5×10^{-6} kg

As the charge remains stationary, the forces must sum to zero and hence,

$mg = qE$, or $q = \frac{mg}{E} = \frac{5 \times 10^{-6} \times 9.8}{12\,500} = -3.92 \times 10^{-9}$ C

As the electric field is directed downwards the charge must be negative to ensure the electric force opposes the gravitational force on the droplet. *(2 marks)*

(d) Millikan reasoned that each droplet would have a whole number of additional electrons and hence each droplet would have a charge that was a multiple of the electron charge.

To find the charge on the electron he looked for a common denominator that would divide evenly into each value of charge.

This common denominator was the quantum of charge; the charge of the electron. *(2 marks)*

Question 32 (Total 5 marks)

(a) $^{210}_{83}\text{Bi} \rightarrow {}^{206}_{81}\text{Tl} + {}^{4}_{2}\text{He}$ *(2 marks)*

(b) We first find the decay constant, $\lambda = \frac{ln2}{t_{\frac{1}{2}}} = \frac{ln2}{5} = 0.1386.$

The amount remaining will then be given by

$N_t = N_0 e^{-\lambda t} = N_0 e^{-0.1386 \times 3} = 0.66N_0$

Hence 66% of the initial isotopes will remain after three days and 34% would have decayed. Alternatively, students could use:

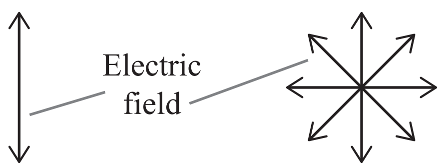
$N_t = N_0(\frac{1}{2})^n$, where n is the number of half-lives that have elapsed.

$n = \frac{3}{5} = 0.6$ half-lives.

Hence, $N_t = N_0(\frac{1}{2})^n = N_0(\frac{1}{2})^{0.6} = 0.66N_0$ and again we get 66% remaining and so 34% of the bismuth-210 would have undergone radioactive decay. *(3 marks)*

Question 33 (Total 5 marks)

(a) Light is a transverse electromagnetic wave, which is made up of changing electric fields and magnetic fields that are perpendicular to each other and to the direction of travel of the wave. As shown in the figure below, a polarised light wave (i) has the electric field in one plane only, while an unpolarised wave (ii) has the electric field in all planes. Note that both diagrams in the figure show the electric field orientation for an electromagnetic wave moving towards the observer (out of the page).



(i) polarised light (ii) unpolarised light

(3 marks)

(b) Applying Malus's law,

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

$$\theta = \cos^{-1}\left(\sqrt{\frac{I}{I_{max}}}\right) = \cos^{-1}\left(\sqrt{\frac{0.25}{1}}\right) = 60°$$ *(2 marks)*

Question 34 (Total 3 marks)

Light emitted from the photosphere of the star passes through the star's atmosphere. The atoms, ions and molecules in the star's atmosphere absorb specific wavelengths of light that are characteristic of the type of atom (i.e. element), ion or molecule.

A spectrometer connected to a telescope can be used to examine the spectrum of light produced by the star. By comparing the wavelengths missing from the star's spectrum to the known absorption spectra of known atoms, ions and molecules (obtained from experiments in the laboratory) the chemical composition of the star's atmosphere can be determined.

In addition the intensity of the absorption lines can be used to estimate the proportion of different atoms, ions and molecules in the star's atmosphere. *(3 marks)*

Question 35 (Total 5 marks)

De Broglie suggested that particles, such as electrons, had an associated wavelength that was related to the momentum (mv) of the particle by $\lambda = \frac{h}{mv}$.

He also proposed that particles would exhibit both particle and wave properties in different circumstances.

De Broglie's hypothesis was first verified by a series of experiments conducted by Davisson and Germer. They showed that when electrons were scattered by a pure nickel crystal the electrons were not scattered randomly, as they expected for a particle, but instead were scattered predominantly in specific directions.

Previous studies with X-rays had shown that the X-rays scattered by atoms in a crystal interfered with one another to produce maxima and minima of interference in the scattered X-rays. For X-rays with the same wavelength as the electrons, the angle of the X-ray maxima corresponded to the angle at which most electrons were scattered. Thus the scattered electrons in Davisson and Germer's experiment exhibited the wave property of interference and hence behaved like waves rather than particles when they were scattered by the crystal.

In addition when Davisson and Germer changed the velocity (i.e. momentum and hence wavelength) of the incident electrons they found that the angle at which most electrons were scattered changed in the same way that the maximum of interference would change if X-rays with these wavelengths had been used. The Davisson and Germer experiment therefore verified de Broglie's hypothesis that electrons would exhibit wave characteristics and that the wavelength associated with the electron was given by $\lambda = \frac{h}{mv}$. *(5 marks)*

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