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YEAR 12 PHYSICS

Mark Butler

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SAMPLE HSC EXAMINATION 1

Try to complete these papers as if they are the real thing. These are the instructions you need to follow in the HSC Exam:

General instructions

- Reading time: 5 minutes
- Working time: 3 hours
- Write using black pen.
- Draw diagrams using pencil.
- NESA approved calculators may be used.
- Use the Data Sheet, Formulae Sheet and Periodic Table in this book.

Total marks: 100

Section I: 20 marks

Section II: 80 marks

- Attempt all questions.

Section I: 20 marks

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

1 **Sandra and John stand side by side and each throw a cricket ball horizontally from shoulder height. If the balls landed the same distance from Sandra and John, what can we deduce?**

A The balls must have been thrown with the same initial velocity.

B If John was taller than Sandra, he must have thrown the ball with a lower initial velocity.

C If Sandra was taller than John, she must have thrown the ball with a greater initial velocity.

D The balls must have been in the air for the same time.

2 **A ball of mass m on the end of a string turns through a radius r as it rotates around a central rod with velocity v, as shown in Figure E1.1.**

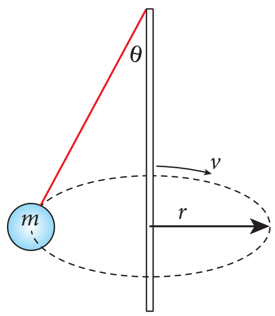

Figure E1.1 Mass on a string moving with uniform circular motion around a vertical rod

What is the angle (θ) between the vertical rod and the string?

A $\sin\theta = v^2/rg$

B $\sin\theta = mv^2/rl$

C $\tan\theta = mv^2/rl$

D $\tan\theta = v^2/rg$

3 **Which of the following statements best describes the energy changes that occur when an Earth satellite moves from a circular orbit of radius r to a circular orbit of radius $2r$?**

A The satellite's kinetic energy halves, its potential energy doubles and the total energy remains constant.

B The satellite's kinetic energy halves, its potential energy halves and the total energy halves.

C The satellite's kinetic energy doubles, its potential energy halves and the total energy halves.

D The satellite's kinetic energy doubles, its potential energy doubles and the total energy remains constant.

4 **An electron travelling with an initial velocity u enters a uniform electric field midway between two charged plates, as described in Figure E1.2. The electron travels a horizontal distance x before colliding with the positively charged plate. (You may ignore gravity in this question.)**

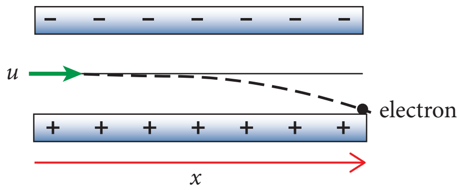

Figure E1.2 An electron fired with velocity u midway between two parallel, charged plates

Where would the electron land if the electric field strength was increased from E to $4E$?

A at $x/2$

B at $x/4$

C at $(\sqrt{2})x$

D at $x/8$

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5 A current I flows in each of the three equally spaced, parallel wires shown in Figure E1.3.

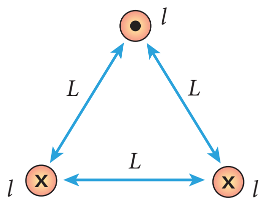
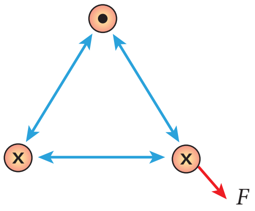


Figure E1.3 Three parallel current-carrying wires

What is the direction of the resultant force on the wire on the lower right?

A



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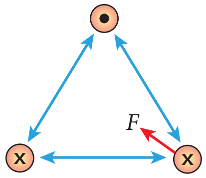

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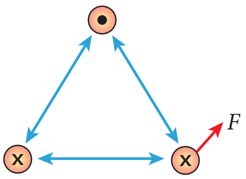
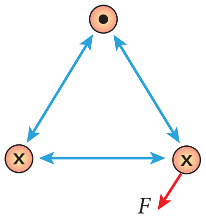


D



6 A permanent magnet is dropped through a loop of wire, as illustrated in Figure E1.4.

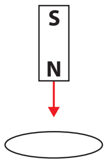


Figure E1.4 Permanent magnet dropped through a loop of wire

When viewed from above the loop, in what direction will the induced current flow in the wire as the magnet falls through the loop?

A momentarily clockwise and then momentarily anticlockwise

B momentarily anticlockwise and then momentarily clockwise

C momentarily clockwise

D momentarily anticlockwise

7 What would happen to the torque produced by a motor if a load was applied that slowed the rate at which the motor was rotating?

A The torque produced by the motor would increase.

B The torque produced by the motor would decrease.

C The torque produced by the motor would remain constant.

D Not enough information has been given for the change in torque to be determined.

8 The details of the absorption spectra of two stars X and Y are set out in Table 1.1.

Table 1.1 Spectral data for star X and star Y

Star	Absorption spectrum detail	Wavelength shift from line on Earth
X	Contains neutral atomic lines and weak ionic lines	All absorption lines are shifted to shorter wavelength
Y	Contains weak atomic lines but strong ionic lines	No wavelength shift

What can we deduce about the stars from Table 1?

A X is moving away from the Earth and is cooler than Y.

B X is moving towards the Earth and is hotter than Y.

C X is moving away from the Earth and is hotter than Y.

D X is moving towards the Earth and is cooler than Y.

9 If the red light used to demonstrate interference with a double slit was replaced with a blue light, how would the interference pattern change?

A The maxima would move further apart if blue light was used.

B The maxima would move closer together with the blue light.

C The intensity of the maxima would decrease if blue light was used.

D The interference pattern would turn blue but otherwise remain unchanged.

10 A light source with a frequency above the threshold frequency was used in a photoelectric experiment. If the power of the source remained constant but the wavelength was halved, how would the photocurrent produced and maximum kinetic energy of the ejected electrons change?

A The photocurrent and maximum kinetic energy would both increase.

B The photocurrent and maximum kinetic energy would both decrease.

C The photocurrent would increase and the maximum kinetic energy would decrease.

D The photocurrent would decrease and the maximum kinetic energy would increase.

11 Why do stars move off the main sequence on a Hertzsprung–Russell diagram?

A An iron core forms in the star and fusion no longer produces energy.

B A shell of helium forms in the star, which increases the outwards radiation pressure.

C A core of helium forms in the star, which decreases the outwards radiation pressure.

D Hydrogen fusion begins to occur through the p–p chain reaction.

12 A cathode ray beam was deflected by an electric field, as shown in Figure E1.5. In what direction must a magnetic field be applied between the charged plates to enable the cathode ray to pass through the electric field without being deflected?

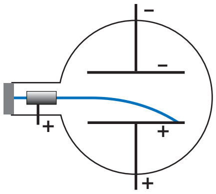


Figure E1.5 Cathode ray deflected by an electric field in an evacuated tube

A into the page **B** out of the page

C to the right **D** to the left

13 Bohr's model of the hydrogen atom enabled the ionisation energy of the ground state ($n = 1$) of the hydrogen atom to be related to Rydberg's constant (R), the speed of light (c) and Planck's constant (h). What relationship did Bohr deduce for the ionisation energy of hydrogen?

A $E = Rh/c$ **B** $E = h/Rc$

C $E = Rc/h$ **D** $E = Rhc$

14 Two radioactive isotopes *A* and *B* both emit alpha particles but *B* has a half-life 10 times longer than *A*. What can we conclude about the isotopes?

A *B* will emit more alpha particles per second than *A*.

B *A* will have a bigger radioactive decay constant than *B*.

C The alpha particles emitted from *B* will be more energetic than the alpha particles emitted from *A*.

D After one half-life, 10 times more isotopes in sample *A* would have decayed than in sample *B*.

15 Why do uranium fission power reactors produce highly radioactive waste?

A Uranium-238 is very radioactive but not fissionable.

B The fission products have a high proton-to-neutron ratio.

C The fission products have a high neutron-to-proton ratio.

D Uranium-235 is very radioactive.

16 Consider a car of mass m travelling with a constant velocity v around a corner of radius r as shown in Figure E1.6. Which of the following statements best describes the net force on the car when it is at the position shown?

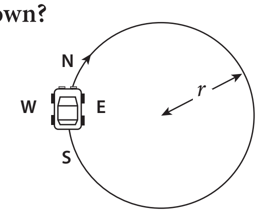


Figure E1.6 Car travelling at constant velocity around a corner of radius r

A There is no net force on the car as it is moving with uniform circular motion.

B The net force depends on the v, m and r and is directed towards the west.

C The net force depends on the v, m and r and is directed towards the east.

D The net force will be the sum of the centripetal force and the gravitational force acting on the car.

17 The radiation emitted from a radioactive isotope is passed into a magnetic field and found to be deflected as shown in Figure E1.7. What type of radioactive isotope is most likely to have emitted this radiation?

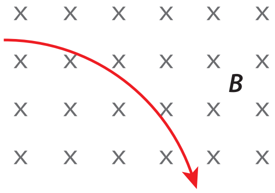


Figure E1.7 Radiation in a magnetic field

A an isotope with a neutron-to-proton ratio that was too high to be stable

B an isotope with a very high binding energy per nucleon

C an isotope with a proton-to-neutron ratio that was too large to be stable

D an isotope with electrons in the nucleus

18 In a Millikan oil drop experiment, an oil droplet of mass 1.635 mg was found to levitate in an electric field of 10^7 NC^{-1}. How many electron changes were on the droplet?

A 10^7 **B** 10^{10}

C 10^4 **D** 10^{13}

19 The black-body emission curves from two main sequence stars *P* and *Q* were compared. Star *Q* was found to exhibit a maximum black-body emission at a much shorter wavelength than star *P*. What does this tell us about the stars?

A Star *P* is smaller and will leave the main sequence faster than star *Q*.

B Star P is smaller and will remain on the main sequence longer than Q.

C Star Q is smaller and will the leave the main sequence faster than star P.

D Star Q is smaller and will remain on the main sequence longer than star P.

20 In a high-energy nuclear collision between hadrons in a particle accelerator, dozens of new particles can be produced. These include photons, hadrons and leptons. Why are no free quarks produced?

A because quarks are fundamental particles

B because the energy used to separate quarks in a hadron produces more quark pairs

C because quarks cannot be produced from energy

D because quarks are imaginary rather than real particles

Section II: 80 Marks

Attempt Questions 21–33.

Allow about 2 hours and 25 minutes for this section.

Instructions

- In the HSC Exam you will 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.

21 A student turns a 50 g mass on a string in circular motion with a radius of 0.60 m in a vertical plane, as shown in Figure E1.8. The centre of the circle was 1.8 m above ground level and the mass was rotated with a period of 0.20 s.

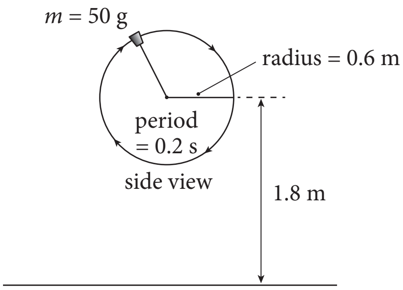


Figure E1.8 Mass on a string turning in uniform circular motion in a vertical plane

a What is the centripetal force required to keep the mass moving in circular motion? (1 mark)

b What is the tension in the string at the bottom of the motion? (1 mark)

c If the string broke when the mass was at the bottom of the motion, how far would it travel horizontally before it hit the ground? (3 marks)

22 A 1200 kg satellite is placed in a circular parking orbit 500 km above the Earth's surface.

a Calculate the velocity and acceleration of the satellite. (2 marks)

b Determine the period of the satellite. (1 mark)

c Explain, qualitatively, how the satellite could be moved efficiently to a circular orbit 1500 km above the surface. (3 marks)

23 The proton synchrotron at CERN is 628 m in circumference and protons circulate around the synchrotron in 2.2 μs as measured from the laboratory frame of reference.

a Find the velocity of the protons. (1 mark)

b Compare the relativistic momentum of the proton to the Newtonian (non-relativistic) momentum at this speed. (2 marks)

c What is the circumference of the synchrotron as measured from the proton's frame of reference? (1 mark)

d What is period as measured from the proton's frame of reference? (1 mark)

e Explain why, even though the speed of the particle is not increasing significantly as energy is imparted to it, the strength of the magnetic field used to keep the proton moving in a circle must be continually increased. (3 marks)

24 Consider the current-carrying wires shown in Figure E1.9.

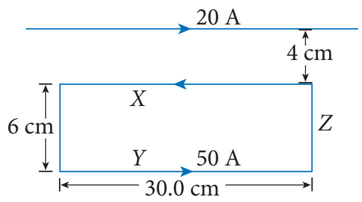


Figure E1.9 Current-carrying wires

a Find the direction of the force on the sides marked X, Y and Z due to the wire above the rectangular loop. (3 marks)

b Find the net force on the rectangular loop of wire due to the wire above it. (3 marks)

25 In an investigation of a DC electric motor a student applies different mechanical loads to the motor and a constant operating voltage, and measures the current that flows through the windings. The results the student obtained are shown in Table 1.2.

Table 1.2 Results of investigation of DC motor operating at 24 V

Load torque (Nm)	Revolutions per minute	Current (mA)
0	200	50
0.5	176	72
1.0	151	143
1.5	124	220
2.0	98	286

a Explain in terms of back EMF why the current increases when the mechanical load on the motor is increased. (3 marks)

b Explain how energy is conserved as the mechanical load on the motor is increased (no calculations required). (2 marks)

26 Figure E1.10 shows a fixed electromagnet and a rotating aluminium disc.

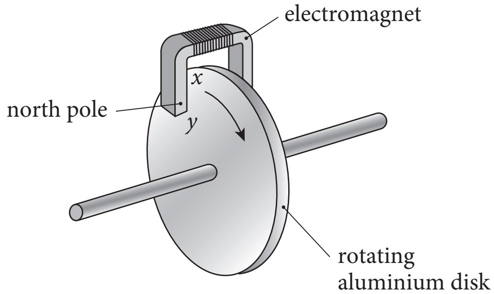


Figure E1.10 Rotating aluminium disc and fixed electromagnet

a Explain why the spinning disc rapidly comes to rest when the electromagnet is switched on. (3 marks)

b Explain how energy is conserved when the disc is brought to rest. (2 marks)

c If the disc was turned when the electromagnet was switched on, would the point marked x be at a higher or lower potential than the point marked y? Explain your answer. (3 marks)

27 This question refers to the Hertzsprung–Russell diagram shown in Figure E1.11.

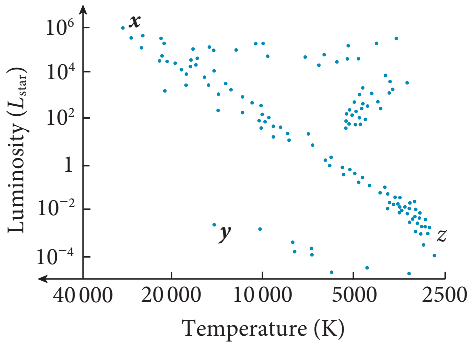


Figure E1.11 A Hertzsprung–Russell diagram

a Name the type of star that would be found at x and y, and compare each star's source of energy. (2 marks)

b Compare the energy source, mass and rate at which mass is converted into energy in stars marked x and z on Figure E1.11. (3 marks)

c Outline the key stages of the lifecycle of a supermassive star. (4 marks)

28 Outline how electricity distribution systems use transformers to efficiently transmit electrical energy. (3 marks)

29 De Broglie made a radical suggestion in his doctoral thesis that had a huge influence on our understanding of atomic physics.

a What was de Broglie's hypothesis? (1 mark)

b Explain how de Broglie's hypothesis provided support for Bohr's stationary state hypothesis. (2 marks)

c Given that the radius of the $n = 4$ orbital of the Bohr hydrogen atom is $r_4 = 8.46 \times 10^{-10}$ m, find the electron wavelength and the momentum of the electron. (2 marks)

30 A diffraction grating is used to separate the visible wavelengths emitted from a discharge tube containing excited hydrogen gas.

a Use Bohr's equation to calculate the wavelength of the two longest wavelength lines emitted from electron transitions that end on the $n = 2$ orbital. (2 marks)

b Calculate the angle of the first order ($m = 1$) maxima of interference for the longest visible wavelength that would be produced if the light from the hydrogen discharge tube was incident on a diffraction grating with 2000 lines per centimetre. (2 marks)

c Outline three limitations of Bohr's model of the atom. (3 marks)

31 Figure E1.12 shows the binding energy per nucleon for the elements in the graph.

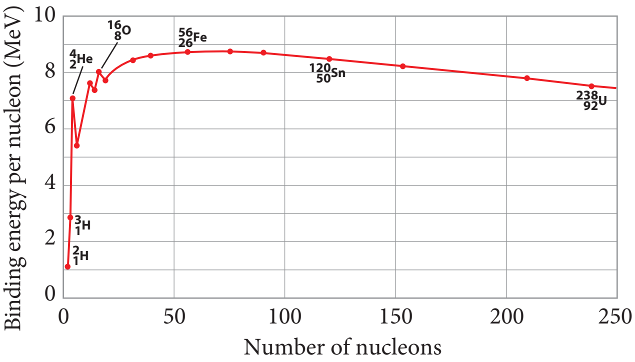


Figure E1.12 Binding energy per nucleon as a function of the number of nucleons

a Use the diagram to determine the binding energy of helium-4 and the mass defect when the nucleus is formed from its constituent nucleons. (3 marks)

b Outline how the diagram can be used to predict which elements will release energy in fusion and fission reactions. (3 marks)

32 a Explain the difference between a polarised electromagnetic wave and an unpolarised wave. (2 marks)

b Explain how a charged particle could be used to produce a polarised electromagnetic wave. (2 marks)

c Unpolarised light of intensity I_0 is passed through three consecutive polaroid filters, each with their axis of polarisation rotated by 30° with respect to the previous filter. Determine the intensity of the light after it passes through each of the filters. (3 marks)

33 Outline the key elements of the standard model of particle physics and explain how particle accelerators influenced the development of the model. (5 marks)

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Section I: 20 Marks

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

1 **Projectile A is fired at an angle θ above the horizontal with an initial velocity u on a level plane. The projectile is found to have a range of x metres. A second projectile B is then fired with the same initial velocity at an angle of $\theta/2$. What can we deduce from this information given?**

A Projectile A will have a greater range than projectile B.
B Projectile B will have a greater range than projectile A.
C The time of flight of projectile A will be greater than the time of flight of projectile B.
D The final velocity of projectile B will be greater than the final velocity of projectile A.

2 **A mechanic applies a force to a spanner, as shown in Figure E2.1. What is the resulting torque?**

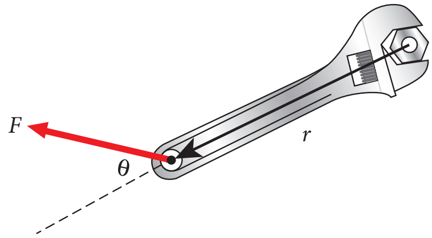

Figure E2.1 Force applied to a spanner

A Torque = Fr
B Torque = $Fr \sin \theta$
C Torque = $Fr / \sin \theta$
D Torque = $Fr \cos \theta$

3 **The gravitational field strength on the surface of planet X is g ms^{-2}. What would be the gravitational field strength on the surface of a planet that was half the radius of X but four times the mass of planet X?**

A 16 g
B 8 g
C 4 g
D 2 g

4 **A satellite moves in an elliptical orbit, as shown in Figure E2.2. What can we say about the energy of the satellite at the point marked X on the diagram?**

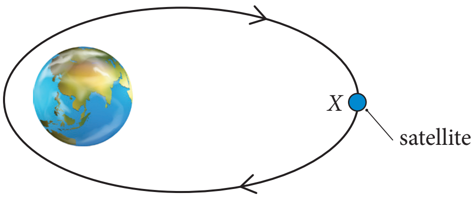

Figure E2.2 Satellite in an elliptical orbit

A The total energy is a maximum.
B The total energy is a minimum.
C The potential energy is a maximum.
D The kinetic energy is a maximum.

5 **A charge enters a magnetic field and collides with a side of the container at point P, as shown in Figure E2.3. What changes to the experiment would result in the charge colliding with the wall at point Q instead of point P?**

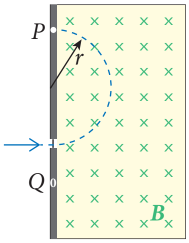

Figure E2.3 A charge moving perpendicularly to a magnetic field

A reversing the magnetic field direction and increasing the particle velocity
B reversing the magnetic field direction and using a negatively charged particle
C using a less massive, negatively charged particle
D using a positively charged particle with a lower initial velocity

6 **A positively charged particle is released at the positive plate of a pair of parallel charged plates, as shown in Figure E2.4.**

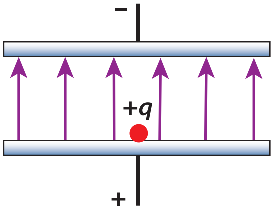

Figure E2.4 A positively charged particle between a pair of charged parallel plates

What quantities do we need to measure to determine the velocity of the particle when it reaches the negatively charged plate?

A The plate separation, the charge on the particle and the electric field strength between the plates.
B The potential difference across the plates and the charge on the particle.
C The mass of the particle, the potential difference between the plates and the charge on the particle.
D The charge on the particle, the electric field strength between the plates and the mass of the particle.

7 **A student uses a slip-ring commutator to connect a battery to a coil in a magnetic field, as shown in Figure E2.5. What will happen when he connects the battery to the coil?**

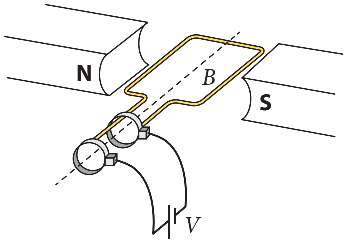

Figure E2.5 Current-carrying coil in a magnetic field

- **A** The coil will rotate continually.
- **B** The side *B* of the coil will move upwards until the plane of the coil is vertical.
- **C** The coil will not move because the student did not use a split-ring commutator.
- **D** The side *B* of the coil will move downwards until the plane of the coil is vertical.

8 **Two solenoids are placed adjacent to one another, as shown in Figure E2.6. One solenoid is connected to an AC power supply and the other solenoid is connected to a resistor (*R*).**

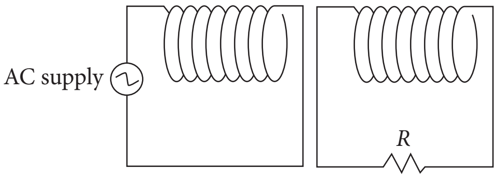

Figure E2.6 Two adjacent solenoids

What would happen if a long, soft iron rod was inserted through the solenoids?

- **A** The iron rod and the resistor would heat up.
- **B** The rod would become magnetised and attract the solenoids together.
- **C** Eddy currents would form in the iron rod, which would decrease the induced current in the resistor.
- **D** The resistor would heat up but the temperature of the iron rod would not change.

9 **How was the speed of light first measured?**

- **A** by combining the laws of electricity and magnetism
- **B** by observing the orbit of the moons of Jupiter at different times of the year
- **C** by reflecting light from a rotating mirror
- **D** by using radio frequency standing waves

10 **How does the rotation of a star affect the absorption lines in the star's spectrum?**

- **A** Each absorption line splits into two lines.
- **B** Each absorption line oscillates backwards and forwards around a central position.
- **C** The absorption lines become narrower.
- **D** The absorption lines become broader.

11 **In Young's double-slit experiment the light emitted from each slit has the same phase. What would happen to the interference pattern if the light emitted from one slit was one half-cycle (π radians) out of phase with the light emitted from the other slit?**

- **A** The interference pattern would not change.
- **B** The distance between the maxima would halve.
- **C** The distance between the interference pattern would double.
- **D** The maxima of interference would become minima and the minima would become maxima.

12 **What new assumption did Max Planck make in his derivation of the radiation emitted from black bodies?**

- **A** The radiation is made up of photons rather than waves.
- **B** Only radiation with a frequency above the threshold frequency will be emitted from a black body.
- **C** Radiation can only be emitted or absorbed by the black body in whole-number multiples of a specific amount of energy.
- **D** Radiation is produced by oscillating electrons in atoms on the surface of the black body.

13 **An observer on the Earth watches a spaceship travel past the Earth at 0.9*c*. What would the space traveller notice about the observer on the Earth?**

- **A** The Earthling's clock would be running slow and the whole planet would appear squeezed up in the direction in which the spacecraft was travelling.
- **B** The Earthling's clock would be running fast and the whole planet would be spread out in the direction in which the spacecraft was travelling.
- **C** The Earthling's clock would be running at the same rate as the clock on the spaceship.
- **D** All light reflected from the Earth would be blueshifted to the ultra violet.

14 **What could we conclude if data from a cluster of stars were plotted on a Hertzsprung–Russell diagram and no stars appeared in the upper half of the main sequence?**

- **A** The stars in the cluster are very young.
- **B** The stars in the cluster must have been formed from the remains of other stars.
- **C** The cluster was too small for large-mass stars to form.
- **D** The stars in the cluster were very old.

15 **Very high energy particle accelerators have been used to produce a huge number of subatomic particles by colliding hadrons together, yet a 'free quark' has never been produced. Why have no free quarks been observed?**

- **A** The mass of each of the quarks is so large that the current generation of particle accelerators simply does not have enough energy to produce them.

B Quarks are theoretical constructs used to classify hadrons rather than actual particles.

C Separating a quark pair just produces two pairs of quarks because the strong colour force increases with quark separation.

D Quarks are bound together by leptons, which make them impossible to separate.

16 Young's double slit experiment demonstrates the interference of light. A similar experiment can be conducted with electrons to demonstrate their wave nature. How would the electron interference pattern change if the speed of incident electrons was increased?

A The interference pattern would become more spread out.

B The interference pattern would move closer together.

C The interference pattern would become much less bright.

D The interference pattern would not change.

17 Consider the experiment shown in Figure E2.7. An upwards external magnetic field is reduced to zero and then reversed. When viewed from above, what will be the induced current direction while the magnetic field is changing?

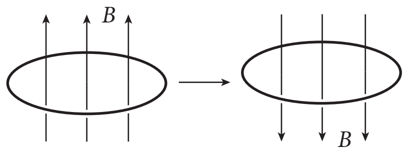

Figure E2.7 A loop of wire and a changing external magnetic field

A The induced current will be clockwise then anticlockwise.

B The induced current will be anticlockwise then clockwise.

C The induced current will be clockwise.

D The induced current will be anticlockwise.

18 The Geiger–Marsden experiment produced a surprising observation. What was the unexpected observation?

A A large number of electrons were diffracted at a specific angle.

B A small number of alpha rays were not scattered at all.

C Some alpha rays were scattered by large angles.

D Alpha particles were scattered by gold nuclei.

19 Oxygen is essential to life on Earth. How were the oxygen atoms on Earth initially produced?

A Oxygen was produced from the condensation of quarks and leptons after the Big Bang.

B Oxygen was produced from fusion in supernova explosions.

C Oxygen is produced by fusion in main sequence stars.

D Oxygen is produced by fusion in supermassive stars.

20 Three electrons a, b and c are projected into perpendicular electric and magnetic fields, as shown in Figure E2.8. How are the velocity of the charges related to one another?

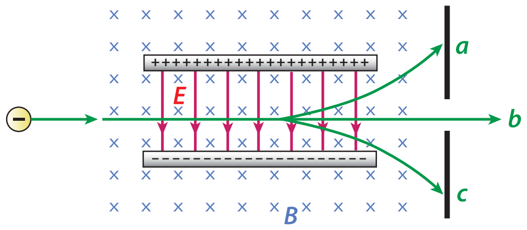

Figure E2.8 Electrons projected into perpendicular electric and magnetic fields

A $v_a = v_b = v_c = \frac{E}{B}$

B $v_a \geq v_b \geq v_c$

C $v_a \leq v_b \leq v_c$

D $v_b \geq v_c \geq v_a$

Section II: 80 Marks

Attempt Questions 21–32.

Allow about 2 hours and 25 minutes for this section.

Instructions
- In the HSC Exam you will 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.

21 Consider the electrical device shown in Figure E2.9.

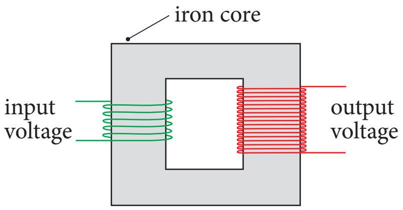

Figure E2.9 Electrical device

a **What is the name of this device?** (1 mark)

b **Explain how the device operates.** (4 marks)

c **State one source of energy loss in this device and explain how this loss may be minimised.** (2 marks)

22 Two football players are standing together. At time $t = 0$, one player starts running north at 5 ms^{-1}, while his team mate remains at rest. The player at rest can kick a ball at 20 m^{-1} at 60° above the horizontal but waits a time t before kicking the ball to ensure the ball will land at the feet of the running player (see Figure E2.10).

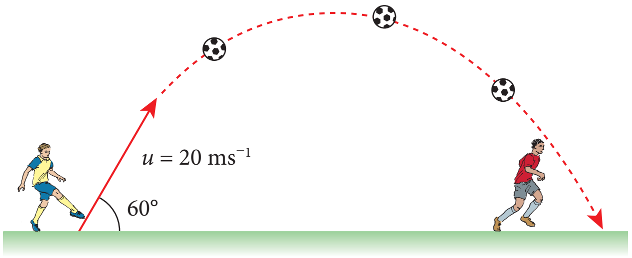

Figure E2.10 Ball kicked at 20 ms^{-1} at 60° above the horizontal

a Find the vertical and horizontal components of the ball's initial velocity. (2 marks)

b Find the time the ball will be in flight when the footballer kicks it. (1 mark)

c Find the range of the ball when it is kicked at 20 ms^{-1} at 60° above the horizontal. (1 mark)

d Determine the time t that the player had to wait before he kicked the ball. (2 marks)

23 Two moons are observed to orbit a distant planet. Moon A has an orbital period of 16 days and an orbital radius of 40 000 km. Moon B has twice the mass of moon A and has an orbital radius of 80 000 km.

a Find the orbital period of the second moon. (2 marks)

b Determine the mass of the central planet. (2 marks)

c Qualitatively compare the velocity, centripetal force and total orbital energy of the two moons. (3 marks)

24 To assist braking, some electric trains disconnect their electric motors from the power supply and place a low resistance across the electrical terminals of the motor.

a With reference to conservation of energy, explain how connecting the motor across a low resistance applies a braking force. (3 marks)

b Explain why changing the amount of resistance placed across the motor changes the braking power of the motor. (2 marks)

25 Stellar spectra can be used to investigate many important stellar quantities. How can stellar spectra be used to:

a determine the surface temperature of a star? (3 marks)

b find the velocity of a star? (2 marks)

c identify the elements in the outer atmosphere of a star? (3 marks)

26 The results from an investigation of the maximum kinetic energy of electrons emitted from zinc when it is irradiated with high-frequency light are shown in Figure E2.11.

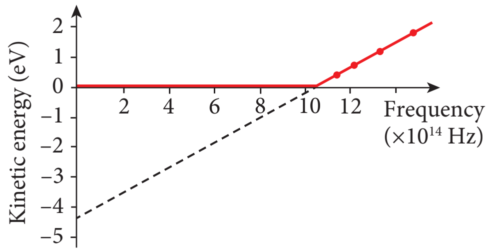

Figure E2.11 The photoelectron kinetic energy as a function of the incident light frequency for zinc

a Explain why no photoelectrons are emitted from the surface when low-frequency light is used. (2 marks)

b Use the graph to determine the threshold frequency and work function for zinc. (2 marks)

c Explain how the gradient of this graph for zinc is related to Planck's constant. (2 marks)

27 Einstein based his special theory of relativity on two postulates.

a State the two postulates. (2 marks)

b Explain how Einstein's postulates account for the null result of the Michelson–Morley experiment. (3 marks)

c Calculate how fast a particle would have to travel for its relativistic momentum to be twice as great as its Newtonian momentum. (2 marks)

28 Consider the following nuclear fission reaction and the masses below.

$$^{1}_{0}n + {}^{235}_{92}\mathrm{U} \rightarrow {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + ?\,^{1}_{0}n$$

$^{1}_{0}n = 1.008665$ u

$^{235}_{92}\mathrm{U} = 235.043915$ u

$^{141}_{56}\mathrm{Ba} = 140.9139$ u

$^{92}_{36}\mathrm{Kr} = 91.8973$ u

a How many neutrons are released in this reaction? (1 mark)

b Calculate the mass defect and energy released in this reaction. (2 marks)

c Barium-141 is radioactive and emits a beta minus particle followed by an alpha particle. Write nuclear equations for each of these decays. (2 marks)

d The half-life for the first beat decay of barium-141 is 18.5 minutes. What percentage of barium-141 would remain after 1 hour? (2 marks)

29 Bohr developed an atomic model based on Rutherford's nuclear atomic model.

a Outline the two limitations of Rutherford's model. (2 marks)

b Explain how Bohr's model overcame these limitations. (2 marks)

c Use the Rutherford–Bohr model to calculate the minimum energy of a photon that would ionise a hydrogen atom from the $n = 3$ state. (2 marks)

30 In a lecture given in 1920 Rutherford suggested the nucleus might contain uncharged nuclear particles that would have a similar mass to the proton. The following year Rutherford named these particles 'neutrons'. The existence of the neutron was not confirmed experimentally until 1932.

a Why did Rutherford think neutral particles might exist in the nucleus? (1 mark)

b Why was it so difficult to prove neutrons existed? (2 marks)

c How did Chadwick experimentally prove that neutrons existed? (3 marks)

d Explain why the neutron is no longer considered to be an elementary particle. (2 marks)

31 A rotating coil generator is connected to a slip-ring commutator, as shown in Figure E2.12. When the generator is turned at 50 Hz it produces a maximum electromotive force of 2 V.

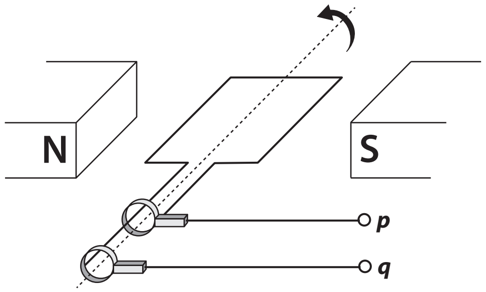

Figure E2.12 Electrical generator with slip-ring commutator

a Explain why an electromotive force is produced by the generator. (2 marks)

b Sketch a graph of the potential difference across the terminals p and q for one complete rotation, starting from the coil position shown in Figure E2.12. (2 marks)

c How would the graph you drew in part **b** change if the rate at which the generator was turned was halved? (2 marks)

32 Particle accelerators have been extremely important to the development of the standard model of particle physics. While the standard model has been spectacularly successful in explaining interactions between particles, it is still believed to be incomplete.

a With the aid of a diagram, outline how a particle accelerator produces beams of high-energy particles. (4 marks)

b State two shortcomings of the standard model. (2 marks)

c What is the difference between a quark and a hadron? (1 mark)

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ANSWERS

SAMPLE HSC EXAMINATION 1

Section I

1 **B.** If John was taller, the ball he threw would be projected horizontally from a greater initial height and hence would stay in the air longer. As the range $s = u_x t$, the only way a ball thrown from a greater height could have the same range as Sandra's ball would be by it having a lower initial velocity (u_x) than Sandra's. **A** is incorrect because it would be true only if the balls were projected from the same height. **C** is incorrect because if a ball had a greater initial velocity and was projected from a greater height it would have a greater range. **D** is incorrect as this would be true only if the balls were projected from the same height.

2 **D.** The tension (T) in the string balances the weight of the ball (mg) and provides the centripetal force (mv^2/r) to move the ball in a circle. Solving the vector addition shown in Figure EA1.1 gives answer **D**. Answers **A**, **B** and **C** are all incorrect as none of the answers is a correct solution for the vector addition shown in Figure EA1.1.

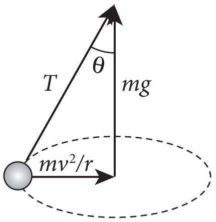

Figure EA1.1 Vector diagram for conical pendulum

3 **B.** Because the kinetic energy is proportional to $\frac{1}{2r}$, the potential energy is proportional to $\frac{-1}{r}$ and the total energy is proportional to $\frac{-1}{2r}$. Doubling r will halve the kinetic energy, potential energy and total energy. Note that because the potential energy and total energy are negative quantities, halving the quantity increases the quantity (making it less negative). **A** and **D** are incorrect because the total energy changes. **C** is incorrect because the kinetic energy decreases with orbital radius.

4 **A.** If the field strength was increased to $4E$, the particle would accelerate downwards four times faster. The time it would take to reach the bottom plate will be given by $s = \frac{1}{2}at^2$ or $t = \sqrt{\frac{2s}{a}}$ and hence, if the acceleration increases by a factor of four, the time to reach the bottom plate will decrease by $\sqrt{\frac{1}{4}} = \frac{1}{2}$. **B**, **C** and **D** are all incorrect numerical answers.

5 **D.** The lower-right wire will be repelled by the top wire (opposite current direction) and attracted by the wire on the lower left. Adding these two vectors gives a force towards the lower left. **A** is incorrect as it would imply both wires were repelling the wire on the lower left. **B** is incorrect as it would imply both wires were attracting the wire on the lower left. **C** is incorrect as it implies the bottom left wire is repelling the bottom right wire.

6 **B.** We solve the problem by applying Lenz's law. The loop acts like a magnet with a magnetic field directed upwards through the loop as the magnet approaches to oppose the change in magnetic flux. Applying the right-hand grip rule gives the induced current as anticlockwise. When the magnet leaves the loop, the loop will act as a magnet with its magnetic field downwards to try to prevent the magnet falling. Applying the right-hand grip rule in this case gives a clockwise induced current flow. **B** is incorrect as this current direction would assist rather than oppose the change. **C** and **D** are incorrect as current must flow in two directions to oppose the change as the bar magnet falls through the loop.

7 **A.** When the motor slows, the back EMF decreases. This increases the current in the coil and hence increases the torque produced by the coil (as the motor torque is proportional to the current in the windings). **B** is incorrect as this would occur only if the current in the motor decreased. **C** is incorrect because changing the speed of operation always changes the back EMF and the current in the motor. **D** is incorrect as there is enough information provided.

8 **D.** The blueshift of the spectrum from star X tells us it is moving towards us and that strong atomic lines and weak ionic lines appear when the outer layer of the star is not hot enough to ionise many of the atoms. **A** and **C** are incorrect because if the star was moving away from the Earth the light would be redshifted. **B** is incorrect because if X was hotter it would have more ionic absorption lines in its spectrum than star Y.

9 **B.** As $n\lambda = d\sin\theta$, decreasing the wavelength will reduce the angle at which interference occurs, which would bring the maxima closer together. **A** and **D** are incorrect as they do not predict a decrease in the separation between the maxima. **C** is incorrect because if the pattern comes closer together, the intensity of the maxima may increase rather than decrease.

10 **D.** Reducing the wavelength increases the photon energy ($E = hc/\lambda$) and hence less photons per second will be in the beam as the power remains constant. This will reduce the photocurrent but give each ejected electron more kinetic energy. **A** and **C** are incorrect as the photocurrent must decrease as less photons per second would hit the metal. **B** is incorrect because the photons have more energy and hence the ejected electrons will have more kinetic energy.

11 **C.** Main sequence stars fuse hydrogen to helium in their cores. When a helium core forms and becomes large enough, hydrogen fusion in the core ceases and gravity collapses the star until the core temperature becomes high enough to fuse helium or, in the case of very low-mass stars, fusion ceases and the star collapses to become a white dwarf. **A** is incorrect as iron cores form only in supermassive stars that are fusing heavy elements in their cores. **B** is incorrect because a helium core decreases the outwards radiation pressure as it restricts the rate at which fusion occurs in the core. **D** is incorrect as most main sequence stars fuse hydrogen to helium using the p–p chain reaction.

12 **B.** An upwards force is required to oppose the force produced by the electric field. Applying the right-hand palm rule to the moving negative charge gives the required magnetic field direction as out of the page. **A**, **C** and **D** specify magnetic field directions that would not produce an upwards force on the negative charge.

13 **D.** When we set $n_i = 1$ and $n_f = \infty$ in Bohr's hydrogen spectra equation we get $1/\lambda = R$. This is the wavelength of the photon that would cause a ground-state hydrogen atom to be ionised. The photon energy is related to the wavelength by $E = hc/\lambda$, and hence $1/\lambda = E/hc$. Combining the two equations for $1/\lambda$ gives $E = Rhc$. **A**, **B** and **C** are incorrect expressions and do not have the units of energy.

14 **B.** As the decay constant is inversely proportional to the half-life $\left(\lambda = \frac{\ln 2}{t_{1/2}}\right)$, a small half-life corresponds to a large decay constant. **A** is incorrect because the rate of decay decreases as the half-life increases. **C** is incorrect as not enough information is given in the question to find the energy of the emitted particles. **D** is incorrect as half of the isotopes in both samples would have decayed in one half-life.

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15 **C.** Massive nuclei have a higher neutron-to-proton ratio than lighter nuclei. Hence if a very large nucleus splits in half, the neutron-to-proton ratio will be much higher than the stable value for a medium-sized element. **A** is true but not related to the highly radioactive daughter products produced in fission. **B** is incorrect because the instability is caused by a very low proton-to-neutron ratio. **D** is incorrect because all uranium isotopes are radioactive but much less radioactive than the daughter products of uranium fission.

16 **C.** The net force on the car is the centripetal force ($F_c = mv^2/r$), which is directed to the centre of the circle. **A** is incorrect because the car is changing direction and hence a net force must be applied to the car. **B** is incorrect because the centripetal force is directed towards the centre of the circle, not away from it. **D** is incorrect because the net force on the car is the sum of the gravity and the reaction force from the road on the car.

17 **A.** The right-hand palm rule shows that the radiation is negatively charged and hence is beta radiation. Beta particles are emitted from isotopes with a high neutron-to-proton ratio because the ratio is reduced when a beta is emitted. **B** is incorrect because a high-binding energy per nucleon is characteristic of a stable nucleus. **C** is incorrect because beta-plus decay results from a high proton-to-neutron ratio, not beta minus. **D** is incorrect as nuclei do not contain electrons.

18 **A.** When the electric force balances the gravitational force, $mg = qE$ or $q = mg/E$. Thus the charge on the droplet is
$q = \frac{1.635 \times 10^{-6} \times 9.8}{10^7} = 1.6 \times 10^{-12}$ or $\frac{1.6 \times 10^{-12}}{1.6 \times 10^{-19}} = 10^7$ electron charges. **B**, **C** and **D** are all incorrect numerical answers.

19 **B.** A shorter wavelength of maximum emission indicates a hotter star and hence star Q has a higher surface temperature than star P. As they are main sequence stars, Q must be larger (as it is hotter) and will leave the main sequence faster as it has to fuse at a much faster rate to balance the inwards force of gravity on the star. **A** is incorrect because larger, hotter stars use up their hydrogen fuel much faster than smaller, cooler main sequence stars. **C** and **D** are incorrect because Q is hotter and hence larger than P.

20 **B.** Quark confinement by the strong (colour) force means that attempting to separate quarks simply makes more quark pairs. **A** is incorrect because quarks are fundamental particles but this is not the reason they cannot be separated. **C** is incorrect because quarks can be produced from energy (i.e. $E = mc^2$). **D** is incorrect because quarks are real particles that have been identified in scattering experiments.

Section II

21 **EM** This question tests students' ability to perform calculations involving circular motion and gravity.

a $F_c = mv^2/r = m\omega^2 r$
$= m(2\pi r/T)^2 r$
$= 4m\pi^2 r/T$
$= 4 \times 0.05 \times \pi^2 \times \frac{0.6}{0.2} = 5.9$ N ✓

b The tension will be the weight plus the centripetal force
$= mg + mv^2/r = 0.05 \times 9.8 + 5.92 = 6.4$ N ✓

c We first calculate the initial velocity:
$v = 2\pi r/T = \frac{2\pi \times 0.6}{0.2} = 18.85$ ms^{-1} horizontally ✓
Now we use the vertical part of the motion to calculate time of flight.
$s = ut + \frac{1}{2}at^2$ and, as the initial vertical velocity is zero:
$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2(1.2)}{9.8}} = 0.5$ s ✓
Horizontal distance travelled $= u_x t = 18.85 \times 0.5 = 9.4$ m ✓

22 **EM** This question tests students' understanding of satellite orbits and their ability to calculate orbital quantities.

a The orbital radius will be $r = 6.371 \times 10^6 + 500 \times 10^3$
$= 6.871 \times 10^6$ m
As gravity provides the centripetal force:
$\frac{GMm}{r^2} = \frac{mv^2}{r}$ and hence
$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{6.871 \times 10^6}} = 7.632$ kms^{-1} ✓
The centripetal acceleration is given by $\frac{v^2}{r} = \frac{(7632)^2}{6.871 \times 10^6}$
$= 8.47$ ms^{-2} ✓

b Applying the equation from uniform circular motion:
$v = 2\pi r/T$ and hence
$T = 2\pi r/v = \frac{2\pi(6.871 \times 10^6)}{7632}$
$= 5757$ s $= 94$ min 17 s ✓

c Refer to Figure EA1.2.

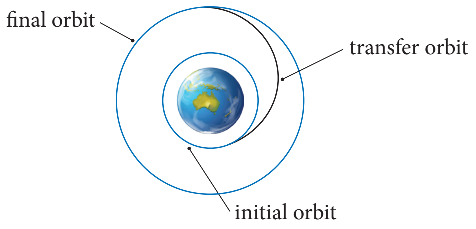

Figure EA1.2 Moving from one circular orbit to another

The satellite first uses a posigrade burn ✓ to increase its velocity and move it into an elliptical transfer orbit. ✓ When the satellite completes half an orbit it uses another posigrade burn to move it from the elliptical transfer orbit to a circular orbit at the higher altitude. ✓

23 **EM** This question tests students' understanding relativity and their ability to calculate quantities using the equations of special relativity.

a Velocity $= s/t = \frac{628}{2.2 \times 10^{-6}} = 2.85 \times 10^8$ ms^{-1} ✓ $= 0.95c$

b The non-relativistic momentum $p = mv = 1.67 \times 10^{-27} \times 2.85 \times 10^8$
$= 4.77 \times 10^{-19}$ Ns ✓
The relativistic momentum is given by:
$$P_v = \frac{m_0 v}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}} = P_v = \frac{1.67 \times 10^{-27} \times 2.85 \times 10^8}{\sqrt{(1 - 0.95^2)}}$$
$= 1.53 \times 10^{-18}$ Ns ✓
At this speed the actual (relativistic) momentum is 3.2 times greater than the Newtonian momentum.

c From the proton's frame of reference it is the synchrotron that is moving and hence the length of the synchrotron will be contracted by:
$$l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)} = 628 \times \sqrt{(1 - 0.95^2)} = 196 \text{ m } ✓$$

d The proton is moving at $0.95c$ around a circle 196 m long in their frame and hence the time to go around once will be given by:
$t = s/v = \frac{196}{2.85 \times 10^8} = 0.69$ μs ✓
Or students could apply the time-dilation equation to obtain the same result.

e Because more energy is added to the proton it will not move significantly faster as it is approaching the speed of light, but its effective mass will increase as the energy goes into mass rather than velocity. Now as the momentum is proportional to the mass ($p = mv$), the momentum will continue to increase even though the velocity is not changing significantly. ✓ For a charge moving perpendicularly to a magnetic field we have:

$mv^2/r = qvB$ or $r = mv/qB$ ✓

Thus to ensure the particle continues to move in a circle of radius r, the magnetic field strength must be increased at the same rate as the momentum increases. ✓

24 EM This question tests students' ability to use the right-hand grip rule and right-hand palm rule and to calculate the force between parallel current-carrying wires.

a Applying the right-hand grip rule to show the magnetic field below the top wire is into the page, and then applying the right-hand palm rule to each wire yields the following results:

The direction of the force on X will be down the page. ✓

The direction of the force on wire Y is up the page. ✓

The direction of the force on wire Z is to the left. ✓

b The force on the vertical wires sums to zero. The force on wire X will be given by:

$$F = \frac{\mu_0}{2\pi}\frac{I_1 I_2 l}{r} = 2 \times 10^{-7} \times \frac{20 \times 50 \times 0.3}{0.04}$$

$= 1.5 \times 10^{-3}$ N ✓ down the page

For wire Y the force will be given by:

$$F = \frac{\mu_0}{2\pi}\frac{I_1 I_2 l}{r} = 2 \times 10^{-7} \times \frac{20 \times 50 \times 0.3}{0.1}$$

$= 6.0 \times 10^{-4}$ N ✓ up the page

The net force on the loop

$= 1.5 \times 10^{-3} - 6 \times 10^{-4}$

$= 9 \times 10^{-4}$ N downwards ✓

25 EM This question tests students' understanding of back EMF in electric motors and its relationship to the conservation of energy.

a When the motor is operating the magnetic flux linking the armature changes, an electromotive force (potential difference) is induced. ✓ By Lenz's law this will oppose the change that created it, which means a back emf will be generated as the motor turns that will oppose the supply emf. ✓ The net effect of the back emf will be to reduce the net emf on the motor and the current that flows in the armature coils. Thus the back emf increases with the speed of rotation and hence the current in the armature decreases with the speed of rotation. Placing a mechanical load on the motor decreases the speed at which it rotates, which reduces the back emf generated and hence increases the current flow in the armature. ✓

b The motor does more mechanical work per unit time when the load is increased. ✓ Because the electrical power supplied to the motor is given by $P = IV$, the increasing current flow (that results in the speed of rotation slowing) increases the electrical power used by the motor. ✓ Thus the electrical power increases as the load increases, ensuring energy is conserved in the system.

26 EM This question tests students' understanding of eddy currents and Lenz's law and their relationship to the conservation of energy.

a The disc is moving rapidly in a magnetic field and the change of magnetic flux experienced by the disc causes eddy currents to be induced in the disc. ✓ By Lenz's law the induced eddy currents will be in a direction that opposes the change that produced them. ✓ That is, the eddy currents will produce magnetic fields that will slow the rate of rotation of the disc. ✓

b Mechanical work must be done to bring the disc to rest. ✓ The induced currents that slow the disc cause resistance heating in the disc and hence the rotational energy of the disc is converted to heat as it is slowed down. ✓

c If we imagine a positive charge moving with the disc through the poles of the magnet and apply the right-hand palm rule ✓ to the moving charge, we see that it will experience a force ($F = qvB$) upwards. ✓ Negative charges moving on the disc would experience a downwards force. Thus charge separation occurs and point x will become more positively charged than point y. As potential difference is defined for positive charge, point x will therefore be a higher potential than point y. ✓

Alternatively, students could justify x being a higher potential by showing that the current must move upwards through the magnetic poles due to Lenz's law.

27 EM This question test students' understanding of the Hertzsprung–Russell diagram and stellar evolution.

a Star y is a star at the end of its lifecycle and is called a white dwarf star. White dwarf stars have ceased fusing light elements and are simply hot embers. The heat in the star was created largely by the gravitational collapse of the star that occurred when fusion ceased. ✓ In contrast, x is a very massive main sequence star, thousands of times larger than a white dwarf star. Main sequence stars like x produce energy by fusing hydrogen to helium in the core of the star. ✓

b Both y and z are main sequence stars that fuse hydrogen to helium in the core of the star. While both fuse hydrogen, z fuses hydrogen through the p–p chain reaction, while x fuses hydrogen through the CNO reaction. ✓ Star x is a massive star and star z is a small, low-mass star. ✓ Because x is much more massive than z, it must fuse hydrogen at a much faster rate to balance the inward pressure from gravity. Thus star x converts mass to energy much faster and has a much shorter lifespan than star z. ✓

c Supermassive stars form when huge clouds of gas and dust condense due to gravity. Eventually the collapse causes the centre of the mass to get hot enough for hydrogen fusion to commence and a protostar appears. When an equilibrium is reached between gravity pushing in and a radiation (fusion) pressure pushing out, the star moves to the main sequence. ✓ Eventually a helium core is formed and hydrogen stops fusing in the core. When this occurs the large star collapses and the temperature of the core increases until helium begins to fuse. A hydrogen shell also begins to fuse and the star expands to become a red giant star. ✓ This pattern repeats as heavier elements fuse in the core until an iron core is formed. When this happens the star collapses and explodes in a supernova. ✓ If the remaining core is large enough it may collapse to become a neutron star or a black hole. ✓

28 EM This question tests students' understanding of how and why transformers are used to transmit electrical power.

The main loss mechanism in electrical distribution systems is line loss due to resistance heating in the lines. Line loss is related to the amount of current that flows and to the resistance of the line ($P_{loss} = I^2R$). ✓ To minimise power loss AC current is transmitted at low currents and high voltages. ✓ Transformers can efficiently increase and decrease AC voltage. By using a transformer to step up the voltage before transmission and then a step-down transformer to reduce the voltage after transmission, line loss is significantly reduced. ✓

29 EM This question tests students' understanding of de Broglie's matter-wave hypothesis and Bohr's model of the atom.

a De Broglie proposed that if waves had particle properties then perhaps particles would have wave properties. De Broglie showed that particles would have an associated wavelength related to the momentum of the particle and Planck's constant $\lambda = h/p$. ✓

b De Broglie showed that the stationary state orbitals of the Bohr atom corresponded to standing electron wave patterns. He showed that the circumference of each orbital was equal to a whole number (n) of electron wavelengths ✓ and wrote:

$2\pi r = nh$ and substituting $\lambda = h/p$ gives the Bohr quantisation condition, $mvr = nh/2\pi$ ✓
Thus Bohr's principal quantum number n corresponded to the number of electron wavelengths in the nth orbital.

c As the circumference of the $n = 4$ orbital contains four electron wavelengths:

$$\lambda = 2\pi r/4 = \frac{2\pi \times 8.46 \times 10^{-10}}{4} = 1.33 \times 10^{-9}\ \text{m} ✓$$

Applying de Broglie's equation $p = h/\lambda = \frac{6.626 \times 10^{-34}}{1.34 \times 10^{-9}}$
$= 4.99 \times 10^{-25}$ Ns ✓

30 EM

a The longest wavelength will be produced when an electron moves from the $n = 3$ to the $n = 2$ orbital:

$$\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right] = 1.097 \times 10^7 \left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

$= 1.5236 \times 10^6$ and hence $\lambda = 656$ nm ✓

The next longest wavelength will be emitted when the electron moves from the $n = 4$ to the $n = 2$ orbital:

$$\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right] = 1.097 \times 10^7 \left[\frac{1}{2^2} - \frac{1}{4^2}\right]$$

$= 2.0569 \times 10^6$ and hence $\lambda = 486$ nm ✓

b The slit separation will be given by $d = \frac{0.01}{2000} = 5 \times 10^{-6}$ m. ✓

The maxima of interference occur when:
$d \sin\theta = m\lambda$ and, with $m = 1$:
$d \sin\theta = \lambda$ and hence $\theta = \sin^{-1}(\lambda/d)$

$$= \sin^{-1}\frac{656 \times 10^{-9}}{5 \times 10^{-6}} = 7.54° ✓$$

c Bohr's model could not explain: the intensity of the spectral lines, ✓ the spectra of elements with more than one electron ✓ or the Zeeman effect. ✓ (Students could also mention the fine spectra of hydrogen.)

31 EM

a The binding energy per nucleon of helium-4 from the graph is approximately 7.2 MeV per nucleon ✓ and hence the total binding energy (BE) is given by:

BE = number of nucleons × binding energy per nucleon
$= 4 \times 7.2 = 28.8$ MeV ✓

The mass defect is therefore:

$$\Delta m = BE \text{ in MeV}/931.5 = \frac{28.8}{931.5} = 0.031\ \text{u} ✓$$

b Energy is produced in nuclear reactions which cause the binding energy per nucleon to increase. ✓ We see from the diagram that the fusion of light elements will produce heavier elements that have a greater binding energy per nucleon. ✓ Providing the daughter product is no heavier then iron, this type of reaction will release energy. Similarly the fission of very large elements will result in daughter products with a higher binding energy per nucleon. ✓ Thus the fission of very heavy elements (e.g. uranium) will result in some mass being converted into energy.

32 EM

a Electromagnetic waves are transverse waves consisting of changing electric and magnetic fields that are perpendicular to one another and to the velocity of the wave. An unpolarised electromagnetic wave has the electric field in all planes perpendicular to the velocity of the wave, ✓ and a polarised wave has the electric field in only one plane. ✓ (Students may also show this with a diagram.)

b If a charged particle was oscillated back and forth in a single direction ✓ in space it would produce polarised electromagnetic waves with their electric field parallel to the direction of oscillation of the charge. ✓ The emitted waves would have a frequency equal to the oscillation frequency of the charged particle.

c Half the intensity of the unpolarised light will be absorbed by the first polarising filter. Hence the intensity after the first filter will be $I_0/2$. ✓ This amount of light will be incident on the second filter and amount of light that passes through will be given by:

$$I = \left(\frac{I_0}{2}\right)\cos^2 30° = \left(\frac{I_0}{2}\right) \times 0.75 = 0.375 I_0 ✓$$

This intensity will be incident on the final filter and hence the amount of light passing through all three filters will be:

$$I = (0.375 I_0)\cos^2 30° = (0.375) \times 0.75 = 0.281 I_0 ✓$$

33 EM

The standard model of particle physics uses the three quantum force field theories (QED, the electroweak theory and QCD) to describe the interactions between elementary particles. ✓ The elementary particles used in the standard model are six quarks, six leptons and the gauge bosons that mediate the three forces (and the Higgs boson, to give particles mass). ✓ The model uses quantum field theories in which force is mediated by the exchange of virtual particles (bosons). ✓

Particle accelerators are machines that accelerate charged subatomic particles to very high energies and collide them into other particles. Studying the particles produced in these reactions by the conversion of energy into mass ($E = mc^2$) has been instrumental in the development and verification of the standard model. For example, a huge number of new subatomic particles were discovered using particle accelerators in the 1950s and 1960s. ✓ These discoveries led physicists towards a theory that was based on elementary particles that were later called quarks. Many of the predictions of the quantum field theories that now form part of the standard model were confirmed in particle accelerators. For example, the W and Z bosons required for the electroweak theory were predicted long before they were proved to exist in accelerators. ✓ Another example is the Higgs boson, which was predicted by the standard model 50 years before particle accelerators had enough energy to produce the particle. Particle accelerators have been instrumental in the creation, development and verification of the standard model.

SAMPLE HSC EXAMINATION 2

Section I

1 **C.** Because the vertical component of the initial velocity is greater for A, it will be in flight for a longer time. **A** and **B** are incorrect because the maximum range occurs when $\theta = 45°$. The maximum range will be determined by which of the two projectiles has a launch angle closer to angle θ, which could be either projectile. **D** is incorrect as the final velocity will be the same as the initial velocity and hence will be the same for both projectiles.

2 **B.** The torque is defined as the product of the applied force and the perpendicular distance between the line of action of the force and the pivot. The expressions in **A**, **C** and **D** are all incorrect as they are inconsistent with the definition of torque and would give the wrong value for the torque.

3 **A.** The gravitational field strength is proportional to m/r^2 and hence a planet with four times the mass and half the radius would have a gravitational field strength 16 times greater. **B**, **C** and **D** are all incorrect expressions that are not consistent with the definition of the gravitational field strength on the surface of a planet.

4 **C.** The potential energy increases with altitude. **A** and **B** are incorrect because the total energy remains constant while the satellite is in orbit. **D** is incorrect because the velocity of a satellite decreases as the orbital radius increases.

5 **C.** The radius of curvature is given by $r = mv/qB$ and hence reducing the mass reduces the radius of curvature of the path in the field. In addition the right-hand palm rule shows that the force on a negatively charged particle entering the field would be downwards. **A** is incorrect because increasing the velocity of the charge would cause it to move in a bigger radius. **B** and **D** are incorrect because the right-hand palm rule shows that the force on the charge when it entered the field in both cases would still be upwards.

6 **C.** Because energy is conserved, the kinetic energy gained is equal to the change in electrical potential energy and hence $\frac{1}{2}mv^2 = qV$ and $v = \sqrt{\frac{2qV}{m}} = \sqrt{\frac{2qEd}{m}}$. **A** and **B** are incorrect because the mass of the particle is also required. **D** is incorrect because the plate separation is required to determine the potential difference across the plates.

7 **B.** The motor force on B will be upwards by the right-hand palm rule. Because the current direction remains constant, the force on side B will also remain constant. **A** is incorrect because this would require a split-ring commutator to reverse the current direction in the coil each half-cycle. **C** is incorrect because a slip-ring commutator will still enable current to flow in the coil and a motor force to appear on the side B. **D** is incorrect because the direction of the motor force is incorrect.

8 **A.** Eddy currents would be induced in the rod and would cause resistance heating in the rod. The iron core would increase the voltage induced in the second coil and hence more power would be dissipated in the resistor. **B** is incorrect because when AC is applied to the coil, the magnetic field in the rod would be constantly reversing direction and Lenz's law would cause the coil to be repelled. **C** is incorrect because even with the losses due to the eddy current the second coil will have a much greater flux change due to the iron core intensifying and linking the field to the second coil. This would result in more current in the resistor, not less. **D** is incorrect because eddy currents produced by the changing magnetic field in the rod would cause resistance heating in the rod.

9 **B.** Romer measured the speed of light by observing the change in the time Jupiter's moon went behind the planet when the Earth was different distances from Jupiter. **A**, **C** and **D** were theoretical estimates or experiments that were performed long after Romer's measurement was made.

10 **D.** Some parts of the star will be moving towards the observer (blueshifting the light), some parts will be moving away (redshifting the light) and some parts will be moving at 90° to the line of sight (neither redshifted nor blueshifted). **A** is incorrect as this would happen only if the light was only redshifted and blueshifted. **B** is incorrect because this would occur only if the line was periodically redshifted then blueshifted. **C** is incorrect because a spinning star could emit only a broader range of wavelengths.

11 **D.** The condition for a maximum is that the light from each slit reaches the point on the screen with the same phase. The condition for a minimum is for the light from each slit to reach the screen one half-cycle out of phase. If the light was initially a half-cycle out of phase, the light from each slit would reach the screen one half-cycle out of phase at each of the points where a maximum previously occurred. **A** is incorrect because the phase change will change the interference pattern. **B** is incorrect because this would occur only if the wavelength was halved. **C** is incorrect because this would occur only if the wavelength was doubled.

12 **C.** Planck assumed that radiation can be emitted or absorbed by the black body only in whole number multiples of a specific amount of energy ($E = hf$). **A** is incorrect as this was an assumption that Einstein made many years later. **B** is incorrect because it relates to the photoelectric effect, not black-body radiation. **D** is incorrect because Planck thought the radiation was emitted and absorbed by 'oscillators' on the surface.

13 **A.** From the spaceship's frame of reference, the Earth would appear to be moving past at $0.9c$. Einstein's theory of special relativity tells us that the moving clock will appear to run slowly and the moving object will squeeze up in its direction of motion. **B** is incorrect because a clock moving with respect to an observer runs slowly. **C** is incorrect because clocks moving with respect to each other run at different rates. **D** is incorrect because the Earth will move towards and then away from the observer in the spacecraft and hence the light from the Earth would be blueshifted and then redshifted.

14 **D.** Large main sequence stars have short lifespans on the main sequence and hence if the cluster was very old it would have no large main sequence stars left. **A** is incorrect because we would expect to see young main sequence stars of all masses. **B** is incorrect because second-generation stars can be both large and small, and hence stars would be found across the main sequence. **C** is incorrect because the size of the cluster has no relationship to the size of stars formed.

15 **C.** Quark confinement prevents free quarks from appearing because pulling a hadron apart simply produces more hadrons. **A** is incorrect because the mass of first-generation quarks is quite low. **B** is incorrect because quarks have been seen in scattering experiments and their reactions have been observed. **D** is incorrect because it is gluons that hold quarks together.

16 **B.** Increasing the velocity decreases the electron wavelength. Now as maxima of interference occur when $d \sin \theta = m\lambda$, decreasing the wavelength (λ) will decrease the separation (θ) between maxima of interference. **A** is incorrect because this would occur only if the velocity was decreased (wavelength increased). **C** is incorrect as this would occur only if the number of electrons per second was decreased. **D** is incorrect as the interference must change if the wavelength (velocity) of the incident electrons is changed.

17 **D.** Lenz's law shows that an anticlockwise current will oppose an upwards field decreasing and a downwards field increasing. **A** is incorrect because an initial clockwise current would enhance rather than oppose a decreasing upwards magnetic field. **B** is incorrect because a clockwise current would enhance rather than oppose an increasing downwards magnetic field. **C** is incorrect because it would enhance rather than oppose both field changes.

18 **C.** This result was not expected from the plum pudding model of the atom that was current at the time. **A** is incorrect as electrons were not used in the experiment. **B** is incorrect as most of the alpha particles passed straight through without being deflected. **D** is incorrect as the nuclear atom was not the current model when the experiment was conducted.

19 **D.** Supermassive stars can produce the core temperatures required to produce energy when smaller nuclei are fused to produce oxygen. **A** is incorrect as only hydrogen and helium and a trace amount of lithium was produced by nuclear synthesis after the Big Bang. **B** is incorrect as nuclei larger than iron are produced in supernova explosions. **C** is incorrect as main sequence stars fuse hydrogen only to helium.

20 **C.** When the forces are balanced $qE = qvB$ or $v = E/B$ and the charge goes straight through. If a charge moves faster than E/B the magnetic force will be greater and it will be deflected downwards. If it moves slower than E/B the electric force will be greater and it will be deflected upwards. **A** is incorrect because the charges would all

move through the crossed fields without being deflected, which is clearly not the case. **B** and **D** are incorrect as the magnetic force is greatest on *c*, and hence *c* must be the fastest moving particle.

Section II

21 EM This question tests students' understanding of electromagnetic induction in transformers.

- **a** step-up transformer ✓
- **b** An AC voltage is attached to the primary coil. The changing current in the primary coil produces a changing magnetic field in the iron core. ✓ The iron core intensifies and confines the magnetic field. ✓ Because the iron core also passes through the secondary coil, the secondary coil experiences a changing magnetic flux that induces an AC voltage on the secondary coil. ✓ The ratio of the input and output voltages will be equal to the ratios of primary and secondary turns. ✓
- **c** Because the magnetic field is changing continually in the iron core, eddy currents are induced in the core that cause resistance heating in the core. ✓ To reduce eddy currents the core is laminated. This involves cutting the core into thin slices perpendicular to the plane of the coils and then re-joining the slices with insulating material between the slices. ✓

22 EM This question tests students' ability to apply the equations of motion to projectile motion.

- **a** The vertical component will be $u_y = u\sin\theta = 20\sin 60° = 17.32\ \text{ms}^{-1}$ ✓

  The horizontal component will be given by $u_x = u\cos\theta = 20\sin 60° = 10.0\ \text{ms}^{-1}$ ✓
- **b** Using the vertical component of the velocity and calling upwards positive, we can write that the final vertical velocity will be equal to, but in the opposite direction of, the initial velocity and hence $v_y = -u_y$. Substituting this condition into the appropriate equation of motion:

  $v_y = u_y + at$ and hence $-u_y = u_y + gt$ or $t = -2u_y/g$

  $t = -2 \times \dfrac{17.32}{-9.8} = 3.53$ s ✓
- **c** Using the horizontal component of the motion:

  Range $= u_xt = 10 \times 3.53 = 35.3$ m ✓
- **d** The time for the boy to run 35.3 m is $t = s/v = 35.3/5 = 7.06$ s ✓ But we must account for the time the ball is in flight and hence the ball must be kicked a time $t = 7.06 - 3.53 = 3.53$ s after the boy starts running. ✓

23 EM This question tests students' ability to perform calculations using Kepler's law of periods and the satellite equation.

- **a** Applying Kepler's law of periods:

  $$\frac{T_A^{\ 2}}{r_A^{\ 3}} = \frac{T_B^{\ 2}}{r_B^{\ 3}} \quad ✓$$

  And hence

  $$T_B = \sqrt{\frac{T_A^{\ 2} r_B^{\ 3}}{r_A^{\ 3}}} = \sqrt{\frac{(16^2 \times 80\,000^3)}{40\,000^3}} = 45.25 \text{ days} \quad ✓$$
- **b** Applying the satellite equation to moon *A* and converting to SI units: ✓

  $\dfrac{r^3}{T^2} = \dfrac{GM}{4\pi^2}$ and hence

  $$M = \frac{4\pi^2 r^3}{GT^2} = \frac{4\pi^2(4\times10^7)^3}{6.67\times10^{-11}(16\times24\times60\times60)^2} = 1.98\times10^{22}\ \text{kg} \ ✓$$
- **c** The velocity of an orbiting satellite is given by $v = \sqrt{\dfrac{GM}{r}}$ and hence the velocity of moon *B* will be less than the velocity of moon *A*. ✓ Or students could write that as $v = \sqrt{\dfrac{GM}{r}}$ the velocities are related by $v_B = \dfrac{v_A}{\sqrt{2}}$.

  The centripetal force is equal to the gravitational attraction between the moon and the central body ($F = \dfrac{GMm}{r^2}$) and, because *B* has twice the mass and twice the orbital radius, the centripetal force will be less on *B* than on *A*. ✓ Or students may write $F_B = \dfrac{F_A}{2}$.

  The orbital energy is given by $U + K = -\dfrac{GMm}{2r}$ and, because *B* has twice the mass and twice the orbital radius, the total energy of each moon will be equal. ✓ Or students may write $E_A = E_B$.

24 EM This question tests students' understanding of electromagnetic braking and conservation of energy.

- **a** When an electric motor is rotated it acts like a generator, converting the mechanical energy of rotation into electrical energy. ✓ By placing a low resistance across the motor, the electrical energy is converted into heat. ✓ The braking force is produced by the induced current in the motor. By Lenz's law this current is in a direction that opposes the change (the rotating wheels) that created it. ✓
- **b** The emf induced depends on the rate of rotation of the motor but the braking effect and electrical power used depends on the current that flows. ✓ As the power dissipated in the resistor depends on the emf and the current ($P = IV$), using a lower resistance will increase the current, the electrical power dissipated and the braking force produced. ✓

25 EM This question tests students' understanding of stellar spectra.

- **a** The radiation emitted from stars is like the radiation emitted by black bodies on Earth. ✓ The temperature of a star can be found by measuring the wavelength of maximum emission intensity (λ) ✓ and then using Wien's black-body relationship, $T = b/\lambda$. ✓ Students may also talk about the relative strength of atomic and ionic lines in the spectrum.
- **b** If a light source moves away or towards an observer, the light is shifted towards the red or blue end of the spectrum, respectively. By comparing the absorption lines from elements on Earth with those in the star, ✓ the amount of redshift or blueshift can be determined and the velocity of the star calculated. ✓
- **c** The absorption lines of each element are unique ✓ and act as a signature for the element. ✓ By comparing the emission/absorption lines from elements on Earth with the absorption lines in the stellar spectrum, the elements in the star's atmosphere can be identified. ✓

26 EM This question tests students' understanding of the photelectric effect and their ability to interpret graphical data.

- **a** There is a specific amount of energy (i.e. the work function = ϕ) required to remove an electron from the surface of zinc. Electrons will not be emitted until the photon energy is equal to or greater than the energy required to remove an electron from the surface. ✓ As photon energy is proportional to the frequency ($E = hf$) this means that no electrons will be emitted below a specific threshold frequency. ✓
- **b** The threshold frequency is where the graph crosses the frequency axis. The threshold frequency is therefore $f_0 = 10.5 \times 10^{14}$ Hz. ✓ The energy to remove an electron from the surface corresponds to the point where the graph crosses the energy axis. The work function is therefore $\phi = 4.4$ eV. ✓
- **c** As one photon releases one electron we can use conservation of energy to write $hf = \phi + k$ or the kinetic energy $k = hf - \phi$, ✓ which is the equation that represents the graph. This equation has the form $y = mx + b$ and the gradient is therefore equal to Planck's constant. But because Figure E2.11 has the energy in

electron volts (rather than joules), the gradient of the graph will be proportional to Planck's constant. ✓

27 EM This question tests students' understanding of Einstein's special relativity postulates and the Michelson–Morley experiment.

a First postulate: All inertial frames of reference are equivalent. ✓ Second postulate: The speed of light in a vacuum is an absolute constant. ✓

b If an ether wind blew past the Earth, light would travel at a different speed parallel to and perpendicular to the direction of the wind. The Michelson–Morley experiment used this assumption in their experiment to measure the speed of the Earth through the ether but they obtained a null result. ✓ The result is explained by either postulate. If the speed of light is an absolute constant that is independent of the speed of the source or the observer, the assumption about light travelling at different speeds upon which the experiment was based is incorrect and the experiment must give a null result. ✓ If all inertial frames are equivalent, then any experiment designed to measure the absolute speed of a frame of reference is doomed to failure. ✓

c The relativist momentum (p_v) is related to the Newtonian momentum (p_0) by:

$$p_v = \frac{p_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

Now as $p_v = 2p_0$, we can write $2 = \frac{1}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$ ✓ and rearranging this gives:

$$v = c\sqrt{\frac{3}{4}} = 0.866c = 2.6 \times 10^8 \text{ ms}^{-1}$$ ✓

28 EM This question tests students' understanding of fission, beta decay and half-life.

a To ensure the same number of nucleons is conserved there must be three neutrons released. ✓

b The mass defect (Δm) is given by:

$$\begin{aligned}\Delta m &= \text{mass of products} - \text{mass of reactants}\\ &= (140.9139 + 91.8973 + 3 \times 1.008\,665)\\ &\quad - (1.008\,665 + 235.043\,915)\\ &= -0.215 \text{ u or } 0.215 \text{ u of mass is converted to energy}\end{aligned}$$ ✓

The energy released is 0.215 × 931.5 = 200 MeV ✓

c For the first decay:

$${}^{141}_{56}\text{Ba} \rightarrow {}^{141}_{57}\text{La} + {}^{0}_{-1}\text{e} + {}^{0}_{0}\bar{\upsilon}$$ ✓

For the next decay:

$${}^{141}_{57}\text{La} \rightarrow {}^{137}_{55}\text{Cs} + {}^{4}_{2}\text{He}$$ ✓

d The number of half-lives in 1 hour is $n = \frac{60}{18.5} = 3.234$ half-lives. ✓

The fraction remaining will be given by $(1/2)^n = \left(\frac{1}{2}\right)^{3.234}$

$= 0.106 = 10.6\%$ ✓

Or students may work out the decay constant and use $N_t = N_0 e^{-\lambda t}$

29 EM This question tests students' understanding of Rutherford's and Bohr's atomic models.

a Rutherford's model was unstable because orbiting electrons should have radiated electromagnetic radiation, lost energy and spiralled into the nucleus. ✓

Rutherford's model also said nothing about atomic emission and absorption spectra. ✓

b Bohr's model was stable because he assumed that when the electron was in specific (stationary state) orbitals it did not radiate electromagnetic radiation. ✓

Bohr's model was able to account for atomic spectra by assuming photons were emitted or absorbed when electrons moved to lower- or higher-energy orbitals, respectively. ✓

c Apply Bohr's equation with $n_i = 3$ and $n_f = \infty$: ✓

$$\frac{1}{\lambda} = R\left[\frac{1}{n_f^{\,2}} - \frac{1}{n_i^{\,2}}\right] = 1.097 \times 10^7\left[\frac{1}{3^2}\right]$$

$= 1.2188 \times 10^6$ and hence $\lambda = 820$ nm

$$E = hc/\lambda = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{891 \times 10^{-9}} = 2.42 \times 10^{-19} \text{ J ✓} = 1.51 \text{ eV}$$

30 EM This question tests students' understanding of the discovery and nature of the neutron.

a The mass number was approximately twice the atomic number. ✓ For example, helium was known to have a mass of approximately 4 u but an atomic number of 2.

b Because neutrons have no charge ✓ they are very penetrating and very poor ionisers. Because they interact so weakly, they do not leave a track in a cloud chamber and are not detected by Geiger counters. ✓

c Joliot and Curie had reported a penetrating radiation was emitted when beryllium was irradiated with alpha particles that was so energetic it could knock protons out of paraffin. Chadwick showed that this would require more energy than a gamma ray and measured the recoil velocity of particles hit by the radiation. ✓ By applying the law of conservation of momentum ✓and kinetic energy to the collisions he showed that the radiation consisted of neutral particles with a mass similar to a proton. ✓ That is, he showed the radiation was a stream of neutrons.

d Neutrons are one of a large number of composite particles called hadrons. Neutrons consist of three quarks: ✓ two down-quarks (each with –1/3 charge) and an up-quark (with a charge of +2/3). ✓ The quarks are held within the nucleus by a strong (colour) force mediated by gluons.

31 EM This question tests students' understanding of electromagnetic induction.

a As the coil rotates, the magnetic flux linking the coil continually changes. ✓ Faraday's law of electromagnetic induction states that if the magnetic flux in a coil changes, an emf will be induced in the coil ✓ ($\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$).

b Figure EA2.1 shows the induced electromotive force. Note that the induced electromotive force is a maximum at $t = 0$. ✓ (Note this mark can be given for correctly drawing this point on the graph.)

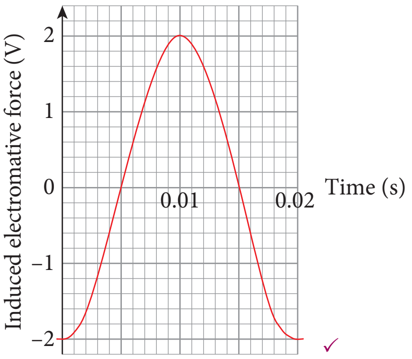

Figure EA2.1 Electromotive force induced in an AC generator

c If the rate of rotation was halved, the maximum induced electromotive force would be reduced to 1 volt ✓ and the period would double to 0.04 seconds. ✓

32 **EM** This question tests students' understanding of particle accelerators and the influence they have had on the development and verification of the standard model.

a In a linear accelerator (Figure EA2.2) charged particles are accelerated between drift tubes of increasing length. ✓ The length increases to ensure a constant-frequency AC radio frequency voltage can be applied. The entire device is evacuated to prevent collisions. ✓

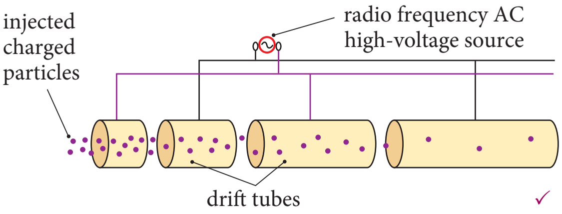

Figure EA2.2 Linear accelerator

Each time a charge particle leaves a drift tube, the polarity of the tube is reversed and the particle is accelerated across a large potential difference before it enters the next drift tube. ✓

b The standard model does not include gravity ✓ and says nothing about dark matter ✓ or dark energy. The model cannot account for the matter–antimatter asymmetry that is critical to the formation of our matter universe in the Big Bang. It requires a large number of experimentally determined parameters to be added before it can be used. (Any two of these answers are suitable for the two marks.)

c Quarks are elementary particles, while hadrons are composite particles composed of two quarks or three quarks. ✓

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