Conquer

Conquer Higher School Certificate Examination

2021 **HIGHER SCHOOL CERTIFICATE EXAMINATION**

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A data sheet, formulae sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 20 marks (pages 2–9)

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

Section II – 80 marks (pages 12–27)

- Attempt Questions 21–36
- Allow about 2 hours and 25 minutes for this section

Examiner:
HeyyyIts2xq#5550

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Section I

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

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

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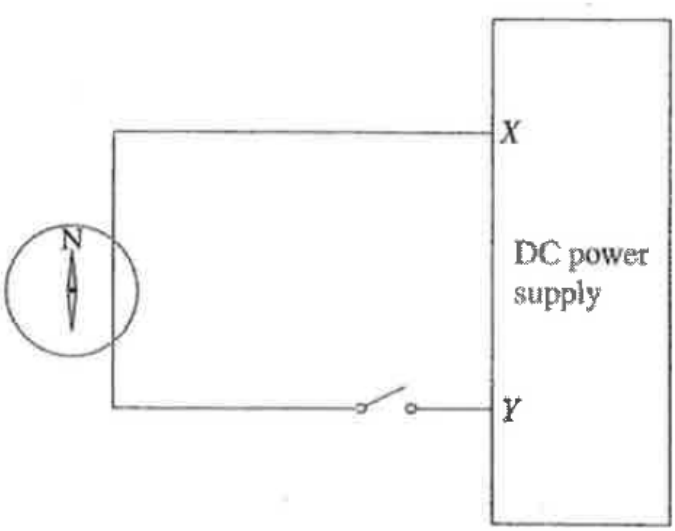
1 A copper wire connected through a switch to a power supply is placed **over** a compass needle as shown below, where the arrow head is pointing north.



When the switch is closed you would expect the needle to

A. Deflect clockwise when Terminal *X* on the power supply is positive.

B. Deflect clockwise when Terminal *X* on the power supply is negative.

C. Deflect anticlockwise when Terminal *X* on the power supply is positive.

D. Not move at all because any magnetic field produced is along the wire.

2 Which of the following does not produce electromagnetic radiation?

A. Turning off a light switch

B. Creating a spark with two wires

C. An electron "orbiting" a nucleus

D. Electrons hitting a metal target

3 Black body radiation is the electromagnetic radiation that is emitted from a body due to its temperature alone. How does the black body radiation emitted from the body change as the temperature of the body is increased?

A. The power radiated remains constant but the frequency at which most of the radiation is emitted decreases.

B. The power radiated increases but the frequency at which most of the radiation is emitted decreases.

C. The power radiated remains constant but the frequency at which most of the radiation is emitted increases.

D. The power radiated increases and the frequency at which most of the radiation is emitted also increases.

4 Consider the statements below.

I. A quantum of red light is more energetic than a quantum of microwave radiation.

II. The frequency of microwave radiation is higher than the frequency of red light.

III. The wavelength of red light is greater than microwave radiation.

IV. A quantum of red light is less energetic than a quantum of microwave radiation.

Which of the following statement(s) is/are correct?

A. I only

B. I and II only

C. I and III only

D. II and IV only

5 A projectile was launched from the ground. It had a range of 100 metres and was in the air for 3.5 seconds.

At what angle to the horizontal was it launched?

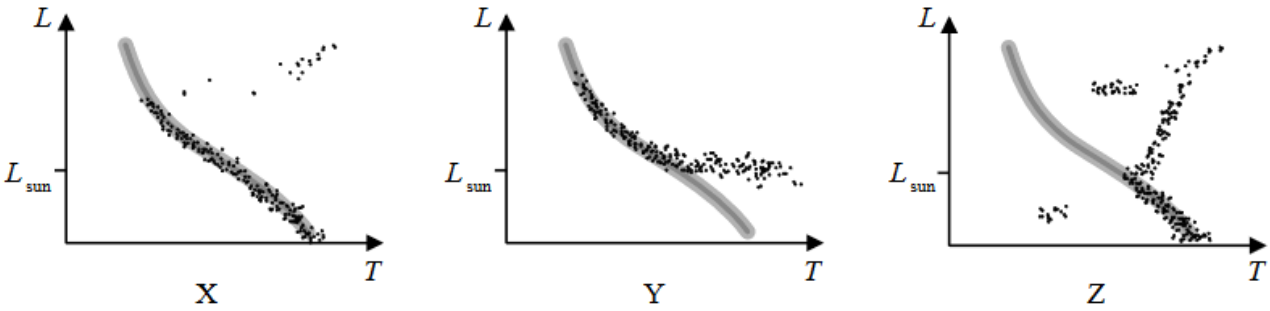
A. 30°

B. 30.9°

C. 30.95°

D. 31°

6 Hertzsprung–Russell diagrams are shown for the three star clusters.



Choose the row that correctly identifies the relative ages of the three clusters from youngest to oldest.

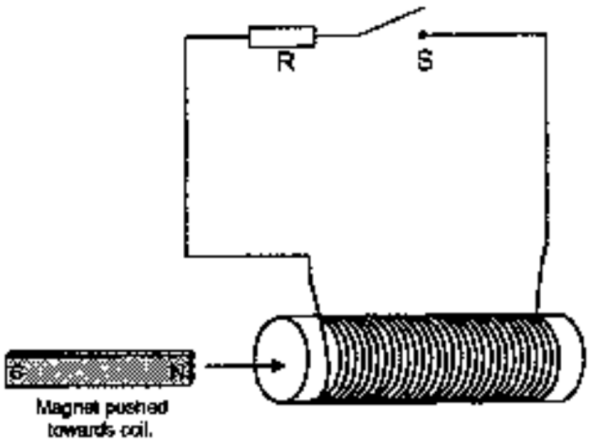
A. XZY

B. YZX

C. YXZ

D. ZXY

7 A bar magnet is placed so that it is initially outside a large coil. The coil is connected with a switch, *S*, and a resistor, *R*, as shown in the diagram below.



The magnet is pushed quickly into the coil in the direction shown by the arrow in the diagram.
The amount of energy required to push the North end of the magnet towards the coil is:

A. zero, whether the switch is opened or closed.

B. non-zero, but the same whether the switch is open or closed.

C. more if the switch is closed than if it is open.

D. more if the switch is open than if it is closed.

8 A counter recording radioactive decay from a radioactive source gives the following counts in equal intervals of time.

Time (minutes)	Counts
0–10	424
10–20	395
20–30	413
30–40	363
40–50	366
50–60	294
60–70	301
70–80	253
80–90	212

What can be deduced from these readings?

A. Radioactivity is random and half-life is 90 minutes.

B. Radioactivity is random and half-life is uncertain.

C. Radioactivity is spontaneous and half-life is 90 minutes.

D. Radioactivity is spontaneous and half-life is uncertain.

9 The Michelson-Morley experiment showed that:

A. objects travelling relative to the ether contracted along their direction of motion.

B. no motion relative to the ether was detectable.

C. the ether doesn't exist.

D. objects travelling relative to the ether show a time dilation.

10 Consider the following nuclear reaction.

$$^{6}_{3}\text{Li} + {}^{1}_{0}\text{n} \longrightarrow {}^{4}_{2}\text{He} + {}^{3}_{1}\text{H}$$

The mass of the reactants is 7.023787704 *u* and the mass of the products is 7.018652532 *u*.

Calculate the energy released by this transmutation reaction in joules.

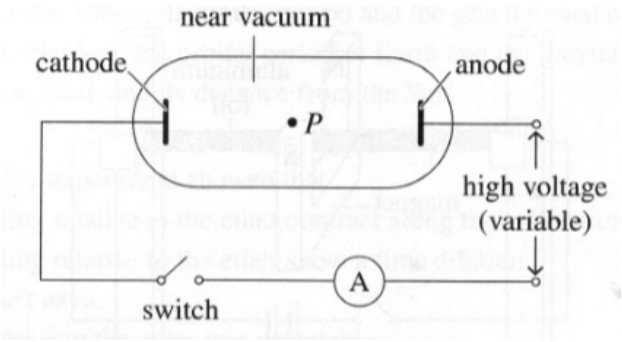
A. 0.005135208 J

B. 4.783 J

C. 8.530×10^{-27} J

D. 7.68×10^{-13} J

11 This diagram shows two metal plates sealed inside an evacuated glass tube. This tube is sitting on a laboratory bench in Canberra.



When the circuit is switched on, which field(s) then exist at point *P*?

A. gravitational field.

B. magnetic and electric fields.

C. gravitational, electric and magnetic fields.

D. electric field.

12 Uranium-238 forms nucleus of plutonium-239 as a result of:

A. Electron capture followed by alpha decay.

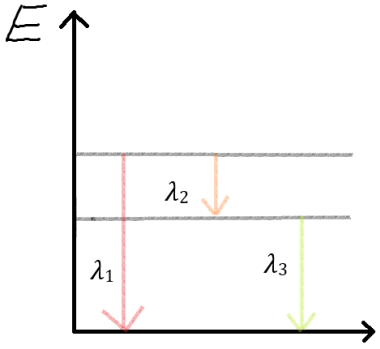
B. Neutron capture followed by beta decay.

C. Electron capture followed by beta decay.

D. Neutron capture followed by two beta decay.

13 The arrows below indicate transitions involving three energy levels of an atom. The wavelength of the photon emitted in each transition is indicated.

Which of the following relationships between the wavelengths is correct?



A. $\lambda_1 = \lambda_2 + \lambda_3$

B. $\lambda_1 = \lambda_3 - \lambda_2$

C. $\frac{1}{\lambda_1} = \frac{1}{\lambda_2} + \frac{1}{\lambda_3}$

D. $\frac{1}{\lambda_1} = \frac{1}{\lambda_2} - \frac{1}{\lambda_3}$

14 A satellite moves in a circular orbit about the Earth.

Which pair of statements about momentum and kinetic energy are correct?

A. Momentum is constant while Kinetic Energy is changing.

B. Momentum and Kinetic Energy are both constant.

C. Momentum and Kinetic Energy are both changing.

D. Momentum is changing while Kinetic Energy is constant.

15 For which quantity can the unit MeVc^{-2} be used?

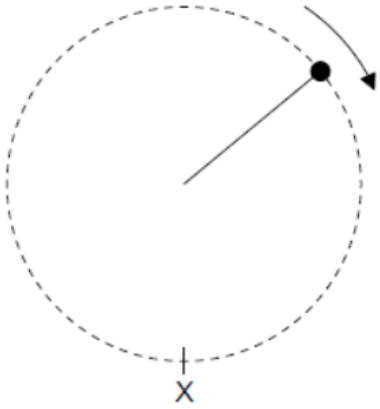
A. Mass

B. Momentum

C. Kinetic Energy

D. Binding Energy

16 A small ball of weight W is attached to a strong and moves in a vertical circle of radius R.



Conservation of Energy:

$$\frac{1}{2}mv_T^2 + 2MgR \text{ (Top)}$$

$$= \frac{1}{2}mv_B^2 \text{ (Bottom)}$$

What is the smallest kinetic energy of the ball at position X for the ball to maintain the circular motion with radius R?

A. $\frac{WR}{2}$

B. $2WR$

C. WR

D. $\frac{5WR}{2}$

17 The type of exchange particle associated with the weak interaction is a

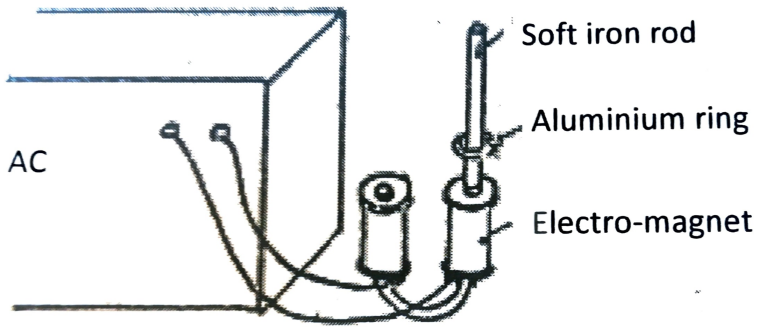
A. Boson

B. Gluon

C. Pion

D. Photon

18 A student made the sketch below of an experiment demonstrated by his teacher. It appears to show a metal ring suspended on a long soft iron rod core of an electromagnet.



Which statement is the best explanation of the record made by the student?

A. The student's diagram has to be incorrect as the aluminium rings cannot stay suspended.

B. The aluminium ring is magnetic and therefore repelled by the magnetic field of the electromagnet.

C. The aluminium ring is a superconductor and is demonstrating magnetic levitation.

D. There are eddy currents set up in the aluminium ring and their magnetic field results in repulsion by the magnetic field of the electromagnet.

19 In a nuclear reaction, 1.60×10^{17} J of energy is released. The nuclear fuel had an initial mass of 2.88 kg.
The final mass of the remaining fuel is closest to:

A. 0.01 kg

B. 1.10 kg

C. 1.28 kg

D. 2.88 kg

20 Which of the following equations is based solely on the nature of electrons in lattices.

A. $\vec{F} = m\vec{a}$

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

C. $E^2 = (mc)^2 + (pc)^2$

D. $\oint \vec{B} \cdot \mathrm{d}\vec{s} = \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt} + \mu_0 I$

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2021 HIGHER SCHOOL CERTIFICATE EXAMINATION

	N	/	A	

Centre Number

Physics

Section II Answer Booklet

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(e.g. Heyyylts2xq#5550)

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

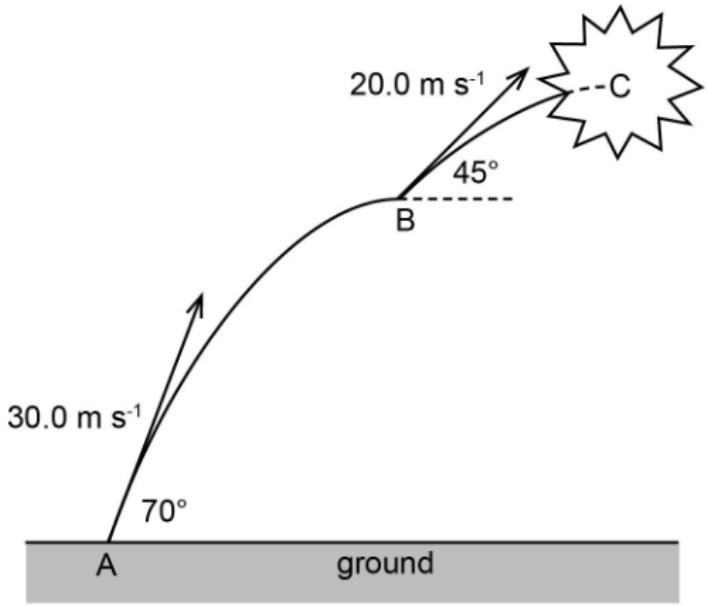
Instructions

- Write your Centre Number and Student Number at the top of this page.
- 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.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

Question 21 (6 marks)

A firework rocket was launched into the air from the ground at point *A* with an initial velocity of 30.0 ms^{-1} at an angle of 70.0° to the horizontal. When the firework rocket reached its first maximum height at point B, there was a second explosion that further propelled the upper part of the rocket with a new velocity of 20.0 ms^{-1} at an angle of 45.0° to the horizontal. This upper part of the firework rocket was propelled to its new maximum height at point C where the firework rocket explodes. Ignore all effects due to air resistance.



(a) Determine the initial velocity of the firework rocket. **1**

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Question 21 continues on page 13

Question 21 (continued)

(b) Calculate the height at point *B*. **2**

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(c) Calculate the total time it takes for the firework rocket to reach point C where it explodes. **3**

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End of Question 21

Question 22 (4 marks)

The mass of an asteroid is calculated by sending a spacecraft into orbit with it. With an orbital radius of 2.00×10^5 m, the orbital period was found to be 22.0 days.

(a) Calculate the mass of the asteroid. **2**

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(b) The mass of the spacecraft in part (a) was not known. Explain why the mass of the spacecraft has no effect on the mass of the asteroid. **2**

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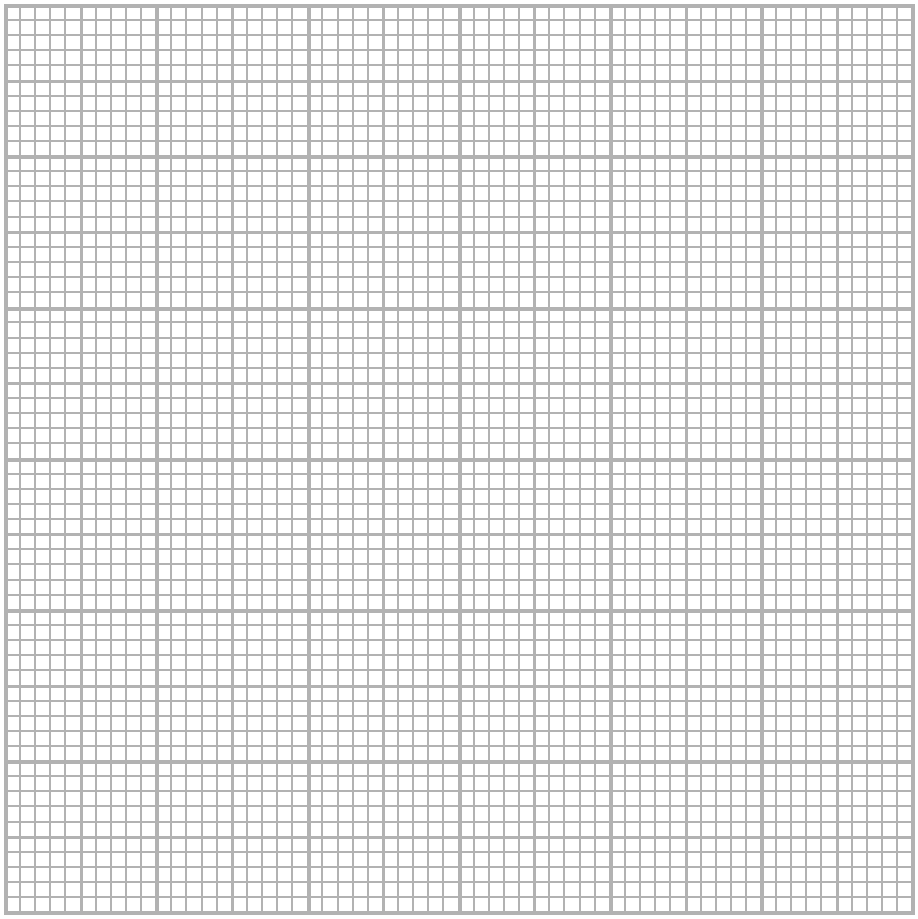
Question 23 (6 marks)

(a) The table shows how the activity of a sample of plutonium-238 varies with time. **4**

Time in years	0	50	100	150	200	250
Activity in Bq	980	660	450	305	205	140

Graph the data on the grid provided and draw a curve of best fit.



(b) Use your graph to find the half-life of plutonium-238. **2**

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Question 24 (4 marks)

Discuss how the concept of quantised energy fitted in with Bohr's postulates and how this in turn led to the mathematical model that accounted for the observed spectrum of hydrogen. **4**

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Question 25 (6 marks)

Bruce the Australian flying ace needs to hide his new experimental high-velocity plane in the hanger, away from the view of foreign spy satellites. "You'll ne'er do it," says Willie, the Scottish flight engineer, "the hangar's barely 80m long but yer plane dere is over 120m."
"She'll be right, mate," replies Bruce, "It's just matter of going fast enough!" Willie stands at the hangar door while he watches Bruce approach in his plane.

(a) Willie sees the plane contract as it speeds up. Calculate how fast it must be travelling for him to be able to quickly close the door with the plane, at least momentarily, contained inside. **1**

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(b) At the speed you determined in part (a), calculate the length of the hangar as seen by Bruce in the approaching plane. Will it fit in the hangar as judged by Bruce? **2**

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(c) Discuss how it is possible for Bruce and Willie to perceive the situation so differently. **3**

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Question 26 (3 marks)

Describe the application of the motor effect in a loudspeaker. **3**

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Question 27 (4 marks)

Explain the particle theory of light in terms of photons with a particular energy and frequency. **4**

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Question 28 (5 marks)

A DC electric motor has a rectangular coil containing 120 loops, 150mm × 100mm. The coil sits in a magnetic field of 250mT. The power supply attached to the motor causes a current of 6.8A to flow through a split-ring commutator to the loops of the motor coil.

(a) Describe, including a diagram, the function of the split-ring commutator. **3**

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(b) What maximum torque acts on the motor coil? **2**

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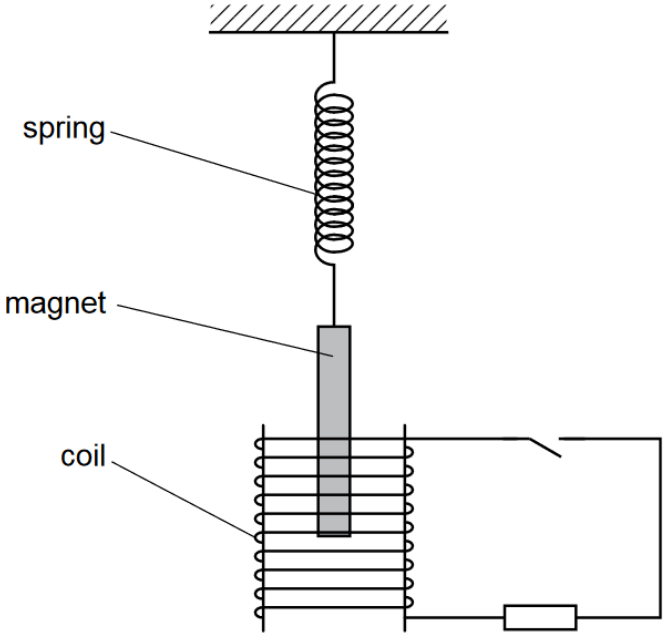
Question 29 (5 marks)

A bar magnet of mass 250g is suspended from the free end of a spring as shown below.

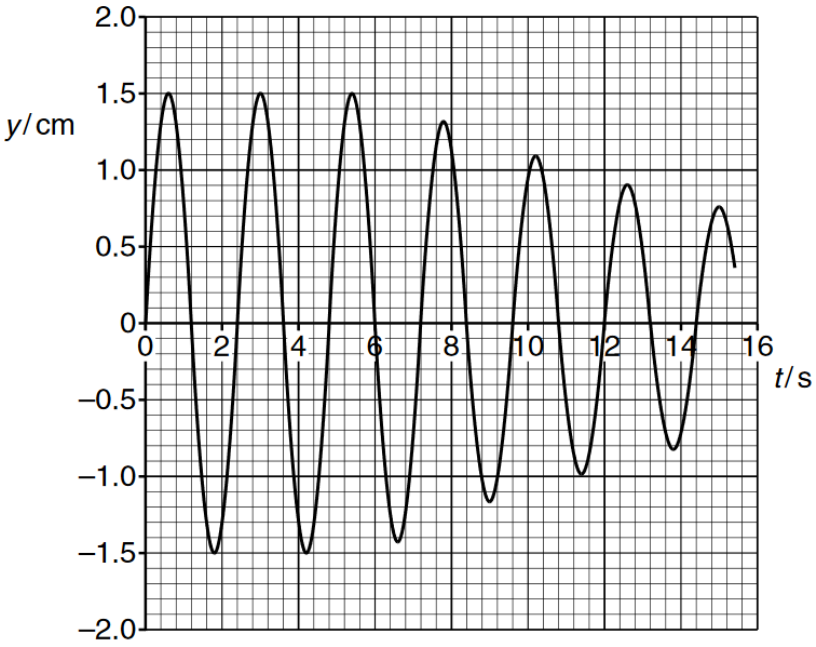


The magnet hangs so that one pole is near the centre of a coil of wire.
The coil is connected in series with a resistor and a switch. The switch is open.

The magnet is displaced vertically and then allowed to oscillate.

At time t = 0, the magnet is oscillating freely. At time t = 6.0 s, the switch in the circuit is closed.

The variation with time t of the vertical displacement y of the magnet is shown below.



Question 29 continues on page 21

Question 29 (continued)

(a) For the oscillating magnet, calculate the frequency and the energy of the oscillations during the time interval $t = 0$ to $t = 6.0$s. (Use $E = \frac{1}{2}m\omega^2 y_0^2$ where y_0 is the maximum displacement) **3**

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(b) When the switch is closed, the oscillations are damped. **2**

Explain with reference to the graph, whether the dampening is light, critical or heavy.

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End of Question 29

Question 30 (6 marks)

(a) Using Newtonian physics, calculate the kinetic energy (in eV) of a proton travelling at 3×10^8 ms^{-1}. **2**

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(b) A student makes the statement that "The maximum kinetic energy a proton can have is 4.7×10^8 eV because it can't travel faster than the speed of light." Assess this statement on the basis of your answer to part (a). **2**

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(c) Particle accelerators can produce protons with kinetic energies greater than 3×10^{10} eV. Discuss this in relation to your answer to part (b). **2**

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Question 31 (7 marks)

The Big Bang theory is an explanation for the start of the Universe. **7**

Explain how the cosmic microwave background radiation supports the Big Bang theory for the start of the Universe. Comment on the relevance of the data shown below concerning the Big Bang theory.

	wavelength of hydrogen line from galaxy / nm	wavelength of hydrogen line on Earth / nm
Andromeda galaxy	485.6	486.1
Virgo cluster	489.8	486.1

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Question 32 (4 marks)

A racing car of mass 800 kg is driven around a banked circular racetrack at a constant speed of 180 km/h. The acceleration of the racing car is measured to be 4.0 ms^{-2}. Calculate the radius of the racetrack. **4**

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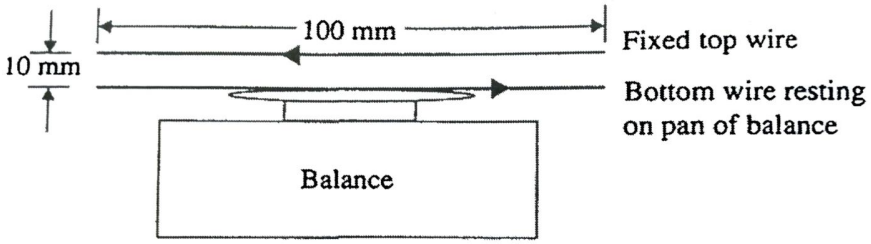
Question 33 (6 marks)

A physics student set up the following experiment to measure the magnetic force between two current-carrying wires. The top wire 100mm long, is fixed in place. with the bottom wire resting on the pan of an electronic balance, insulated from the balance. Currrents flow in the wires in the directions shown by the arrows in the diagram below.



The balance gives the force applied to it in Newtons. When there is NO current flowing in either wire, the reading on balance is 0.25N.

(a) Calculate the magniture of the magnetic force between the wires if there is a current of 2.0A flowing in each of the wires. **1**

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(b) Without giving a numerical value, describe how the magnetic force between wires would affect the reading on the balance. **1**

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Question 33 continues on page 25

(c) School laboratory balances can measure accurately to a mass of 0.01g. (This is a weight force of about 0.0001N). A school balance would not be successful in the experiment. Explain why. **2**

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(d) How could you modify the experiment so that the school balance could be used? Include quantities in your modification. **2**

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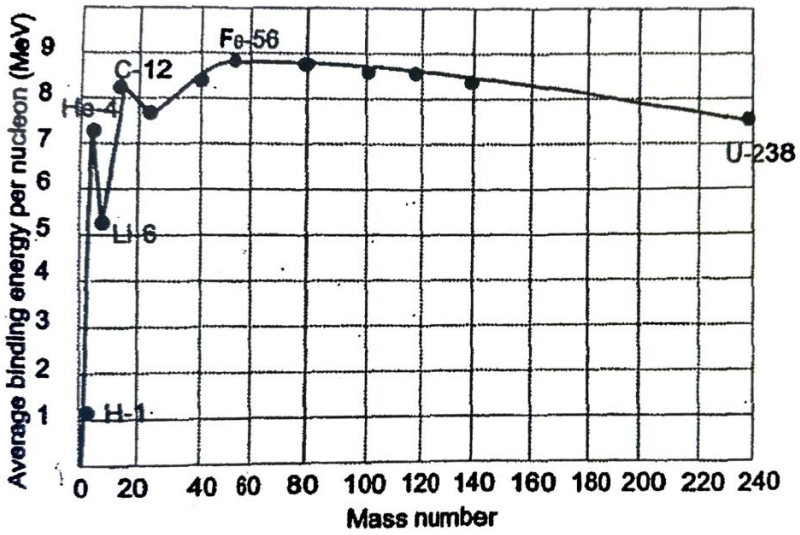
End of Question 33

Question 34 (7 marks)

The figure below shows a graph of a binding energy per nucleon versus mass number for all elements.



(a) Define the term "binding energy". **1**

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(b) Describe the source of this energy. **2**

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(c) Explain why this binding energy is necessary. **2**

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(d) Predict which nucleus is more stable, Helium-4 OR Lithium-6. Explain your reasoning. **2**

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Question 35 (7 marks)

Describe the key features and components of the Standard Model of Matter and analyse the role of particle accelerators in developing this model. **7**

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Section II extra writing space

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

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CONQUER

SOLUTIONS

Discord Username (e.g. HeyyyIts2xq#5550)

2021
HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

Section I - Multiple Choice

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

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

A ○ B ● C ○ D ○

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

A ● B ⊗ C ○ D ○

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

A ⊗ B ⊗ ← correct C ○ D ○

Start Here →

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

Conquer HSC Physics Trial Worked Solutions

Section I

1. **A** – Only A is correct. D is incorrect as the field is around the wire, not along it. Use the right hand grip rule for the wire and work out the magnetic field lines below the wire. By convention, the N needle end will point with the field.
2. **C** – Atoms are stable, while all other options produce electromagnetic radiation.
3. **D** – This is in accordance to Wien's Law, $\lambda_{\max} = \frac{b}{T}$.
4. **A** – $E \propto f, E \propto \frac{1}{\lambda}$. Microwave has a longer λ than red light.
5. **D** –
   $u_x = \frac{\Delta x}{t} = \frac{100}{3 \cdot 5} \approx 28.6 ms^{-1}$
   $s = ut + \frac{1}{2}at^2$
   $0 = 3.5u_y + \left(\frac{-9.8}{2}\right)(3.5)^2$
   $u_y = \frac{4.9(3.5)^2}{3.5} = 17.15 ms^{-1}$
   $Angle = \tan^{-1}\left(\frac{17.15}{28.6}\right) = 31°\ (2\ significant\ figures)$
6. **C** – Star's life cycle involves it moving from:
   Main Sequence -> Giants -> White Dwarf -> Brown Dwarf.
   There are no giants in Y, so this is the youngest. Z has some white dwarfs and so is the oldest. Thus, C where the order from youngest to oldest is YXZ.
7. **C** – Applications of Electromagnetic Induction. When switch is closed, the magnet will experience an opposing force when entering the coil, thus, requires more energy to be pushed towards the coil than if the switch is open.
8. **B** – The random error is too high to accurately determine the half-life.
9. **B** – A, C and D are all "explanations" of the Michelson-Morley result summarised by B.
10. **D** – Mass Defect = 7.023787704 u – 7.018652532 u = 0.005135208 u
    $= 8.530 \times 10^{-27}$ kg
    $E = mc^2 = 8.530 \times 10^{-27} \times (3.00 \times 10^{-8})^2 = 7.68 \times 10^{-13}$ J
11. **C** – The circuit produces an electric field and the Earth produces both magnetic and gravitational fields.
12. **D** – It is the only option which gives the correct mass and atomic numbers.
13. **C** – This is in accordance to $E = hf = \frac{hc}{\lambda}$ [i.e. $\frac{1}{\lambda} \propto E$ (release)]
14. **D** – Momentum is a vector quantity, so it changes with direction. Note that the speed will always be the same and so Kinetic Energy is constant.
15. **A** – MeVc^{-2} is the unit for mass according to $m = \frac{E}{c^2}$.
16. **D** – At the top: $w = \frac{mv^2}{R}, mv^2 = WR, K = \frac{mv^2}{2} = \frac{WR}{2}$. At the bottom:
    $K = \frac{WR}{2} + 2mgh = \frac{WR}{2} + 2WR = \frac{5WR}{2}$
17. **A** – Pions are the lightest mesons and, more generally, the lightest hadrons. Gluons are associated with the strong interaction. Photons are associated with electromagnetism.
18. **D** – The eddy currents induced in the aluminium ring opposes the magnetic field of the electromagnet.
19. **B** – $m = \frac{E}{c^2} = 1.78\ kg\ which\ is\ the\ mass\ defect.\ 2.88 - 1.78 = 1.10 kg$
20. **B** – Photoelectric Effect is solely based on the nature of electrons in lattices.

NOTE: SAMPLE ANSWERS DO NOT NECESSARILY CORRESPOND TO A FULL MARK RESPONSE!

Section II

Question 21 (MISTAKE IN THE EXAM)

a) Determine the initial vertical velocity of the firework rocket.

Criteria	Marks
- Correctly determines the initial vertical velocity of the firework rocket. - Correctly states the velocity in the question (with direction)	1

Sample Answer

$u = 30.0 \times \sin 70° = 28.2\ \text{ms}^{-1}$

Sample Answer

$u = 30\ \text{ms}^{-1}$ 70 degrees above the horizontal

b) Calculate the height of point *B*.

Criteria	Marks
- Correctly calculates the height of point *B*.	2
- Show some relevant calculation steps.	1

Sample Answer

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

$0^2 = 28.19^2 + 2 \times (-9.80) \times s$

$794.7 = 19.62\ s$

$s = 40.5\text{m}$

c) Calculate the total time it takes for the firework rocket to reach point C where it explodes.

Criteria	Marks
- Correctly calculates the height of point *B*.	3
- Show some relevant calculation steps.	2
- Provides some relevant information.	1

Sample Answer

Time taken to reach point B

$$v = u + at$$

$$0 = 28.19 - 9.80\ t$$

$$t = \frac{28.2}{9.8}$$

$t = 2.88$ s

Time taken to reach point C

$20 \sin 45° = 14.14$

$$v = u + at$$

$$0 = 14.1 - 9.80\ t$$

$$t = \frac{14.1}{9.8}$$

$t = 1.44$

Total time

$2.88 + 1.44 = 4.32$ s

Question 22

a) Calculate the mass of the asteroid.

Criteria	Marks
- Correctly calculates the mass of the asteroid.	2
- Show some relevant calculation steps.	1

Sample Answer

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

$M = \frac{4\pi^2 r^3}{GT^2} = \frac{4\pi^2(2.00\times10^5)^3}{6.67\times10^{-11}(22.0\times24\times60\times60)^2} = 1.31\times10^{15}\text{kg}$

b) The mass of the spacecraft in the previous question was not known. Explain why the mass of the spacecraft has no effect on the mass of the asteroid.

Criteria	Marks
- Explains why the mass of the spacecraft has no effect on the mass of the asteroid. - Includes derivation of orbital velocity.	2
- Provides some relevant information.	1

Sample Answer

The orbital motion of the spacecraft is governed by the gravitational force at that altitude, supplying the centripetal acceleration to the spaceship which is independent of the spaceship's mass:

$$\frac{mv^2}{r} = \frac{GmM}{r}$$
$$v^2 = \frac{GM}{r}$$
$$v = \sqrt{\frac{GM}{r}}$$

Mass of asteroid, orbital radius & period are the only variables required for a solution to be possible. Mass (Asteroid) >>Mass (Spaceship).

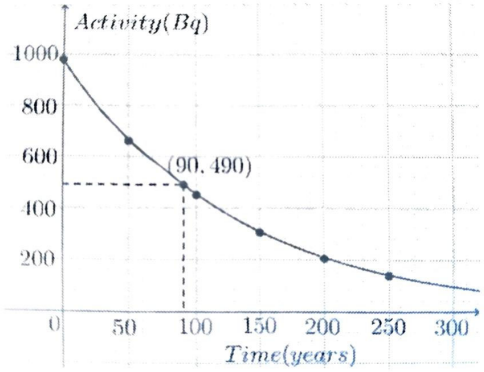
Question 23

a) Graph the data on the grid provided and draw a curve of best fit.

Criteria	Marks
- Suitable linear scale chosen (>50% of the grid used). - Axes labelled with quantities and units. (This includes the graph title) - Plotting correct to the nearest half square. - Curve of best fit acceptable.	4
- Graph has 3 of the 4 features mentioned above.	3
- Graph has 2 of the 4 features mentioned above.	2
- Graph has 1 of the 4 features mentioned above.	1

Sample Answer

Activity of Plutonium-238 as time passes.



b) Use your graph to find the half-life of plutonium-238.

Criteria	Marks
- Appropriate working shown on graph OR numerically. - Correctly determines the half-life of plutonium-238. (85-95 years) NOTE: Allowed ECF from graph in part (a)	2
- Provides only one of the above.	1

Sample Answer

The time associated with activity of 490 Bq (Half of the initial 980 Bq) will be the half-life. From the curve of best fit shown in the graph, this corresponds to a value of 90 years.

Question 24

Discuss how the concept of quantised energy fitted in with Bohr's postulates and how this in turn led to the mathematical model that accounted for the observed spectrum of hydrogen.

Criteria	Marks
- The concept of energy quantisation is discussed - Bohr's postulates are related to quantised energy - The Rydberg equation is used with respect to hydrogen spectrum	4
- The concept of energy quantisation is outlined - Bohr's postulates are identified, and a link is made	3
- An aspect of quantised energy is identified AND - Bohr's postulates are identified OR - Features of the hydrogen spectrum are identified	2
- ANY one of the above is identified.	1

Sample Answer

Energy exists in discrete amount (quanta) can be applied to Bohr's postulates that state that electrons can only exist in certain energy levels in the hydrogen atom. For an electron to change energy levels it must absorb energy ($E = hf$) in the form of photons, moving to a higher energy level or emit photons of energy, moving to a lower energy level. The pattern of wavelengths observed in the hydrogen spectrum was used to develop the empirical Rydberg equation: $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ where n_f and n_i are the final and initial allowed orbitals and R is the Rydberg's constant. The wavelength, λ associated with the transition between the final and initial orbital (n_f and n_i) due to the absorption or emission of photons. If energy was not quantised, then the hydrogen spectrum would be a continuous one.

Question 25

a) Willie sees the plane contract as it speeds up. Calculate how fast it must be travelling for him to be able to quickly close the door with the plane, at least momentarily, contained inside.

Criteria	Marks
- Correctly calculates how fast the plane must be travelling for Willie to see the plane contract enough to momentarily be contained in the hangar.	1

Sample Answer

$$80 = 120\sqrt{1 - \frac{v^2}{c^2}}$$

$$v = 0.745c = 2.24 \times 10^8 ms^{-1}$$

b) At the speed you determined in part (a), calculate the length of the hangar as seen by Bruce in the approaching plane. Will it fit in the hangar as judged by Bruce?

Criteria	Marks
- Correctly calculates the length of the hangar as seen by Bruce in the approaching plane. - Correctly states that the plane WILL NOT fit.	2
- ANY one of the above is identified.	1

Sample Answer

$l_v = 80\sqrt{1 - 0.745^2} = 53.4m$. Bruce would see the hangar contract to 53.4m! The plane wouldn't fit.

c) Discuss how it is possible for Bruce and Willie to perceive the situation so differently.

Criteria	Marks
- Discusses how it is possible for Bruce and Willie to perceive the situation so differently. - Provides effective reasoning in support this possibility.	3
- Provides some reasoning in supporting this possibility.	2
- Shows some relevant information	1

Sample Answer

This is because time is passing differently for Bruce and Willie. Bruce is travelling at quite a high speed while inside the hangar – so it takes longer for light to reach him from the closing door (behind him) than from the concrete wall (in front). Thus, in his frame of reference, the plane has already burst out of the hangar before the door closes behind it. But in Willie's frame of reference, the two events (nose of plane hitting concrete wall and door swinging close) were simultaneous and the plane did fit, momentarily!

Question 26

Describe the application of the motor effect in a loudspeaker.

Criteria	Marks
- Defines the term "motor effect". - Correct description of the structure of a speaker - For variation in current in the coil, (signal) causes vibrations in the cone which produces sound.	3
- ANY two of the above.	2
- ANY one of the above.	1

Sample Answer

A coil connected to an external power source is located in a radial magnetic field produced by radial permanent magnets in the loudspeaker. The cone of the loudspeaker is connected to the coil. The external power source is varied according to the recording being played which results in a varying current. The motor effect (due to a current-carrying coil in the magnetic field) causes it to move back and forth. This causes the cone to vibrate generating longitudinal sound waves of various frequencies and volume.

Question 27

Explain the particle theory of light in terms of photons with a particular energy and frequency.

Criteria	Marks
- Explains the particle theory of light in terms of photons with particular energy and frequency.	4
- Explains the particle theory of light in terms of photons with a particular energy OR - Explains the particle theory of light in terms of photons with a particular frequency.	3
- Outlines the particle theory of light.	2
- Provides some relevant information.	1

Sample Answer

Light can be considered to be packets of energy.

A photon is the smallest amount of energy a particular frequency of light can have.

The energy of a photon is given by $E = hf$

Energy can be transferred to matter from light in photons.

However, a photon cannot transfer parts of its energy, but all or none of it.

The intensity of light is dependent on the number of photons in a given area.

All photons, regardless of their frequency, have zero rest mass and travel at the speed of light.

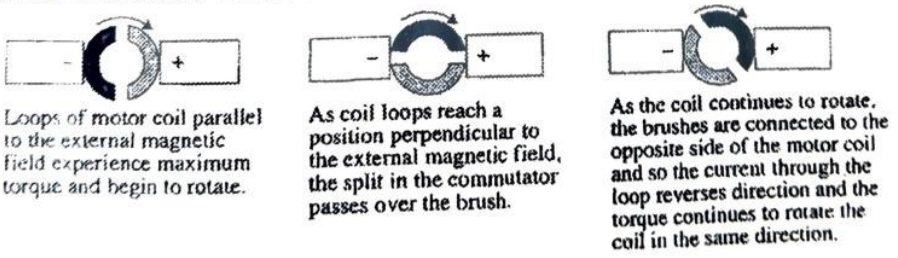
Question 28

a) Describe, including a diagram, the function of the split-ring commutator.

Criteria	Marks
- Describes the function of the split-ring commutator. - Utilises the included relevant diagram to support response.	3
- Outlines the function of the split-ring commutator. - Includes a relevant diagram.	2
- Outlines the function of the split-ring commutator. OR - Includes a relevant diagram.	1

Sample Answer

(a) For the torque to continue to act in the same direction, the current in a DC motor must reverse in direction as the plane of the coil reaches the position where it is perpendicular to the external magnetic field. The split in the commutator means that the potential difference reverses as the split passes between the contacting brush. In the diagram, the brushes are attached to the positive and negative terminals of the DC power supply. The darker section of the split ring is in contact with one end of the coil while the other lighter section is in contact with the other end of the coil.



b) What maximum torque acts on the motor coil?

Criteria	Marks
- Determines the maximum torque on the motor coil. - Correct units and formula.	2
- ANY one of the above.	1

Sample Answer

$$\tau = nBIA\sin\theta = (120 \times 0.25 \times 6.8) \times (0.15 \times 0.10)\sin 90° = 3.06 \text{ Nm}$$

The torque produced on the motor coil is $3.06\ Nm$.

Question 29

a) For the oscillating magnet, calculate the frequency and the energy of the oscillations during the time interval t = 0 to t = 6.0s. (Use $E = ½m\omega^2 y_0^2$ where y_0 is the maximum displacement)

Criteria	Marks
- Correctly calculates the frequency. - Correctly calculates the energy of the oscillations during the time interval t = 0 to t = 6.0s. - Correct units and significant figures.	3
- ANY two of the above.	2
- ANY one of the above.	1

Sample Answer

Frequency

$$f = \frac{1}{T} = \frac{1}{\frac{6.0}{2.5}} = 0.42\ Hz\ (2 significant figures)$$

Energy of oscillations during time interval t = 0 to t = 6.0s

$$E = \frac{1}{2} m\omega^2 y_0^2$$

$$= \frac{1}{2} m \left(\frac{2\pi}{T}\right)^2 (y_0^2)$$

$$= \frac{1}{2} m (2\pi f)^2 (y_0)^2$$

$$= \frac{1}{2} \times 0.25 \times 4\pi^2 \times \frac{1}{\frac{6.0}{2.5}}^2 \times (1.5 \times 10^{-2})^2$$

$$= 1.9 \times 10^{-4}\ J\ (2\ significant\ figures)$$

b) Explain with reference to the graph, whether the dampening is light, critical or heavy.

Criteria	Marks
- Correctly states that the dampening is light. - Provides evidence from the graph to support judgement.	2
- ANY one of the above.	1

Sample Answer

According to the graph, there is a *gradual* decrease in amplitude and so the dampening is light.

Question 30

a) Using Newtonian physics, calculate the kinetic energy (in eV) of a proton travelling at 3×10^8 ms^{-1}.

Criteria	Marks
- Correctly calculates the kinetic energy of a proton travelling at 3×10^8 ms^{-1}. - Correct units and formula.	2
- Correct units and formula.	1

Sample Answer

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

$= \frac{\frac{1}{2} (1.673 \times 10^{-27}) \times (3 \times 10^8)^2}{1.602 \times 10^{-19} \text{ eV}}$

$= 4.67 \times 10^8$ eV

b) A student makes the statement that "The maximum kinetic energy a proton can have is 4.7×10^8 eV because it can't travel faster than the speed of light."
Assess this statement on the basis of your answer to part (a).

Criteria	Marks
- States that the statement is true for Newtonian Physics. - Provides evidence to support judgement.	2
- States that the statement is true for Newtonian Physics.	1

Sample Answer

If a proton travelling at the speed of light (the speed for part (a)) has a kinetic energy of 4.67×10^8 eV then this appears to be its maximum kinetic energy. The statement appears to be true according to Newtonian Physics.

c) Particle accelerators can produce protons with kinetic energies greater than 3×10^{10} eV.
Discuss this in relation to your answer to part (b).

Criteria	Marks
- States that there is something incorrect in relation to Newtonian Physics. - Provides a reason for it to be incorrect.	2
- States that there is something incorrect in relation to Newtonian Physics.	1

Sample Answer

This is more than 60 times as great as calculated, therefore something must be incorrect. Relativity shows that as velocity approaches 'c' mass increases (relativistic momentum). The added energy goes into mass increase rather than velocity increase.

Question 31

Explain how the cosmic microwave background radiation supports the Big Bang theory for the start of the Universe. Comment on the relevance of the data shown below (See Question Paper) concerning the Big Bang theory.

Guidance

Big Bang Theory

1. Predict that all galaxies are receding.
2. Galaxy velocity proportional to distance from Earth.

Red Shift

3. Radiation from Virgo shows increase in wavelength or red shift.
4. Change in wavelength caused by motion of galaxy or reference to Doppler Effect.
5. Evidence that Virgo is receding from Earth.
6. Support for the Big Bang theory.

Blue Shift

7. Andromeda shows blue shift.
8. Andromeda approaching Earth
9. Caused by gravitational attraction.

Cosmic Microwave Background Radiation

10. Formed as gamma radiation at Big Bang
11. Galactic red shift to microwave wavelength
12. Intensity is uniform in all directions
13. Corresponds to a temperature of 2.7K
14. (Very small) ripples in intensity corresponding to formation of first stars or galaxies.

Criteria	Marks
- Includes all the above information (i.e. points 1-14) in a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.	6-7
- Includes points 1-8, 10. - Includes ANY three of the following points: 11-14. - Information presented is in the most-part relevant and supported by some evidence with some structure.	4-5
- Includes EITHER points 1 OR 2. - Includes points 3, 8. - Includes EITHER points 4 OR 7. - Includes AT LEAST one of the following points: 10-14. - The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.	2-3
- Provides some relevant information.	1

Question 31 (continued)

Sample Answer

Response should include the following information:

Big Bang Theory

1. Predict that all galaxies are receding.
2. Galaxy velocity proportional to distance from Earth.

Red Shift

3. Radiation from Virgo shows increase in wavelength or red shift.
4. Change in wavelength caused by motion of galaxy or reference to Doppler Effect.
5. Evidence that Virgo is receding from Earth.
6. Support for the Big Bang theory.

Blue Shift

7. Andromeda shows blue shift.
8. Andromeda approaching Earth
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Cosmic Microwave Background Radiation

10. Formed as gamma radiation at Big Bang
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12. Intensity is uniform in all directions
13. Corresponds to a temperature of 2.7K
14. (Very small) ripples in intensity corresponding to formation of first stars or galaxies.

Question 32

A racing car of mass 800 kg is driven around a banked circular racetrack at a constant speed of 180 km/h. The acceleration of the racing car is measured to be 4.0 ms^{-2}. Calculate the radius of the racetrack.

Criteria	Marks
- Utilises correct formulae. - Shows logical numerical reasoning. - Correctly calculates the radius of the racetrack. - Correct number of significant figures and units.	4
- ANY three of the above.	3
- ANY two of the above.	2
- ANY one of the above.	1

Sample Answer

$180\ km/h\ =\ 50\ m/s$

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

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

$= \frac{50^2}{4.0}$

$= 625$

$= 6.3 \times 10^2\ m$ (2 significant figures)

NOTE: Use of the centripetal force formula is also acceptable.

Question 33

a) Calculate the magnitude of the magnetic force between the wires if there is a current of 2.0A flowing in each of the wires.

Criteria	Marks
- Correctly calculates the magnitude of the magnetic force between the wires.	1

Sample Answer

$F_{mag} = k\frac{I_1 I_2}{d} l = 2 \times 10^{-7} \cdot \frac{2 \times 2}{1 \times 10^{-2}} \cdot 0.100 = 8.0 \times 10^{-6}\text{N}$

b) Without giving a numerical value, describe how the magnetic force between the wires would affect the reading on the balance.

Criteria	Marks
- Correctly describes how the magnetic force between the wires affects the reading on the balance.	1

Sample Answer

The two wires will be repelled from each other by the magnetic force. The force on the bottom wire will increase the reading on the balance.

c) School laboratory balances can measure accurately to a mass of 0.01g. (This is a weight force of about 0.0001N). A school balance would not be successful in the experiment. Explain why.

Criteria	Marks
- Provides the correct explanation as to why the school balance cannot be used for this experiment.	2
- Provides some relevant information.	1

Sample Answer

The school balance would not be suitable, as the change in the reading is of the order of 10^{-5} N. The balance is only sensitive to changes of the order of 10^{-4} N.

d) How could you modify the experiment so that the school balance could be used? Include quantities in your modification.

Criteria	Marks
- Provides two modifications that would be suitable for this experiment.	2
- Provides one modification that would be suitable for this experiment.	1

Sample Answer

The easiest way to increase the size of the forces would be to use coils of wire, rather than a single wire. Coils of 100 similar wires would increase the force to a value of 8×10^{-4} N, while keeping the current constant. This would register on the balance.

Using much higher currents (e.g. 20A each) and reduce separation of wires (e.g. to 2mm) would also provide for the same increase in the size of the forces.

Question 34

a) Define the term "binding energy".

Criteria	Marks
- Correctly defines “binding energy”.	1

Sample Answer

The binding energy is the minimum energy needed to split a nucleus into constituent parts.

b) Describe the source of this energy.

Criteria	Marks
- Relates mass defect to binding energy **through Einstein’s mass-energy equivalence ($E = mc^2$)**	2
- Provides some relevant information.	1

Sample Answer

The energy is related to the mass defect, that is, the mass of an atom is less than the sum of the masses of its components. The loss of mass is converted into binding energy (by Einstein’s mass-energy equivalence, $E = mc^2$).

c) Explain why this binding energy is necessary.

Criteria	Marks
- Explains the necessity of binding energy.	2
- Provides some relevant information.	1

Sample Answer

Protons are positively charged and so repel each other. To keep them together in the nucleus required a lower energy state – the binding energy.

NOTE: Could also relate to nuclear force of attraction.

d) Predict which nucleus is more stable, Helium-4 OR Lithium-6. Explain your reasoning.

Criteria	Marks
- Correctly identifies that Helium-4 is more stable. - Provides a succinct logical reason to draw this conclusion.	2
- Correctly identifies that Helium-4 is more stable. - Provides an unsuitable reason/no attempt at a reason.	1

Sample Answer

Helium-4 is more stable than Lithium-6 since it has a **higher binding energy per nucleon**. This means that each nucleon is held together more tightly in Helium-4 than in Lithium-6.

Question 35

Describe the key features and components of the Standard Model of Matter and analyse the role of particle accelerators in developing this model.

Criteria	Marks
- States what the Standard Model of Matter is. - States what matter is made up of. - States the names, number, generations and charges of quarks and what they constitute to. - States the names, number, generations and charges of leptons. - States the number, names and the forces bosons associate with. - States the role of particle accelerators and provides an example of one. - Links the role of particle accelerators to developing the Standard Model of Matter.	7
- ANY six of the above	6
- ANY five of the above	5
- ANY four of the above	4
- ANY three of the above	3
- ANY two of the above	2
- ANY one of the above	1

Sample Answer

The Standard Model is a theory which attempts to give order to the over 200 particles discovered (mainly through particle accelerator collisions) in the second half of the 20^{th} century.

Matter is made up of two fundamental particles – 6 quarks and 6 leptons.

The 6 quarks are made up of 3 generations: the up (u) and down (d) quarks with charges of +2/3 e and -1/3 e respectively make up the 1^{st} generation and are constituents of protons (uud) and neutrons (udd). Respective quarks in 2^{nd} and 3^{rd} generations are charm (c) and strange (s), top (t), and bottom (b) respectively.

The 6 leptons also are grouped into 3 generations. The electron is the 1^{st} generation lepton, the 2^{nd} and 3^{rd} being the muon and the tau. All 3 have a charge of -e. All 3 also have an associated neutrino (charge = 0) making a total of 6 leptons.

The 4 fundamental forces of nature are mediated by 4 boson-force carrier particles.

1. Photon -> Electromagnetic Force
2. Gluon -> Strong Force
3. Intermediate vector bosons (w^+, w^-, and Z^0) -> Weak Force (responsible for beta decay)
4. Graviton (yet to be discovered) -> Gravitational Force

Particle accelerators are complex machines that use electric and/or magnetic fields to accelerate charged particles to extremely high speeds (very close to the speed of light). An example is the large Hadron Collider (LHC) which uses both a linear accelerator and a synchrotron to achieve this.

Particle accelerators have been crucial in the development of the Standard Model as it is only through the high energy collisions made possible using particle accelerators such as the LHC that experimental evidence supporting the existence of 2^{nd} and 3^{rd} generation quarks and leptons have been confirmed (due to their very large masses – especially 3^{rd} generation).