NSW Education Standards Authority

Centre Number

Student Number

2023 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
- Write your Centre Number and Student Number at the top of this page

Total marks: 100

Section I – 20 marks (pages 2–13)

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

Section II – 80 marks (pages 17–39)

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

Section I

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

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

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1 The gravitational field strength acting on a spacecraft decreases as its altitude increases.

This is due to a change in the

A. mass of Earth.

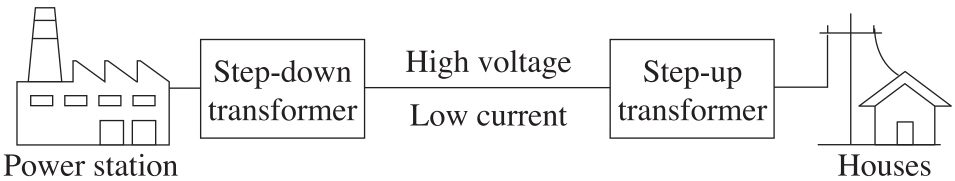
B. mass of the spacecraft.

C. density of the atmosphere.

D. distance of the spacecraft from Earth's centre.

2 Which diagram best represents the transmission of energy from a power station to people's houses?

A.



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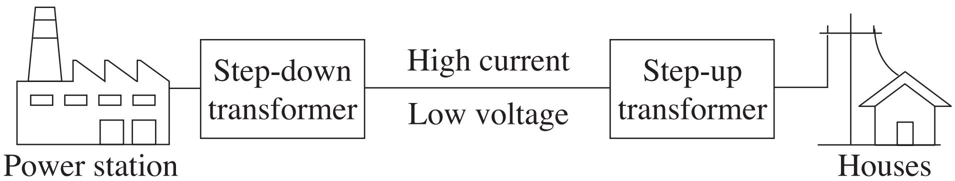

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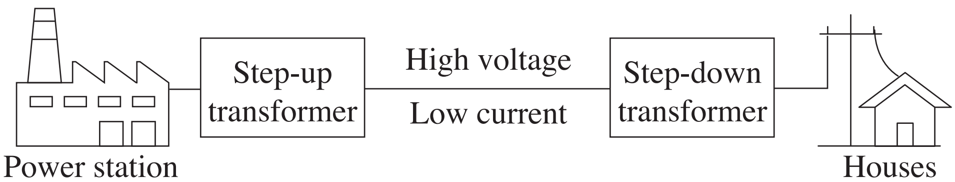

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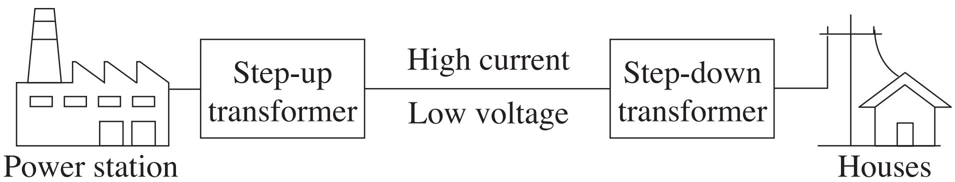
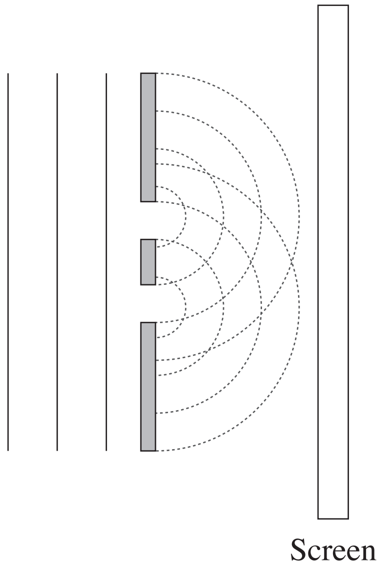


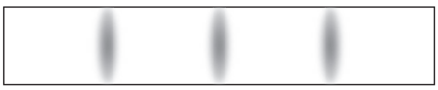
3 A diagram representing a double slit experiment using light is shown.



Which of the following best represents the expected pattern on the screen?

A. 

B. 

C. 

D. 

4 Caesium-137 has a half-life of 30 years.

What mass of caesium-137 will remain after 90 years, if the initial mass was 120 g?

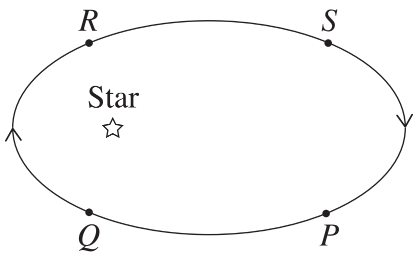
A. 4 g

B. 15 g

C. 40 g

D. 60 g

5 An exoplanet is in an elliptical orbit, moving in the direction shown. The distances between consecutive positions P, Q, R and S are equal.



Between which two points is the exoplanet's travel time the greatest?

A. P and Q

B. Q and R

C. R and S

D. S and P

6 An electron would produce an electromagnetic wave when it is

A. stationary.

B. in a stable hydrogen atom.

C. moving at a constant velocity.

D. moving at a constant speed in a circular path.

7 A proton and a neutron travel at the same speed.

Which statement correctly explains the difference between their de Broglie wavelengths?

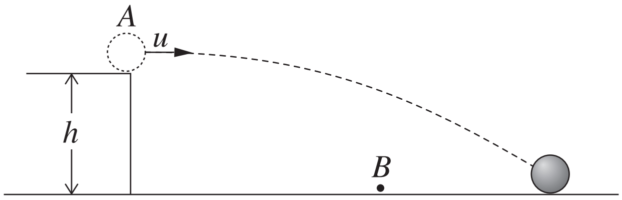
A. The proton has a longer wavelength because its mass is greater.

B. The proton has a shorter wavelength because its mass is smaller.

C. The neutron has a shorter wavelength because its mass is greater.

D. The neutron has a longer wavelength because its mass is smaller.

8 A ball is launched from a platform at position *A* with velocity *u*. It lands in the position shown.



The ball could be made to land at position *B* by increasing the

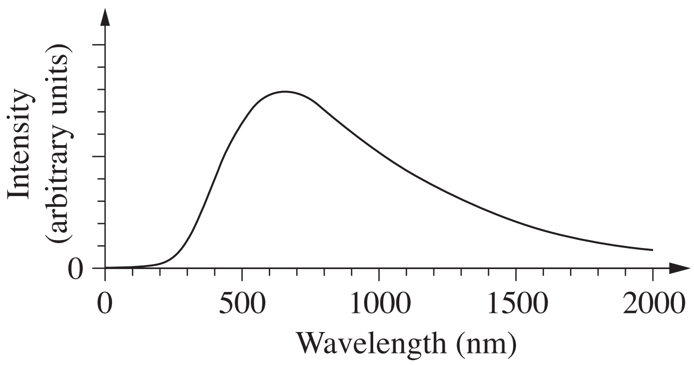
A. velocity *u*.

B. launch angle.

C. mass of the ball.

D. height of the platform.

9 The graph shows the relationship between radiation intensity and wavelength for a black body at 4500 K.



Which statement describes the expected difference in the graph for a black body at 4000 K?

A. Intensity at all wavelengths will be less.

B. Intensity at all wavelengths will be greater.

C. The peak intensity will occur at a higher frequency.

D. The peak intensity will occur at a shorter wavelength.

10 Figure I shows a current flowing through a loop of wire that is in a uniform magnetic field.

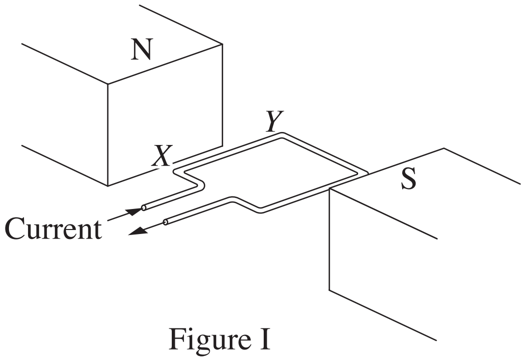


Figure I

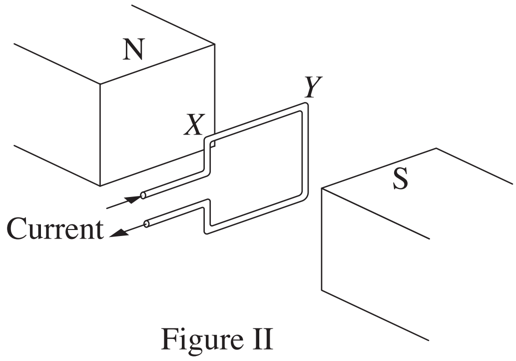


Figure II

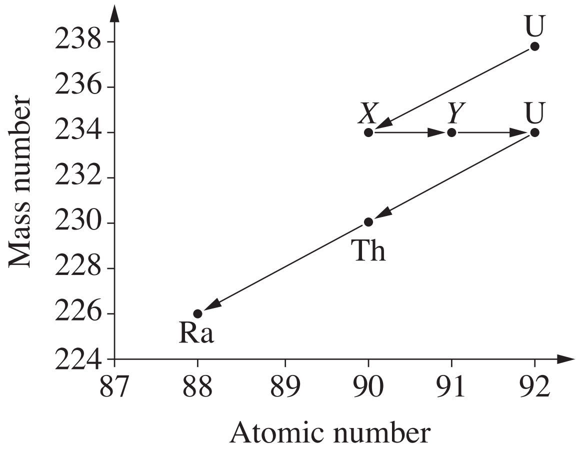
The loop is then rotated to the position shown in Figure II.

The magnitude of the force on the side *XY* and the magnitude of the torque on the loop in Figure II are compared to those in Figure I.

Which row of the table correctly describes the comparison?

	Force	*Torque*
A.	I > II	I = II
B.	I > II	I > II
C.	I = II	I = II
D.	I = II	I > II

11 The chart shows part of a nuclear decay series beginning with uranium.



Which option correctly identifies *X* and *Y* and the process by which each was produced?

	X	*Y*
A.	$^{234}_{90}Th$ alpha decay	$^{234}_{91}Pa$ beta decay
B.	$^{234}_{90}Th$ alpha decay	$^{234}_{91}Pa$ alpha decay
C.	$^{234}_{91}Pa$ beta decay	$^{234}_{90}Th$ beta decay
D.	$^{234}_{91}Pa$ beta decay	$^{234}_{90}Th$ alpha decay

12 Figure I shows a positively charged particle accelerating freely from X to Y, between oppositely charged plates. The change in the particle's kinetic energy is W.

The distance between the plates is then doubled as shown in Figure II. The same charge accelerates from rest over the same distance from X to Y.

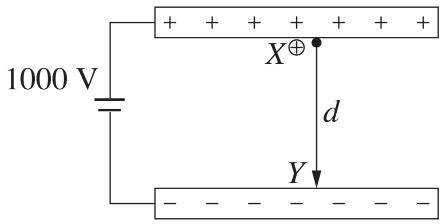


Figure I

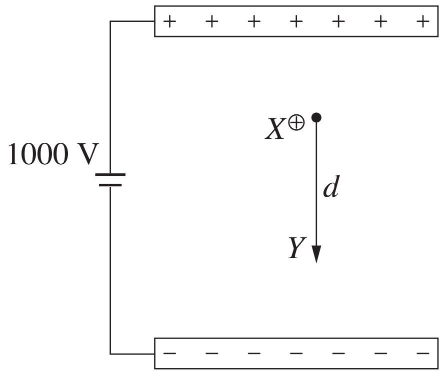


Figure II

What is the change in kinetic energy of the positively charged particle shown in Figure II?

A. W

B. $\frac{W}{2}$

C. $\sqrt{W}$

D. $2W$

13 Nucleus X has a greater binding energy than nucleus Y.

What can be deduced about X and Y?

A. X is more stable than Y.

B. Y is more stable than X.

C. X has a greater mass defect than Y.

D. Y has a greater mass defect than X.

14 Planet X has a mass 4 times that of Earth and a radius 3 times that of Earth. The escape velocity at the surface of Earth is $11.2\ \text{km s}^{-1}$.

What is the escape velocity at the surface of planet X?

A. $8.40\ \text{km s}^{-1}$

B. $9.70\ \text{km s}^{-1}$

C. $12.9\ \text{km s}^{-1}$

D. $14.9\ \text{km s}^{-1}$

15 What evidence resulting from investigations into the photoelectric effect is consistent with the model of light subsequently proposed by Einstein?

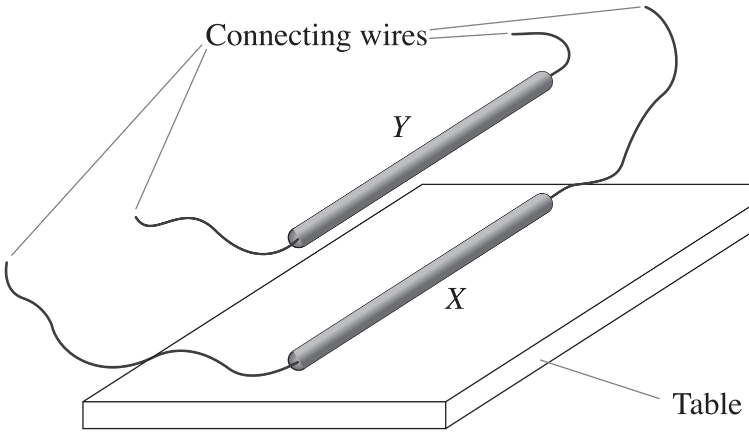
A. Photoelectrons were only ejected from a metal if the light was less than a specific wavelength.

B. Increasing the intensity of light on a metal increased the maximum kinetic energy of the photoelectrons.

C. If photons had sufficient energy to eject photoelectrons from a metal, the maximum kinetic energy was independent of the type of metal used.

D. The probability of photoelectrons being emitted from a metal was proportional to the duration of exposure to light for any given wavelength used.

16 In a thought experiment, two identical parallel aluminium rods, *X* and *Y*, are carrying electric currents of equal magnitude. Rod *X* rests on a table. Rod *Y* remains stationary, vertically above *X*, as a result of the magnetic interaction. The masses of the connecting wires are negligible.



Which statement must be correct if rod *Y* is stationary?

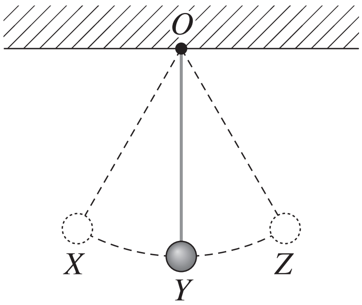
A. The magnetic force acting on *X* is upward.

B. The currents through *X* and *Y* are in the same direction.

C. The force the table exerts on *X* is equal and opposite to the total weight of *X* and *Y*.

D. The force the table exerts on *X* is equal and opposite to the force of gravity acting on *Y*.

17 A mass attached to a lightweight, rigid arm hanging from point *O*, oscillates freely between *X* and *Z*.



Which statement best describes the torque acting on the arm as it oscillates?

A. It is constant in magnitude and direction.

B. It is zero at *Y* and a maximum at *X* and *Z*.

C. It is zero at *X* and *Z* and a maximum at *Y*.

D. It is constant in magnitude but its direction changes.

18 The diagrams show the trajectories of two particles with the same mass and charge and which initially have the same velocity u, as shown. The subsequent motion of each particle is determined by its properties and by its interaction with the field in which it is moving.

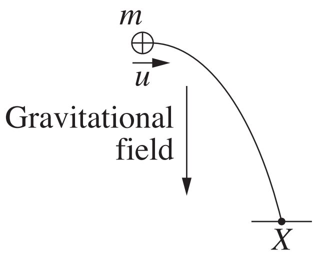


Figure I

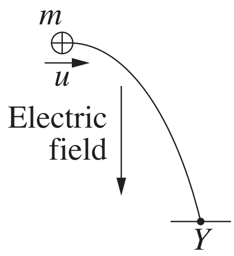
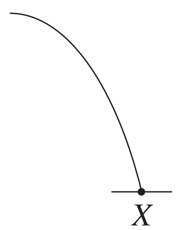
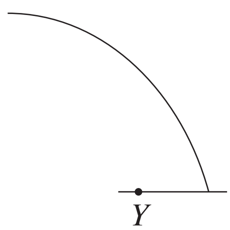
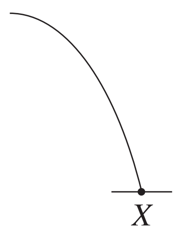
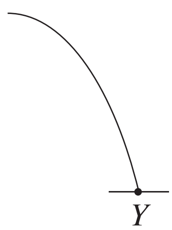
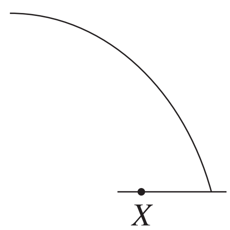
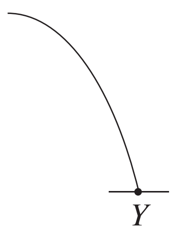
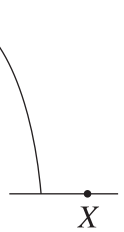
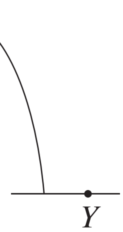


Figure II

X and Y represent the landing points in Figures I and II.

Which row of the table shows the correct paths of the particles if the mass of each is increased by the same amount and they are given the same initial velocity u?

	Gravitational field	Electric field
A.		
B.		
C.		
D.		

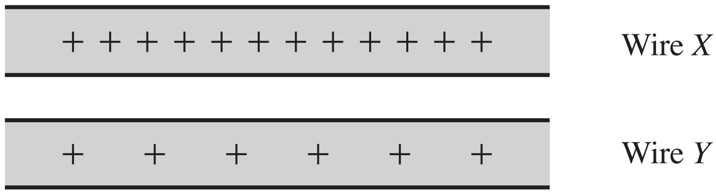
19 The diagram represents the distribution of positive charges in identical wires when no current is flowing.

Equal currents then flow in each wire, but in opposite directions. These currents are considered conventionally as the flow of positive charge.

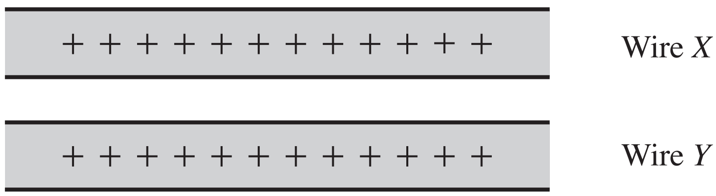
Which diagram represents the charge distribution in the wires, from the frame of reference of a positive charge in wire Y?

A.

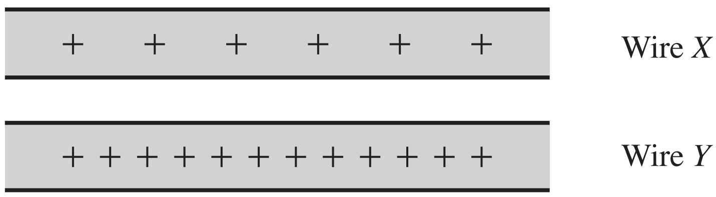
B.



C.



D.

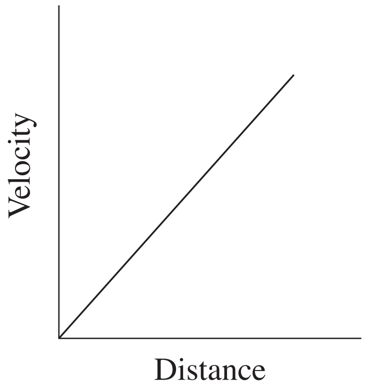


20 In 1995, observational evidence showed that Hubble's description of the expansion of the universe was inaccurate.

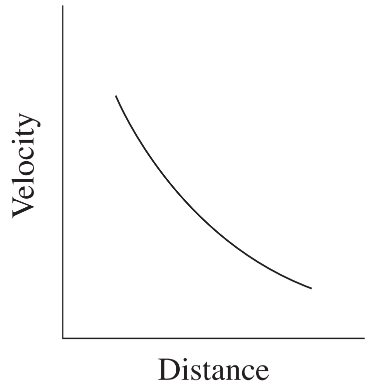
It was discovered that the expansion of the universe was accelerating. This discovery was based on observations of light from galaxies whose distances from Earth could be accurately measured, and were significantly more distant than any observed by Hubble.

Which graph relating velocities of galaxies to their distances from Earth is consistent with an accelerating rate of expansion of the universe?

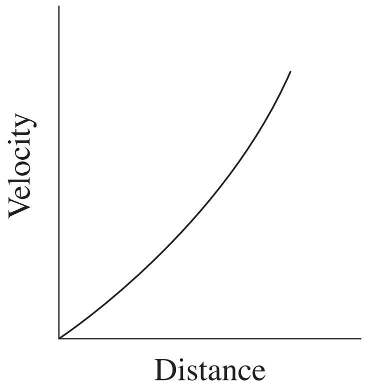
A.



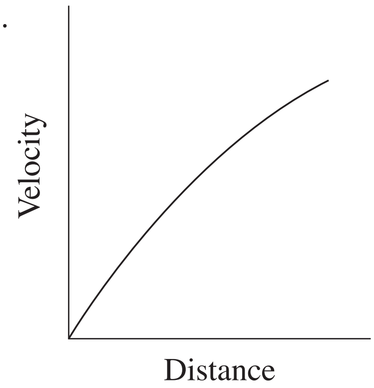
B.



C.



D.



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2023 HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Student Number

Physics

Section II Answer Booklet

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80 marks
Attempt Questions 21–34
Allow about 2 hours and 25 minutes for this section

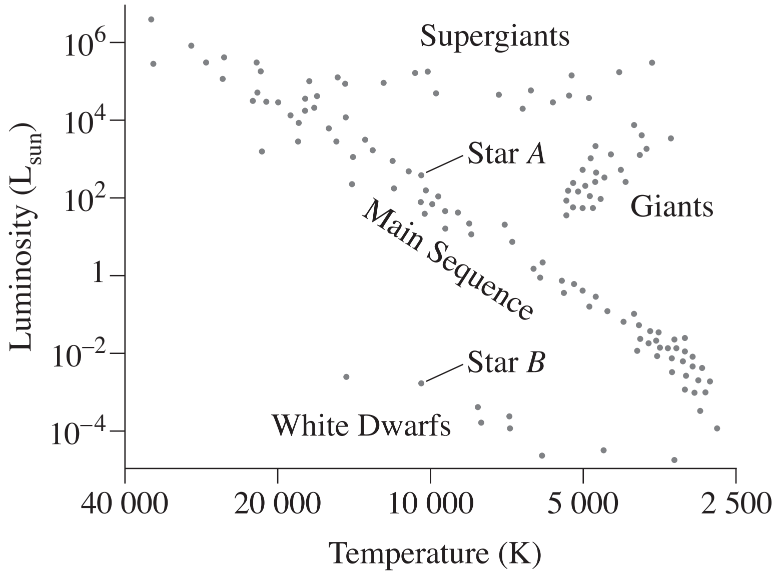
Instructions

- 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 (5 marks)

A Hertzsprung–Russell diagram is shown.



(a) Identify TWO variables that determine the luminosity of a star. **2**

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(b) Describe differences between stars *A* and *B*. **3**

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Question 22 (3 marks)

A spacecraft passes Earth at a speed of $0.9c$. The spacecraft emits a light pulse every 3.1×10^{-9} s, as measured by the crew on the spacecraft. **3**

What is the time between the pulses, as measured by an observer on Earth?

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Please turn over

Question 23 (7 marks)

The James Webb Space Telescope (JWST) has a mass of 6.1×10^3 kg and orbits the Sun at a distance of approximately 1.52×10^{11} m.

(a) The Sun has a mass of 1.99×10^{30} kg. **2**

Calculate the magnitude of gravitational force the Sun exerts on the JWST.

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(b) The telescope is sensitive to wavelengths from 6.0×10^{-7} m to 2.8×10^{-5} m. **3**

What is the minimum photon energy that it can detect?

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(c) The JWST observed an exoplanet emitting a peak wavelength of 1.14×10^{-5} m. **2**

Calculate the temperature of the exoplanet.

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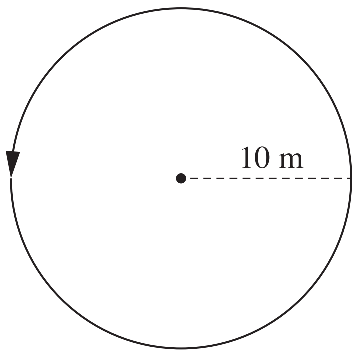
Question 24 (3 marks)

An electron is travelling at 3.0×10^6 m s^{-1} in the path shown. **3**



Calculate the magnetic field required to keep the electron in the path.

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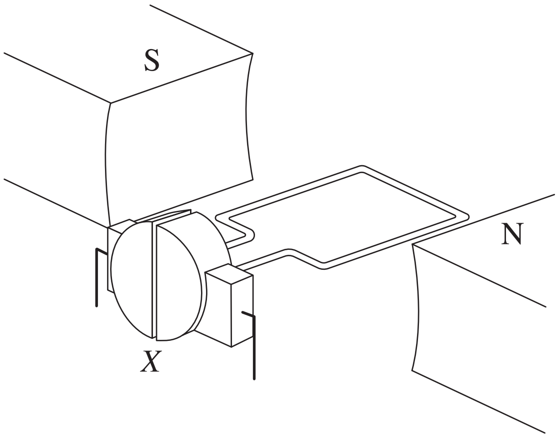
Please turn over

Question 25 (4 marks)

(a) The diagram represents one type of electric motor. **2**



Describe the function of part *X*.

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(b) Explain why the torque of a DC motor decreases as its rotational speed increases. **2**

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Question 26 (3 marks)

Consider the following nuclear reaction. **3**

$$^{12}_{6}\mathrm{C} + ^{1}_{1}\mathrm{H} \longrightarrow ^{9}_{5}\mathrm{B} + ^{4}_{2}\mathrm{He}$$

The masses of the isotopes in this process are shown in the table.

Isotope	*Mass* (*u*)
$^{12}_{6}\mathrm{C}$	12.064
$^{9}_{5}\mathrm{B}$	9.013
$^{4}_{2}\mathrm{He}$	4.003
$^{1}_{1}\mathrm{H}$	1.008

Calculate the energy released in this reaction.

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Question 27 (8 marks)

(a) Explain how the composition and temperature of a star can be determined from its spectrum. **4**

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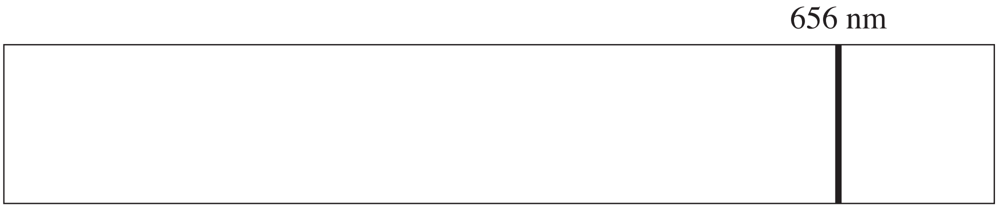
Question 27 continues on page 25

Question 27 (continued)

(b) The diagram represents one hydrogen emission line from the spectrum of a star. **4**



Explain the changes to this spectral line that would be observed as a result of the star's rotational velocity. Modify the diagram to support your answer.

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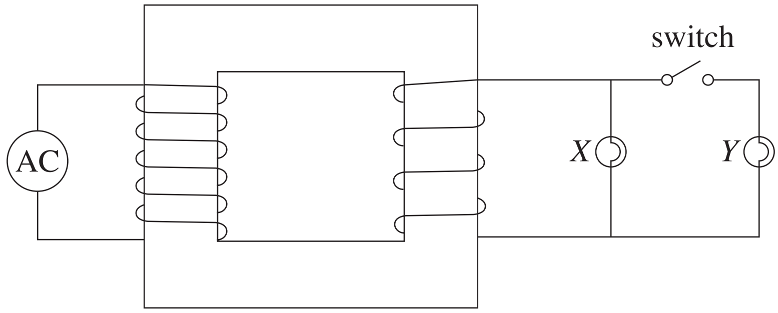
End of Question 27

Question 28 (5 marks)

An ideal transformer is connected to a 240 V AC supply. It has 300 turns on the primary coil and 50 turns on the secondary coil.

It is connected in the circuit with two identical light globes, *X* and *Y*, as shown.



(a) Calculate the voltage across light globe *X* when the switch is open. **2**

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(b) Explain why, after the switch has been closed, the current in the primary coil is different from when the switch is open. **3**

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Question 29 (4 marks)

When light from an incandescent lamp is passed through a plane polarising filter, the intensity of the light is reduced. **4**

Explain this phenomenon.

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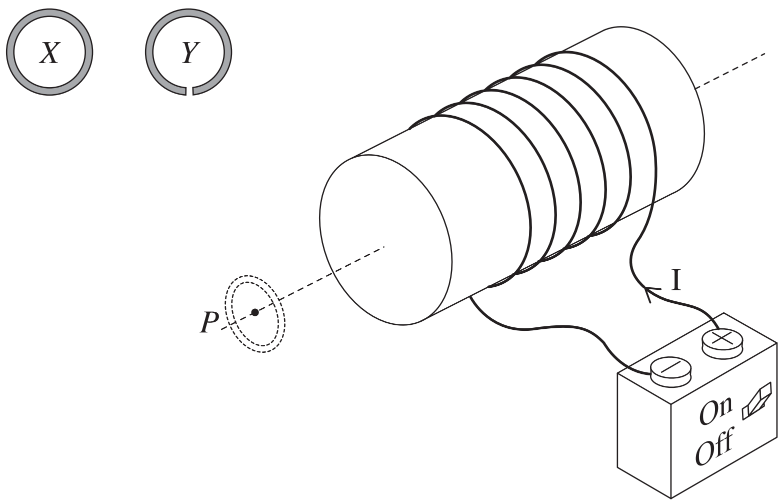
Please turn over

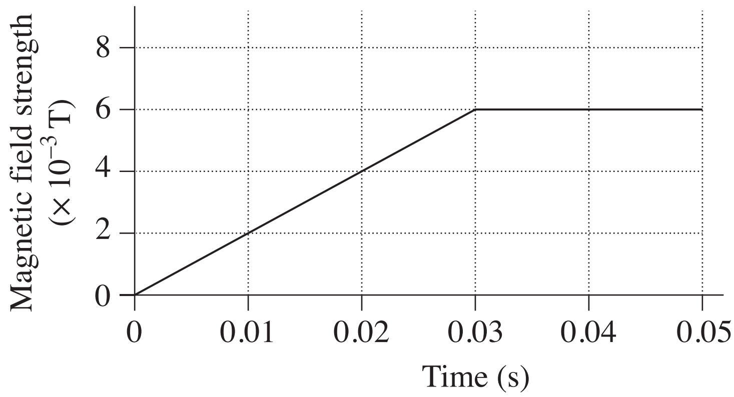
Question 30 (8 marks)

The diagram shows apparatus that is used to investigate the interaction between the magnetic field produced by a coil and two copper rings X and Y, when each is placed at position P, as shown.



Ring X is a complete circular ring, and a small gap has been cut in ring Y. Each of the rings has a cross-sectional area of 4×10^{-4} m^2.

The power supply connected to the coil produces an increasing current through the coil in the direction shown, when the switch is turned on. This produces a magnetic field at P that varies as shown in the graph.



Question 30 continues on page 29

Question 30 (continued)

(a) In the first part of the investigation, ring X is held near the end of the electromagnet at position P. **4**

Account for the force acting on the ring from 0 to 0.05 seconds after the power supply is turned on.

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(b) (i) In the second part of the investigation, ring Y is placed at P, and the power supply is turned on. **2**

Explain the behaviour of the ring.

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(ii) Calculate the maximum induced emf in ring Y. **2**

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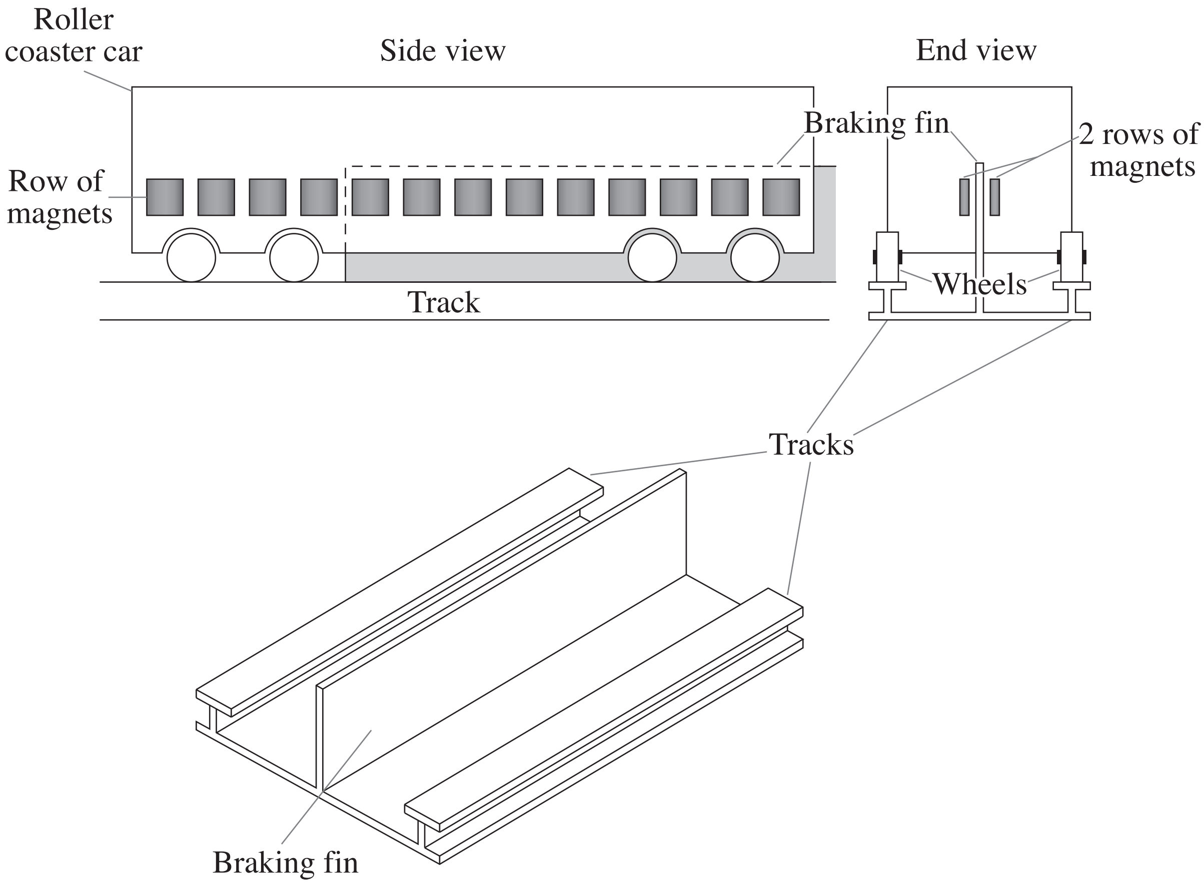
End of Question 30

Question 31 (5 marks)

A roller coaster uses a braking system represented by the diagrams. **5**

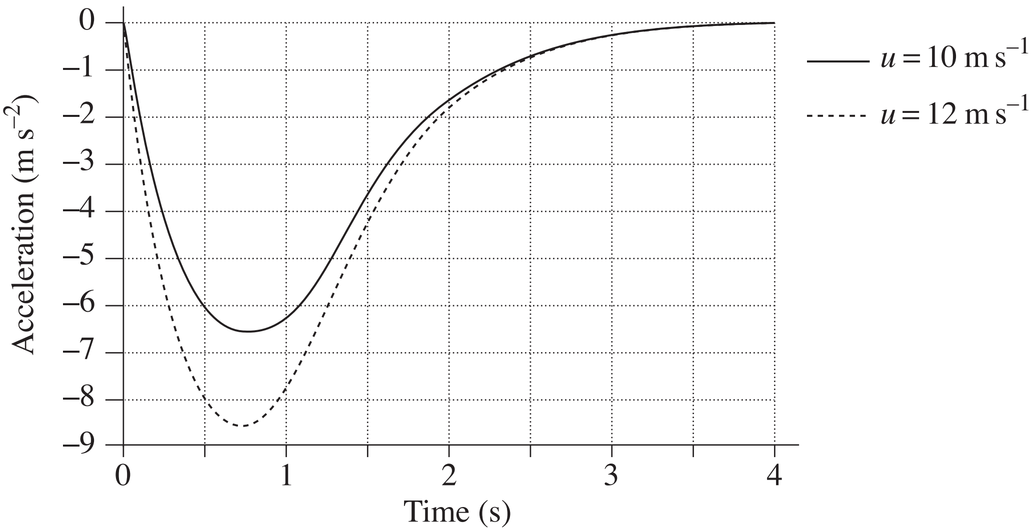


When the roller coaster car reaches the end of the ride, the two rows of permanent magnets on the car pass on either side of a thick aluminium conductor called a braking fin.

Question 31 continues on page 31

Question 31 (continued)

The graph shows the acceleration of the roller coaster reaching the braking fin at two different speeds.



Explain the similarities and differences between these two sets of data.

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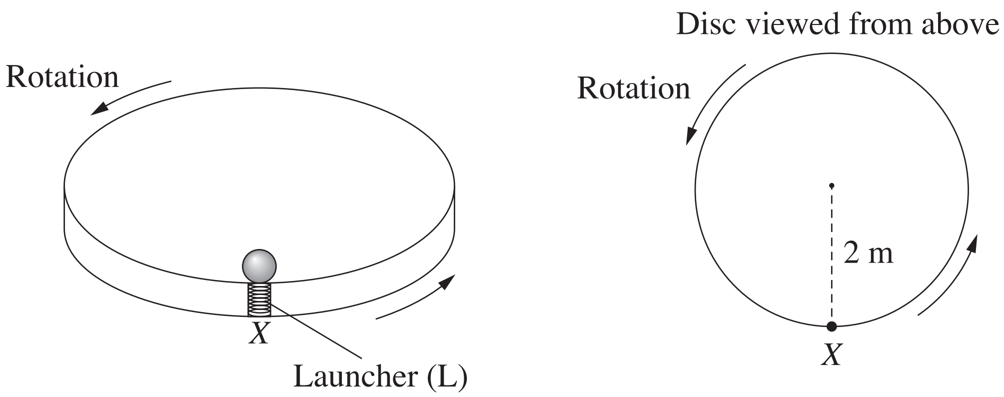
End of Question 31

Question 32 (7 marks)

A horizontal disc rotates at 3 revolutions per second around its centre, with the top of the disc at ground level. **7**

At 2 m from the centre of the disc, a ball is held in place at ground level on the top of the disc by a spring-loaded projectile launcher. At position X, the launcher fires the ball vertically upward with a velocity of 5.72 m s^{-1}.



Calculate the ball's position relative to the launcher's new position, at the instant the ball hits the ground.

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Question 33 (9 marks)

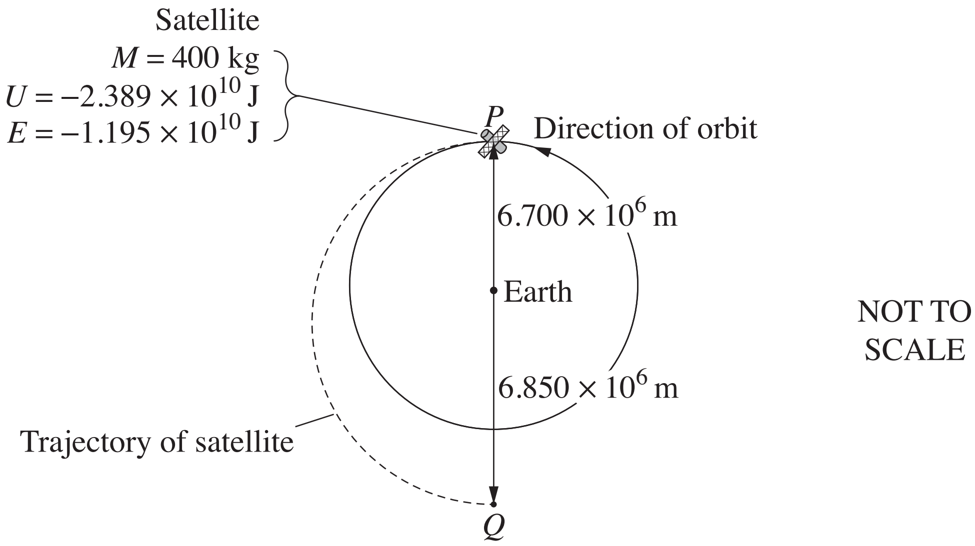
Consider the following statement. **9**

> The interaction of subatomic particles with fields, as well as with other types of particles and matter, has increased our understanding of processes that occur in the physical world and of the properties of the subatomic particles themselves.

Justify this statement with reference to observations that have been made and experiments that scientists have carried out.

Question 34 (9 marks)

A 400 kg satellite is travelling in a circular orbit of radius 6.700×10^6 m around Earth. Its potential energy is -2.389×10^{10} J and its total energy is -1.195×10^{10} J.



At point P, the satellite's engines are fired, increasing the satellite's velocity in the direction of travel and causing its kinetic energy to increase by 5.232×10^8 J. Assume that this happens instantaneously and that the engine is then shut down.

The satellite follows the trajectory shown, which passes through Q, 6.850×10^6 m from Earth's centre.

(a) Analyse qualitatively the energy changes as the satellite moves from P to Q. **2**

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Question 34 continues on page 35

Question 34 (continued)

(b) Show that the kinetic energy of the satellite at Q is 1.194×10^{10} J. **4**

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(c) Explain the motion of the satellite after it passes through Q. **3**

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Physics

DATA SHEET

Charge on electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	340 m s^{-1}
Earth's gravitational acceleration, g	9.8 m s^{-2}
Speed of light, c	$3.00 \times 10^{8} \text{ m s}^{-1}$
Electric permittivity constant, ε_0	$8.854 \times 10^{-12} \text{ A}^2 \text{ s}^4 \text{ kg}^{-1} \text{ m}^{-3}$
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7} \text{ N A}^{-2}$
Universal gravitational constant, G	$6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
Mass of Earth, M_E	6.0×10^{24} kg
Radius of Earth, r_E	6.371×10^{6} m
Planck constant, h	6.626×10^{-34} J s
Rydberg constant, R (hydrogen)	$1.097 \times 10^{7} \text{ m}^{-1}$
Atomic mass unit, u	1.661×10^{-27} kg $931.5 \text{ MeV}/c^2$
1 eV	1.602×10^{-19} J
Density of water, ρ	$1.00 \times 10^{3} \text{ kg m}^{-3}$
Specific heat capacity of water	$4.18 \times 10^{3} \text{ J kg}^{-1} \text{ K}^{-1}$
Wien's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

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

$$v = u + at$$

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

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

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

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

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

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

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

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

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

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

$$a_{\text{c}} = \frac{v^2}{r}$$

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

$$F_{\text{c}} = \frac{mv^2}{r}$$

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

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

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

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

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

Waves and thermodynamics

$$v = f\lambda$$

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

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

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

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

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

$$n_{\text{x}} = \frac{c}{v_{\text{x}}}$$

$$\sin\theta_{\text{c}} = \frac{n_2}{n_1}$$

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

$$I_1r_1^2 = I_2r_2^2$$

$$Q = mc\Delta T$$

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

Electricity and magnetism

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

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

$$W = qV$$

$$W = qEd$$

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

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

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

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

$$\frac{V_\mathrm{p}}{V_\mathrm{s}} = \frac{N_\mathrm{p}}{N_\mathrm{s}}$$

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

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

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

$$V = IR$$

$$P = VI$$

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

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

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

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

$$V_\mathrm{p} I_\mathrm{p} = V_\mathrm{s} I_\mathrm{s}$$

Quantum, special relativity and nuclear

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

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

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

$$E = mc^2$$

$$E = hf$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_\mathrm{f}^2} - \frac{1}{n_\mathrm{i}^2}\right)$$

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

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

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

$$N_\mathrm{t} = N_0 e^{-\lambda t}$$

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

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

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

Standard atomic weights are abridged to four significant figures.
Elements with no reported values in the table have no stable nuclides.
Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).
The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

2023 HSC Physics
Marking Guidelines

Section I

Multiple-choice Answer Key

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

Section II

Question 21 (a)

Criteria	Marks
• Identifies TWO variables that determine the luminosity of a star	2
• Identifies ONE variable that determines the luminosity of a star	1

Sample answer:

The luminosity of a star is determined by the size and temperature of the star.

Answers could include:

- Star colour
- Mass of a star
- Surface area of a star
- Power output of the star

Question 21 (b)

Criteria	Marks
• Describes differences between Star *A* and Star *B*	3
• Identifies features of Star *A* and/or Star *B*	2
• Provides some relevant information	1

Sample answer:

Star *A* is a main sequence star and is fusing hydrogen into helium, whereas no nuclear reactions are taking place in Star *B* which is a white dwarf. Star *A* has a greater luminosity than Star *B*.

Answers could include:

- Radius
- Composition
- Mass

Question 22

Criteria	Marks
• Calculates the time between the pulses, relative to an observer on Earth	3
• Provides some correct steps in calculating the time between the pulses, relative to an observer on Earth	2
• Provides some relevant information	1

Sample answer:

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

$$= \frac{3.1\times 10^{-9}}{\sqrt{1-0.9^2}}$$

$$= 7.1\times 10^{-9}\,\text{s}$$

Question 23 (a)

Criteria	Marks
• Calculates the magnitude of gravitational force	2
• Provides some relevant information	1

Sample answer:

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

$$= \frac{6.67\times 10^{-11}\times 1.99\times 10^{30}\times 6.1\times 10^{3}}{\left(1.52\times 10^{11}\right)^2}$$

$$= 35\,\text{N}$$

Question 23 (b)

Criteria	Marks
• Calculates the minimum photon energy the telescope can detect	3
• Provides some correct steps in calculating the minimum photon energy	2
• Provides some relevant information	1

Sample answer:

$$
\begin{aligned}
E &= hf \\
&= \frac{hc}{\lambda} \\
&= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{2.8 \times 10^{-5}} \\
&= 7.1 \times 10^{-21}\ \text{J}
\end{aligned}
$$

Question 23 (c)

Criteria	Marks
• Calculates the temperature of the exoplanet	2
• Provides some relevant information	1

Sample answer:

$$\lambda = \frac{b}{T}$$

$$
\begin{aligned}
T &= \frac{b}{\lambda} \\
&= \frac{2.898 \times 10^{-3}}{1.14 \times 10^{-5}} \\
&= 254\ \text{K}
\end{aligned}
$$

Question 24

Criteria	Marks
• Calculates the required magnetic field	3
• Provides some correct steps in calculating the required magnetic field	2
• Provides some relevant information	1

Sample answer:

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

$$B = \frac{mv}{rq}$$

$$= \frac{\left(9.109 \times 10^{-31} \times 3.0 \times 10^{6}\right)}{10 \times 1.602 \times 10^{-19}}$$

$$= 1.7 \times 10^{-6}\ \text{T out of the page}$$

Question 25 (a)

Criteria	Marks
• Describes the function of part *X*	2
• Provides some relevant information	1

Sample answer:

Its function is to reverse the current in the loop, so that the loop continues in the same direction.

Question 25 (b)

Criteria	Marks
• Explains why the torque decreases	2
• Provides some relevant information	1

Sample answer:

As the speed increases, the back emf increases reducing the motor current and hence the torque.

Question 26

Criteria	Marks
• Calculates the energy released	3
• Provides some correct steps in calculating the energy released	2
• Provides some relevant information	1

Sample answer:

$$\begin{aligned}\Delta m &= m_p - m_r \\ &= (9.013u + 4.003u) - (12.064u + 1.008u) \\ &= -0.056u\end{aligned}$$

Hence $0.056 \times 931.5 = 52.16$ MeV

Answers could include:

8.356×10^{-12} J

Question 27 (a)

Criteria	Marks
• Explains how the composition and temperature of a star can be determined from its spectrum	4
• Explains how the composition OR temperature of a star can be determined by its spectrum	3
• Identifies features of a star's spectrum	2
• Provides some relevant information	1

Sample answer:

Composition can be deduced by looking at the absorption and emission spectra, because the lines present are unique for each element.

Temperature of the surface of the star can be determined from the measurement of the wavelength at which the radiation is at its peak intensity. This is because as a black body, this wavelength is related to its temperature.

Answers could include:

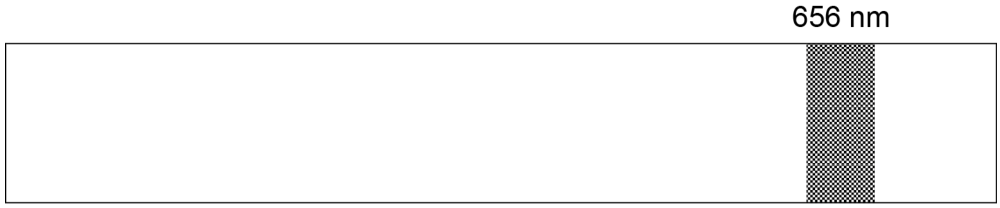
Presence of certain elements as an indication of temperature

Question 27 (b)

Criteria	Marks
• Explains the changes that would be observed in the spectral line AND correctly modifies the diagram	4
• Explains the effect of the star's rotation on the light detected	3
• Describes features in relation to the motion of the star OR correctly modifies the diagram	2
• Provides some relevant information	1

Sample answer:

As the star rotates on its axis, light on the side of the star approaching Earth is blue-shifted and the light on the receding side is red-shifted. Light from the centre is not Doppler shifted, as it is not approaching or receding. Because this effect increases towards the edges of the star, this will appear on the spectrum as shown.



Answers could include:

The motion of a star in a binary system

Question 28 (a)

Criteria	Marks
• Calculates the voltage output when the switch is open	2
• Shows a correct substitution	1

Sample answer:

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

$$= 240 \times \frac{50}{300}$$

$$= 40 \text{ V}$$

Question 28 (b)

Criteria	Marks
• Relates the increase in current in the primary coil to the conservation of energy in the transformer	3
• Makes a correct statement about the conservation of energy in the coils	2
• Provides some relevant information	1

Sample answer:

With the switch closed, the lamps *X* and *Y* are in parallel, the total resistance is less than the resistance of lamp *X* alone. Therefore, the current through the secondary coil is greater when the switch is closed.

Since power out = power in, the current in the primary coil is greater when the switch is closed.

Question 29

Criteria	Marks
• Relates the interaction between the filter and differing planes of oscillation of the electromagnetic waves to the reduction of light intensity	4
• Relates the differing planes of polarisation of the light to the absorption of radiation by the polarising filter	3
• Outlines a relevant feature of light from an incandescent lamp OR • Outlines a feature of the interaction of electromagnetic radiation with a polarising filter	2
• Provides some relevant information	1

Sample answer:

Light from an incandescent lamp is unpolarised.

A polarising filter absorbs the component of the electric field of the electromagnetic wave that are not parallel to the polarisation direction of the filter.

The intensity of the light would be reduced as only the parallel components will pass through the filter.

Question 30 (a)

Criteria	Marks
• Relates the repulsive force, and the absence of force, on the ring to the induced current in the ring caused by the flux variation from the coil, and the interaction of the magnetic fields	4
• Relates some aspects of the force on the ring to electromagnetic induction	3
• Identifies electromagnetic induction in the ring	2
• Provides some relevant information	1

Sample answer:

From 0 to 0.03 seconds the magnetic field strength of the coil increases at a constant rate.

Hence the flux through ring *X* induces an electric current around the ring which produces a field that opposes the field of the coil, causing a repulsive force on ring *X*.

From 0.03 s to 0.05 s, the flux through the ring is constant and so no current is induced in the ring and hence there is no force of magnetic origin acting on ring *X*.

Question 30 (b) (i)

Criteria	Marks
• Explains the effect of the magnetic field on the ring	2
• Provides some relevant information	1

Sample answer:

The ring does not move because the gap in the ring means no current will flow. Therefore, there is no force on the ring.

Answers could include:

Reference to the production of eddy currents in the ring.

Question 30 (b) (ii)

Criteria	Marks
• Correctly calculates the voltage	2
• Makes any correct substitution into an appropriate formula	1

Sample answer:

$$\text{emf} = \frac{\Delta\varphi}{\Delta t}$$

$$= \frac{6 \times 10^{-3} \times 4 \times 10^{-4}}{3 \times 10^{-2}}$$

$$= 8 \times 10^{-5} \text{ volts}$$

Question 31

Criteria	Marks
• Explains the similarities and differences between the two sets of data	5
• Explains the similarities in the data sets AND describes the difference(s) OR • Explains the differences in the data sets AND describes the similaritie(s)	4
• Demonstrates some understanding of the similarities AND/OR differences between the data sets	3
• Compares features of the two sets of data	2
• Provides some relevant information	1

Sample answer:

Both lines have a similar shape which represents that the similarities are:

- The increasing engagement with the braking fin in both cases until it reaches a maximum at approximately 0.8 s. This is caused by more magnets engaging with the fin, causing a greater flux change in the fin, causing an increasing braking effect.
- After maximum braking, both cases have a reduction in braking due to slowing down of the roller coaster, meaning less opposing eddy currents are produced.

The differences are:

- The faster case has a greater maximum braking, because the high speed of the roller coaster created a greater maximum change in flux.
- The faster case also has greater braking for most of the time, until 3 s. This is because it is travelling faster and creating greater opposing eddy currents than in the slower case.

Answers could include:

Difference in the rate of change of acceleration between the cases.

Question 32

Criteria	Marks
• Calculates the position of the ball relative to the launcher's position	7
• Provides substantial working to calculate the range of the ball and the position of the launcher	5–6
• Provides some correct calculations in determining the range of the ball and the position of the launcher	3–4
• Describes the trajectory of the ball OR the motion of the launcher	2
• Provides some relevant information	1

Sample answer:

Calculating u_x

$$u_x = v_L = \frac{2\pi r}{t} = \frac{2\pi \times 2}{0.334} = 37.62\,\text{m}\,\text{s}^{-1}$$

Noting t is the time for one revolution.

$$u_y = 5.72\,\text{m}\,\text{s}^{-1}$$

Calculating time of flight from $v = u + at$

$$t = \frac{-2u_y}{-9.8} = 1.167\,\text{s}$$

Range:

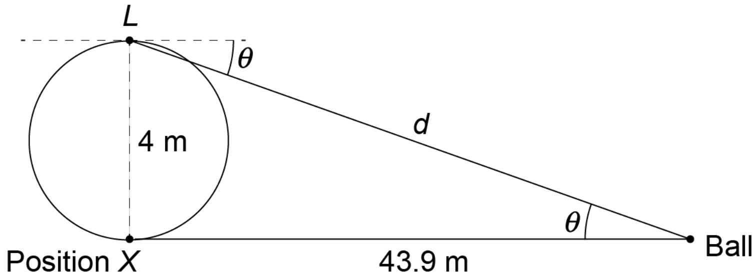
$$\begin{aligned} s &= u_x t \\ &= 37.62 \times 1.167 \\ &= 43.90\,\text{m} \end{aligned}$$

Calculating position L after t:

$$\Delta\theta = 3 \times \frac{rev}{\text{sec}} \times 1.167\text{ s} = 3.50$$

So L ends up half a revolution away from original position.

Calculating relative positions:



NOT TO SCALE

$$d = \sqrt{\left(43.9^2 + 4^2\right)} = 44.08\text{ m} \text{ from the launcher}$$

$$\theta = \tan^{-1}\left(\frac{4}{43.9}\right) = 5.2^\circ$$

Answers could include:

Variations in methods to calculate quantities and rounding leading to distances up to ≈ 44.20 m and θ down to ≈ 5.11°.

Question 33

Criteria	Marks
• Provides a reasoned detailed justification for the statement with explanation referencing at least TWO observations and at least TWO experiments	9
• Provides a justification for the statement with explanation referencing at least TWO observations and at least TWO experiments	7–8
• Provides a justification for the statement with an explanation of an observation/experiment of particle–field interactions and an observation/experiment of particle–particle interactions	5–6
• Provides details of TWO experiments or observations and how they relate to the statement	3–4
• Relates the statement to an experiment or observation OR • Describes relevant experiments or observations	2
• Provides some relevant information	1

Answers could include:

Reference to

- Thomson's experiment (particle–field) – q/m ratio of the electron
- Millikan's experiment (particle–field) – q of electron
- Photoelectric observations/experiments (particle–field) – quantum nature of light
- Particle accelerator observations/experiments (particle–particle and particle–field) – discovery of quarks and the standard model
- Chadwick's experiment (particle–particle) – neutron
- Geiger–Marsden (particle–particle) – nucleus
- Nuclear radiation experiment (particle–field) – charge of nuclear radiation
- Nuclear decay observations (particle–particle) – nature of the nucleus
- Davisson–Germer experiment (particle–particle) – wave nature of matter
- Observations of muons (particle–particle) – standard model, special relativity

And other related experiments/observations.

Question 34 (a)

Criteria	Marks
• Analyses qualitatively the energy changes as the satellite moves	2
• Provides some relevant information	1

Sample answer:

As the satellite moves, its kinetic energy decreases and is transformed into an increasing gravitational potential energy, consistent with the law of conservation of energy.

Question 34 (b)

Criteria	Marks
• Shows the kinetic energy is equal to 1.194×10^{10} J	4
• Provides calculations which show understanding of the system	3
• Provides a relevant calculation OR • Relates conservation of energy to the system	2
• Provides some relevant information	1

Sample answer:

Due to conservation of energy

$$E_Q = U_Q + K_Q = E_P + K_{engine}$$

$$\therefore K_Q = E_P + K_{engine} - U_Q$$

$$\text{So } U_Q = -\frac{GMm}{r} = -\frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 400}{6.85 \times 10^6}$$

$$= -2.337 \times 10^{10}$$

$$\therefore K_Q = -1.195 \times 10^{10} + 5.232 \times 10^8 - \left(-2.337 \times 10^{10}\right)$$

$$= 1.194 \times 10^{10}\,\text{J}$$

Question 34 (c)

Criteria	Marks
• Explains the motion of the satellite after it passes through *Q*	3
• Outlines the motion of the satellite with reference to relevant physics principles	2
• Provides some relevant information	1

Sample answer:

As it passes *Q*, the satellite has a velocity that exceeds the orbital velocity required for circular motion

$$K_Q = \frac{1}{2}mv_Q^{\,2} \qquad \therefore \quad v_Q = \sqrt{\frac{2K_Q}{m}} = \sqrt{\frac{2 \times 1.194 \times 10^{10}}{400}} = 7.727 \times 10^3 \text{ m s}^{-1}$$

v_{req} to maintain circular orbit

$$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{6.85 \times 10^6}} = 7.644 \times 10^3 \text{ m s}^{-1}$$

ie $v_Q > v$

This means the satellite will continue on its trajectory increasing its distance from Earth.

Answers could include:

- a response based on the interpretation that *P*, Earth and *Q* are on the same line
- a response without calculations
- aspects of the conservation of energy.

2023 HSC Physics Mapping Grid

Section I

Question	Marks	Content	Syllabus outcomes
1	1	Mod 5 Motion in Gravitational Fields	PH12-12
2	1	Mod 6 Electromagnetic Induction	PH12-13
3	1	Mod 7 Light Wave Model	PH12-14
4	1	Mod 8 Properties of the Nucleus	PH12-15
5	1	Mod 5 Motion in Gravitational Fields	PH12-12
6	1	Mod 7 Electromagnetic Spectrum	PH12-14
7	1	Mod 8 Quantum Mechanical Nature of the Atom	PH12-15
8	1	Mod 5 Projectile Motion	PH12-12
9	1	Mod 7 Light Quantum Model	PH12-14
10	1	Mod 6 Applications of the Motor Effect	PH12-13
11	1	Mod 8 Properties of the Nucleus	PH12-15
12	1	Mod 6 Charged Particles, Conductors and Electric and Magnetic Fields	PH12-13
13	1	Mod 8 Properties of the Nucleus	PH12-15
14	1	Mod 5 Motion in Gravitational Fields	PH12-6, 12-12
15	1	Mod 7 Light Quantum Model	PH12-14
16	1	Mod 6 The Motor Effect	PH12-13
17	1	Mod 5 Circular Motion	PH12-12
18	1	Mod 5 Projectile Motion	PH12-5, 12-12, 12-13
19	1	Mod 7 Light and Special Relativity	PH12-1, 12-13, 12-14
20	1	Mod 8 Origins of the Elements	PH12-6, 12-15

Section II

Question	Marks	Content	Syllabus outcomes
21 (a)	2	Mod 8 Origins of the Elements	PH12-15
21 (b)	3	Mod 8 Origins of the Elements	PH12-6, 12-15
22	3	Mod 7 Light and Special Relativity	PH12-12
23 (a)	2	Mod 5 Motion in Gravitational Fields	PH12-6, 12-12
23 (b)	3	Mod 7 Light Quantum Model	PH12-6, 12-14
23 (c)	2	Mod 7 Light and Special Relativity	PH12-14
24	3	Mod 6 Charged Particles, Conductors and Electric and Magnetic Fields	PH12-6, 12-13
25 (a)	2	Mod 6 Applications of the Motor Effect	PH12-7, 12-13
25 (b)	2	Mod 6 Applications of the Motor Effect	PH12-13
26	3	Mod 8 Properties of the Nucleus	PH12-5, 12-15

Question	Marks	Content	Syllabus outcomes
27 (a)	4	Mod 7 Electromagnetic Spectrum	PH12-7, 12-14
27 (b)	4	Mod 7 Electromagnetic Spectrum	PH12-6, 12-14
28 (a)	2	Mod 6 Electromagnetic Induction	PH12-13
28 (b)	3	Mod 6 Electromagnetic Induction	PH12-13
29	4	Mod 7 Light Wave Model	PH12-7, 12-14
30 (a)	4	Mod 6 Electromagnetic Induction	PH12-13
30 (b) (i)	2	Mod 6 Electromagnetic Induction	PH12-13
30 (b) (ii)	2	Mod 6 Electromagnetic Induction	PH12-13
31	5	Mod 6 Application of The Motor Effect Mod 8 Structure of the Atom	PH12-5, 12-13
32	7	Mod 5 Circular Motion Mod 5 Projectile Motion	PH12-6, 12-12
33	9	Mod 8 Properties of Nucleus	PH12-7, 12-15
34 (a)	2	Mod 5 Motion in Gravitational Fields	PH12-5, 12-12
34 (b)	4	Mod 5 Motion in Gravitational Fields	PH12-12
34 (c)	3	Mod 5 Motion in Gravitational Fields	PH12-12