CSSA

2023

TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

DO NOT REMOVE PAPER FROM EXAMINATION ROOM

Centre Number

Student Number

Physics

Afternoon Session
Tuesday, 8 August 2023

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
- Use the Multiple-Choice Answer Sheet provided
- A data sheet, formulae sheet and Periodic Table are provided SEPARATELY
- Write your Centre Number and Student Number on the top of this page

Total marks: 100

Section I – 20 marks (pages 2–12)

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

Section II – 80 marks (pages 13–31)

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

Section I

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

Use the Multiple-Choice Answer Sheet for Questions 1–20.

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1 What feature of a body does the maximum wavelength of the thermal radiation emitted by it depend upon?

A. The density of it

B. The area of its surface

C. The nature of its surface

D. The temperature of its surface

2 Which statement best explains why the aether model for the transmission of light was adopted.

A. The speed of light was found to be constant.

B. Time and distance were found to be relative to the motion of the aether.

C. Light was found to have wave characteristics and it was thought waves needed a medium in which to propagate.

D. Light was found to have particulate nature and momentum needed to be conserved as it was discovered that light slowed on its journey from the Sun to the Earth.

3 Niels Bohr modified Rutherford's model of the atom to help explain some of the limitations of Rutherford's model. Which of the following four pieces of evidence supported Bohr's modification?

A. Alpha particles are deflected when fired at thin gold foil.

B. Different atoms give off distinct colours of light when exposed to flame or electric fields.

C. Electrons emit radiation when travelling in a circular path.

D. The brightness of the fine spectral lines of different elements.

4 The power input of an ideal transformer with a primary voltage of 240 V is 480 W. The potential difference across the secondary coil is 120 V. What is the maximum power output and current in the secondary coil respectively?

A. 480 W, 4 A

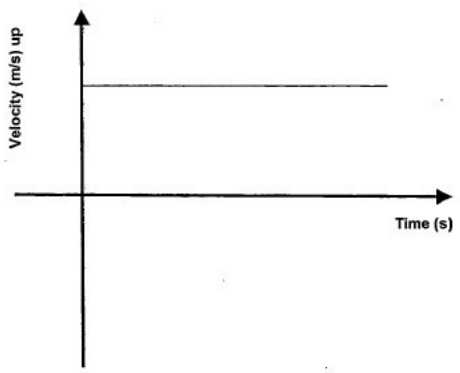
B. 480 W, 1 A

C. 240 W, 4 A

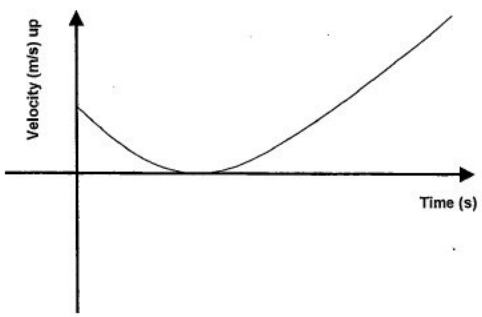
D. 240 W, 1 A

5 A ball is thrown from a height of 10 m at an angle of 45^0 to the horizontal. The initial velocity of the ball is 10 ms^{-1}. Which graph best represents the ball's motion?

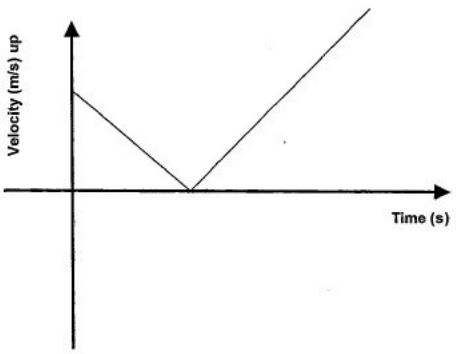
A.



B.



C.



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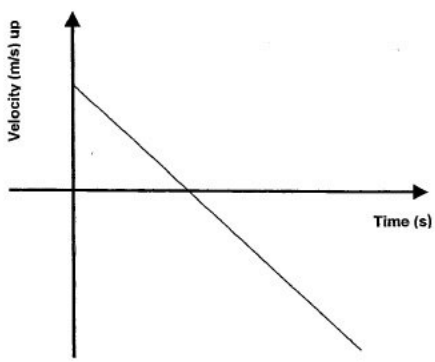
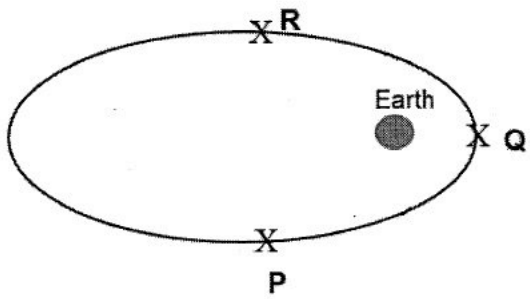


6 The elliptical orbit of a satellite around the Earth is shown below.



The satellite moves from P to Q and Q to R.

Which row of the table describes the change in orbital speed of the satellite?

	Movement from P to Q	*Movement from Q to R*
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

7 Which of the following are fundamental particles in the Standard Model of matter?

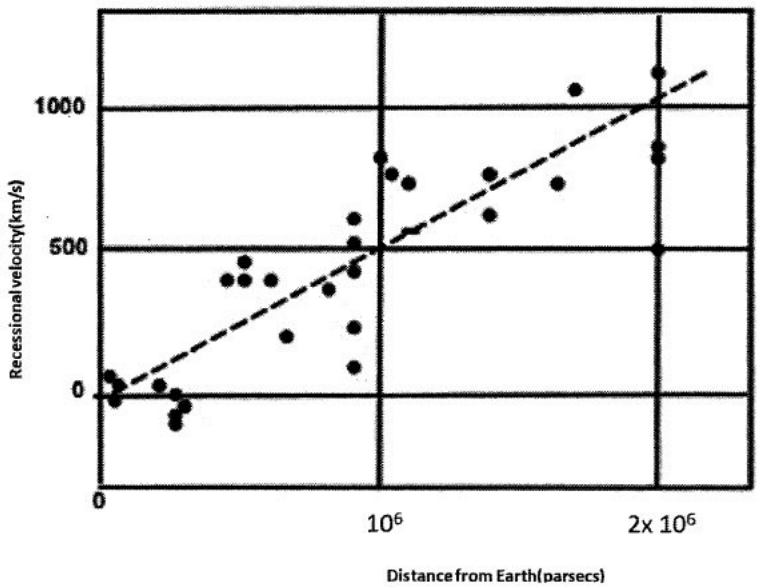
A. Quarks, Leptons and Bosons

B. Hadrons, Baryons and Mesons

C. Photons, Gluons and Electrons

D. Protons, Neutrons and Electrons

8 Hubble plotted the speed at which galaxies move away from Earth. This is shown in the graph below.



It is known that 1 parsec = 3.26 light years.

Which statement supports Hubble's conclusions from this graph?

A. The Universe is contracting.

B. The Universe is in a steady state.

C. The Universe is accelerating in its expansion.

D. The Universe is expanding at a constant rate.

9 James Clerk Maxwell predicted light behaviour with his discovery of the equations of electromagnetism.

Which statement explains how Maxwell concluded light was an electromagnetic wave.

A. Light was already known to be a wave.

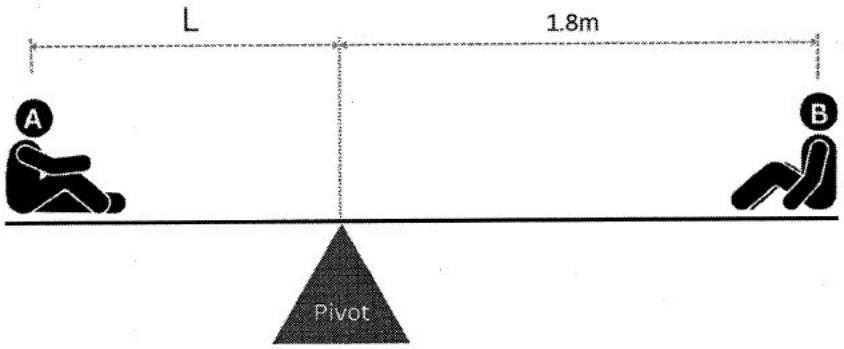
B. He measured, experimentally, the electric and magnetic fields of a ray of light.

C. He calculated the speed of electromagnetic waves to be the same as the known speed of light.

D. He performed a double slit experiment with a range of electromagnetic waves, to prove that light performed the same as other types of electromagnetic radiation.

10. Two children, Anna (A) and Bill (B), are sitting on a balance beam with no mass.

The mass of Anna is 40 kg. The mass of Bill is 30 kg.



How far from Anna (A) should the pivot be placed to balance the beam horizontally?

A. 0.74 m

B. 1.35 m

C. 1.80 m

D. 2.40 m

11 Which of the following is Schrodinger's contribution to the quantum mechanical model of the atom?

A. Generation of a mathematical model of distribution of electrons in the atom.

B. Proposition of the matter-wave hypothesis and electrons' wave properties.

C. Quantisation of the energy of electrons in the atom.

D. Calculation of the mass of electrons in the atom.

12 A red light with a wavelength of 660 nm passes through double slits. If blue light with a wavelength of 450 nm is used instead, how will the fringes change?

A. The fringes would be wider.

B. The fringes would be fainter.

C. The fringes would be brighter.

D. The fringes would be narrower.

13 Technetium 99m is a radioisotope used in nuclear medicine. It is used to inject into the body, as it has a half-life of 6 hours and only emits gamma rays. It becomes the stable isotope Technetium 99 according to the following equation:

$$^{99m}_{43}Tc \longrightarrow {}^{99}_{43}Tc + {}^{0}_{0}\gamma$$

16 mg of Technetium 99m is injected into the body of a patient.

How much Technetium 99 is present in the body, produced as a result of this reaction, after 12 hours?

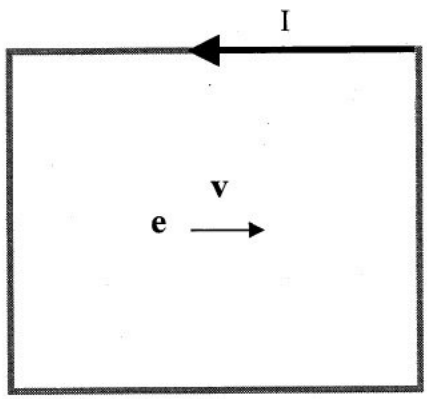
A. 4.0 mg

B. 8.0 mg

C. 12 mg

D. 16 mg

14 An electron at the centre of a current carrying square loop is represented below. The electron is travelling with a velocity of 1.5×10^7 m/s. The direction the electron is travelling is also represented on the diagram below.



The strength of magnetic field at the centre of the loop is 30 μT. What is the force experienced by the electron?

A. 7.2×10^{-17} N down the page

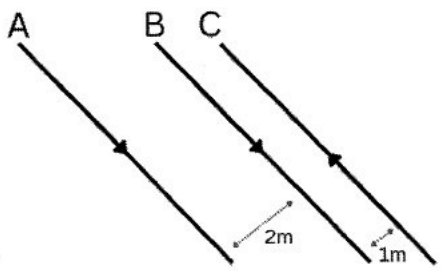
B. 7.2×10^{-17} N up the page

C. 3.6×10^{-17} N into the page

D. 0 N

15 There are three parallel wires A, B and C. Each wire carries 2 Amperes of current in the directions shown.

What is the force per unit length acting on wire B?



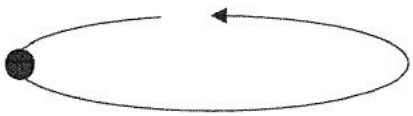
A. 1.2×10^{-6} N towards A

B. 1.2×10^{-6} N towards C

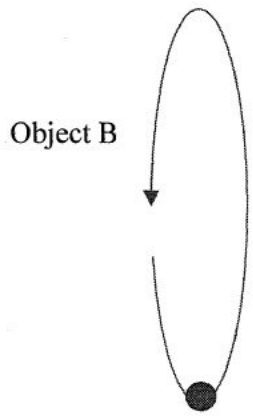
C. 8.0×10^{-7} N towards C

D. 4.0×10^{-7} N towards A

16 Two identical objects are undergoing uniform circular motion. Both have the same radius and angular velocity. Object A is on a horizontal plane. Object B is on a vertical plane.



Object A

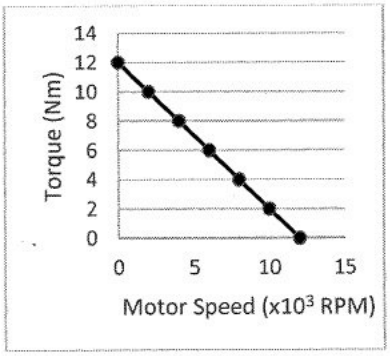


Which of the following rows correctly describes their total energy and the work done on each object as it orbits?

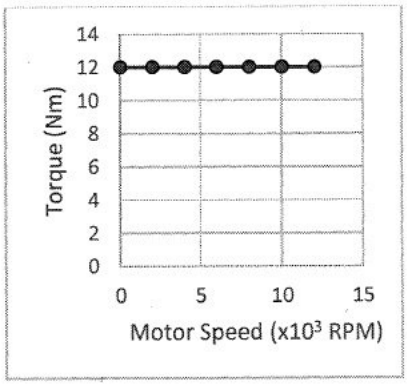
	Net Work Done on Object in One Orbit		*Total Mechanical Energy of Object*	
	Object A	*Object B*	*Object A*	*Object B*
A.	Not Zero	Not Zero	Constant	Changes
B.	Zero	Not Zero	Changes	Constant
C.	Zero	Zero	Constant	Changes
D.	Zero	Zero	Changes	Constant

17 Which of the graphs below correctly shows the torque of a coil in a DC motor powered by a constant external EMF, from stationary to its maximum operating speed (12 x 10^3 Rotations per Minute)?

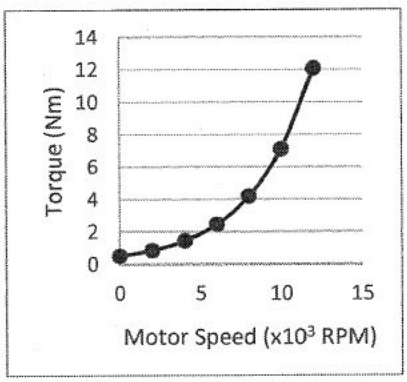
A.



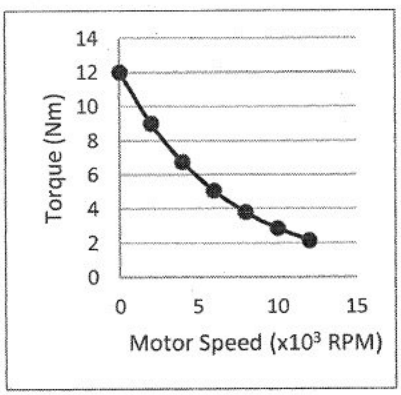
B.



C.

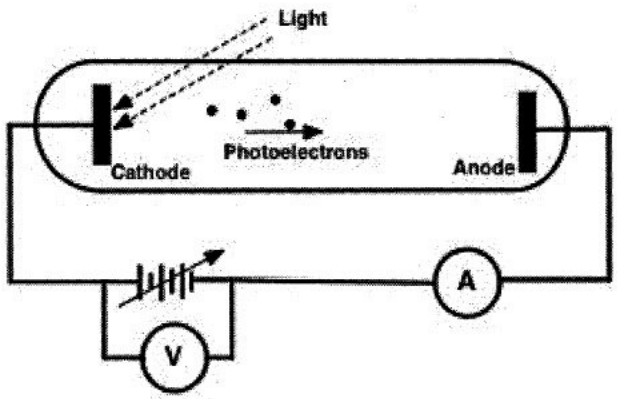


D.



18 A radiation with a wavelength of 200 nm was shone on the cathode of a photoelectric cell. The produced photocurrent was reduced to zero by applying a voltage of 4.2 V. This voltage is called the stopping voltage and is used to calculate the maximum kinetic energy of the produced photoelectrons.

What is the work function (in eV) of the cathode?



A. 1.2

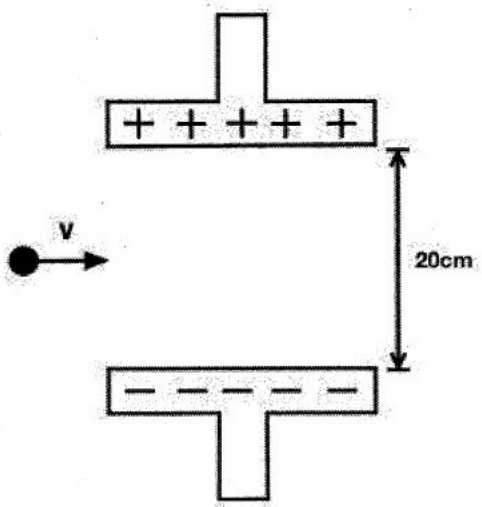
B. 2.0

C. 3.0

D. 3.2

19 A voltage of 20 V is applied between two metal plates with lengths of 25 cm separated by 20 cm. An electron enters at a velocity of 3500 m/s horizontally exactly halfway between positive and negative plates.

Calculate the distance of the impact point from the left end of the positive plate. (Ignore the gravitational force in your calculations).



A. 7.46×10^{-2} m

B. 3.73×10^{-2} m

C. 7.46×10^{-4} m

D. 3.73×10^{-4} m

20 An electron has a kinetic energy of 3.4 eV. What is its de Broglie wavelength?

A. 6.68×10^{14} m

B. 2.67×10^{5} m

C. 6.65×10^{-10} m

D. 2.67×10^{-19} m

Section II

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

- 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.
- SEPARATE writing booklets are available if required. If you use a SEPARATE writing booklet, clearly indicate which question you are answering by writing the question number before beginning the response.

Question 21 (5 marks)

(a) Calculate the kinetic energy of a 550 kg satellite in a geostationary orbit. **2**

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(b) Explain why more energy is required to launch a satellite into a geostationary orbit than a Low Earth Orbit. In your answer, refer to the total energy of the two orbits. **3**

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Question 22 (5 marks)

The comparison and interpretation of spectra has been very important in developing our understanding of stars. Describe how the spectra of stars can be used to provide information about their characteristics. **5**

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Question 23 (3 marks)

An object was travelling at the speed of v relative to the Earth. There was a difference of 1% in its length as observed by a person on the Earth compared with someone on the object. What is the speed of the object? **3**

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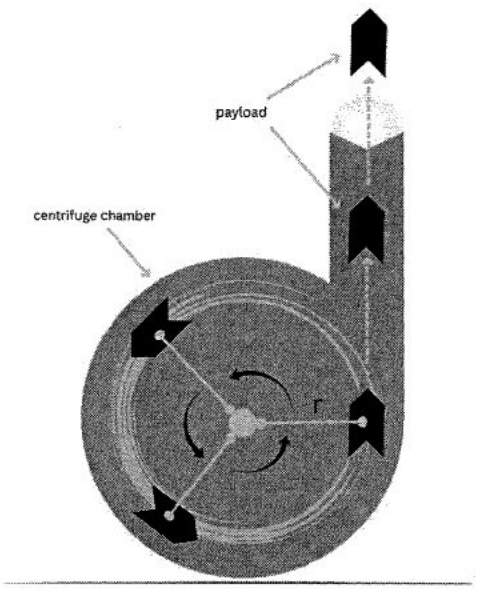
Question 24 (5 marks)

An aerospace engineering start-up company has made proposals to launch satellites into orbit using a giant centrifuge chamber which would spin payloads up to the required energy and release them vertically upwards as projectiles into space. **5**

The payloads will each weigh 200 kg. The arm on the centrifugal launcher (r) is shown below. The arm (r) is 50 m long.



The launch centrifuge is located on the surface of the Earth and facing vertically upwards.

Calculate the required angular velocity of the launch arm for the payload to achieve escape velocity.

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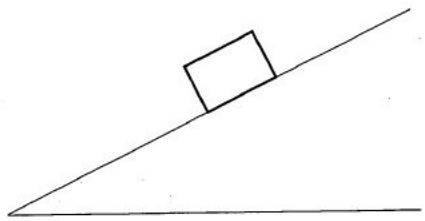
Question 25 (5 marks)

Banked corners are used by engineers to allow for greater cornering speeds.

(a) In the space below, draw a vector diagram to show how centripetal force can be created using a banked corner without friction. **2**



(b) An engineer wishes to have a cornering velocity of 20 ms^{-1} with the radius of the corner being 344 m. Calculate the banking angle required to ensure friction is not required to turn the corner. **3**

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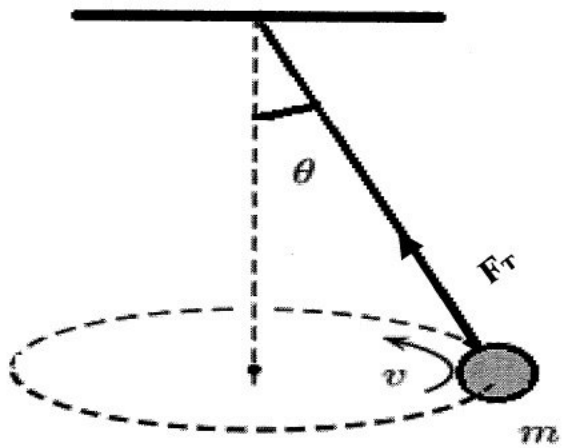
Question 26 (5 marks)

A small ball of mass m is suspended from a string. The object revolves with constant speed v in a horizontal plane with radius r.



(a) Show using the force vectors that the following equation is correct for the angle of inclination to the vertical. **2**

$$tan\theta = \frac{v^2}{rg}$$

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(b) Calculate the tension of the string if the mass of the ball is 50.0 g and it revolves 40.0 times per minute in a horizontal circle of radius 20.0 cm. **3**

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Question 27 (5 marks)

With reference to applicable laws of physics, explain why the current in the rotor coils of an efficient DC electric motor approaches zero as the motor approaches maximum speed. **5**

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Question 28 (6 marks)

A student conducted an investigation to verify Malus' Law. Their procedure, results table and graph are shown below.

Procedure:

1. *On a smartphone or laptop, install Physics Toolbox Suite (or a similar application) that can record light intensity and the inclination (angle) of the smartphone.*
2. *Obtain a source of polarised light – e.g. a laptop screen with a blank, white page.*
3. *Record maximum light intensity (illuminance)of the polarised light.*
4. *Use a piece of polarised material and check the orientation of the source light so that maximum light passes through the polarised material.*
5. *Using sticky tape, attach the polarising material on the light sensor of the smartphone in the direction that maximum light passes through.*
6. *Holding the phone at a constant distance from the polarised light source, record the light intensity as the phone's inclination is varied from 0° through to 90° from the polarised light source.*
7. *Record the results in a table, calculating and recording for $\cos^2\theta$.*
8. *Plot the transmission intensity, I/Io %, against the square of $\cos\theta$ (i.e. $\cos^2\theta$).*

Results Table

Angle θ^o	*$Cos^2\theta$*	*Transmission Intensity (I/Io %)*	*Theoretical Transmission Intensity (I/Io %)*	*Difference (%)*
0	*1.0*	*98*	*100*	*2*
15	*0.93*	*93*	*97*	*2*
30	*0.75*	*73*	*70*	*3*
45	*0.5*	*50*	*50*	*0*
60	*0.25*	*25*	*20*	*5*
75	*0.07*	*9*	*7*	*2*
90	*0*	*3*	*0*	*3*

Question 28 continues on page 20

Question 28 (continued)

(a) Evaluate the validity, accuracy and reliability of this investigation. **4**

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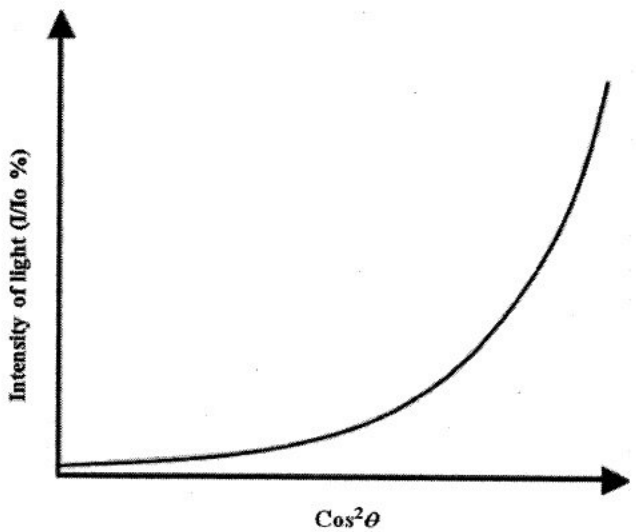
Question 28 (continued)

(b) The student's results graph from their investigation is shown below. **2**



Assess the student's results graph.

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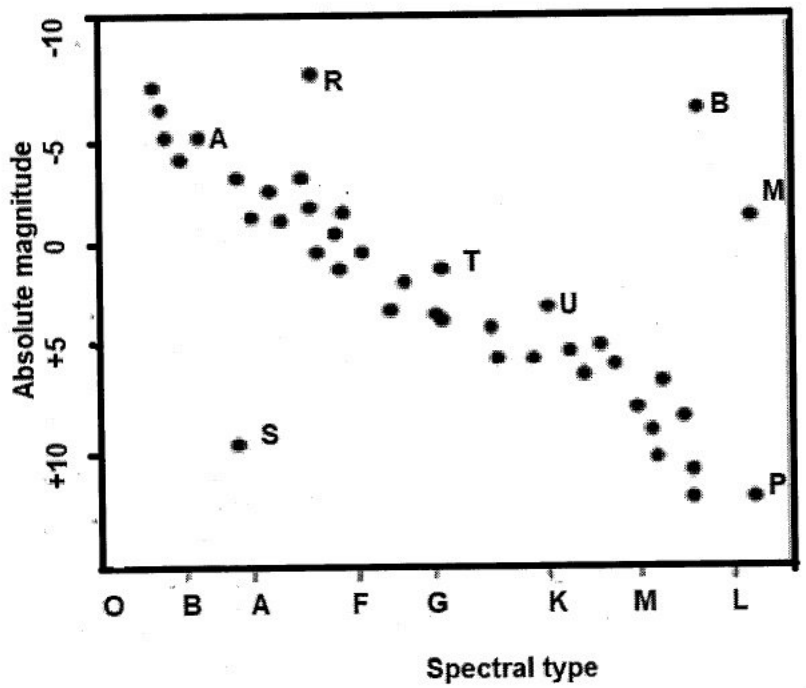
Question 29 (9 marks)

The following questions refer to the H-R diagram below.



(a) Identify from the labelled points on the H-R diagram which stars are undergoing proton - proton chain as their main nucleosynthesis reaction. **1**

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Question 29 continues on page 23

Question 29 (continued)

(b) Calculate the energy released in the stars in the first two steps of the proton–proton chain as shown in the following reactions: **3**

$^{1}H + {}^{1}H \rightarrow {}^{2}H + e^{+} + \nu$
$^{2}H + {}^{1}H \rightarrow {}^{3}He + \gamma$

Mass of proton = 1.00784 amu
Mass of Deuterium ^{2}H =2.014 amu
Mass of ^{3}He = 3.016029 amu
Mass of e^{+} = 0.000548756 amu

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(c) i. Identify the type of stars for B and S. **1**

B: ....

S : ... .

ii. Compare and contrast characteristics of star B and star S. **4**

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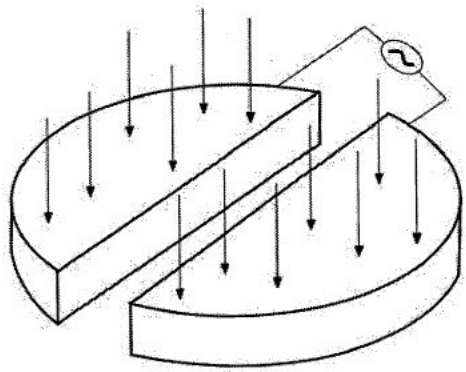
Question 30 (5 marks)

The image below shows a cyclotron which consists of two hollow D-shaped electrodes known as dees, in a vacuum chamber. In each dee there is a magnetic field with the strength of 2.0 T perpendicular to the plane of the dees as shown in the diagram. In the gap separating the dees a high frequency 50 kV alternating voltage is applied across the electrodes. A proton is released from rest in the gap and accelerates across the entire gap into one of the dees. (Ignore the relativistic effect).



(a) Calculate the speed of the proton when it reaches the electrode. **2**

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(b) Calculate the radius of the cyclotron if the proton leaves it with kinetic energy of 20 MeV. **3**

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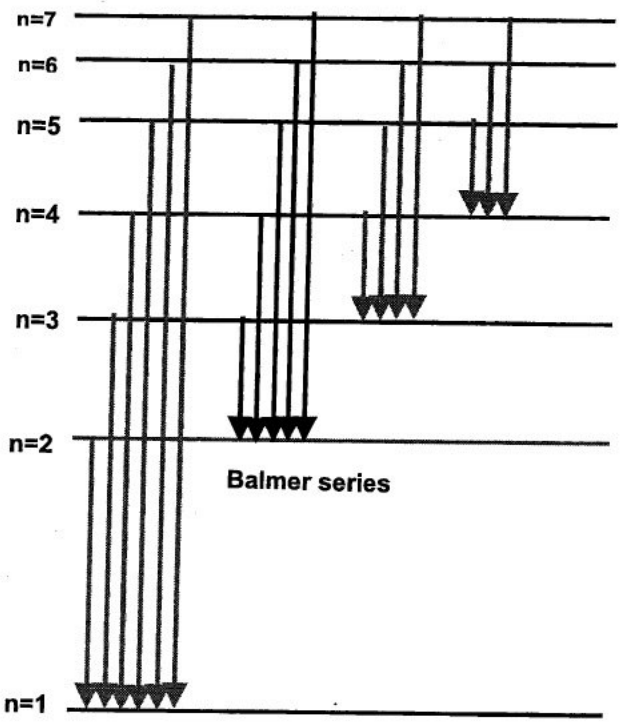
Question 31 (6 marks)

The following diagram illustrates the possible electron transition states of the electron in the Hydrogen atom.



The human eye can detect wavelengths of light in the region between 380 nm to 700 nm.

(a) Justify that the lines of the Balmer series can be detected by the human eye. **4**

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Question 31 continues on page 26

Question 31 (continued)

(b) Calculate the difference in energy required to move an electron in the Hydrogen atom from n=2 shell to n=3 shell and from n=2 shell to n=7 shell. **2**

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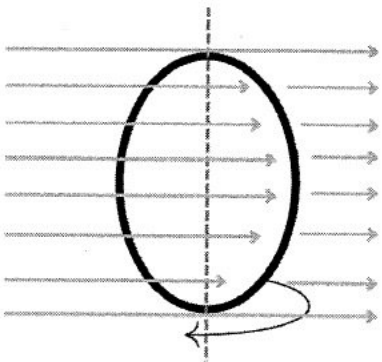
Question 32 (5 marks)

A circular coil with radius 0.500 m is spinning in space about an axis, as shown below. The coil is entirely within a magnetic field of 5.00×10^{-5} T.



(a) Calculate the maximum change of flux experienced by the coil as it rotates through 90°. **2**

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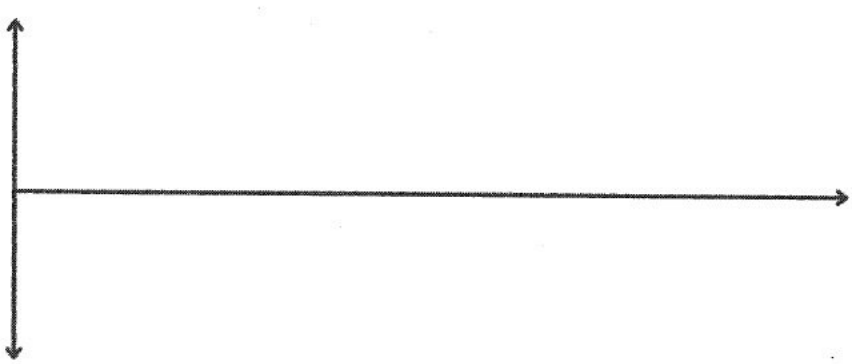
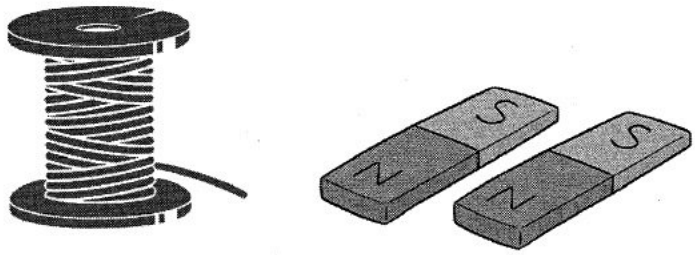
(b) Draw a graph to represent induced EMF in the coil as the coil turns 2 full rotations. Start the rotation from the point of maximum positive flux through the coil. **3**



Question 33 (7 marks)

Two students, Jonathan and Stacy, make their own DC electric motors from supplies they found around the classroom. They use the same equipment, including identical magnets, the same length of wire and a 6 Volt battery. 7



They wind both motor coils to be square. The number of turns in Jonathan's motor is twice as many as Stacy's.

Show that the maximum torque produced by Stacy's motor is double that of Jonathan's and suggest two changes to other factors, so that Jonathan's motor may match the torque produced by Stacy's. Justify your answer using relevant laws and conventions.
Include quantitative analysis in your answer.

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Question 33 continues on page 29

Question 33 (continued)

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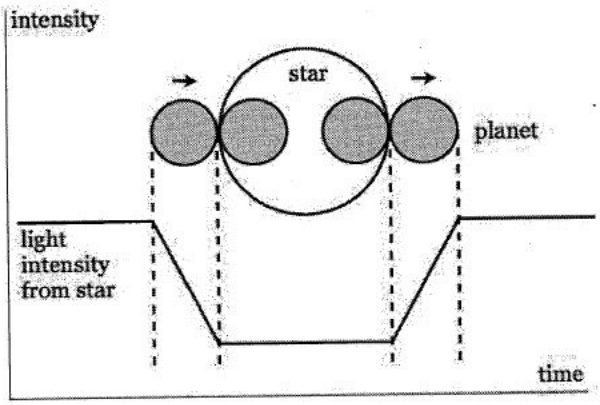
Turn to page 30 for Question 34

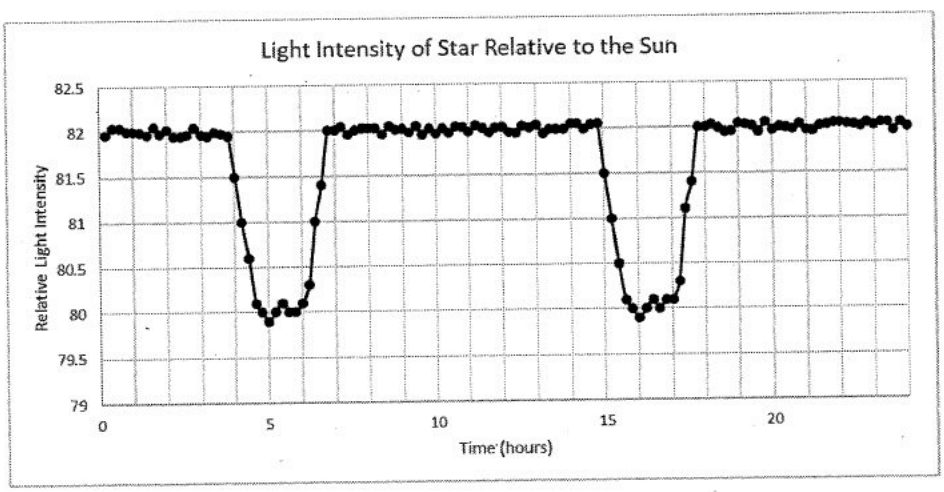
Question 34 (9 marks)

The Kepler Space Telescope analyses the light intensity and spectra of stars to find and study exoplanets. An exoplanet is a planet that orbits a star outside our solar system. **9**



When a planet passes in front of a star being observed, the planet absorbs some light from the star, so the observed light intensity is reduced. During this time of reduced intensity, the observed spectra of the star changes.

The following is light intensity data obtained from a star with an orbiting exoplanet.



The mass of the star was determined to be 9.9×10^{30} kg. The star was observed to be moving and its speed was determined to be 150 m/s, which is much slower than the planet.

Using the data and given relationships, calculate the orbital period, orbital radius and mass of the exoplanet and explain the cause of the star's movement and its slower orbital speed than the planet and how its motion was deduced.

Question 34 continues on page 31

Question 34 (continued)

End of Examination

EXAMINERS

Lily Okati (Convenor)	Santa Sabina College, Strathfield
Matthew Bentley	St Ignatius College Riverview, Riverview
Peter Blanch	Catholic Education Diocese of Parramatta
Sue Farroukh	Marist College Eastwood, Eastwood
Andrew Latham	Stella Maris College, Manly