2023/8888
Web version of 2022/56023

Government of **Western Australia**
**School Curriculum and Standards Authority**

# ATAR course examination, 2022

# Question/Answer booklet

# PHYSICS

Place one of your candidate identification labels in this box.

Ensure the label is straight and within the lines of this box.

WA student number: In figures

In words

## Time allowed for this paper

Reading time before commencing work: ten minutes
Working time: three hours

Number of additional answer booklets used (if applicable):

## Materials required/recommended for this paper

***To be provided by the supervisor***

This Question/Answer booklet
Formulae and Data booklet

***To be provided by the candidate***

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course examination, drawing templates, drawing compass and a protractor

## Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

## Structure of this paper

| Section | Number of questions available | Number of questions to be answered | Suggested working time (minutes) | Marks available | Percentage of examination |
|---|---|---|---|---|---|
| Section One<br>Short response | 11 | 11 | 50 | 58 | 30 |
| Section Two<br>Problem-solving | 6 | 6 | 90 | 91 | 50 |
| Section Three<br>Comprehension | 2 | 2 | 40 | 38 | 20 |
| | | | | **Total** | 100 |

## Instructions to candidates

1. The rules for the conduct of the Western Australian external examinations are detailed in the *Year 12 Information Handbook 2022: Part II Examinations*. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.

3. You must be careful to confine your answers to the specific questions asked and to follow any instructions that are specific to a particular question.

4. When calculating or estimating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning.

   In calculations, give final answers to three significant figures and include appropriate units where applicable.

   In estimates, give final answers to a maximum of two significant figures and include appropriate units where applicable.

5. Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

6. The Formulae and Data booklet is not to be handed in with your Question/Answer booklet.

**See next page**

**Section One: Short response** **30% (58 Marks)**

This section has **11** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 50 minutes.

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**Question 1** **(5 marks)**

Light with a wavelength of 341 nm is shone onto a potassium metal plate in a photoelectric cell, causing a photocurrent to flow. The work function of potassium is 2.30 eV. Calculate the maximum speed of the electrons emitted by the plate.

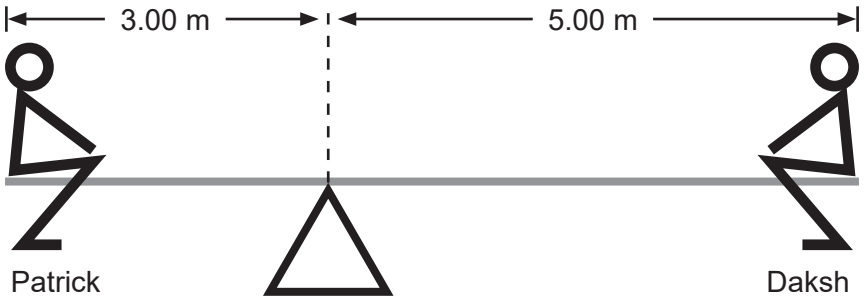
Answer: _____ m $s^{-1}$



**See next page**

**Question 2** **(4 marks)**

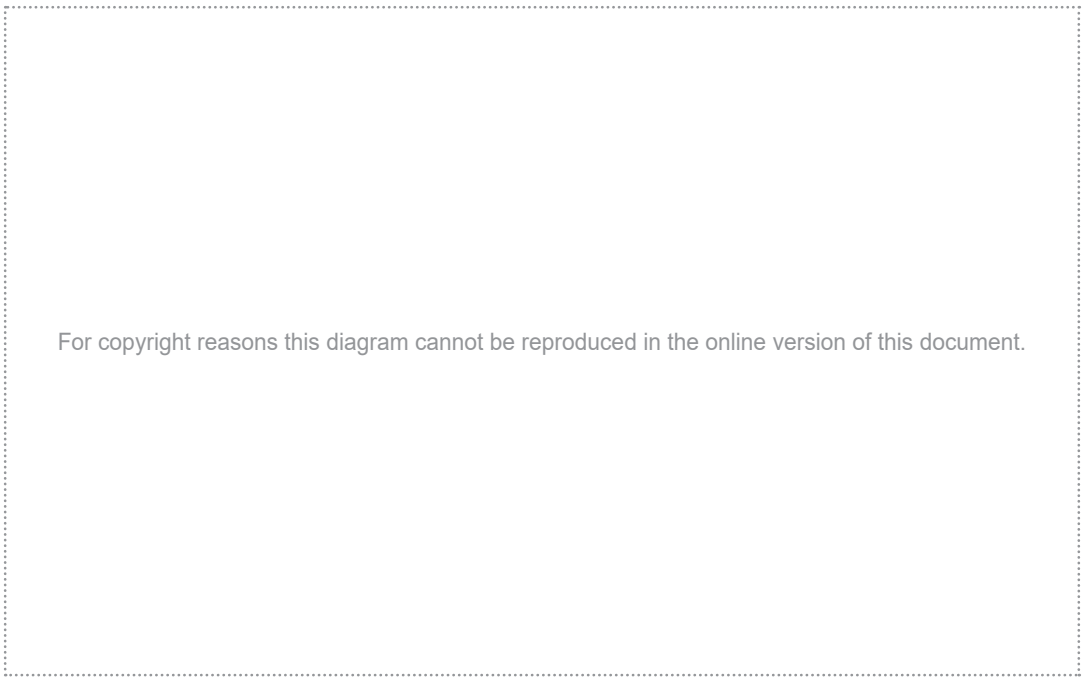
Patrick and Daksh are sitting on a seesaw discussing physics. They decide to place the uniform 15.0 kg beam on the pivot as shown in the diagram below. Daksh estimates that the system is balanced and tells Patrick to lift his feet off the ground. As usual, Daksh is correct and the system is balanced with neither of them touching the ground. Daksh has a mass of 60.0 kg. What is Patrick's mass?




Answer: _____ kg

**Question 3** **(4 marks)**

A simple AC generator is shown in the diagram below. A coil is manually rotated in a fixed magnetic field, producing an alternating current in the external circuit. Explain how the alternating current is produced, making specific reference to the labelled parts in the diagram.

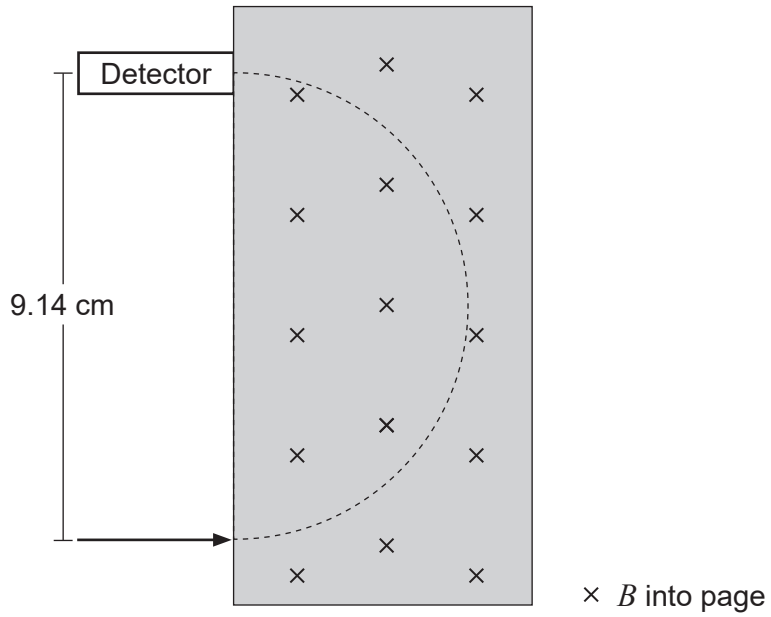





**See next page**

**Question 4** **(5 marks)**

A charged particle enters a 0.350 mT magnetic field at right angles to the field with a velocity of $2.81 \times 10^6$ m s$^{-1}$. The magnitude of the charge of the particle is $1.60 \times 10^{-19}$ C. It lands on the detector 9.14 cm from where it entered after completing 180° of its circular path.




(a) Calculate the mass of the particle. (4 marks)

Answer: _____ kg

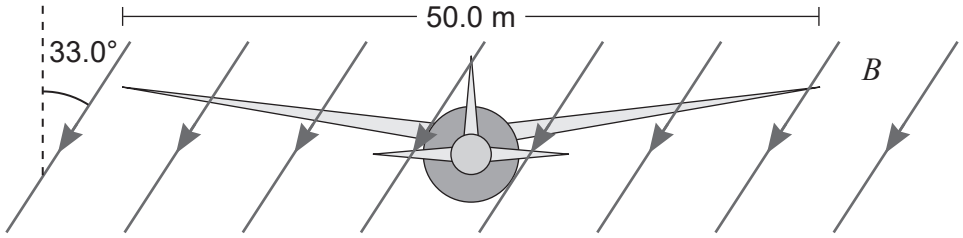
(b) Which of the following could the particle be? Circle your answer. (1 mark)

A proton
B electron
C anti-proton
D positron
E none of the above

**See next page**

**Question 5** **(5 marks)**

An aircraft with a wingspan of 50.0 m flies due east parallel to the Earth's surface. The Earth's magnetic field strength at that location is $5.84 \times 10^{-5}$ T and it makes an angle of 33.0° to the vertical. The aircraft is travelling at $7.20 \times 10^{2}$ km hr$^{-1}$.




(a) Using the appropriate component of the magnetic field, calculate the electromotive force (EMF) induced between the ends of the aircraft's wings. (4 marks)

Answer: _____ V

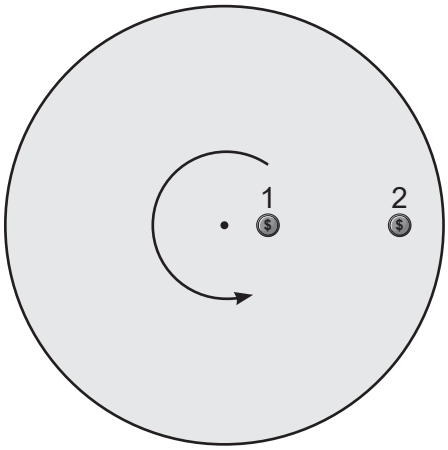
(b) A wire runs between the ends of the wings, parallel to each wing, so as to set up a complete circuit. A sensitive ammeter is placed in the circuit. If the total resistance of the circuit is 1.78 Ω, what will be the reading on the ammeter? (1 mark)

Answer: _____ A

**See next page**

**Question 6** **(6 marks)**

Two identical 25.0 g coins are placed on a rotating disc, 0.30 m and 1.20 m respectively from the centre of the disc. The disc begins to rotate. When the frequency of rotation reaches 2.00 Hz, the outer coin flies off the disc. Calculate the frequency of rotation when the inner coin flies off.

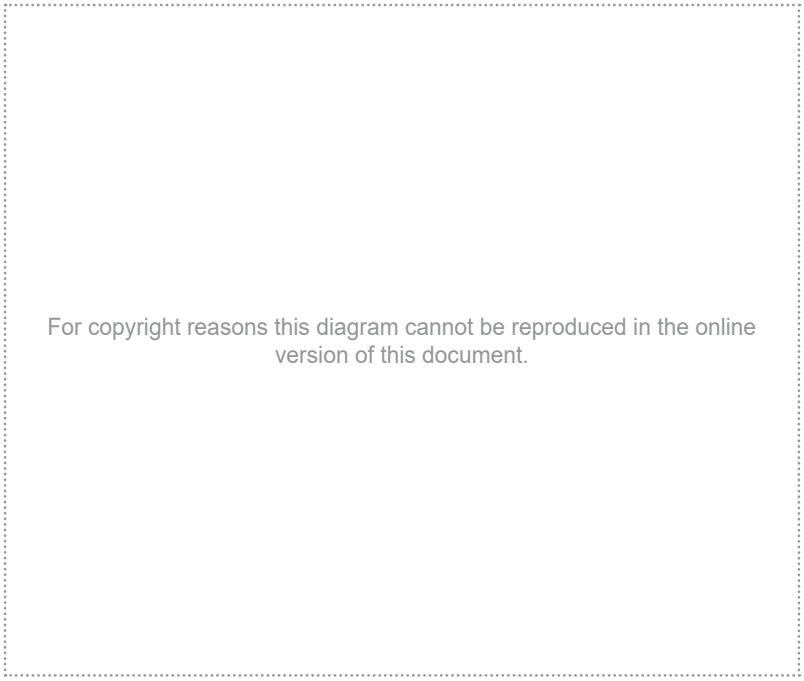



Answer: _____ Hz

**See next page**

**Question 7** **(4 marks)**

A group of students place a metal bar in a DC circuit, as shown in the diagram below. The bar is arranged horizontally between the poles of a horseshoe magnet. When they turn on the switch (K), they notice that the bar moves.



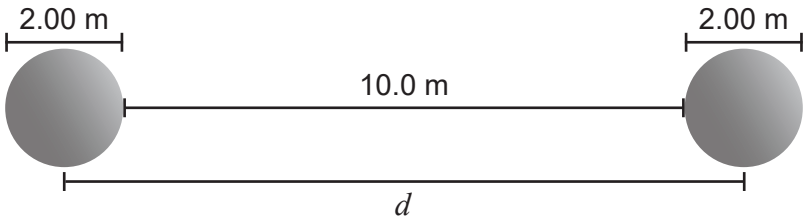

(a) In which direction is the initial movement of the bar? Circle your answer. (1 mark)

Left Right

(b) Explain why the bar moved when the circuit was turned on. (3 marks)

**Question 8** **(7 marks)**

Two identical solid and uniform spheres are separated by a distance of 10.0 m from surface to surface. The distance between their centres is called $d$.



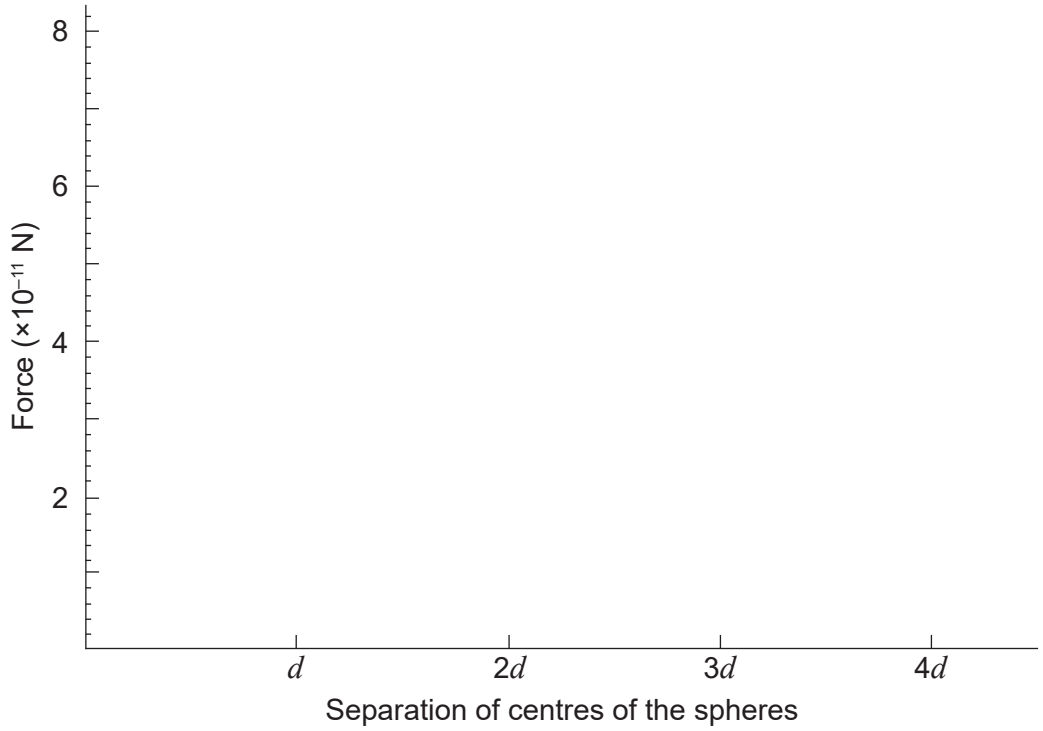

(a) If each sphere has a mass of 12.50 kg and a diameter of 2.00 m, calculate the gravitational force between them. (3 marks)

Answer: _____ N

**See next page**

(b) On the axes below, show how the gravitational force between the two spheres varies as they move apart. Indicate the magnitude of the forces on the y-axis at the points $2d$ and $4d$ on the x-axis. If you could not obtain an answer to part (a), use $7.50 \times 10^{-11}$ N.

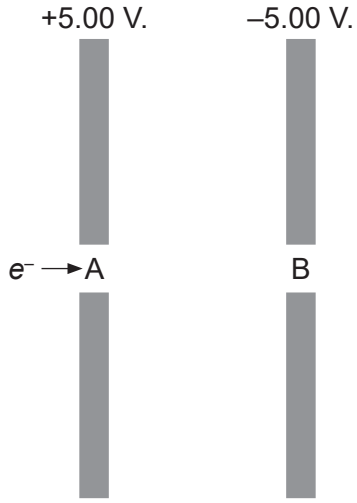
(4 marks)




A spare axes is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare axes.

**Question 9** **(5 marks)**

Two parallel conducting metal plates are held at a potential difference of 10.0 V. An electron in a vacuum arrives at a small hole in the first plate at point A with 20.0 eV of kinetic energy, and travels through an electric field to B as shown in the diagram. Calculate the de Broglie wavelength of the electron as it exits at B.



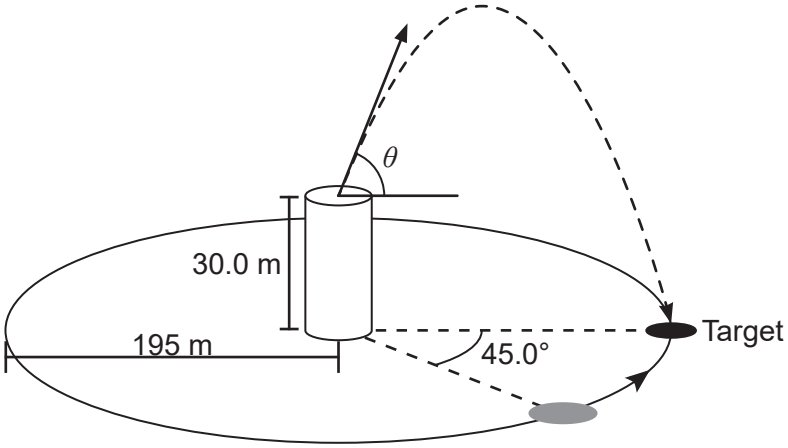

Answer: _____ m



**See next page**

**Question 10** **(7 marks)**

In a video game, the players fire arrows from the top of a 30.0 m high castle tower at a flat, 4.00 m wide target moving in a circular path ($r$ = 195 m) around the castle. The player can adjust the vertical angle but the direction of fire is fixed. The launch speed is also fixed at 50.0 m s$^{-1}$. It takes 32.0 s for the target to complete one revolution of the tower. The shooter fires the arrow when the target has 45.0° of a full revolution to go, as shown in the diagram below.




(a) At what angle $\theta$ must the shooter fire the arrow above horizontal for it to hit the centre of the target? (4 marks)

Answer: _____ °

(b) With the use of a calculation, confirm that the arrow hits the target. (3 marks)

**Question 11** **(6 marks)**

Salman and Priyanka have identical 1.00 m rulers. Priyanka takes her ruler and sets off in a rocket. She travels past Salman at a speed of 0.800 $c$. Their metre rulers are aligned in the direction of Priyanka's travel. Each then measures the length of the other's ruler by carefully determining the position of each end of the ruler at the same instant, and measuring the distance between these positions.

(a) How long does Salman measure Priyanka's ruler to be? (2 marks)

Answer: _____ m

(b) How long does Priyanka measure Salman's ruler to be? (1 mark)

Answer: _____ m

(c) When Priyanka returns, she and Salman compare the results of their measurements. How are they able to explain their seemingly contradictory results? (3 marks)

_____

_____

_____

_____

_____

_____

**End of Section One**

**See next page**

**Section Two: Problem-solving** **50% (91 Marks)**

This section has **six** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 90 minutes.

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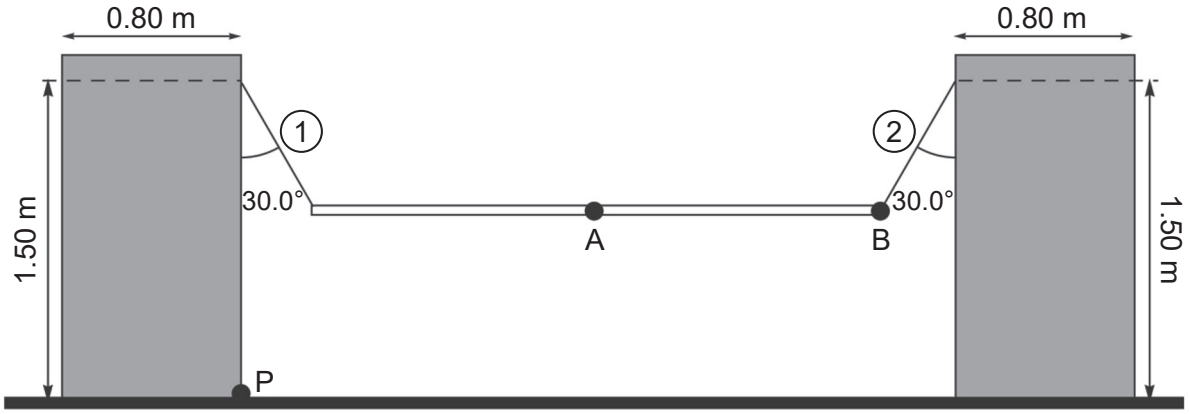
**See next page**

**Question 12** **(12 marks)**




An ultra-lightweight 2.00 kg aluminium plank is suspended between two 70.0 kg uniform free-standing supports as part of a children's obstacle course. It is attached to the supports by two chains of equal length. Due to safety restrictions, the apparatus has a maximum load of 60.0 kg. A father with a mass of 80.0 kg mistakenly sits on the plank, halfway between the two supports at point A. His mass exceeds the safety limit, so the free-standing supports should tip inward.

(a) Calculate the tension in each chain when the father sits on the plank, assuming the supports do not tip over. (4 marks)

Answer: _____ N

(b) Calculate the horizontal component of the tension in each chain. (1 mark)

Answer: _____ N

**See next page**

(c) With the use of a calculation, confirm that the supports do tip over when the father sits on the plank. Take moments around P. (5 marks)

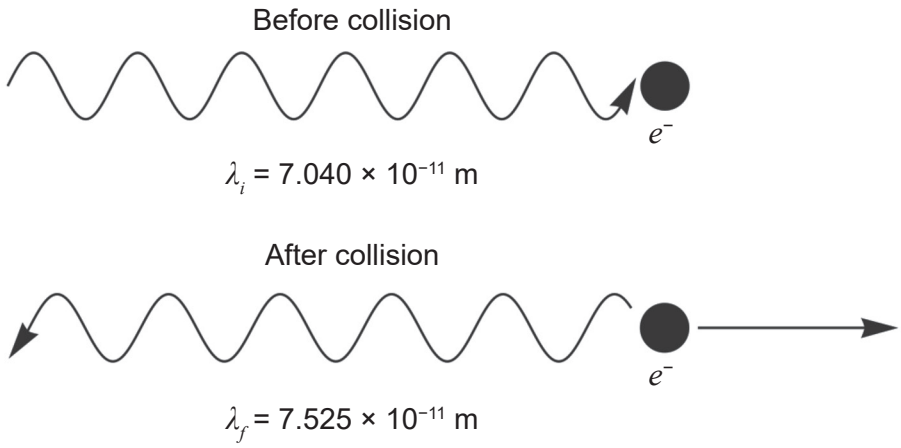


(d) Without the use of additional calculations, describe how the tension in each chain would be affected if a 50.0 kg person sitting at A moved to B? Select either increases, decreases or remains constant. (2 marks)

| Chain 1 | Chain 2 |
|---|---|
| | |

See next page

**Question 13** **(14 marks)**




A stationary free electron and a photon collide. In such collisions, both momentum and energy are conserved. In one such collision, a photon of wavelength $7.040 \times 10^{-11}$ m is travelling in the direction shown in the diagram above. After the collision, the photon returns in the direction it came from (i.e. 180°) with a new wavelength of $7.525 \times 10^{-11}$ m and the electron is no longer stationary. No other particles or photons are produced in the collision.

(a) What is the original energy of the photon in eV? (3 marks)

Answer: _____ eV

(b) What is the momentum of the photon before the collision? (2 marks)

Answer: _____ N s

**See next page**

(c) Explain why the wavelength of the photon is greater after the collision. (3 marks)

(d) Calculate the speed of the electron after the collision. (Hint: use the principles of conservation of energy.) (6 marks)

Answer: _____ m $s^{-1}$

**Question 14** **(15 marks)**

When a stationary neutron decays into a proton, an electron and an electron anti-neutrino are also produced. Total energy is conserved during the decay process. The reaction is described by the following equation:

$$n^0 \longrightarrow p^+ + e^- + \bar{\nu}_e$$

(a) In the reaction, the quark composition of a neutron changes from udd to uud. Show how the reaction conserves both baryon number and lepton number by filling in the table below. (6 marks)

| | $n^0$ | $\longrightarrow$ | $p^+$ | + | $e^-$ | + | $\bar{\nu}_e$ |
|---|---|---|---|---|---|---|---|
| Baryon number | | $\longrightarrow$ | | + | | + | |
| Lepton number | | $\longrightarrow$ | | + | | + | |

(b) The mass of a stationary neutron is $1.675 \times 10^{-27}$ kg. The mass of a proton is $1.673 \times 10^{-27}$ kg. The mass of an electron is $9.109 \times 10^{-31}$ kg. If we assume the total energy of the anti-neutrino is 0 J, calculate the total kinetic energy of the particles emitted in keV. (5 marks)

Answer: _____ keV

**See next page**

(c) If the electron accounts for 90.0% of the kinetic energy produced, calculate the velocity of the emitted proton in terms of $c$. If you could not determine an answer for part (b), use 581 keV ($9.30 \times 10^{-14}$ J). (4 marks)

Answer: _____ $c$



See next page

**Question 15** **(19 marks)**

In 1880, Johannes Rydberg established a mathematical relationship between the wavelengths of light and changes in the relevant energy levels of the hydrogen atom, which is observed in the emission spectrum.

$$\frac{1}{\lambda} = \frac{R}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$\lambda$ = wavelength of light emitted
$R$ = Rydberg's constant
$n$ = the number of the energy levels between which the electron falls ($n_2$ is always larger than $n_1$)

The wavelengths of the Lyman series of photons emitted for a hydrogen atom are shown in the diagram below. The Lyman series is made up of all electron transitions to $n$ = 1 i.e. $n_1$ = 1.

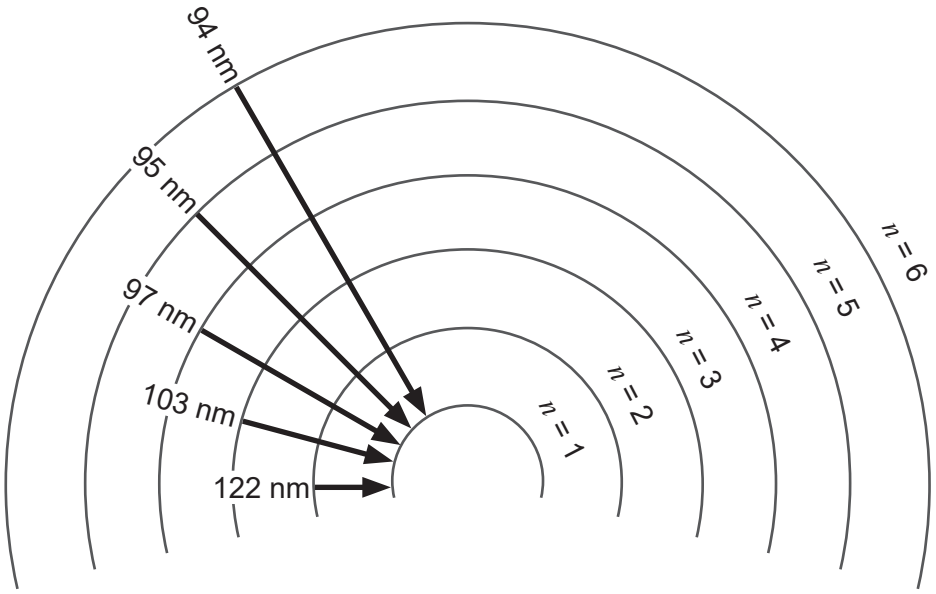


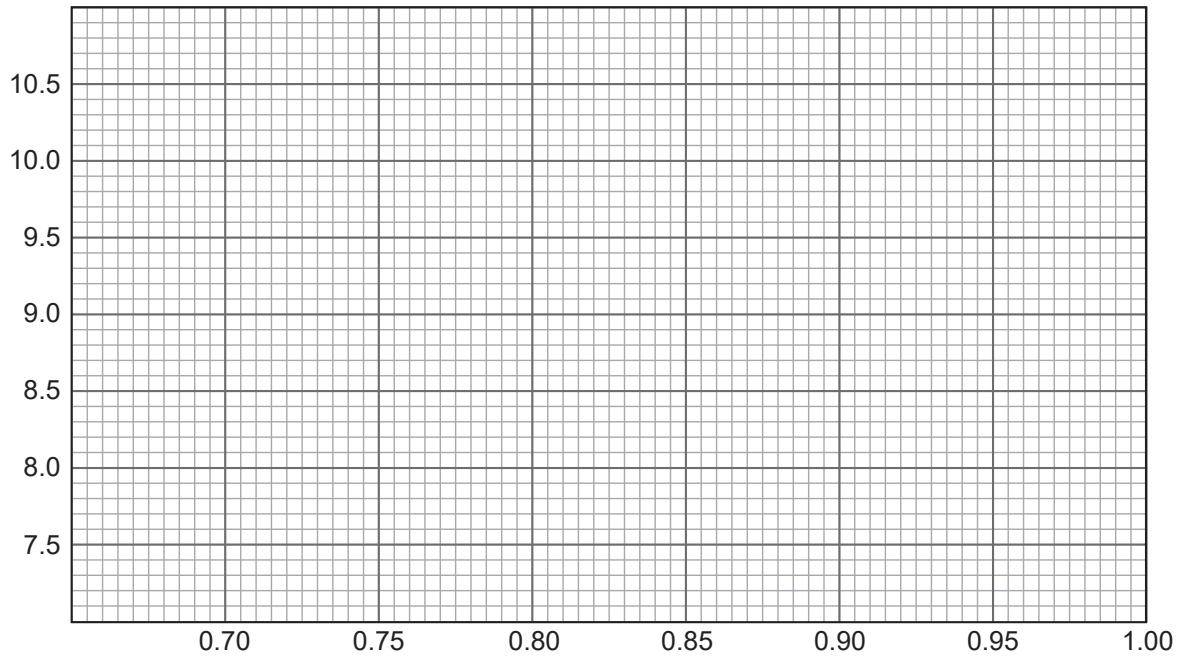

Figure 1: The Lyman series for hydrogen

(a) Fill in the table below using the values in Figure 1. Give your answers to **three** significant figures. (5 marks)

| $\Delta n$ | **2 → 1** | **3 → 1** | **4 → 1** | **5 → 1** | **6 → 1** |
|---|---|---|---|---|---|
| $\frac{1}{n_1^2} - \frac{1}{n_2^2}$ | | | | | |
| $\frac{1}{\lambda}$ ($10^6$ $m^{-1}$) | | | | | |

**See next page**

(b) Graph $\frac{1}{\lambda}$ vs $\frac{1}{n_1^2} - \frac{1}{n_2^2}$ on the grid below. Label the axes clearly and draw a line of best fit. (5 marks)




A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare grid.

(c) Use your line of best fit to calculate Rydberg's constant. Indicate clearly the points you have used. Give your answer to **two** significant figures. (5 marks)

Answer: _____ J

**See next page**

**Question 15** (continued)

Rydberg's equation can also be applied to one-electron ions of different elements. The formula is modified to:

$$\frac{1}{\lambda} = Z^2 \frac{R}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$Z$ is the atomic number of the element. Figure 2 shows a selection of energy levels for a helium ion ($Z = 2$) and hydrogen atom ($Z = 1$).

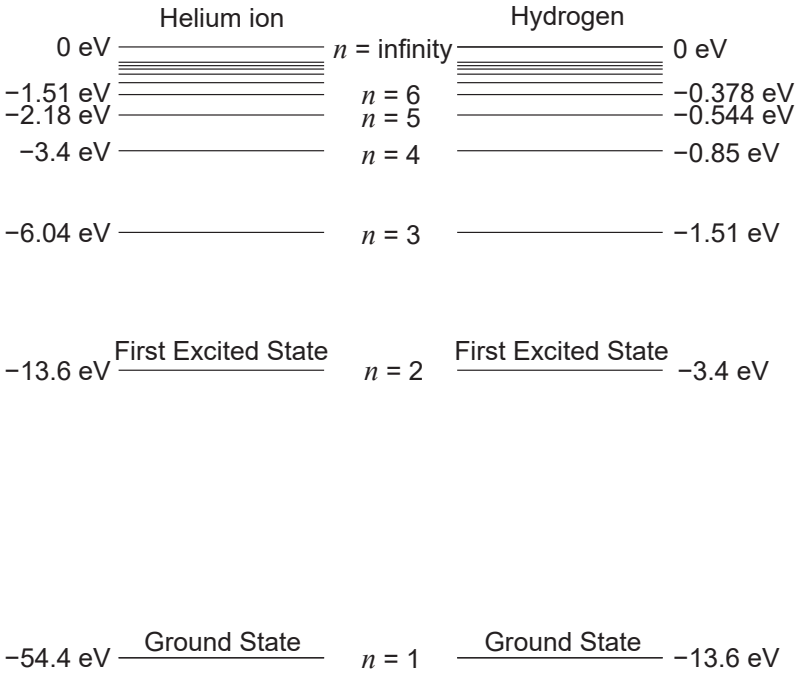



Figure 2: Energy levels for a helium ion and a hydrogen atom



**See next page**

(d) Identify and explain **two** differences you would see between the graph of $\frac{1}{\lambda}$ vs $\frac{1}{n_1^2} - \frac{1}{n_2^2}$ for hydrogen and the helium ion. (4 marks)

One: _____

Two: _____



See next page

**Question 16** **(15 marks)**

Figure 1 shows a power station that supplies electricity to a small community. The owners decided to switch from DC generation to AC (Figure 2) to save costs and reduce greenhouse gas emissions.

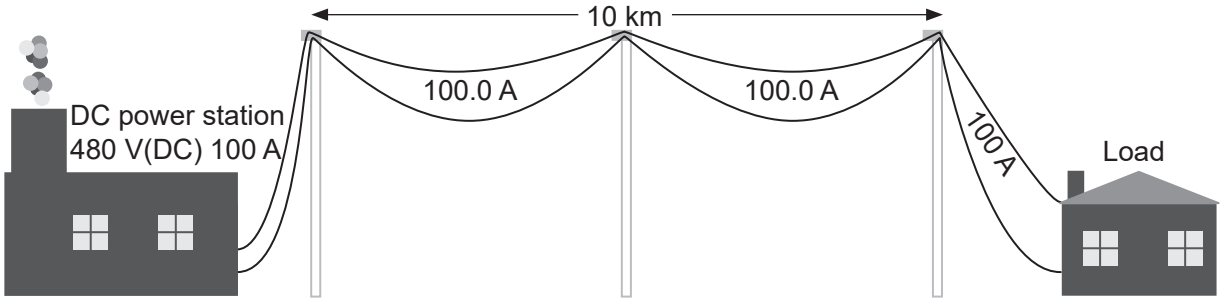



Figure 1: A DC power station

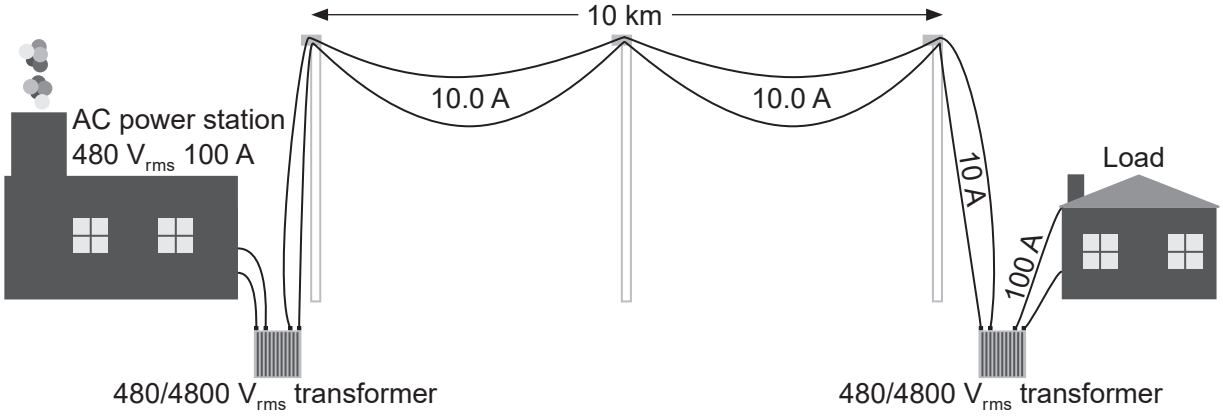



Figure 2: An AC power station

(a) Calculate the power output of both stations in kW. (2 marks)

DC power station

Answer: _____ kW

AC power station

Answer: _____ kW

**See next page**

(b) If the resistance of the transmission lines between the pylons is $2.19 \times 10^{-4}\ \Omega\ m^{-1}$, estimate the efficiencies of both systems by calculating power loss in the wires. Assume negligible power losses in the lines to the pylons from the station, and from the pylons to the houses. (6 marks)

DC power station: _____ % AC power station: _____ %

**Question 16** (continued)

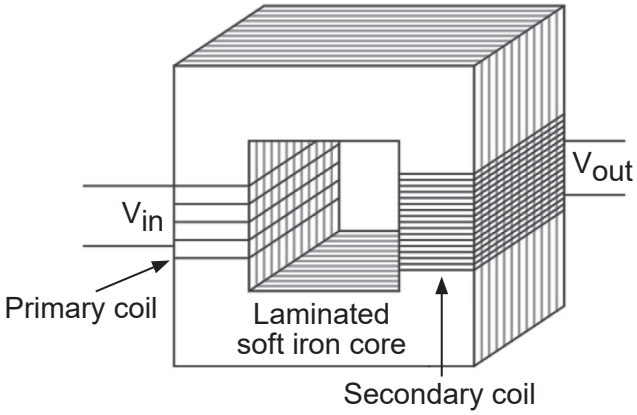



Figure 3: A step-up transformer with a laminated core

(c) Figure 3 shows a step-up transformer. One of the features that increases efficiency is the laminated soft iron core. Explain why laminating the core increases the transformer's efficiency. (3 marks)

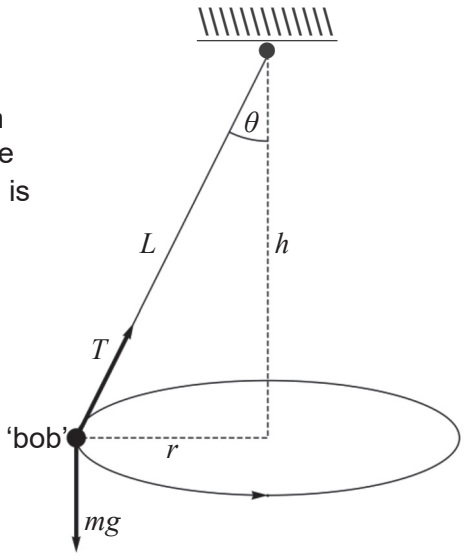
(d) Explain why transformers require AC current to function in electricity transmission.
(4 marks)



See next page

**Question 17** **(16 marks)**

The diagram to the right shows the two forces acting on a conical pendulum as it spins at a set frequency. The vector addition of these two forces provides the centripetal force on the 'bob'. The mass of the 'bob' is 255 g and the length of the pendulum string $L$ is 1.20 m. When the frequency of rotation is 0.490 Hz, the angle $\theta$ = 30.0°.




(a) Calculate the tension in the string when $\theta$ = 30.0°. (4 marks)

Answer: _____ N

(b) Calculate the radius of the circular path the 'bob' is moving in when the angle is 30.0°. (2 marks)

Answer: _____ m

**See next page**

(c) Calculate the new angle between the pendulum string and the vertical if the frequency of rotation is doubled. (6 marks)

Answer: _____ °

(d) Explain why $\theta$ can never equal 90.0°, regardless of how great the frequency of the pendulum becomes. You may use mathematical relationships in your answer. (4 marks)

_____

_____

_____

_____

_____

_____

_____

_____

**End of Section Two**

**See next page**

**Section Three: Comprehension** **20% (38 Marks)**

This section has **two** questions. You must answer **both** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 40 minutes.

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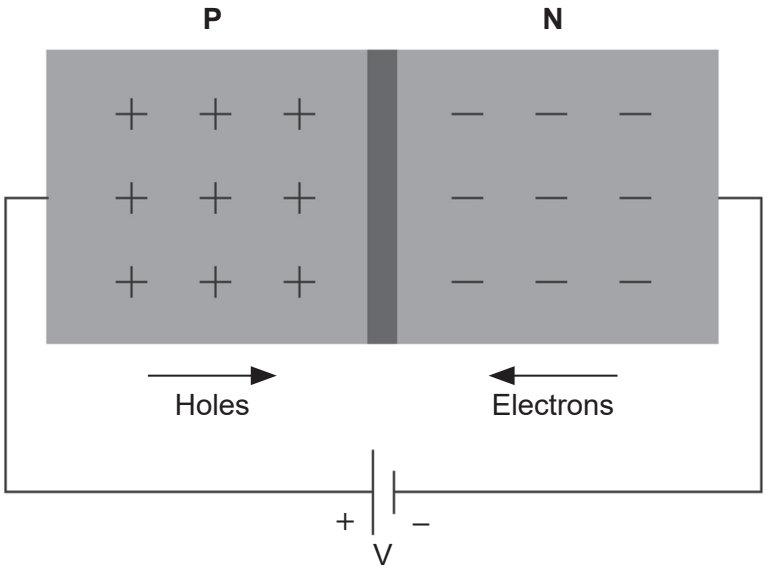
**Question 18** **(21 marks)**

**Light-emitting diodes (LEDs)**





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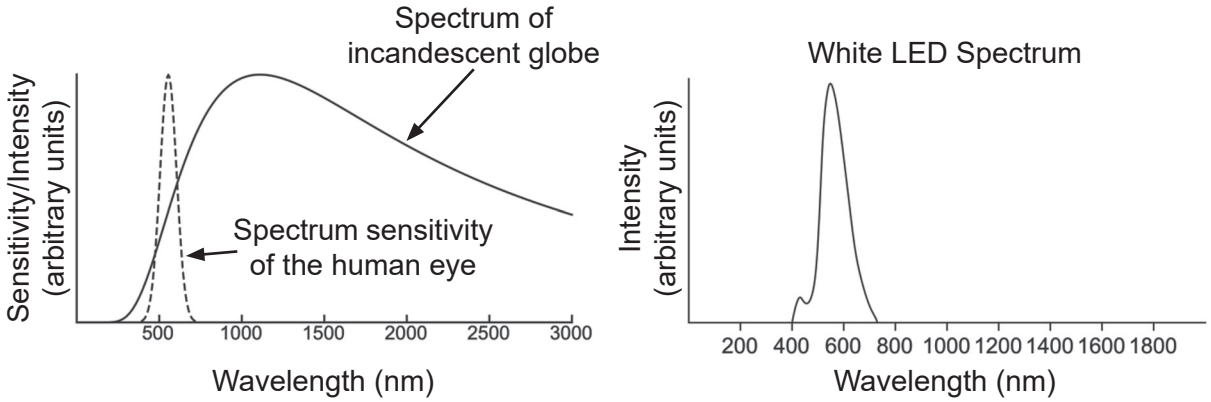
**Efficiency**






**Efficacy**

LEDs are also known for having the best 'efficacy' of all light sources. Efficacy is the measure of how well a light source produces visible light. It is measured in lumens per watt, or how much light is provided for every watt of power consumed. The power is calculated by multiplying the forward voltage (the lowest voltage at which current starts to flow in the normal conducting direction, $V_F$) by the operating current measured in amperes. In order to make sure that the correct voltage gets dropped across the LED, a voltage greater than the minimum required to produce the desired wavelength is used. A table of specific crystals, their forward voltages and the wavelengths they produce is given below. To increase brightness, the current is increased.

| Typical LED characteristics | | | |
|---|---|---|---|
| **Semiconductor material** | **Wavelength (nm)** | **Colour** | **$V_F$** |
| GaAs | 850–940 | Infra-red | 1.20 V |
| GaAsP | 630–660 | Red | 1.80 V |
| GaAsP | 605–620 | Amber | 2.00 V |
| GaAsP:N | 585–595 | Yellow | 2.20 V |
| AlGaP | 550–570 | Green | 3.50 V |
| SiC | 430–505 | Blue | 3.60 V |
| GaInN | 450–650 | White | 4.00 V |



**See next page**

**Question 18** (continued)

(a) Explain how a PN junction produces visible light. (4 marks)

The Law of Conservation of Energy states: 'Energy is neither created nor destroyed; it only moves from one place to another - from one type of energy to another.'

(b) LEDs and incandescent light bulbs are equally efficient at converting energy drawn from the mains into different types of energy. Why then does the passage on page 33 state that LEDs are far more efficient than incandescent light bulbs? Reference must be made to the graphs of intensity versus wavelength. (4 marks)



**See next page**

(c) The efficacy of a particular LED is 120 lumens $W^{-1}$. Using information in the passage and table on page 33, calculate how much current would need to run through a blue SiC LED light bulb operating at minimum $V_F$ to produce 840 lumens. (4 marks)

Answer: _____ A

(d) With the use of a calculation and data from the table on page 33, show how the minimum $V_F$ for SiC crystals is large enough to produce photons with the lowest energy required for blue light. (4 marks)



See next page

**Question 18** (continued)

(e) Lighting accounts for 15% of yearly global electricity consumption (194 EJ or $194 \times 10^{18}$ J). Roughly 40% of this is supplied by LEDs. Each tonne of coal produces, on average, 21 GJ of energy. Eighty per cent of world energy consumption is derived from fossil fuels. Using the efficiencies stated in the passage, estimate the mass of coal the world could save per year if 100% of lighting was provided by LEDs. (5 marks)

Answer: _____ Tonnes

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**See next page**

**Question 19** **(17 marks)**

**Kepler's Laws**

Kepler's three laws of planetary motion can be stated as follows:

I All planets move about the Sun in elliptical orbits, having the Sun as one of the foci.

II A radius vector joining any planet to the Sun sweeps out equal areas in equal lengths of time.

III The squares of the periods (of revolution) of the planets are directly proportional to the cubes of their mean distances from the Sun.

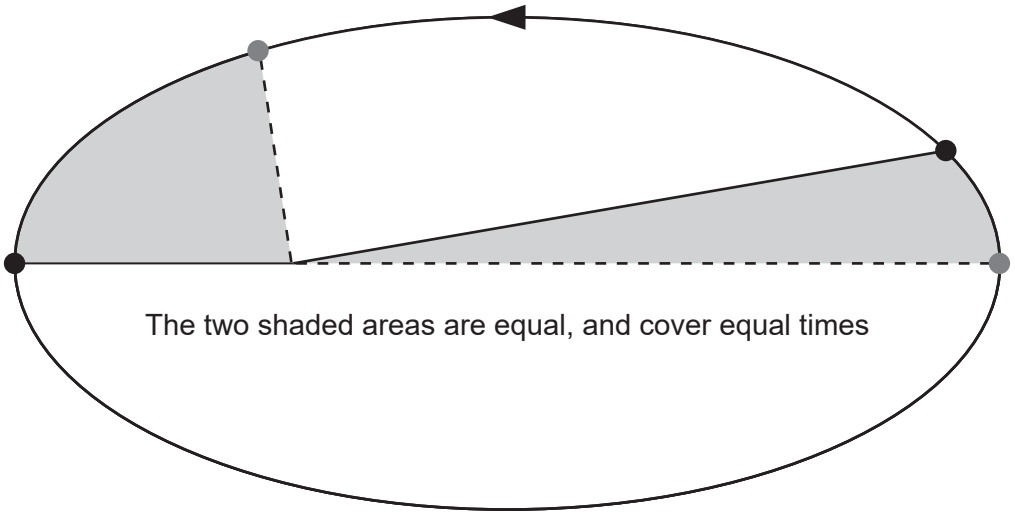



Figure 1: Kepler's 2nd Law

Kepler's 3rd Law, which appears on the Formulae and Data booklet, can be derived for a circular orbit from first principles: the centripetal force between the planet and the Sun is provided by Newton's Law of Gravitation, and $S = vT$, where $S$ is the orbiting circumference and $T$ is the period.

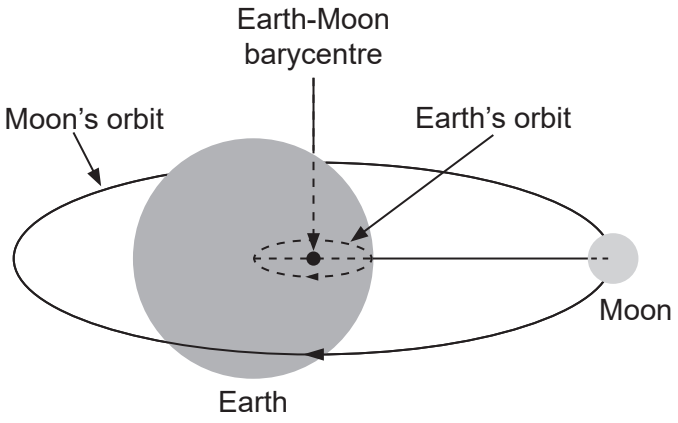



Figure 2: Location of Earth-Moon barycentre

The system of any large celestial body, and its satellite, orbits around a 'barycentre'. This represents the centre of mass of the system. The barycentre of the Earth–Moon system is shown in Figure 2. The system could be seen as a balance beam, with the barycentre located where the fulcrum would be placed to achieve equilibrium. The gravitational field strength due to the Sun is identical for both the Earth and Moon and therefore cancels out when calculating moments around the barycentre.

When the mass of the satellite represents a significant percentage of the system, the barycentre is outside either body. When its mass is significantly less, the barycentre is usually found within the more massive body which appears to 'wobble'. When the mass of the orbiting satellite is insignificant compared to the mass of the body it is orbiting, the barycentre can be assumed to be the centre of mass of the larger body.

**See next page**

(a) (i) Using Kepler's 2nd Law, describe the relationship between the distance a planet is from the Sun it orbits and its orbiting speed by filling in the blank below. (1 mark)

As the distance from the planet increases, the orbiting speed _____.

(ii) Without completing a calculation, justify this relationship with reference to Figure 1. (3 marks)

_____

_____

_____

_____

_____

(b) Using the instructions given in the article, derive Kepler's 3rd Law from first principles, showing each step of the derivation. The final expression must match the equation in the Formulae and Data booklet. Assume the orbit is perfectly circular and the mass of the satellite is insignificant compared to the mass of the body it is orbiting. (5 marks)

**Question 19** (continued)

(c) Using moments, estimate how far the barycentre of the Earth–Moon system is from the centre of the Earth. (4 marks)

Answer: _____ m

(d) With the use of a calculation and your answer to part (c), show that the Moon is travelling roughly 81 times faster than Earth as they orbit the barycentre. If you could not get an answer to part (c), use $4.81 \times 10^6$ m and show that the ratio of the Moon's orbiting velocity to that of the Earth is roughly 80. (4 marks)

**End of questions**

Supplementary page

Question number: _____

Supplementary page

Question number: _____

Supplementary page

Question number: _____

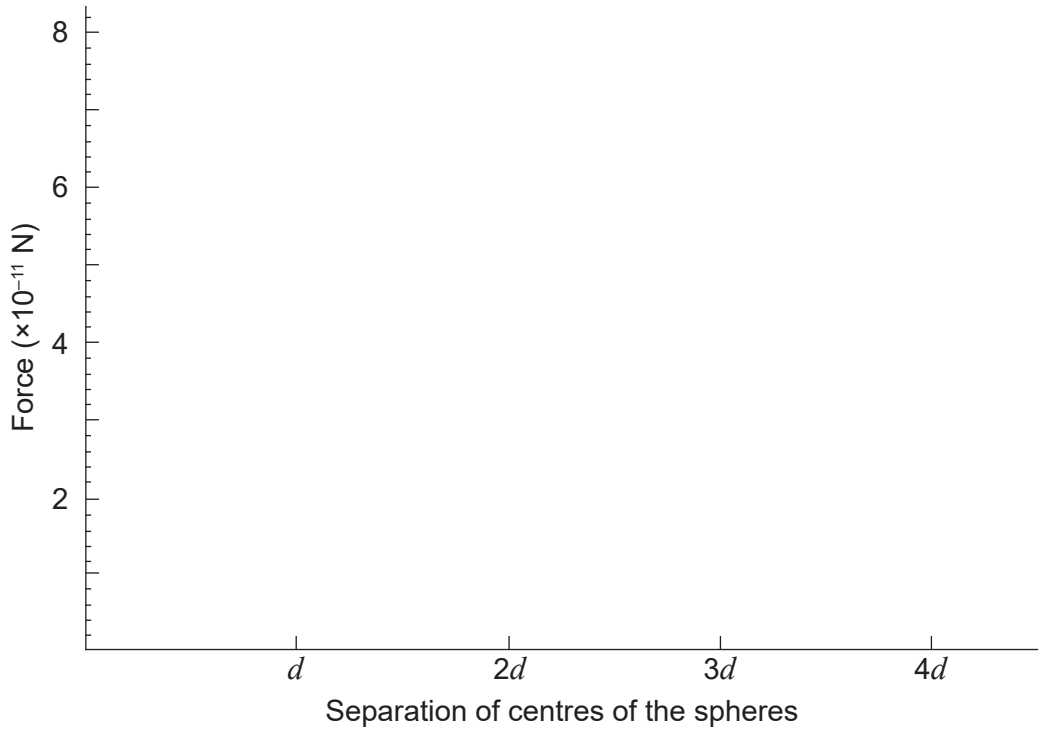
Supplementary page

Question number: _____

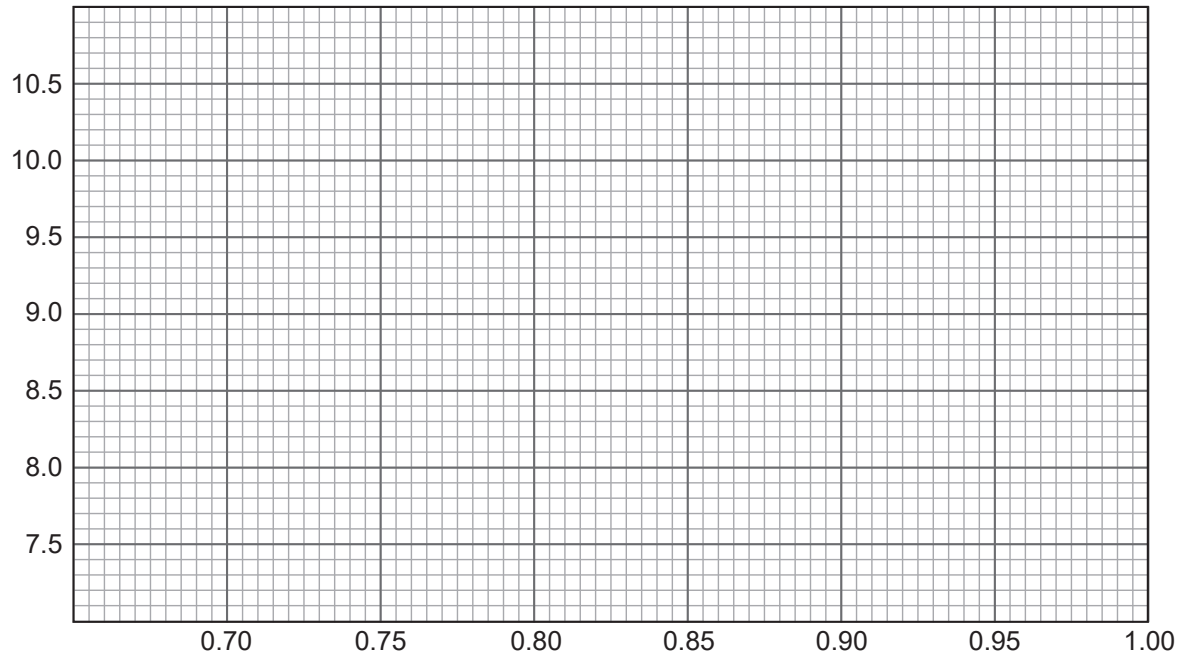
Supplementary page

Question number: _____

Spare axes for Question 8(b)



Spare grid for Question 15(b)



## ACKNOWLEDGEMENTS


**Question 3** Adapted from: Mini Physics. (2015). [Diagram of an AC generator]. Retrieved April, 2022, from https://www.miniphysics.com/a-c-generator.html

**Question 7** Diagram adapted from: Sen, M. (n.d.). *Fig. (1) - A current-carrying rod, AB, experiences a force perpendicular to its length and the magnetic field*. Retrieved April, 2022, from https://edurev.in/studytube/Theory--Procedure--Force-on-a-Current-Carrying-Con/4c3037c5-9a24-4358-8ba5-1dbb473329d9_t

**Question 18** LED text adapted from: Baguley, R., & McDonald, C. (2014). *Appliance science: The illuminating physics behind LED lights*. Retrieved April, 2022, from https://www.cnet.com/home/kitchen-and-household/
appliance-science-how-led-lights-work/

**Question 19** Lines 1–6 (from "Kepler's three laws…" to "…from the sun") from: The editors of Encyclopaedia Britannica. (n.d.). *Kepler's laws of planetary motion*. Retrieved April, 2022, from https://www.britannica.com/science/Keplers-laws-of-planetary-motion





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