Government of **Western Australia**
Curriculum Council

WACE
Western Australian Certificate of Education

Tertiary Entrance Examination, 2009

Question/Answer Booklet

PHYSICS

Please place your student identification label in this box

Student Number: In figures | | | | | | | | |

In words _____

_____

Time allowed for this paper

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

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer Booklet
Physics: Formulae, Constants and Data Sheet (inside front cover of this Question/Answer Booklet)

To be provided by the candidate

Standard items: pens, pencils, eraser, correction fluid, ruler, highlighters

Special items: MATHOMAT and/or Mathaid, drawing compass, protractor, set square and calculators satisfying the conditions set by the Curriculum Council for this subject

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 notes or other items of a non-personal nature in the examination room. 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	Number of questions to be attempted	Marks available
A: Short Answers	15	15	60
B: Problem Solving	7	7	100
C: Comprehension and Interpretation	2	2	40
		Total marks	200

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2009*. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in the spaces provided in this Question/Answer Booklet.

3. You may remove the enclosed *Physics: Formulae, Constants and Data Sheet* from the booklet and use as required. This sheet is not to be handed in at the end of the examination.

4. Your answers to questions involving calculations should be evaluated and given in decimal form. It is suggested that you quote all answers to three significant figures, with the exception of questions for which estimates are required, in which either one or two significant figures is appropriate. In the case of an incorrect final result, marks may be awarded for method and working, provided these are set out clearly and legibly.

5. Questions containing the specific instruction **'show working'** should be answered with a complete, logical, clear sequence of reasoning showing how you arrived at your final answer. For these questions, correct answers which do not show working will not be awarded full marks.

6. Questions containing the instruction **'estimate'** may give insufficient numerical data for their solution. You should provide appropriate figures to enable an approximate solution to be obtained.

7. When descriptive answers are required, you should display your understanding of the relevant Physics within the context of a question. An answer which does not display an understanding of Physics principles will not attract marks.

See next page

Section A: Short Answers **60 Marks**

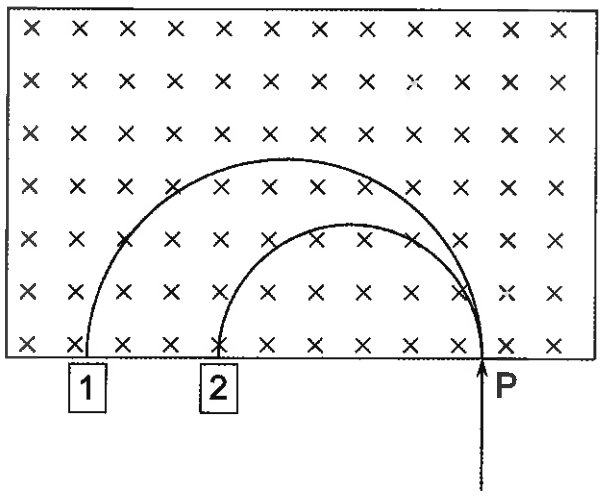
Attempt **all** 15 questions in this section. Each question is worth 4 marks. Answers are to be written in the space provided.

---

1. Two identical tuning forks vibrate at a frequency of 256 Hz. One of them has a drop of wax placed on it. This lowers its frequency. When the two tuning forks are sounded, 6 beats per second are heard. What is the frequency of the tuning fork with the wax on it? Show your working.

Answer: _____

2. Two particles of the **same mass** enter a magnetic field at point P with the **same speed** and follow the paths shown. The magnetic field is uniform, perpendicular to and into the plane of the paper.



(a) Which particle's charge has the larger magnitude?_____

(b) Are the two charges positive or negative?_____

See next page

3. A workplace health and safety inspector uses a sound meter to check the loudness in a restaurant kitchen. Five identical food processors are to be used. With one food processor switched on, the meter reads 60 dB. What is the meter's new sound level with all five food processors being used? You should assume the inspector is the same distance from all five food processors.

Answer: _____

4. A satellite is in a low Earth orbit, 790 km above the surface.

   (a) Calculate the satellite's orbital speed.

Answer: _____

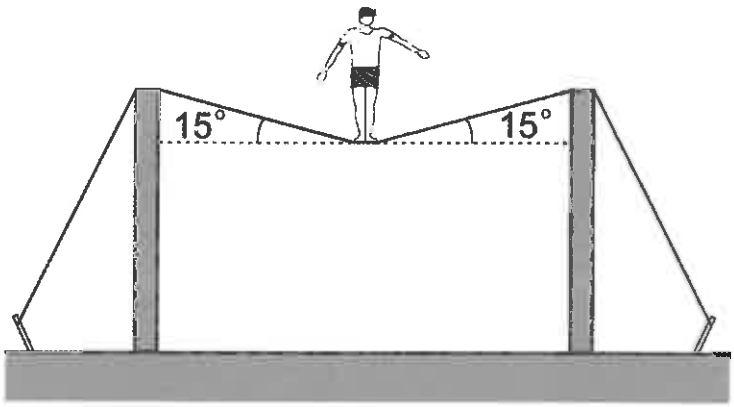
   (b) Hence, calculate the period of its orbit.

Answer: _____

See next page

5. A circus performer of mass 65 kg is walking along a high wire. The wire sags under the weight of the performer and makes an angle of 15° with the horizontal, as shown in the diagram.

Calculate the tension in the wire between the poles.



Answer: _____

See next page

6. A student would like to swing a bucket of water in a vertical circle without spilling it.

(a) Explain why the water does not fall out of the bucket at the top of the swing.

(b) Calculate the minimum speed required to keep the water from coming out of the bucket at the top of the swing. Assume the distance from his shoulder to the centre of mass of the bucket is 1.1 m and that the speed of the bucket is constant.

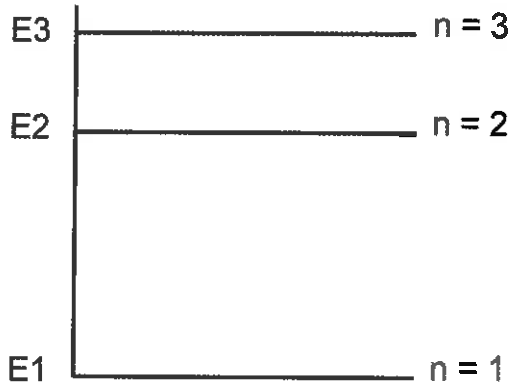
Answer: _____

7. In June 2008 *New Scientist* magazine reported the fabrication of a new kind of paper that it claimed was 'stronger than cast iron'. The paper has a breaking stress of 214 megapascal. How much force could a piece of this paper with a cross-section 8.50×10^{-3} cm by 2.00 cm support before breaking?

Answer: _____

See next page

8. The energy level diagram for a hypothetical atom is shown below. On this diagram draw arrows to show the transitions that would produce emission and absorption spectra for this atom. Indicate which transitions are responsible for the absorption spectrum and which for the emission spectrum.



9. A 1.0 mW light source emits a narrow beam that shines on a screen. The wavelength of the light is 633 nm.

(a) Calculate how many photons strike the screen per second.

Answer: _____

(b) If the power of the beam is doubled, which of the following statements is true?

A. The photons travel faster.

B. Each photon has more energy.

C. More photons hit the screen every second.

D. The frequency of the light is doubled.

Answer: _____

10. Some materials emit visible light when illuminated by ultraviolet light.

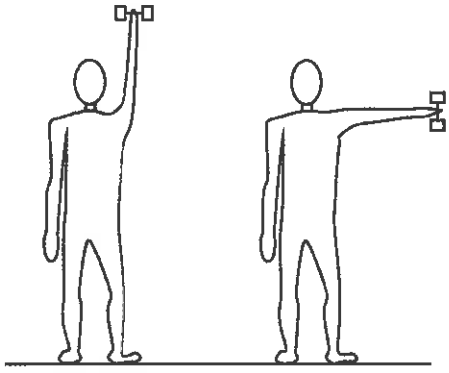
(a) What is this phenomenon called?

(b) Explain how this phenomenon occurs. You may wish to draw a diagram to aid your explanation.

11. In the following diagrams a person is holding a dumbbell (heavy mass) above their head and at a right angle to their body. In which position will the person experience greater difficulty in maintaining the position of the dumbbell? Circle your answer.

(a) Above head (b) At right angles to body

Justify your answer. You **must** use the diagram to **assist** your explanation.



See next page

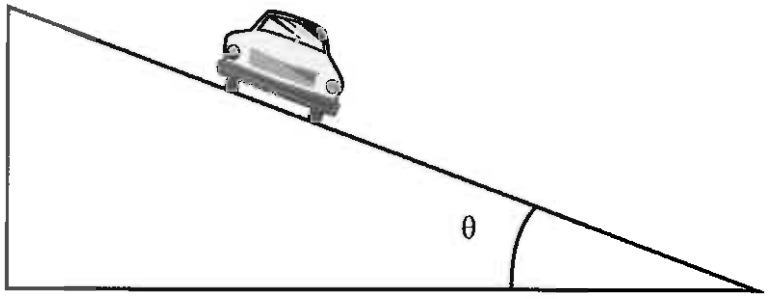
12 A child swings on a gate moving through 90°. The child is at the opposite end of the gate to the hinge. Estimate the magnitude of the centripetal force experienced by the child.

Answer: _____

13. A transformer with 25 turns on its input coil is connected to a constant DC supply of 24 V. Explain why there is no output voltage in this case.

See next page

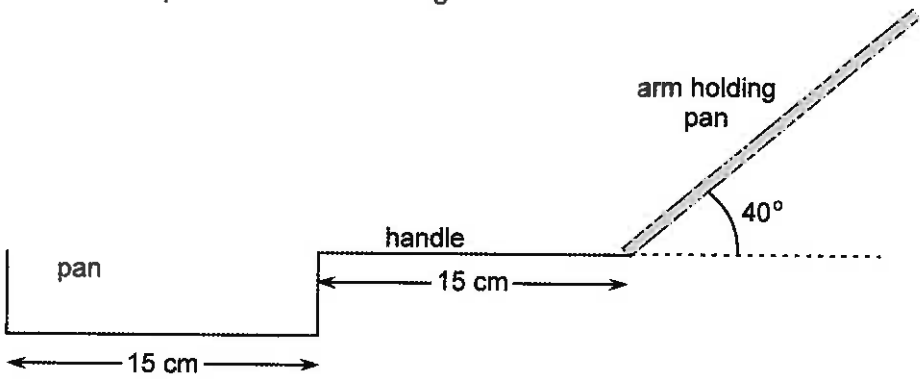
14. Calculate the maximum speed at which a 900 kg car can travel on a curve of radius 250 m banked at 30° without sliding.



Answer: _____

See next page

15. An empty pan has a mass of 450 grams without the handle. The handle has a mass of 50 grams. The pan is being held at the end of the handle. Assume that both the pan and handle are uniform. The pan has 2.0 kg of water in it. The water is uniformly distributed in the pan and is not moving.



What moment should be supplied by the person holding the pan to stop it from tilting? You should give the size and direction of this moment.

Size of moment: _____ Direction: _____

See next page

Section B: Problem Solving **100 Marks**

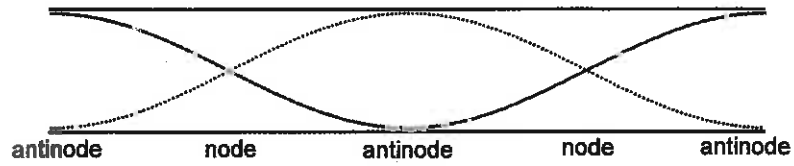
Attempt **all** 7 questions in this section.

---

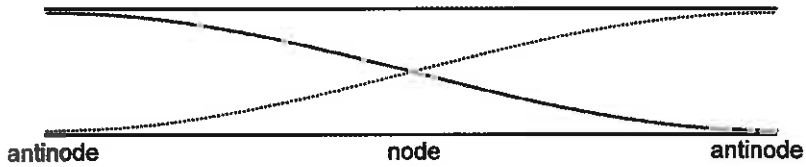
1. **(15 marks)**

An organ pipe X, with both ends open, sounds its fundamental frequency of 300 Hz. Dry air at 25° C is in the pipe.

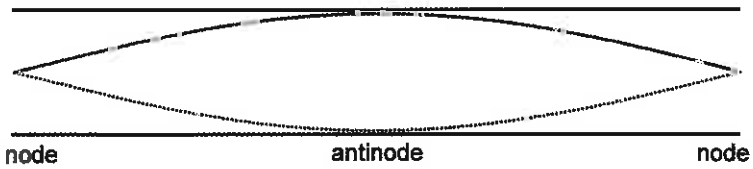
(a) Which of the diagrams below best represents the particle displacement in the pipe? (4 marks)



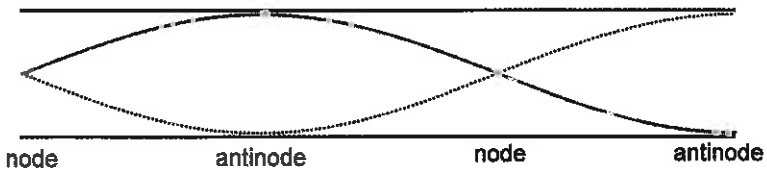
A



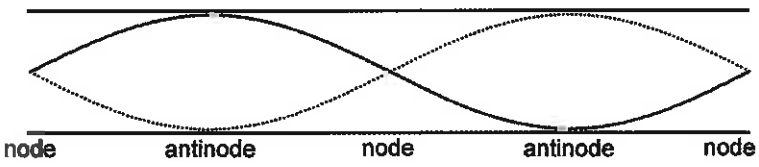
B



C



D



E

Answer: _____

See next page

(b) Calculate the length of this organ pipe. (3 marks)

Answer: _____

A second pipe Y is closed at one end. Dry air at 25° C is in the pipe.

(c) Why do closed pipes only have odd-numbered harmonics? You may illustrate your answer with a diagram. (4 marks)

_____

_____

_____

_____

_____

_____

_____

_____

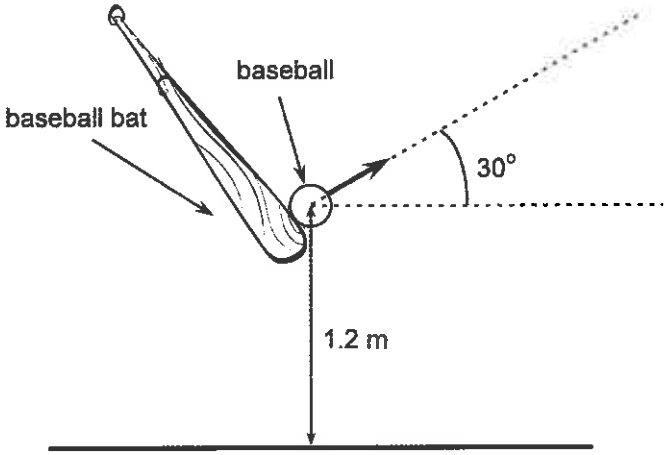
The third harmonic (first overtone) of pipe Y has the same frequency as the second harmonic (first overtone) of pipe X.

(d) Calculate the length of the pipe Y. (4 marks)

Answer: _____

2. **(14 marks)**

A baseball leaves a bat at angle of 30° with respect to the horizontal, 1.2 m above the ground and with an initial velocity of 47 m s^{-1}.



You may assume that air resistance is negligible.
You **must** show your working to gain full marks for this question.

(a) Calculate the maximum height reached by the baseball above the ground. (4 marks)

Answer: _____

(b) Calculate the vertical component of the velocity when the ball hits the ground. (3 marks)

If you were unable to determine an answer to part (a), you should use 27 m as a value for the maximum height.

Answer: _____

See next page

(c) Calculate the time of flight of the baseball. (4 marks)

If you were unable to determine an answer to part (b), you should use 20 m s^{-1} as a value for the vertical component of velocity when the ball hits the ground.

Answer: _____

(d) Calculate the horizontal range of the baseball. (3 marks)

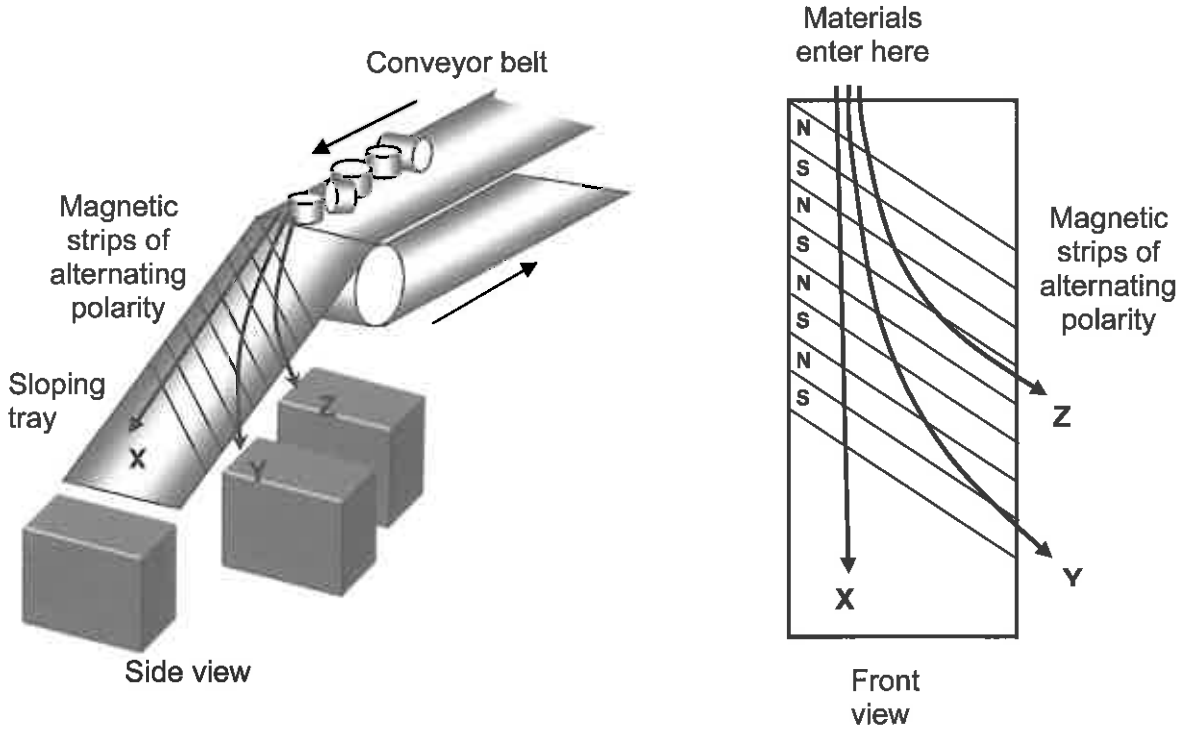
If you were unable to determine an answer to part (c), you should use 3 s as a value for the time of flight.

Answer: _____

See next page

3. **(13 marks)**

One method of sorting rubbish in a recycling centre utilises the magnetic and non-magnetic nature of metals. All items to be recycled are placed on a conveyor belt; iron and other ferrous metals are removed first using electromagnets. The remaining solids can then be sorted using a technique called **eddy current separation.**
The diagram below shows a design of an eddy current separator. It consists of magnetic strips of alternating polarities mounted on a sloping tray.



(a) A piece of iron that has not been removed by the electromagnets enters the eddy current separator. Describe what would happen to this piece of metal. (2 marks)

(b) Explain why a non-magnetic metal will experience a magnetic force as it moves across the magnets in the eddy current separator. (5 marks)

See next page

The path followed by different solids on the eddy current separator conveyor belt depends on the value of electrical conductivity (how well a material conducts electricity) divided by density. Aluminium has a ratio of 14.0 $m^2 \Omega^{-1} kg^{-1}$, copper 6.7 $m^2 \Omega^{-1} kg^{-1}$ and glass 0.0 $m^2 \Omega^{-1} kg^{-1}$. The paths followed by three materials have been marked on the diagram.

(c) Identify which material has followed which path and explain your reasoning. (6 marks)

X is _____

Reason: _____

_____

_____

_____

Y is _____

Reason: _____

_____

_____

_____

Z is _____

Reason: _____

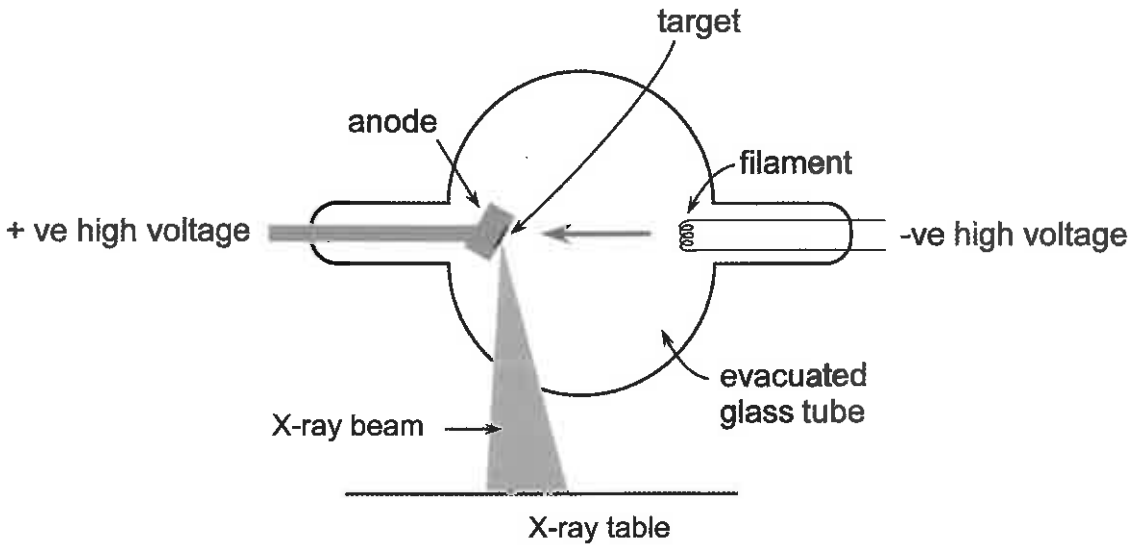
_____

_____

_____

4. **(13 marks)**

The diagram below shows the basic components of a stationary anode X-ray tube.



(a) Describe how X-rays are produced in the tube. (5 marks)

(b) An X-ray tube with a tungsten anode is operating at a peak voltage of 100 kilovolts. Determine the upper limit in electron volts for the energy of an X-ray photon emitted from the tungsten target. (2 marks)

Answer: _____

See next page

(c) Exposure to X-rays is potentially more harmful than exposure to ultraviolet light.

(i) Explain why X-rays are so harmful compared with ultraviolet light.

(2 marks)

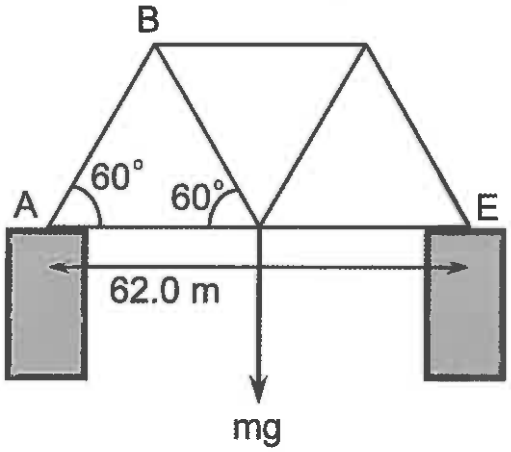
(ii) Describe and justify **two** precautions that an X-ray operator must take to reduce their risk of exposure. (4 marks)

One:

Two:

5. **(15 marks)**

Bridges that must be strong and light are often made of trusses. The structural components are connected by pin joints and the entire structure is free to slide horizontally to accommodate thermal expansion and contraction. The following diagram shows a truss bridge 62.0 m long that supports a uniform load of a roadway of mass 1.20×10^6 kg. The angle between the bars is 60°. The structure is resting on two smooth piers A and E. Assume that the weight of the trusses is negligible compared to the roadway and neglect any deformation of the structure.



(a) Calculate the force exerted by each support A and E. (5 marks)

Answer: _____

(b) Calculate the force in the bar AB. State whether the force you have calculated is tensile or compressive. (5 marks)

Answer: _____

(c) Calculate the minimum cross-sectional area each bar must have to withstand the load of the roadway with a safety factor of 5. A safety factor of 5 means that the stress applied to a bar should not exceed one-fifth of the value of the breaking stress. Assume all bars are made of mild steel and are of equal lengths and cross-sectional area. (5 marks)

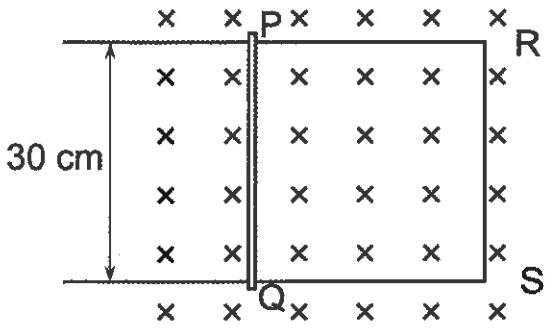
If you were unable to determine an answer to (b), use 3.5×10^6 N as a value for the force in a bar.

Answer: _____

See next page

6. **(14 marks)**

In the diagram below a conducting rod PQ makes contact with the metal rails QS and PR that are 30 cm apart in a uniform magnetic field of 0.50 T perpendicular to and into the plane of the paper as shown. The only resistance in the circuit PQRS is 2.0 Ω in the arm RS. An applied force F_a is moving the rod to the left at a **constant** velocity of 6.0 m s^{-1}.



(a) Calculate the emf induced between the ends P and Q. (3 marks)

Answer: _____

(b) Calculate the size of the current in the section of wire RS. In which direction does the current flow? You should give your answer in terms of conventional current flow. (4 marks)

Size of current: _____ Direction: _____

See next page

(c) Calculate the magnitude and direction of the magnetic force acting on PQ. (4 marks)

Answer: _____

(d) The frictional force between the rod and the rails is negligible. Calculate the size and direction of the force F_a. (3 marks)

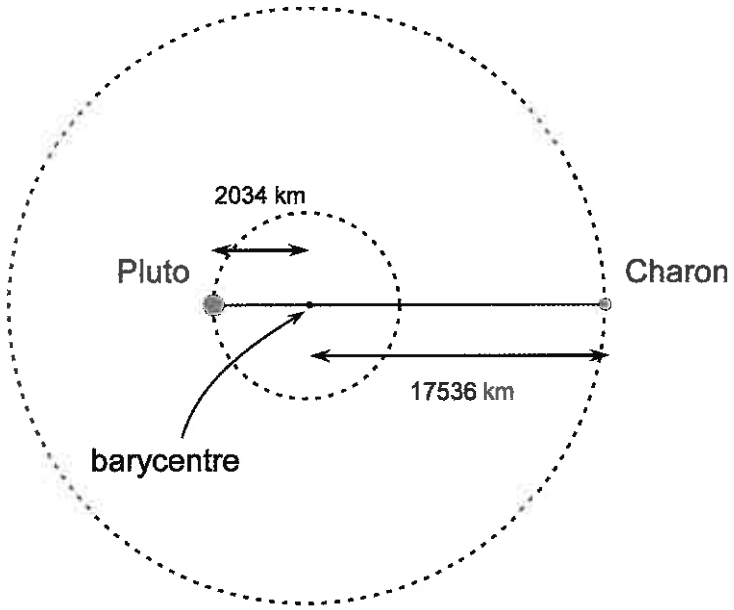
Answer: _____

See next page

7. **(16 marks)**

The dwarf planets Pluto and Charon form part of the Kuiper belt that orbits the Sun. The centres of Pluto and Charon are **always** 19 570 km apart. In addition to orbiting the Sun, Pluto and Charon orbit a point between them called the *barycentre*. The barycentre **always** lies on a straight line between Pluto and Charon. This is illustrated in the diagram below. The diagram is not drawn to scale.

Pluto has a mass of 1.305×10^{22} kg; Charon has a mass of 1.52×10^{21} kg.



(a) Calculate the magnitude of the gravitational force of attraction between Pluto and Charon. (4 marks)

Answer: _____

(b) Calculate the speed of Pluto around the barycentre. (4 marks)

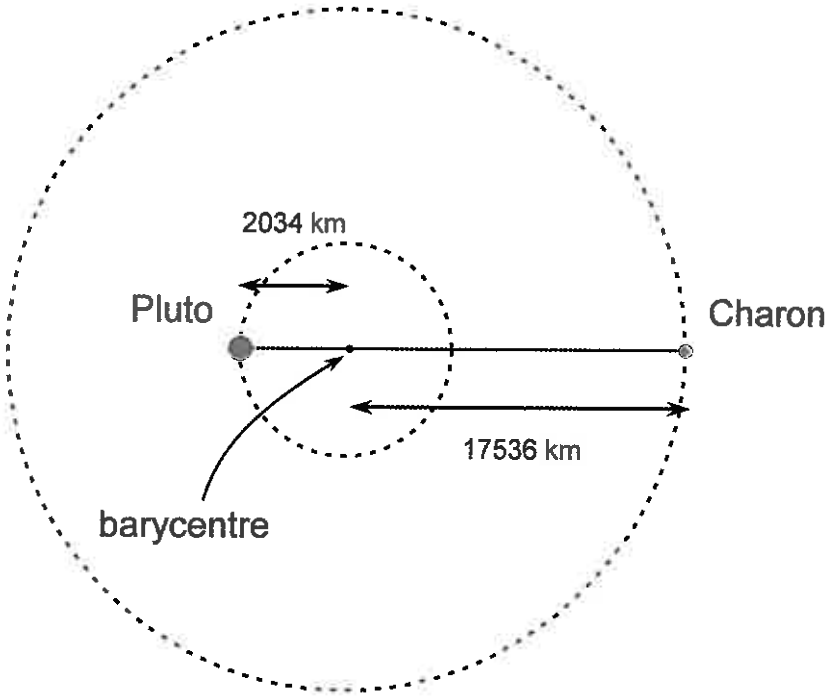
Answer: _____

See next page

(c) (i) How long, in Earth days, does it take Pluto to orbit the barycentre? If you were unable to determine a speed in part (b), use 24 m s^{-1}. (4 marks)

Answer: _____

(ii) Mark on the diagram the position of both Pluto and Charon 1.60 Earth days after their initial position on the diagram. Assume Pluto orbits in a clockwise direction. (4 marks)



Section C: Comprehension and Interpretation **40 Marks**

Both questions should be attempted.

Read the following passages and answer the questions at the end of each of them. Candidates are reminded of the need for the clear and concise presentation of answers. Diagrams (sketches), equations and/or numerical results should be included as appropriate.

---

1. Standing Wave on a Stretched String (20 marks)

Background

The properties of standing waves on stretched strings are of special significance to musical instruments. In all stringed instruments, for example guitar or violin, a string is plucked or bowed which generates a note.

For all waves the speed of a wave is given by the equation $v = f\lambda$

The speed of a wave on a stretched string can also be expressed as $v = \sqrt{\frac{T}{\mu}}$

where v = wave speed (m s^{-1})
f = frequency (Hz)
T = tension in string (N)
μ = mass per unit length of string (kg m^{-1})

When a stretched string is vibrating at its fundamental frequency, the wavelength $\lambda = 2L$

where L = length of the string.

Substituting for wavelength and equating the equations for speed leads to the equation

$$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$$

On a guitar the different notes are supplied by strings with different mass per unit length. The mass per unit length is the only variable in the equation that can be easily changed on a guitar; the length is determined by the length of the guitar and it would place strain on the guitar if the strings were under significantly different tensions.

For a particular manufacturer of guitar strings, the values of mass per unit length (μ), for the different notes are shown below.

String (note)	Mass per unit length, μ (kg m^{-1} x 10^{-3})
E	0.401
B	0.708
G	1.140
D	2.333
A	4.466

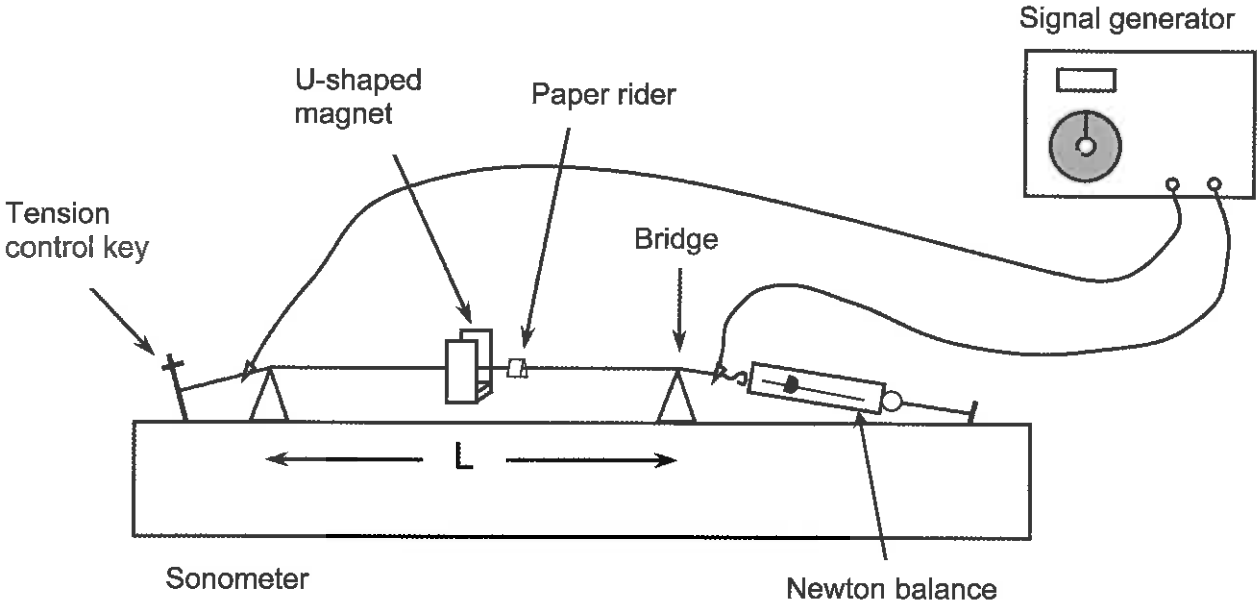
See next page

(a) A very simple description of an acoustic guitar follows.
An acoustic guitar is a box with a hole in it. Strings are stretched across the hole. To produce a note, a string is plucked.
Why does the presence of a hollow box behind a string increase the volume of the sound produced? (4 marks)

See next page

Experiment

A student is challenged by their teacher to determine the mass per unit length of an unknown guitar string. The equipment used is illustrated in the following diagram. The student can vary the frequency of alternating current passing through the guitar string, the string vibrates in the presence of the magnet and the student is able to identify the resonant frequency by measuring the maximum displacement of the paper rider. The student changes the length of the string, maintains the same tension throughout the experiment and records the resonant frequency each time.



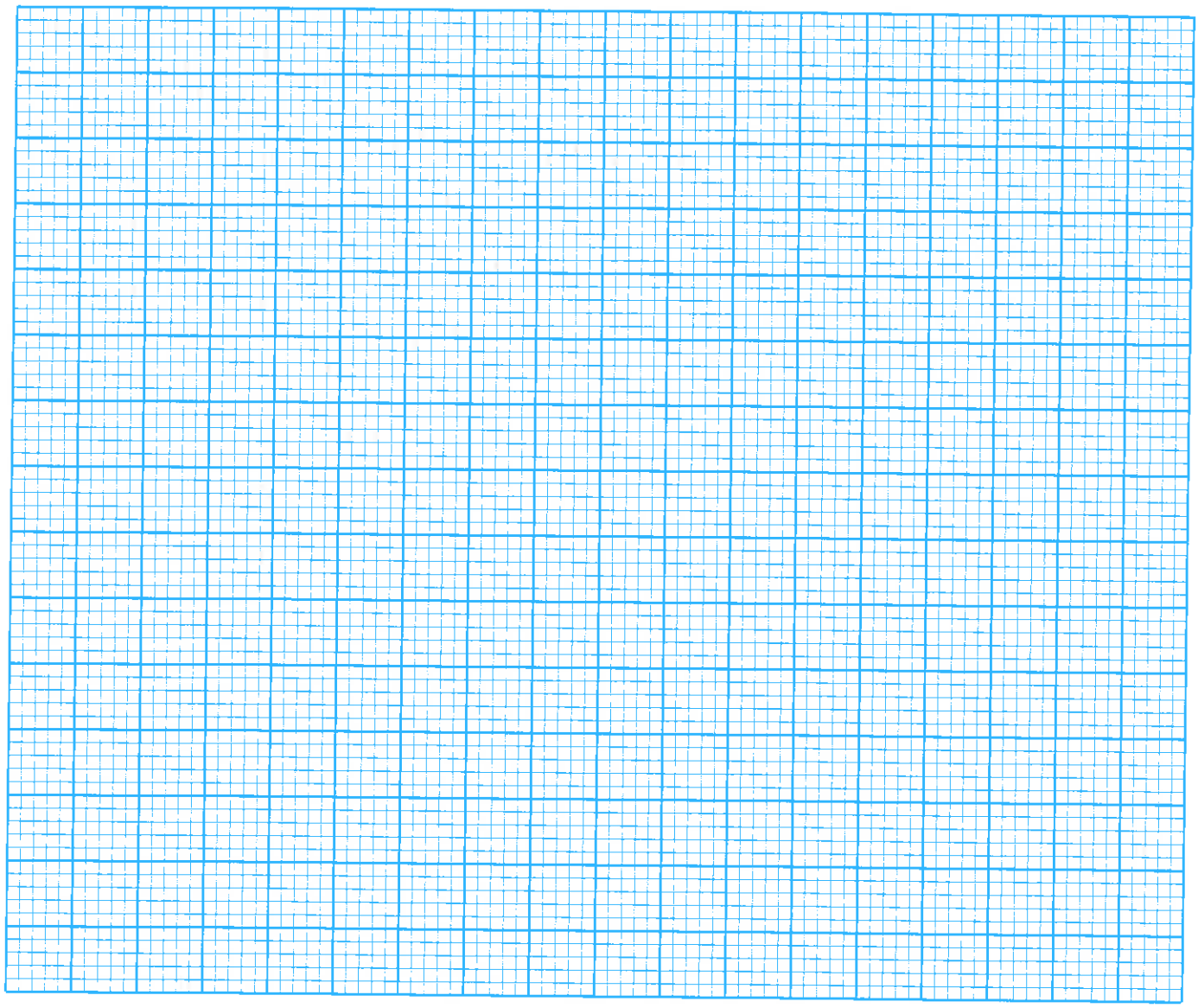
(b) Explain why the wire vibrates when it is in a magnetic field with an alternating current through the wire. (4 marks)

(c) Make the necessary calculations and enter the results into the students table of results below, in the column headed $\frac{1}{2L}$.

The student's experimental results are recorded in the table below:

Length (m)	Tension (N)	Resonant frequency (Hz)	$\frac{1}{2L}$
0.8	7.6	86	
1.0	7.6	69	
1.2	7.6	57	
1.4	7.6	49	
1.6	7.6	43	
1.8	7.6	38	

Use the data to plot a graph of frequency against $\frac{1}{2L}$ using the graph paper below. Draw a line of best fit. (5 marks)



See next page

(d) Using either the graph or a graphics calculator, determine the gradient of the graph.
(3 marks)

Answer: _____

(e) Use the table of μ values and your answer to part (d) to determine the guitar string used in this experiment. (4 marks)

If you were unable to determine a value in part (d), you should use a numerical value of 57 for the gradient.

Answer: _____

See next page

2. Wind turbine generator (20 marks)

A wind turbine generator extracts energy from the prevailing wind and converts it to useful electrical power using an electrical generator connected to the rotating shaft.
The power in moving air is the flow rate of kinetic energy per second:

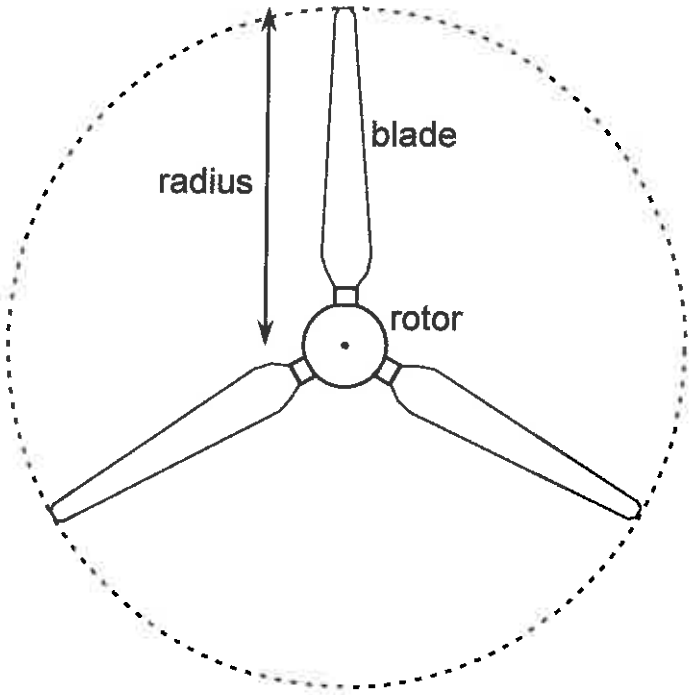
$$P_{wind} = \tfrac{1}{2}\rho A v^3$$

where ρ = density of air (~ 1.22 kg m^{-3})
A = area (in m^2) swept by the rotor blades (πr^2) for radius r
v = wind speed (m s^{-1})

The power extracted from the wind by a wind turbine is usually expressed in terms of a power coefficient C_P:

$$P_{extracted} = \tfrac{1}{2} C_p \rho A v^3$$

where C_p is the fraction of upstream wind power extracted by the turbine.



A common turbine design has a three-bladed rotor that rotates in the wind. One end of the central shaft connects via a gearbox to a rotating solenoid. The solenoid rotates at the rotor frequency times the gear ratio. The solenoid has coils of conducting wire that are connected via slip-rings to an electrical network. Around these coils a rotating magnetic field is established using a power source operating at a fixed frequency.

See next page

If resistive losses in the generator are negligible the power can be written as:

$$P_{em} = \frac{3V_T V_G}{X}$$

where P_{em} is the electrical power generated in watts
V_T is the terminal voltage at the output of the device
V_G is the internal generated voltage
X is a parameter measured in ohms that depends on the coil windings on the rotor and the particular materials and dimensions of components

For a generator coil with N turns with an area A, the amplitude of the generated voltage V_G is given by

$$V_G = 2\pi f N B A$$

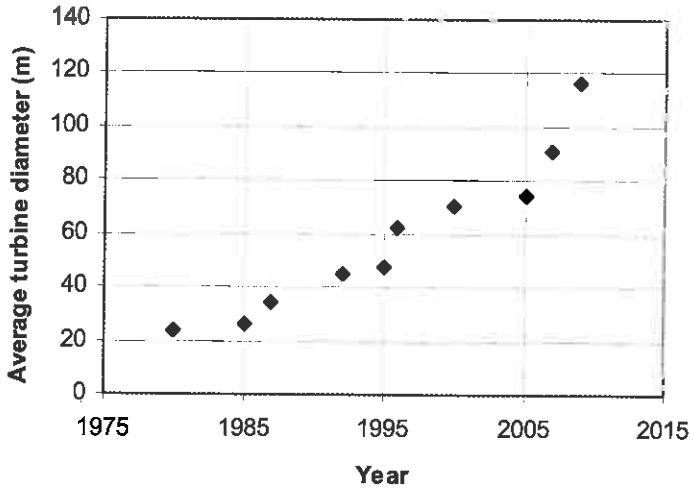
where f is the frequency of rotation (Hz)
B is the magnitude of the magnetic field (T)

(a) The turbine generates electricity at 1000 V. Calculate the turns ratio required in a transformer that connects the turbine to the electrical grid with a voltage of 20 kV.

(3 marks)

Answer: _____

Turbine diameter trends



(b) The graph above shows how the average rotor diameter of large, commercially-available wind turbines has varied over the past 30 years.
Suggest one practical reason for the trend observed in the graph. (4 marks)

Consider a particular design of wind turbine that offers 15 kW maximum power for a rotor diameter of 10 m at an average wind speed of 10 m s^{-1}.

(c) Calculate the power coefficient C_p. (3 marks)

Answer: _____

A commercially-available wind generator can be used to generate up to 3000 kW of electrical power. The rotor has a diameter of 90 m and in winds of 15 m s^{-1} has a speed of 16 revolutions per minute (rpm).

(d) When operating at maximum power, the terminal voltage is 1000 V and the parameter X has a value of 10 Ω. Calculate the generator voltage V_G. (3 marks)

Answer: _____

(e) Calculate the ratio of the speed of the generator solenoid to the speed of the rotor so that the generator solenoid rotates with a frequency 50 Hz. (3 marks)

Answer: _____

(f) If there are 10 000 turns in the solenoid each having a cross-sectional area of 0.126 m^2, calculate the magnetic field strength *B* when operated at maximum power. (4 marks)

The generator solenoid rotates with a frequency of 50 Hz.

Answer: _____

End of questions

Check that you have written your Student Number on the front cover of this booklet.

Extra working space

Extra working space

Extra working space

ACKNOWLEDGEMENTS

Section A

Question 7 Adapted from: Evans, J. (2008, 6 June). New 'Super paper' is stronger than cast iron. Retrieved March 10, 2009 from http://www.newscientist.com/article/dn14084- new-superpaper-is-stronger-than-cast-iron.html

Published by the Curriculum Council of Western Australia
27 Walters Drive
OSBORNE PARK WA 6017

Physics Year 12 : Formulae and Constants Sheet

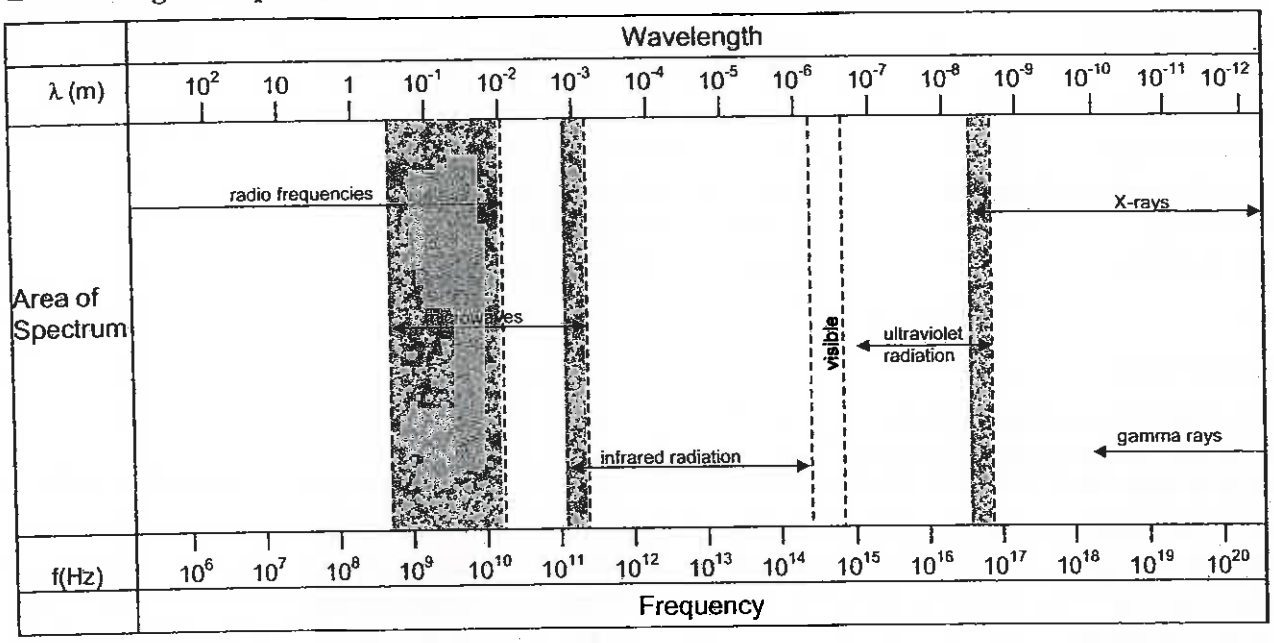
Area of Study: Movement

Average velocity	$v_{av} = \frac{s}{t} = \frac{v+u}{2}$
Acceleration	$a = \frac{v-u}{t}$
Momentum	$p = mv$
Force	$F = ma$
Weight	$\text{weight} = mg$
Work done	$W = Fs$
Kinetic energy	$E_k = \frac{1}{2}mv^2$
Gravitational potential energy	$E_p = mgh$
Equations of motion	$a = \frac{v-u}{t}$; $s = ut + \frac{1}{2}at^2$; $v^2 = u^2 + 2as$
Centripetal acceleration	$a = \frac{v^2}{r}$
Centripetal force	$F = ma = \frac{mv^2}{r}$
Newton's Law of Universal Gravitation	$F = G\frac{m_1 m_2}{r^2}$
Gravitational field strength	$g = G\frac{M}{r^2}$

Area of Study: Structures and Materials

Moment of a force	$M = rF$
Principle of moments	$\Sigma M = 0$
Stress	$\text{Stress} = \frac{F}{A}$
Strain	$\text{Strain} = \frac{\Delta \ell}{\ell}$
Young's Modulus	$Y = \frac{F/A}{\Delta \ell / \ell}$

Electromagnetic spectrum

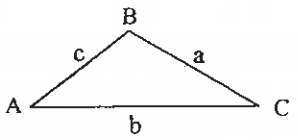


Note: 1. Shaded areas represent regions of overlap.

2. Gamma rays and X-rays occupy a common region.

Mathematical expressions

Given $ax^2 + bx + c = 0$, $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$



$$b = \sqrt{a^2 + c^2 - 2ac\cos B}$$

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

Prefixes of the Metric System

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{12}	tera	T	10^{-3}	milli	m
10^{9}	giga	G	10^{-6}	micro	μ
10^{6}	mega	M	10^{-9}	nano	n
10^{3}	kilo	k	10^{-12}	pico	p