PC1131 Notes

Foundations in Physics I

Chapters 2 to 15

This is a compilation of questions and notes provided in PC1131.

Made by LQ (uwu)

Links of All LQ Notes: LQ Notes Links Document

Legend

Yellow: Common Test 1
Orange: Midyear Exam
Red: EOY Exam
Purple: Practical Test

Chapter 2: Mathematics and Physics I

2.1 SI Units

SI units is the designated **universal classification of units.**

2.1.1 SI Base Units

There are **7** SI base units.

Base physical quantities	SI base unit	
	Name	Symbol
length	meter	m
mass	kilogramme	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

2.1.2 SI derived units

Derived quantity	SI derived unit	
	Name	Symbol
area	square meter	m^2
volume	cubic meter	m^3
speed (velocity)	meter per second	m/s (m s^{-1})
acceleration	meter per second squared	m/s^2 (m s^{-2})
density	kilogram per cubic meter	kg/m^3 (kg m^{-3})

2.1.3 SI derived units with special names

Derived quantity	Name	Symbol	in SI base units
force	newton	N	m kg/s^2 (m kg s^{-2})

pressure	pascal	Pa	kg / m s^2 (kg m^{-1} s^{-2})
energy	joule	J	kg m^2/s^2 (kg m^2 s^{-2})
frequency (Used for calculating frequency of a wave: See 8.8 Frequency)	hertz	Hz	s^{-1}

2.2 Prefixes

Prefixes are used to express physical quantities that are very big or small by making use of factors of 10, similar to scientific notation.

The prefix is used in front of the unit (e.g. **kilo**meter, **centi**meter)

Prefix	Symbol	Sci. Notation
Femto-	f	10^{-15}
Pico-	p	10^{-12}
Nano-	n	10^{-9}
Micro-	µ	10^{-6}
Milli-	m	10^{-3}
Centi-	c	10^{-2}
Deci-	d	10^{-1}
Kilo-	k	10^{3}
Mega-	M	10^{6}
Giga-	G	10^{9}
Tera-	T	10^{12}

Common Test 1 Revision Package Question 2

The following shows 3 values of length:

X = 1.23×10^8 µm Y = 1.23×10^{-7} Mm Z = 1.23×10^6 nm

What is the correct order of the lengths from the longest to the shortest? [1]

A) X, Y, Z
B) Y, X, Z
C) Y, Z, X
D) Z, X, Y

Answer

Firstly, it is a very common strategy to convert all the measurements into just meters.

X = $1.23 \times 10^8 \times 10^{-6}$ m = 1.23×10^2 m
Y = $1.23 \times 10^{-7} \times 10^6$ m = 1.23×10^{-1} m
Z = $1.23 \times 10^6 \times 10^{-9}$ m = 1.23×10^{-3} m

The orange portions is the original value given, while the green section is accounting for the prefix. (e.g. For X, 1 μm becomes 10^{-6} m)
(also looks like carrot lmao)

From this, we can now compare the values and we see that X > Y > Z.
Hence, the answer is (A).

2.3 Scientific Notation

Scientific Notation is expressed as a product of two numbers.
The first number is between 1 and 10, while the second is a power of 10. E.g. 6.9×10^2

2.4 Why SI Units?

Course Pack, Chapter 2, Page 10, Example 1

In the Egyptian Middle Kingdom (1600 BC to 600 BC), the units for length used included the palm and the cubit (which is the distance from the human elbow to the end of the middle finger). Here is the conversion: **1 cubit = 6 palms = 56.3 cm**

a) An Egyptian Pharaoh once ordered a pyramid to be built. The pyramid has a square base with sides of length of 420 cubits each and a vertical height of 1500 palms. Given that the volume of a square-base pyramid is $\frac{1}{3}$ **× base area × height**, calculate the volume of the pyramid:

i) in cubic cubits,
ii) in cubic meters.

b) suggest 2 advantages in using the meter compared to the cubit as a unit of length.

Answers

a) i) …in cubic cubits.

First, we convert the height of the pyramid to cubits. 1500 palms = 250 cubits

Now, volume = $\frac{1}{3}$ × base area × height.

$\frac{1}{3}$ × 420^2 square cubits × 250 cubits = **14 700 000 cubic cubits (1.47 × 10^7 cubic cubits)**

ii) …in cubic meters.

First, we convert 1 cubic cubit to cubic meters.

Given that 1 cubit = 56.3 cm, 1 cubic cubit = $(56.3\ \text{cm})^3$ = $(0.563\ \text{m})^3$ = 0.178 m^3 (3 sf).

Now, we convert 1.47 × 10^7 cubic cubits = 1.47 × 10^7 × 0.178 m^3 = **2.61 × 10^6 m^3** (3 sf).

b) Suggest 2 advantages in using the meter compared to the cubit as a unit of length.

The meter **does not change** unlike the length between the human elbow to the end of the middle finger, which varies from person to person.

It is in **multiples of powers of 10**.

Chapter 3: Measurements

3.1 Basic Arithmetic Precision

We follow 3 rules:

1. When adding/subtracting, we round the result to the number with the lowest decimal place (dp).
2. When multiplying/dividing, we round the result to the number with the lowest significant figures (sf).
3. A constant has infinite significant figures. (E.g. while taking the average of 2 things, division by 2 has infinite sf)

3.2 Errors

Error is the difference between the true value and the measured value.

3.2.1 Random Error

Random Errors are random and can occur from:

- quantities that change with time (e.g. BMI)
- human judgement
- manufacturing faults
- estimation of the last significant figure
- background noise or mechanical vibrations in the laboratory (e.g. sound)

Random Errors can be minimised by taking a large number of readings and taking the average.
Note: Random Errors can NOT be eliminated completely.

Under the same conditions, it can cause errors of different sizes and signs. This is why Random Errors cannot be eliminated completely.

3.2.2 Systematic Error

A Systematic Error is a constant error caused by an imperfection in the instrument being used, from mistakes the individual makes while taking the measurement, or from certain extreme conditions such as a very high or very low temperature.

Repeating the measurement under the same conditions will cause errors of the same size and sign. Hence, Systematic Errors **can be completely eliminated**.

3.2.2.1 Zero Error

Zero Error refers to instruments of length losing the zero mark or causing the instrument to be slightly deformed from prolonged use.

This can be found on instruments to measure length like Vernier Calipers and Micrometer Screw Gauges. (See Chapter 4: Measurements of Length)

Since it is a systematic error, zero errors can be **eliminated completely**.

3.2.2.2 Parallax Error

While using an instrument that measures volume, if your eye is not at water level while reading the measurement, you might misread the measurement.

3.2.3 Summary

Random Error	Systematic Error
Inconsistent Diameter of Solid Human Reaction Time Inconsistent Measurements (Wind, Sound, etc)	Zero Error Parallax Error

Common Test 1 Question Modified

Which of the following errors can be completely eliminated? [1]

1. Zero error
2. Background noise when measuring sound
3. Diameter of wooden rod not being constant

a) 1 only
b) 1 and 2
c) 2 and 3
d) All of the above

Answer

Note that (1) is the only Systematic Error, while (2) and (3) are Random Errors. Systematic Errors can be completely eliminated, while Random Errors cannot. Hence, the correct option is (a).

Semester 1 Revision Package Question 2

When comparing systematic and random errors, the following pairs of properties are considered:

A1: error can possibly be eliminated
A2: error cannot possibly be eliminated
B1: error is of constant sign and size

B2: error is of varying sign and size
C1: error is reduced by averaging repeated measurements
C2: error is not reduced by averaging repeated measurements

Which properties apply to systematic errors?

a) A1, B1, C1
b) A2, B2, C2
c) A1, B1, C2
d) A2, B1, C2

Answer

Systematic Errors are errors with constant sign and size (B1) and can be eliminated (A1). However, when taking the average of repeated measurements, the error is not reduced (C2), since all the measurements have an error with a constant sign and size.

Hence, the correct option is (c).

3.3 Precision and Accuracy

Accuracy and Precision are characteristics of measured values.

3.3.1 Precision

Precision refers to how **reproducible a measurement is** (i.e. the less the value changes throughout the measurements, the more precise), along with a measure of how exact the measurement is.

Precision refers to how close measurements of the same item are to each other.

3.3.2 Accuracy

Accuracy refers to how **close the average values obtained from a series of test results is to the (accepted) true result**. It depends on how well the systematic errors are controlled.

Accuracy refers to how close a measurement is to the true or accepted value.

Note: Precision and Accuracy are NOT the same things!

Chapter 4: Measurements of Length

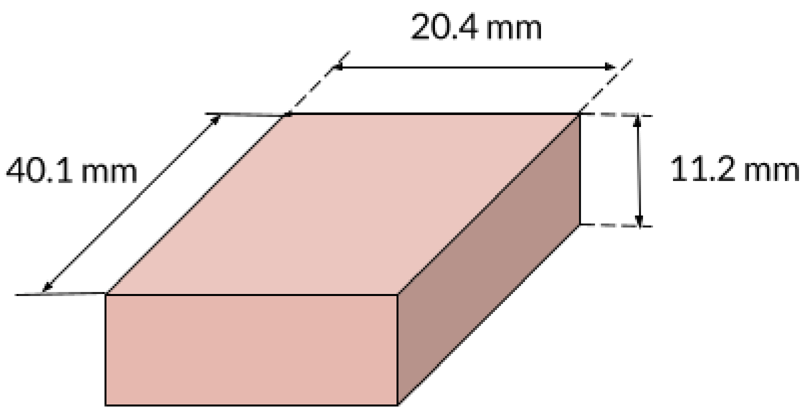
The SI unit for length is **meter (m)**.

4.1 Instruments to Measure Length

Here are the instruments used to measure length.

Instrument	Most suitable range	Precision
Meter Ruler	About 10 cm to 1m	1 cm
Tape Measure	More than 1m	1 mm (0.1 cm)
Vernier Calipers	About 2cm to 10cm	0.01 cm (0.1mm)
Micrometer Screw Gauge	Less than 2cm	0.01 mm

<u>Remedial WS 3 Question 9 (a) Modified</u>



The student has written down every digit on the readings from the measuring instrument that he used.

Suggest the instrument used by the student.

<u>Answer</u>

Since the measurements are to the nearest 0.1mm, this means that the instrument has a smallest division of 0.1mm, or 0.01 cm.

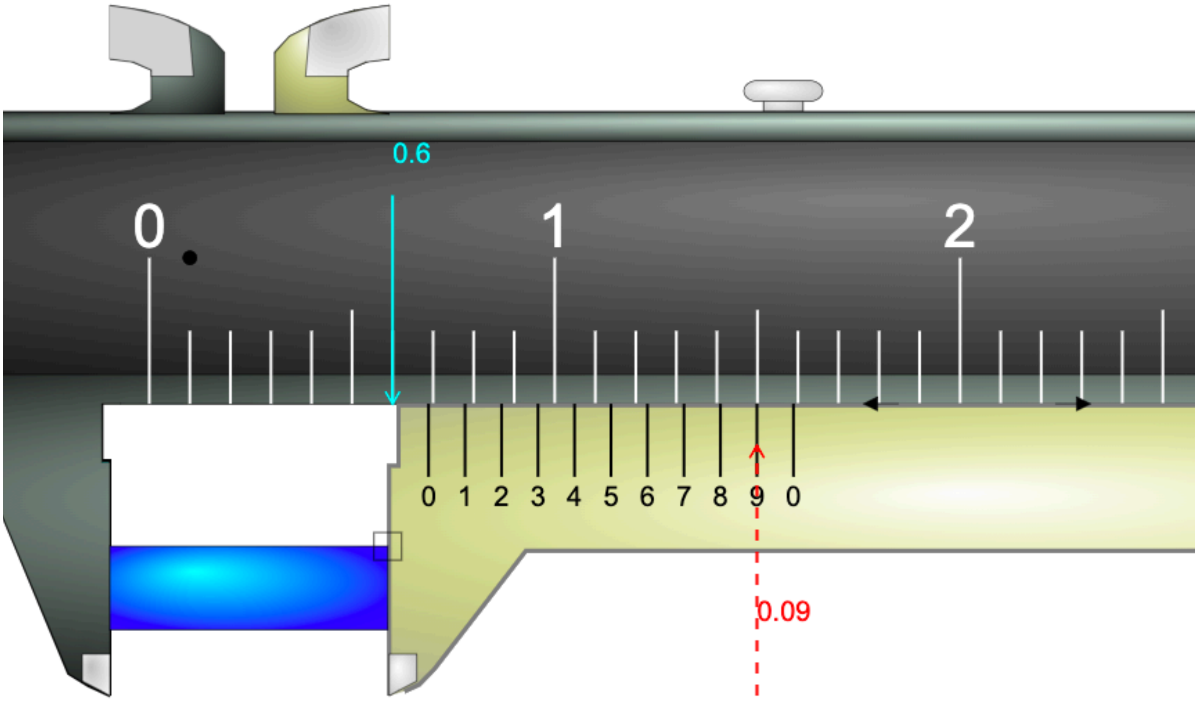
Hence, we can determine that the instrument is a **vernier caliper**.

4.2 Vernier Calipers

Vernier calipers measure accurately to 0.01 cm.

Note: You should use 0.01 cm instead of 0.1 mm. Although both are technically correct, 0.01 cm is commonly more accepted.

4.2.1 Taking a Measurement



We first read off the main scale, counting the number of markings before the “0” mark on the vernier scale.

In this example, the main scale reads 0.6cm.

Note: We measure the main scale from the “0” mark on the vernier scale.

We then read off the vernier scale, looking for the line that coincides with a line on the main scale.

In this example, the measurement on the vernier scale reads 0.09cm.

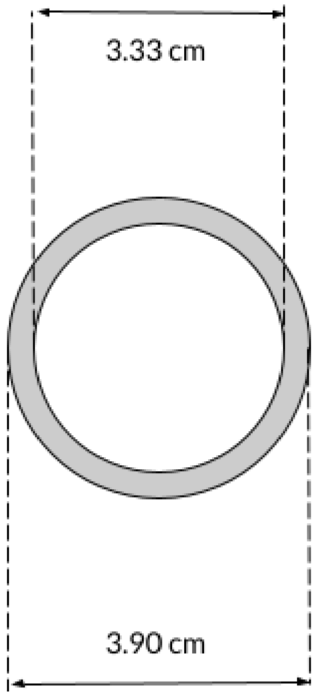
Hence, by adding the numbers together, we get 0.69cm. (nice)

Common Test Revision Package Question 9 (c) Modified

Given the internal diameter of the metal pipe is 3.33 cm and the external diameter of the metal pipe is 3.90 cm, calculate the thickness of the metal pipe. [2]

Answer

To avoid careless mistakes, it is worth it to spend some time drawing a rough diagram.



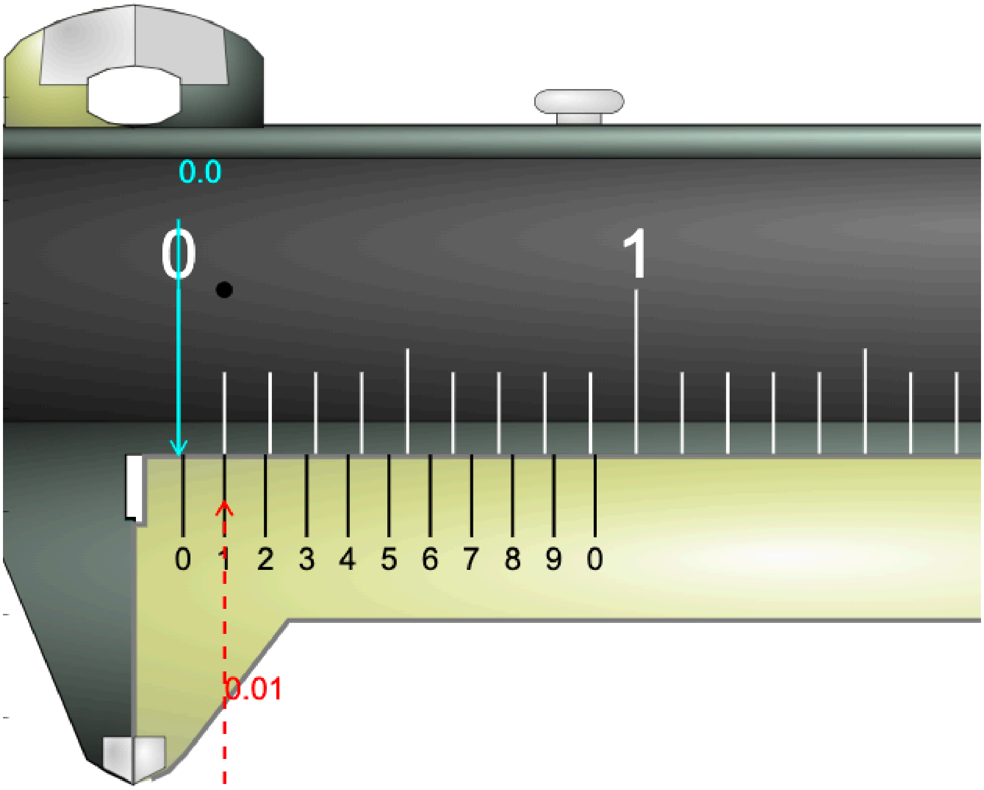
Let d be the thickness of the metal pipe.

Note that 3.33 cm + 2d = 3.90 cm.
2d = 0.57 cm (2 dp)
d = 0.29 cm (2 sf - Remember to correct to the correct sf)

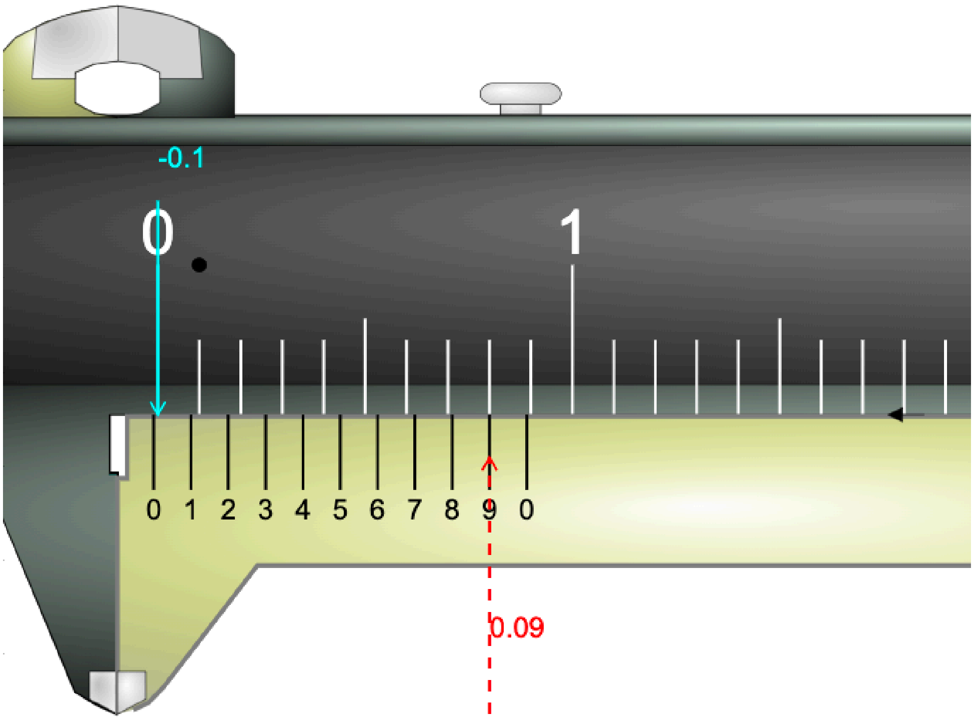
Hence, the thickness of the metal pipe is 0.29cm. [2]

4.2.2 Zero Errors

The zero error refers to the instrument not reading 0.00cm when the jaws are completely closed.



In this case, the vernier calipers read 0.01cm when closed. Hence, the zero error is +0.01cm.



In this case, we can imagine a -0.1cm line before 0.0cm on the main scale. Hence, the reading on this pair of vernier calipers read -0.01cm when its jaws are closed.

The sign must be stated unless the zero error is **exactly** 0.00cm.

4.2.3 Correcting for Zero Error

Since the Zero Error is a Systematic Error (See 3.2: Errors), we can correct for the Zero Error simply by taking away the Zero Error from the reading.

For example, if the Zero Error is +0.01 cm, and the Observed Reading is 4.21cm, we can correct for the Zero Error by:

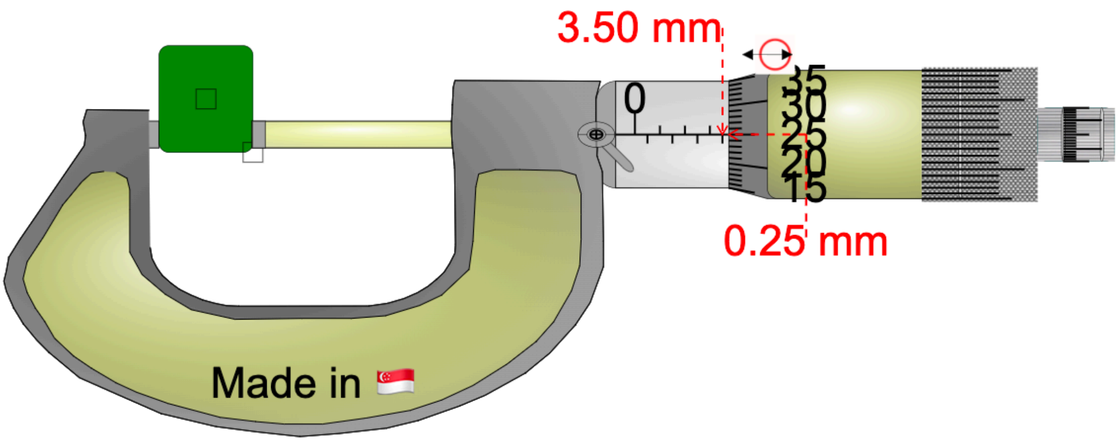
4.21cm - (+0.01cm) = 4.20cm (nice)

Note: Although perhaps not necessary, you should still add the sign for zero error while doing calculations just in case the marking scheme is strict.

4.3 Micrometer Screw Gauge

The Micrometer Screw Gauge measures up to 0.01 mm.

4.3.1 Taking a Measurement



We first read off the main scale.

The top lines on the main scale denote 0.00 mm, 1.00 mm, 2.00 mm and so on.
The bottom lines on the main scale denote 0.50 mm, 1.50 mm, 2.50 mm and so on.

In this case, the main scale reads 3.50 mm.

We then read off the thimble scale, looking at which line coincides with the main scale.

In this case, the thimble scale reads 0.25 mm.

Lastly, we add the two measurements together, obtaining 3.75 mm.

4.3.2 Zero Errors

We find the Zero Error by taking the measurement when the spindle touches the anvil of the Micrometer Screw Gauge.

To tell between a positive Zero Error and a negative Zero Error, we see if the “0” line is covered.

If the “0” line is covered, then the Zero Error is negative.
If the “0” line is not covered, then the Zero Error is positive.

Chapter 5: Measurements of Time

The SI Unit for time is the **second (s)**.

Note: Do NOT write "sec" or "secs" for seconds. Instead, write "s".

5.1 Stopwatch

A Stopwatch is an instrument used to measure time.

Even though it can read up to 0.01s, we have to round it to the nearest 0.1s because of human reaction time.

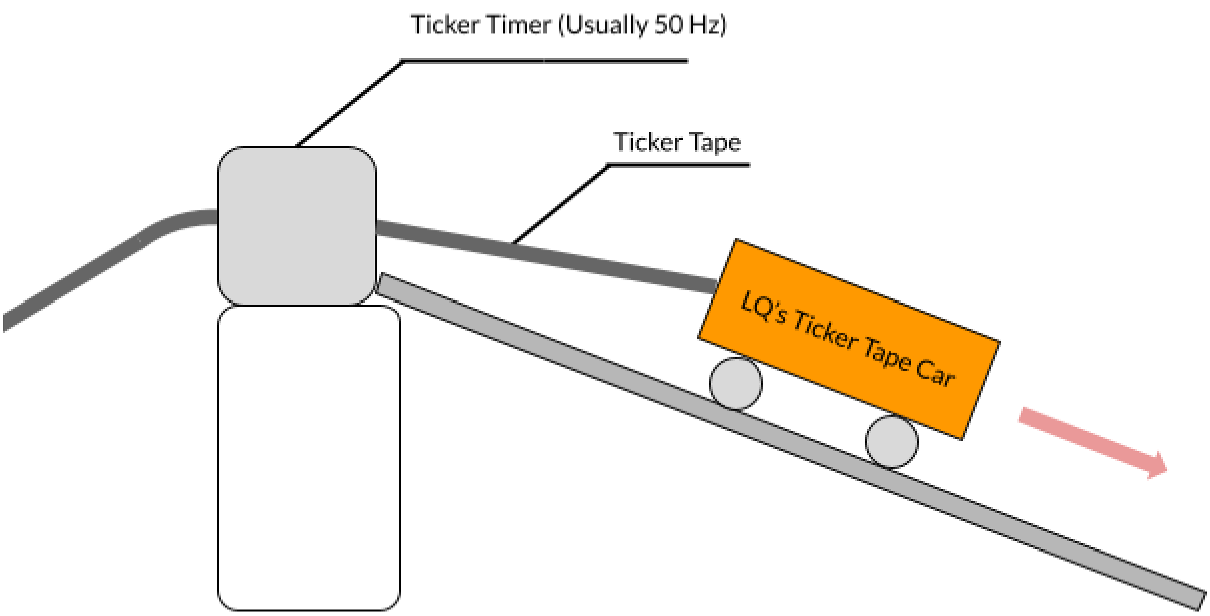
5.2 Ticker-Tape Timer

A normal Ticker-Tape Timer ticks at 50Hz (hertz: times per second), which means it ticks 50 times every second.

Hence, the interval between two points generated by a ticker-tape timer represents $\frac{1}{50}$s, or 0.02s. Note that we count the **number of intervals** (or gaps), not the number of points.

However, **do note that this is NOT always the case**, and assuming that it is always 50 Hz can cause a loss of marks. (which, by the way, is not good)

This is what a regular Ticker-Tape Timer looks like:

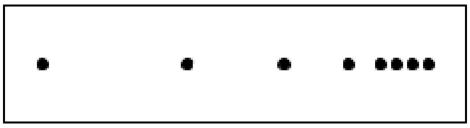


As the car goes in the direction of the red arrow, it pulls the ticker tape down along with it. As the ticker tape falls, you can imagine a pen on the ticker timer that keeps creating dots on the ticker tape.

This is how the ticker-tape timer tracks time.

Example 5.2

Given that the ticker tape below ticks at 50 Hz, how long did it take for the below ticker-tape to be generated?

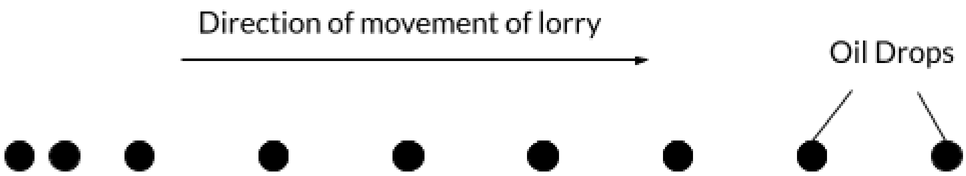


Answer

Since there are 7 gaps in this ticker tape above we find that the time taken is: 7 × 0.02s, or 0.14s for this ticker tape to be generated.

Semester 1 Examination Revision Package Question 15

A lorry with an oil leak is driven along a level road. Drops of oil fall at regular time intervals from the lorry.



Which of the following statements best describes the motion of the lorry?

a) The lorry accelerates uniformly.
b) The lorry moves with a constant velocity and then slowed down.
c) The lorry first decelerates and then moves with a constant velocity.
d) The lorry first accelerates and then moves with a constant velocity.

Answer

This question, in a sense, is a ticker-tape timer as well, as oil drips at regular intervals.

We can see that the interval between the first and second drops is less than that between the second and third, which is, in turn, less than that between the third and the fourth.

This means the car's speed was increasing at first, which means it first accelerated.

However, after around the fourth drop, the gap seems to remain about the same. This means the car's speed was constant after accelerating.

Hence, the correct option is (d).

5.3 Pendulum

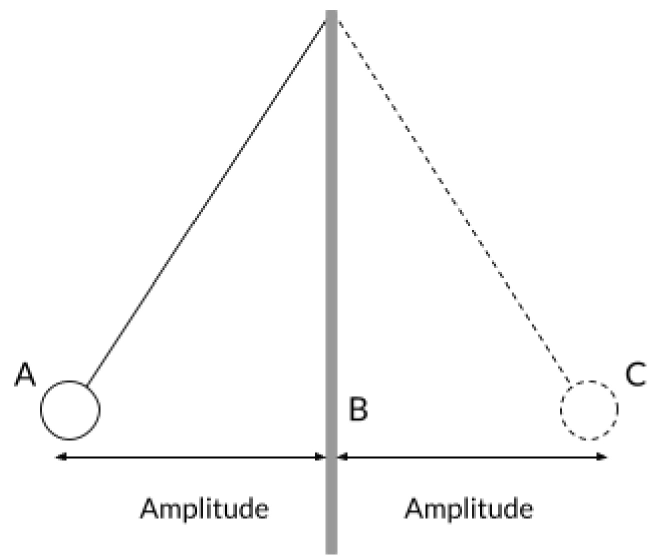
A pendulum is the simplest type of clock.

5.3.1 Definitions

The amplitude of the oscillation, A, is the maximum horizontal distance the pendulum bob gets away from its starting point.

The period, T, is the **time taken** for one oscillation.

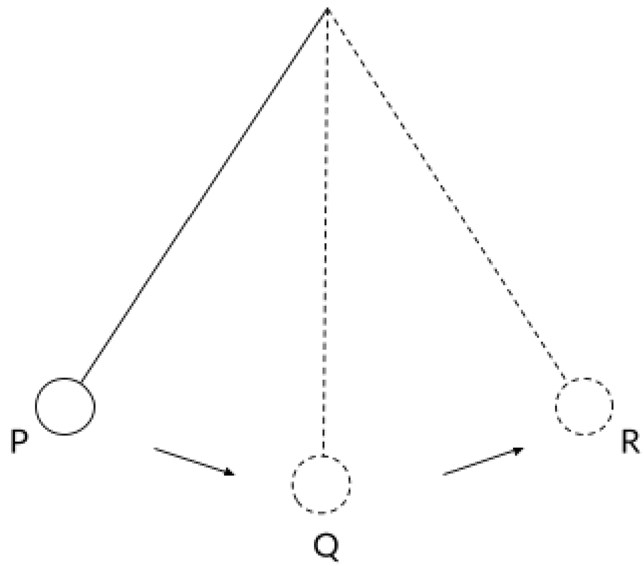
Note: The period and the oscillation is NOT the same thing. The oscillation refers to the movement, while the period refers to the time taken for the movement.



The oscillation, in this case, is the bob moving from A to B to C, then back to B and A.
The period is the time taken for the bob to make one oscillation.

<u>In-Class Assignment 1 Question 5 (a)</u>

The figure shows a simple pendulum. The bob of the pendulum was pulled to position P and then released.



Using the diagram (in terms of **P, Q** and **R**), explain what is meant by the period of the pendulum. [1]

Answer

The period of the pendulum is the time taken for the bob to go from P to Q to R and back from R to Q to P. [1]

Note: Since the question specified, you **must** answer with reference to P, Q, R and where they are in the diagram. Otherwise, [0] will probably be awarded.

5.3.2 Precautions

When taking a measurement, make sure you **release the bob with minimum force applied** (i.e. don't push the bob) and make sure you have a **small angle of release** (i.e. less than 10°).

When measuring the length of the pendulum, ensure that you measure up to the **centre of the pendulum bob**.

5.3.3 Period of Pendulum

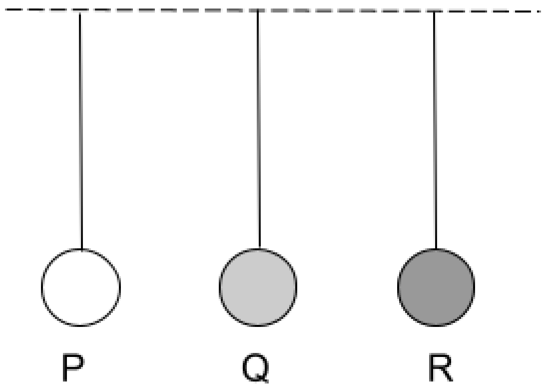
The length of the pendulum, L, is the **only** thing that affects the period of a pendulum, T, that you are required to know.

Although counter-intuitive, the angle of release of the pendulum bob and the mass of the pendulum bob **does not affect the period of the pendulum**.

FYI: The Gravitational Field Strength also actually affects the period of pendulum.

Remedial WS 2, Question 4

Which of the following statements is true, given that pendulum P is 1 kg, pendulum Q is 10 kg, pendulum R is 100 kg, and the effect of air resistance is negligible? Explain the reason for your choice.



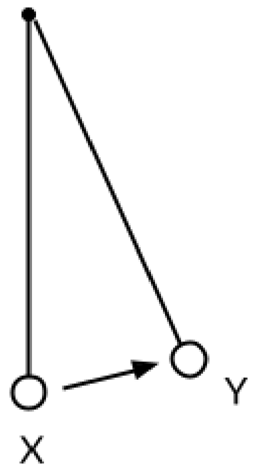
a) They will have the same period.
b) Pendulum P will oscillate the fastest.
c) Pendulum R will oscillate the fastest.
d) They will all swing at different periods.

Answer

The correct answer is (a) as the mass of the pendulum does not affect the period of oscillation.

Common Test 1 Revision Package Question 6

The time taken for a pendulum to swing from position X to its maximum displacement at position Y is 1.0 s, as shown below.



What is the period of the pendulum? [1]

A) 1.0 s C) 4.0 s
B) 2.0 s D) 8.0 s

If we let the time taken for the bob to travel distance XY be u, the period of the pendulum will be 2 × 2u = 4u.

u = 1.0 s
4u = 4.0 s

Hence, the answer is (C).

Common Test 1 Revision Package Question 10 (d)

Suggest and explain if measuring the time taken for 60 oscillations and dividing by 60 would be feasible to increase the accuracy of the measurement. [2]

Answer

No, as the oscillation **would have died off by then/would be too small to observe**. [2]

Saying simply the effects of air resistance or the pendulum bob losing kinetic energy is not accepted, as when the pendulum slows down but doesn't stop, **the period of the pendulum will not change** if you can **still measure the oscillation**.

This is true as the angle of release does **not** affect the period of a pendulum.

Chapter 6: Mathematics and Physics II

6.1 Tabulation

Tabulation is a method of recording data using a table.

6.1.1 Rules of Tabulation

1. When tabulating readings in a table, the heading of each column should be the symbol (e.g. ρ for density) or the name of the measured or calculated quantity. the unit should be included.

   Example: ρ / gcm^{-2} (See 7.6: Density)

2. All readings under the same column **MUST** be recorded to the same number of decimal places.

3. The number of significant figures given for calculated quantities should be based on our knowledge of basic arithmetic precision. (See 3.1: Basic Arithmetic Precision)

6.2 Graphing

Graphing refers to recording data using a graph.

6.1.2 Rules of Graphing

Here is what you should look out for when drawing a graph.

1. **Label Axes**

   This refers to the naming of the axes, including the units.
   Regularly spaced numerical labels should also be placed along the axes.
   The precision of axes labels should follow the data provided.

2. **Appropriate Scale**

   Use scales for the axes that allow the graph to be read easily, like 1, 2 or 5 units per 10 small squares, and not something like 3 units per 10 small squares.

   Remember: It's very troublesome to calculate fractions when it comes to reading graphs.

   The plotted points must occupy **AT LEAST** half of the grid provided.

   The scale need not start at the origin (i.e. $(0, 0)$) if appropriate.

3. **Plotting**

All data points should be plotted based on the data provided.
Points should be plotted to half the size of the smallest square.
Points should be about the same size as a small square and represented by ×.

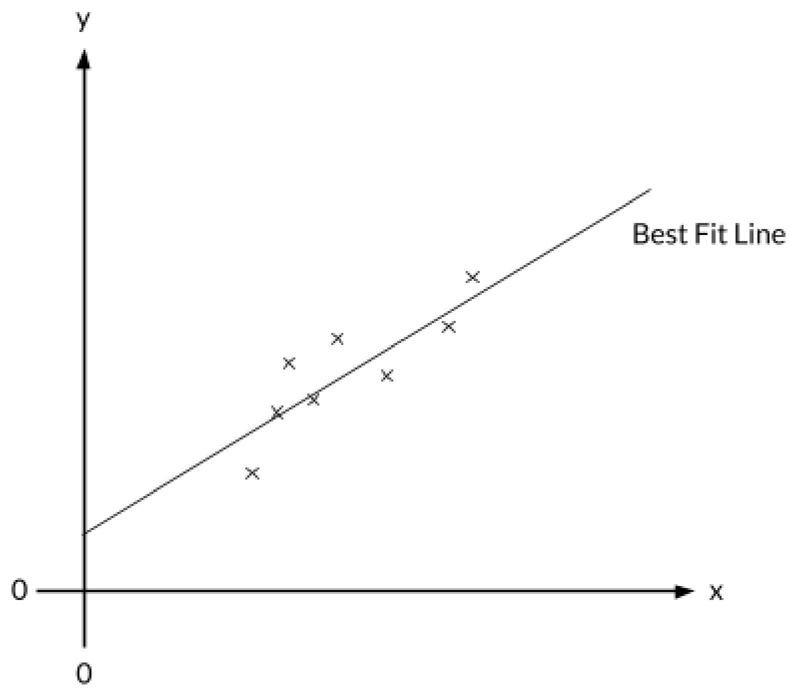
4. **Best Fit Line**

There should be an **even distribution of points on either side** of the best-fit line.

When drawing a best fit line**, don't draw the line thicker than the thickest line on the graph grid provided**.

The best fit line **need not pass through any data points nor the origin**, unless you are trying to show direct proportionality, in which case, it must pass through the origin.

The best fit line should look something like this:



Chapter 7: Mass, Weight and Density

7.1 Mass

Mass is the measure of the amount of substance in a body.

It depends on the number of atoms in the body and the composition of said atoms.
It **cannot** be changed by location or shape.

Its SI Unit is the kilogram (kg).

It is measured by Beam Balances and Electronic Mass Balances.

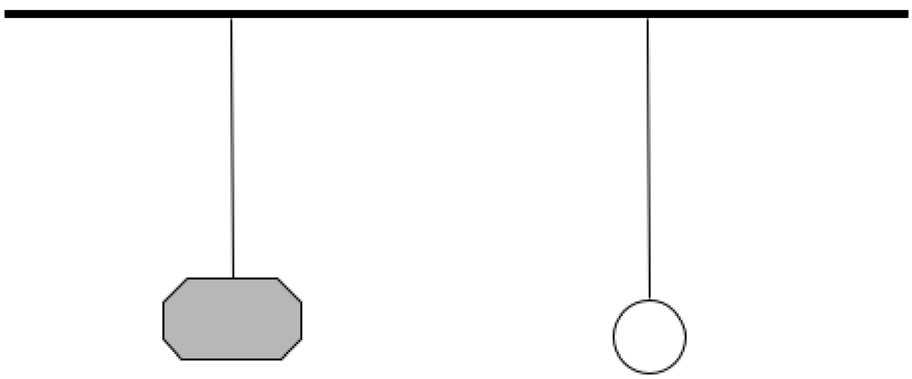
7.2 Inertia

Inertia is the property of a mass which refers to its **resistance to change** from its state of rest or motion.

The greater the mass, the greater the force is needed to overcome its inertia.

Course Pack, Chapter 7, Page 59, Example 10 (b) Modified

A pendulum bob and a stone are suspended as shown below.



(very nice looking stone, I know yes very nice I know)

If the stone has a mass of 20 g and the pendulum bob has a mass of 15 g, which object can be moved more easily when given a push?

Answer

The pendulum bob has less mass since 15 g < 20g. Objects with less mass have less inertia, so the pendulum bob has less inertia and can be pushed more easily.

7.3 Gravitational Field Strength

A gravitational field refers to the region where a mass experiences a gravitational force.

The Earth has a gravitational field strength of approximately **9.81 N/kg** (This is also written as 9.81 ms^{-2} or 9.81 m/s^2) at its surface.

This is typically denoted g.

In a test paper, it should be stated at the front **"Take gravitational field strength on Earth, g = 9.81 N/kg if necessary."**

7.3.1 Factors Affecting Gravitational Field Strength

The only factor affecting gravitational field strength is **altitude**, although insignificant changes can be omitted.[verify]

<u>Remedial WS 3, Question 6</u>

Which of the following experiences the same gravitational field strength?

(1) A 50 kg mass resting on the floor.
(2) A 50 kg mass hanging on a 20 m tall tree.
(3) A 50 kg mass dropping down from a 20 m tall tree.
(4) A 100 kg mass resting on the floor.

A) (1) and (2) only
B) (1), (2) and (3) only
C) (1), (2) and (4) only
D) (1), (2), (3) and (4)

<u>Answer</u>

The correct option is D as a difference of 20m is insignificant for a change in gravitational field strength.[verify]

7.4 Weight

Weight is a measure of **the gravitational force exerted on that material in a gravitational field**.

Weight is calculated: **W = mg**

Where m is the mass and g is the gravitational field strength.

Since mass has the SI unit of kg, and gravitational field strength has the SI derived unit N/kg, we can see that weight has the SI unit of N (Newton).

Weight is measured using a spring balance, also called the force meter or the Newton meter. It makes use of the force of gravity acting on an object to extend or compress a spring.

7.5 Volume

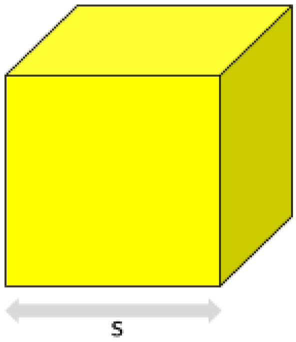
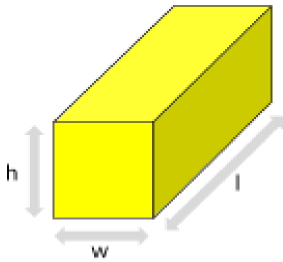
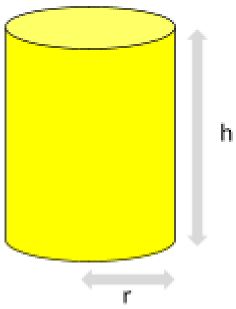
Volume is a measure of **the amount of space a body takes up**.
The SI Derived Unit for volume is m^3 (cubic meters), although cm^3 and ml are also used.
Do note that usually in physics, we measure to the smallest division on the instrument. However, on instruments used to measure volume, we can measure to **half the smallest division**.

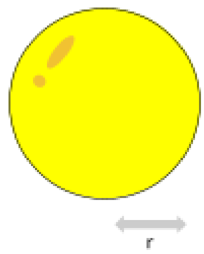
7.5.1 Volume of Liquids

The measuring cylinder, burette and pipette are some apparatus to measure liquid volumes.

7.5.2 Volume of Regular Solids

We can use a ruler to measure its dimensions, then use a standard equation to find its volume.

Type of Regular Solid	Diagram	Equation
Cube		s^3
Cuboid		lwh
Cylinder		$\pi r^2 h$

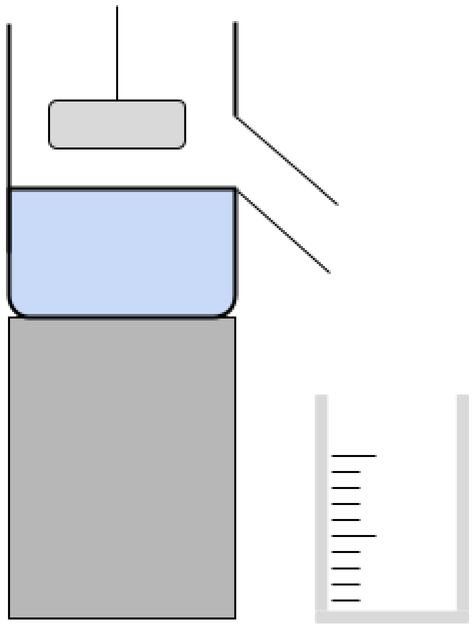
Sphere		$\frac{4}{3}\pi r^3$

Note: This is covered in MA1132 Chapter 5 [verify]: Mensuration

7.5.3 Volume of Irregular Solids

If the solid sinks in water, you can place it in a measuring cylinder and measure the volume change when the solid is placed into the water.

You can also use a displacement can to measure the volume.



If the solid doesn't sink in water, we can use a lid or a stick to press the solid into the water and use the displacement can method.

However, we must make sure that the solid is fully submerged, while the object used to push the solid into the water is not submerged at all.

7.6 Density

Density is defined as **mass per unit volume**.

Density is defined: $\rho = \frac{m}{v}$

Note: Density is denoted ρ (the greek letter 'rho') as the letter d is typically used for distances.

Where m is the mass, and v is the volume.

Since mass has the SI unit of the kilogram (kg), and the volume has the SI derived unit of the cubic meter (m^3), density has the **SI derived unit of kilogram per cubic meter (kg/m^3)**.

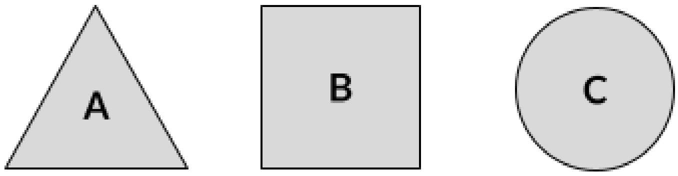
It can also use the unit g/cm^3.

Objects **less dense** than the surrounding fluid **floats** while objects that are **denser** than the surrounding fluid **sink**.

An object with the same density as the surrounding fluid remains where it is in the fluid. This object is then said to be **neutrally buoyant** in that fluid.

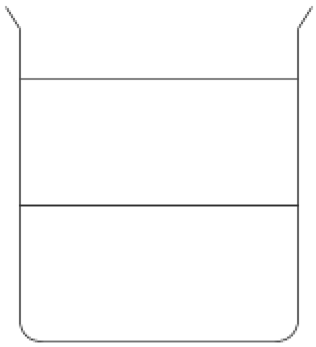
Course Pack, Chapter 7, Page 57, Example 7

Draw and label clearly on the figure below what you will observe when the following three objects are placed in a container will equal volumes of water and glycerine, which are immiscible.



1.8 g/cm^3 0.8 g/cm^3 1.0 g/cm^3

Density of water = 1.0 g/cm^3
Density of glycerin = 1.3 g/cm^3



Answer

Note that "immiscible" refers to the property that **the two liquids do not mix**.

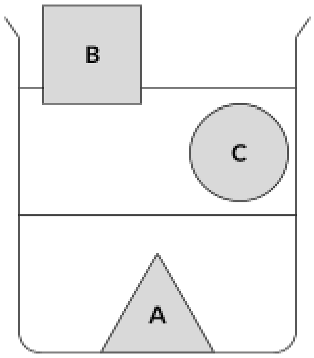
Since the density of glycerin, at 1.3 g/cm^3 is higher than that of water at 1.0 g/cm^3, **glycerin is the liquid at the bottom, while water is the liquid at the top**.

Since Object A has a density of 1.8 g/cm^3, which is higher than the density of both water and glycerin, **it will sink to the bottom of both the water and glycerin**.

Similarly, Object B has a density of 0.8 g/cm^3, which is lower than the density of both water and glycerin, **it will float on top of both water and glycerin**.

Object C has a density of 1.0 g/cm^3, which is the same as the density of water, so it will float in glycerin but is neutrally buoyant in water. Hence, **it'll just float wherever it is released in the water.**

Hence, the diagram should be annotated as such:



Do note that Object C can be anywhere in the water as where it is will depend on where it is released.

<u>In-Class Assignment 2 Question 4 (c), (d)</u>

A beaker can hold 250 cm^3 of liquid. When it is filled with turpentine (density 700 kg/m^3), the total weight is 3.0 N. Assume g = 9.81 N/kg.

(c) Calculate the mass of turpentine in the beaker. [2]
(d) Calculate the mass of the beaker. [2]

<u>Answer for (c)</u>

First, we convert 700 kg/m^3 into g/cm^3.

700 kg/m^3 = 0.7 g/cm^3

Now, we use:
M = ρV [M1]
= 0.7 g/cm^3 × 250 cm^3
= 175 g [A1]

<u>Answer for (d)</u>

First, we use:
W = mg
Rearranging, we get m = $\frac{W}{g}$.
Mass of beaker and turpentine = $\frac{3.0\ N}{9.81\ N/kg}$ [M1]
= 0.31 kg (2sf)
= 310 g

With the result in (a) and the result above:

Mass of beaker = Mass of beaker and turpentine - Mass of turpentine
= 310 g - 175 g
= 135 g [A1]

Chapter 8: General Wave Properties I

8.1 What is a Wave?

A wave is an **organised disturbance** that travels with a certain speed. They **transfer energy without transferring matter**, through oscillations.

Example: You can call out to your friend (i.e. transferring sound energy) while no matter is transferred.

In the above example, the medium the wave is travelling through is air and the particles that oscillate are the air particles.

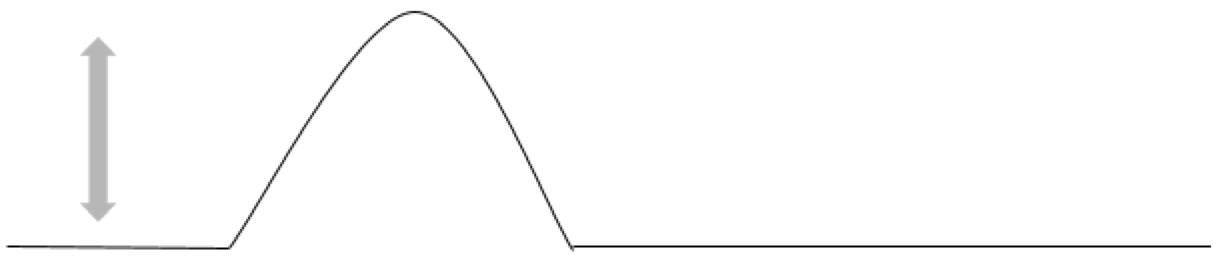
Certain waves need a medium to travel through while others don't. For example, sound needs a medium to travel through (i.e. air) while light doesn't.

8.2 Transverse Waves

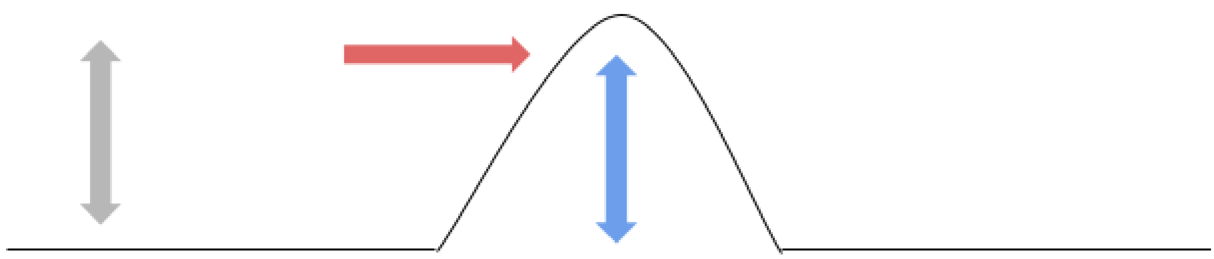
A transverse wave is a wave where the particles in the medium are **perpendicular** to the direction where the wave travels.

Imagine a long string as such:

Now imagine giving a hard pull (Grey arrow), creating sort of a wave.



As this wave travels, it moves towards the right (Red arrow); But if you look at a certain point on the string, you can see that it goes up and down again (Blue arrow).



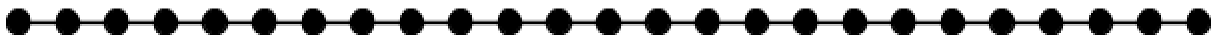
This property that **the red arrow is perpendicular to the blue arrow defines a transverse wave**.

Do note that the particles in the string involved in transferring the wave return to their original positions after the wave has passed.

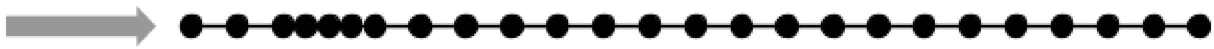
8.3 Longitudinal Waves

Longitudinal waves refer to waves in which the displacement of the particles in the medium is **parallel** to the direction in which the wave travels.

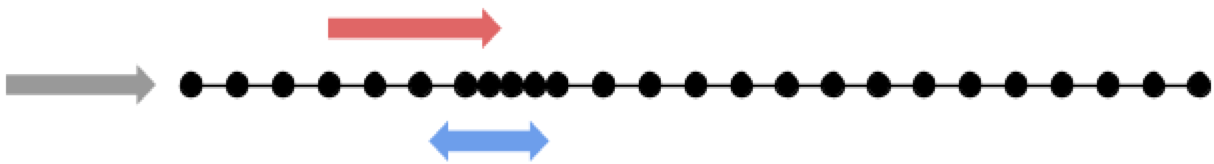
Imagine a chain of 25 dots as such:



Now imagine pushing on one end of the chain (Grey arrow).



As this compressed section travels (which you can imagine as a wave), it moves to the right (red arrow). The particles move left and right (blue arrow), as you can imagine this chain as being elastic so the particles would move back.

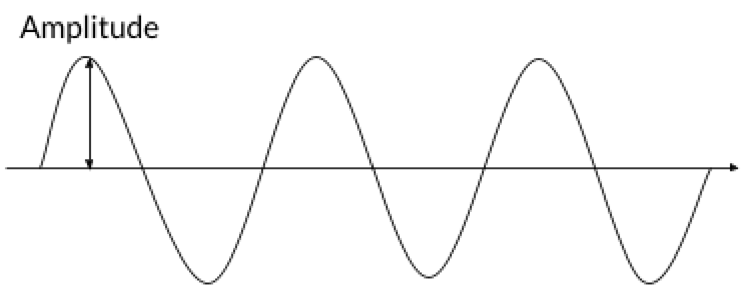


This property that **the red arrow is parallel to the blue arrow defines a longitudinal wave**.

Do note that, again, the dots involved in transferring the wave will return to their original positions after the wave has passed.

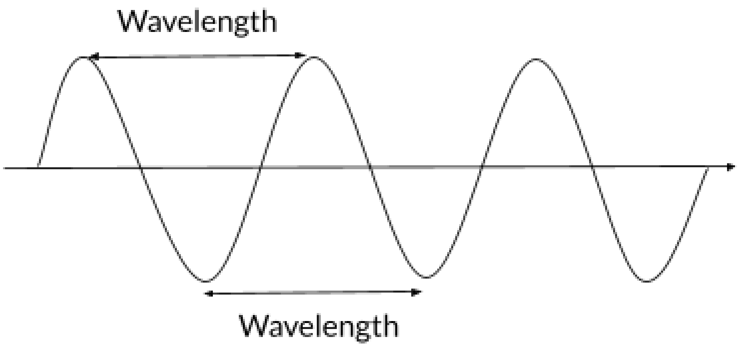
8.4 Amplitude

The amplitude of a wave refers to the maximum displacement of a point from its equilibrium point. It is denoted A.



8.5 Wavelength

The wavelength is the distance between two crests or two troughs.



The wavelength is denoted λ (The greek letter ‘lambda’).

8.6 Period

The period is the time taken for the particle to **oscillate once**.
It can also be defined as the time taken for the wave to travel **one wavelength**.

The period is denoted T.

8.7 Wave Speed

Waves travel at a certain speed, called wave speed.
Wave speed is denoted V.

The wave speed is calculated:

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

Only the **medium** in which the wave is travelling through affects the wave speed. This means that in the **same medium**, the **wavelength and the period** are **directly proportional**, and likewise, the **wavelength and frequency** are **inversely proportional**.

The **more dense** the medium is, the faster the wave travels through it.

Hence, waves like sound travels faster in solids than in liquids and gases.

8.8 Frequency

The frequency refers to how many periods are in one second.
Frequency is measured in Hertz (Hz), or s^{-1}. (literally: per second)

Hence, we calculate the frequency f using:

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

The frequency is only affected by the **oscillator**. (i.e. the thing creating the wave).

Hence, when two different springs are attached together, both will vibrate at the same frequency when you swing it from side to side.

In-Class Assignment 3, Question 2

A wave source of frequency 1.0 kHz emits waves of wavelength 0.10 m. How long does it take for the waves to travel 2500 m?

a) 2.5 s
b) 4.0 s
c) 25 s
d) 100 s

Answer

v = fλ
= 1.0 kHz × 0.10 m
= 1000 Hz × 0.10 m
= 0.10 × 1000 mHz
= 100 m/s (2sf)

2500 m ÷ 100 m/s = 25s (2sf)

Hence, the answer is (c).

Note: During physics exam, you do not need to show full working for MCQ questions to save time. (unless otherwise stated for some whatever reason)

8.9 Deriving Equations

Note: This section is not in the Course Pack.

In physics, many equations can be derived and replaced or rearranged into other useful forms.

For example, we can use $V = \frac{\lambda}{T}$ to derive $V = f\lambda$ or $VT = \lambda$.

8.10 Common Characteristics of Waves

The common characteristics of waves are:

1. The source of a wave is a **vibration** or an **oscillation**.
2. Waves **transfer energy** from one point to another.
3. In waves, energy is transferred **WITHOUT** the **medium** being transferred.

8.11 Displacement-Position Graph and Displacement-Time Graph

Displacement-position and displacement-time graphs are used to describe waves.

8.11.1 Displacement-Position Graph

The displacement-position graph can be thought of as taking a picture of a string with a constant oscillation applied to it.

The displacement-position graph can be used to find the amplitude, a, and the wavelength, λ.

8.11.2 Displacement-Time Graph

The displacement-time graph can be thought of as looking at one specific particle on a string and tracking its displacement over time.

The displacement-time graph can be used to find the period, T, and can be used to derive the frequency, f, using f = $\frac{1}{T}$.

8.11.3 Summary

The displacement-position and displacement-time graphs together tell you **the properties of a wave**, including its amplitude, wavelength, period, frequency and wave speed.

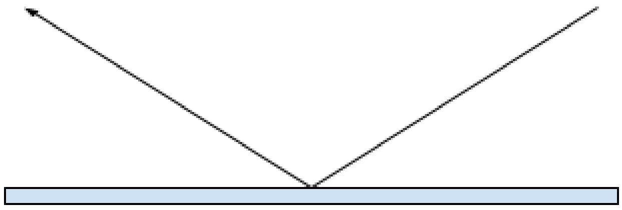
Chapter 9: General Wave Properties II: Reflection & Refraction of Waves

9.1 Intro

A wave can undergo **reflection** and **refraction.** Refer to Chapter 13: Light I - Reflection and Chapter 14: Light II - Refraction.

9.2 Reflection

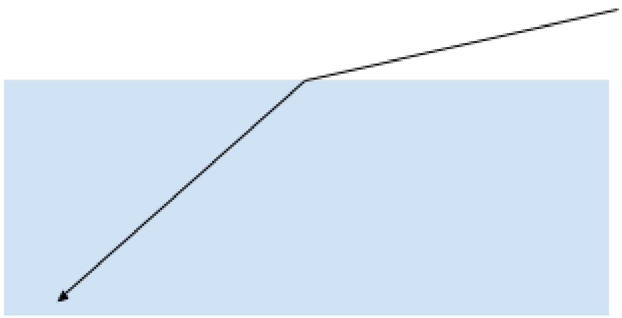
Reflection refers to the wave bouncing from a surface as such:



Refer to Chapter 13: Light I - Reflection.

9.3 Refraction

Refraction refers to a wave changing direction due to a change in the speed of the wave. For example, a light wave travelling into water will change direction as the speed of the wave changes.



This is why a straw can appear disconnected and bent when you look at the side of a drink.

Refer to Chapter 14: Light II - Refraction.

Chapter 10: Sound

10.1 What is Sound?

Sound is a form of **energy** which is propagated from **one point to another** as a **wave**.

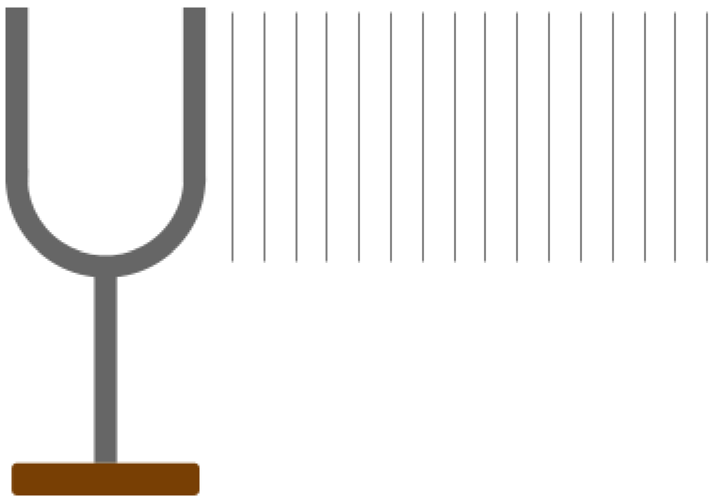
Sound waves are produced by **vibrations placed in a medium**. The medium can be a gas, a liquid, or a solid.

Hence, Sound cannot travel through space, which is why if two astronauts were shouting at each other during a spacewalk, neither of them would hear each other.

10.2 How is Sound Produced?

Sound waves are produced when a vibrating object alternately **pushes and pulls** on the air adjacent to it, causing small but rapid **changes in air pressure** known as **compressions and rarefactions** (rarefaction: /ˌrɛːrɪˈfakʃ(ə)n/, rare-ree-faction).

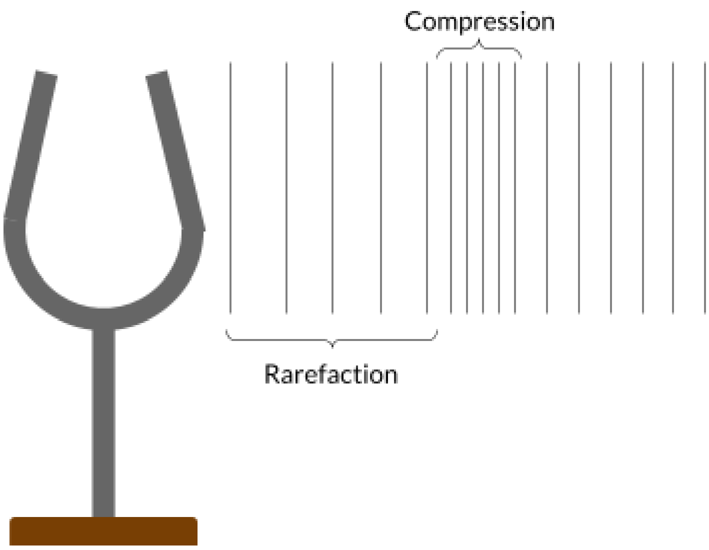
Let’s consider a tuning fork as shown below. (The lines on the right of the tuning fork refers to layers of air)



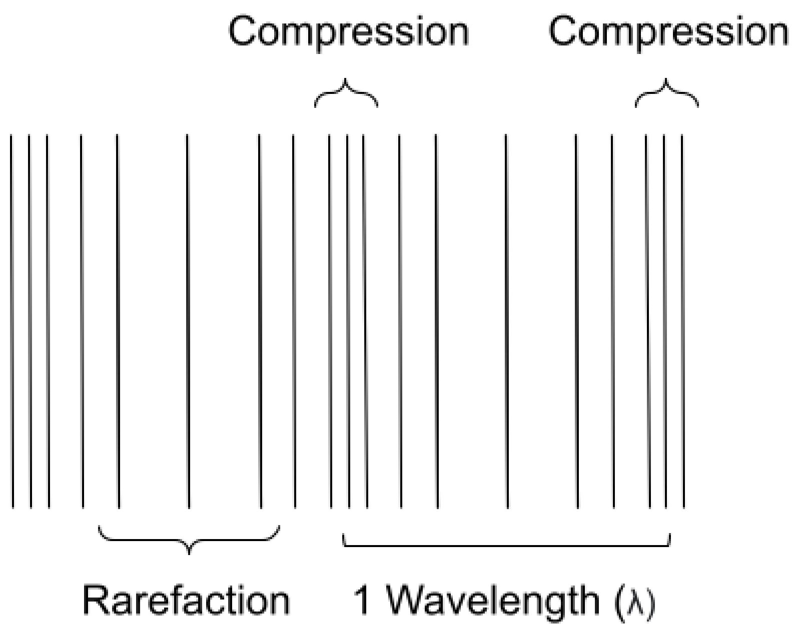
A region of compression has a **higher air pressure**, whereas a region of rarefaction has **lower air pressure**.

A rarefaction is essentially the opposite of a compression, as illustrated in the diagram below.

When we hit the tuning fork, its prongs will vibrate inward and outwards, creating rarefactions and compressions as shown below.



Now, as the tuning fork continues to vibrate, a series of **compressions and rarefactions** is generated, that looks something like this.



Chapter 13: Light I - Reflection

13.1 The Ray Model of Light

Here are some properties of light as described by the Ray Model of Light.

1. Light travels through transparent materials in straight lines called **light rays**.
2. Light rays **do not interact** with each other. Two rays **can cross without either being affected** in any way.
3. Light will travel forever unless it interacts with matter.
4. Light Rays originate from every point on the object, and each point sends rays in all directions.
5. The speed of light, also known as *c*, is 3.00×10^8 *m/s (3sf)* in a vacuum.
   This is the fastest speed attainable for any object in the universe.
6. Light travels in straight lines.

13.1.1 How Does the Eye See?

The eye "sees" an object when diverging bundles of rays from each point on the object enter the pupil and are focused to an image on the retina.

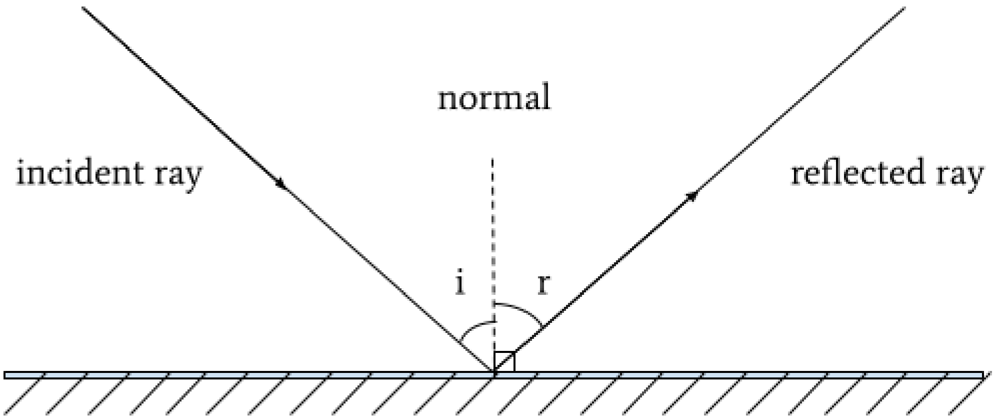
From the movements the eye's lens has to make to focus the image, your brain "computes" the distance at which the rays originated and you perceive the object as being at that point.

13.2 What is Reflection?

Reflection of light is simply defined as the **bouncing** of light off a surface.

We are able to see an object when either of the two conditions is met:
1. It is a light source (known as a **luminous object**) and emits its own light; or
2. Light from a light source **reflects off the object** (known as **non-luminous**) into our eyes.

13.3 The Law of Reflection



Note: The normal is defined as the perpendicular line passing through the point of incidence, i.e. where the incident ray meets the surface.

The law of reflection states that:

1. The incident ray, reflected ray, and the normal all lie **on the same plane** as the point of incidence; and
2. The angle of incidence is **exactly equal to** the angle of reflection.

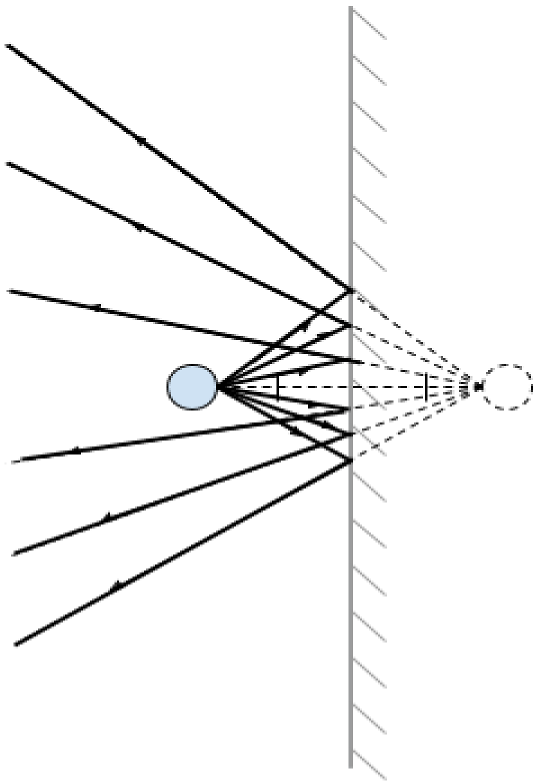
The second statement is often denoted $\angle i = \angle r$.

13.4 Images in a Plane Mirror

When an object is seen in a mirror, an **image** is formed.

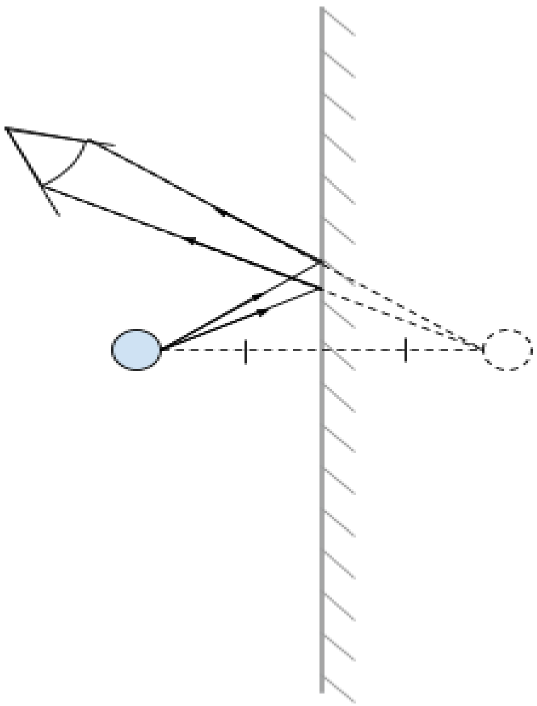
13.4.1 Construction of a Ray Diagram

To construct a ray diagram, we first reflect the object across the mirror, to an equidistant point "in the mirror", as shown, then we connect rays as demonstrated.



13.4.2 Properties of Images in a Plane Mirror

Here is how a ray diagram of an image should be constructed.
Do remember to indicate the equal line segment lengths using the dash and don't forget the arrow heads! Virtual rays (the ones that don't make up the reflected rays) must be drawn using dotted lines!



Here are some properties that you need to memorise of images formed by a plane mirror.

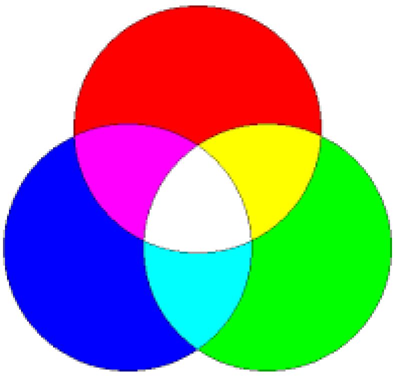
Images in a plane mirror are:
1. Upright
2. Same size as object
3. Distance from image to mirror = Distance from object to mirror (equidistant)
4. Laterally inverted (i.e. Flipped left-right)
5. Virtual

Note - Definition of Virtual: An image is **virtual** if it **cannot be projected on a screen**.

13.5 Colours

The 3 primary colours are **red, green** and **blue**.

We can combine these colours to form other colours, as seen from the image below.



Colours to Combine		Resultant Colour
Blue	Green	Cyan
Blue	Red	Magenta
Green	Red	Yellow

When you combine two primary colours to get **cyan**, **magenta** or **yellow,** we call them **Secondary Colours**.

Now, if we combine all three primary colours, we get white light.

Similarly, if we combine a secondary with the other primary colour (e.g. cyan (blue and green) with red), we also get white light. These colours, **cyan** and **yellow**, are called **complementary.**

Chapter 14: Light II - Refraction

14.1 What is Refraction?

Refraction is the **bending** of light when it passes from one transparent medium to another.

It is responsible for many phenomena, for example, a straw can look “broken” from the top of a drink. This is because of refraction.

14.1.1 Why does Refraction take place?

Light travels at different speeds in different optical media. This sudden change in the s peed of light causes the path of light to bend, resulting in refraction. The greater the difference in optical density of one transparent medium to another, the greater the extent of bending.

14.2 Refractive Index

Refractive index, n, is calculated as the ratio of the speed of light in vacuum to the speed, v, in a given medium, using the formula:

$$n = \frac{c}{v}$$

Where:
- n is the refractive index;
- c is the speed of light in a vacuum, *3.00 × 10⁸ m/s*; and
- v is the speed of light in the medium

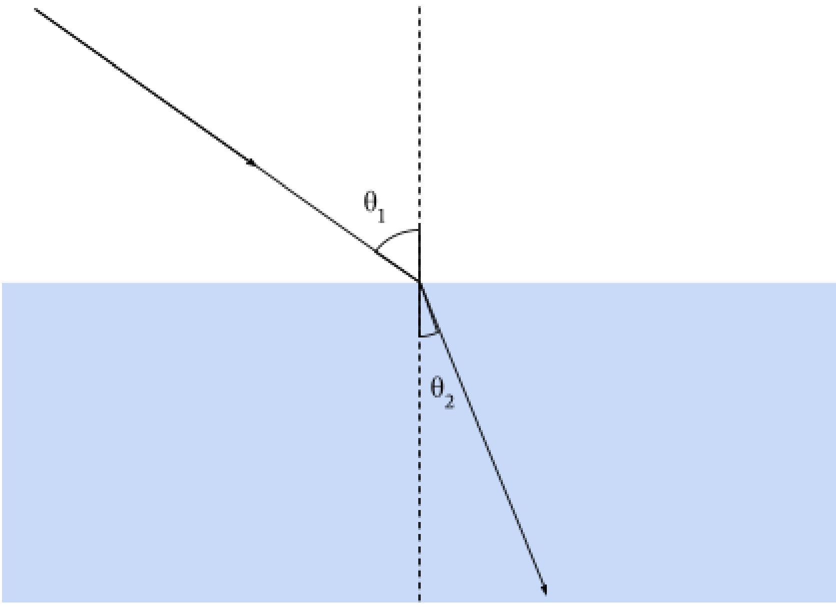
There is only 1 value you have to memorise for refractive indexes, that is the refractive index of air, which is taken as *1.00 (3sf)*.

14.3 Snell’s Law

Snell’s Law states,

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

Where:
- n_1 is the refractive index of the first medium;
- θ_1 is the angle of incidence;
- n_2 is the refractive index of the second medium; and
- θ_2 is the angle of refraction



In-Class Assignment 7: Refraction of Light (MCQ) Q1

A ray of light is refracted at the boundary between optical media A and B, as shown in Figure **1.**

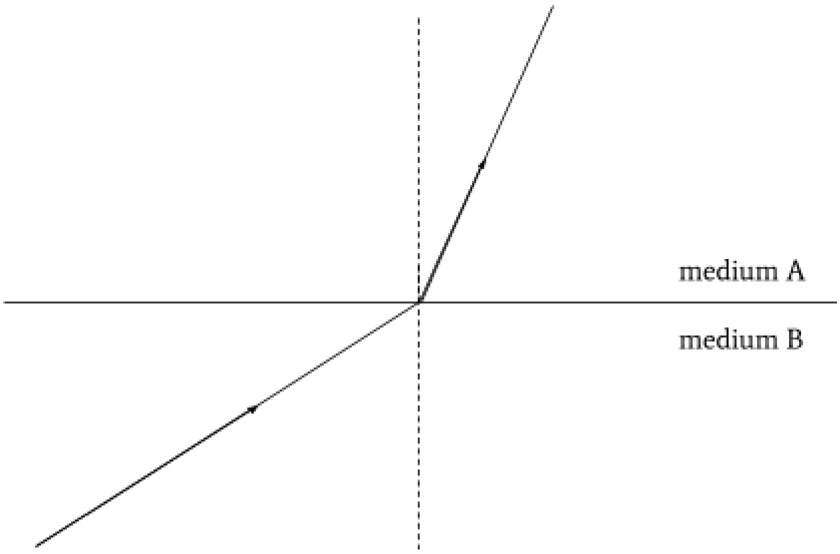


Figure 1

Which of the following statements is true?

A Medium A has a smaller refractive index than B.
B Medium A is optically denser than medium B.
C Light travels at a lower speed in medium B.
D When the direction of the light ray is reversed, the refracted ray bends towards the normal.

Solution

Let's compare the refractive indexes of medium A and B, using **Snell's Law**.

Let n_1 be the refractive index of medium A, n_2 be the refractive index of medium B.

By **Snell's Law**, $n_1 \sin \theta_1 = n_2 \sin \theta_2$.
We observe that $\theta_1 < \theta_2$.
It is then clear that $\sin \theta_1 < \sin \theta_2$. *[Not really important why, refer to note below]*

If $\sin \theta_1 < \sin \theta_2$, but $n_1 \sin \theta_1 = n_2 \sin \theta_2$, then clearly we get $n_1 > n_2$.

Hence, **B** is the correct option.

Note: The mathematical reasoning behind why this is true is not important, as it is covered in MA2131 Chapter 5. Put simply, we can imagine $\sin$ as a square root in this case, where if $\theta_1 < \theta_2$, then it is clear $\sqrt{\theta_1} < \sqrt{\theta_2}$.

Learning Point

Through this example, we can infer a property of refraction - **if a ray bends towards the normal after refraction, then the second medium is more optically dense than the first medium**, and vice versa.

14.4 Misconception of Depth

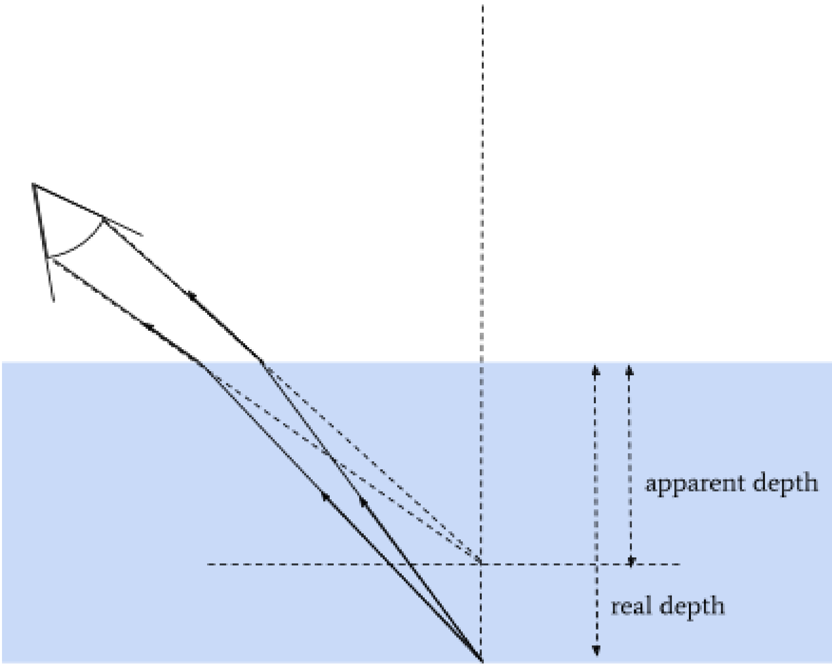
Refraction can cause people to misinterpret depths, for example, a pool can be seen as much shallower than it truly is.

The apparent depth and the real depth can be linked by the formula:

$$n = \frac{real\ depth}{apparent\ depth}$$

14.4.1 Ray Diagram

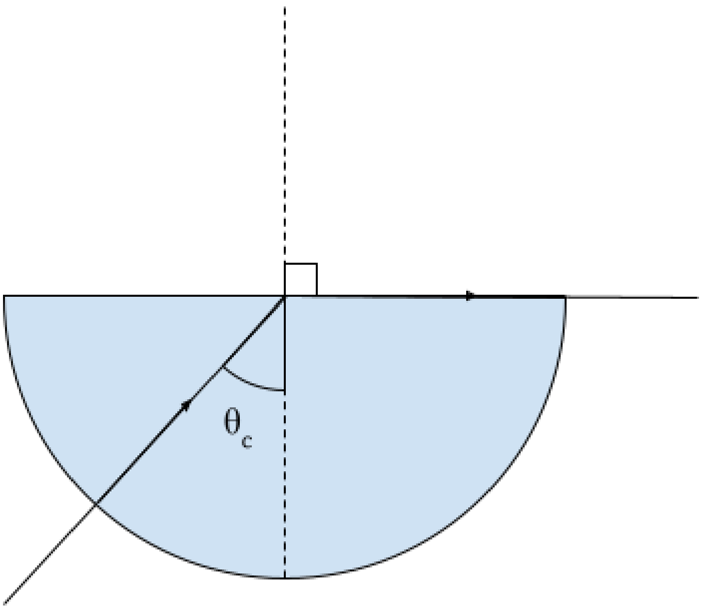
This is the Ray Diagram for Depth Drawings.



14.5 Critical Angle

When light travels from **more optically dense** (i.e. higher refractive index) medium to a **less optically dense** (i.e. lower refractive index) medium:

Then, the critical angle is defined as the **incidence angle** when the **refracted angle** is exactly 90°.



14.5.1 Calculating Critical Angle using Snell's Law

By Snell's Law, we have $n_1 \, sin \, \theta_c = n_2 \, sin \, 90°$.

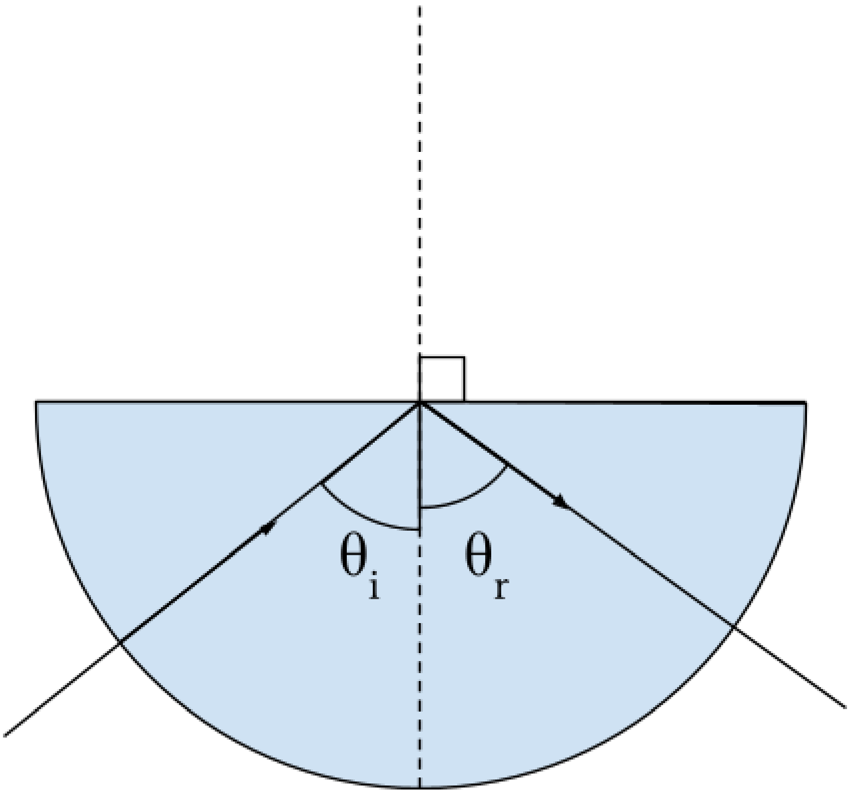
Using $sin\ 90° = 1$, we can rearrange the equation as such:

$$sin\ \theta_c = \frac{n_2}{n_1}$$

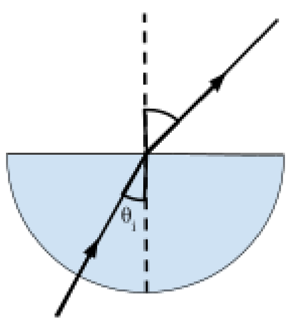
This is how we calculate critical angle.

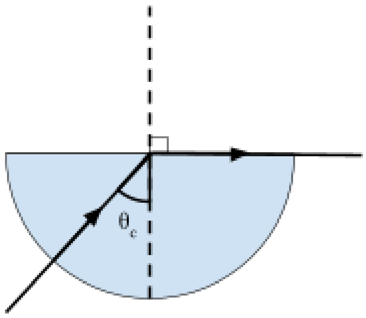
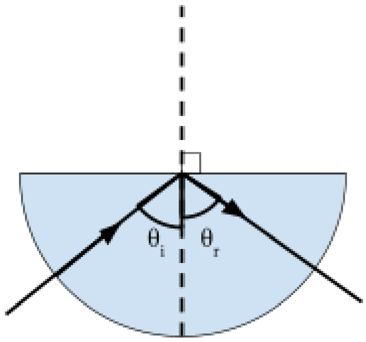
14.6 Total Internal Reflection

Total Internal Reflection occurs when the angle of incidence exceeds the critical angle.



Note that total internal reflection will now follow the Law of Reflection, instead of Snell's Law.

$\theta_i < \theta_c$	Refraction occurs. 
$\theta_i = \theta_c$	Refraction occurs, refracted ray perpendicular to normal.

	
$\theta_i > \theta_c$	Total Internal Reflection occurs. 

<u>In-Class Assignment 7: Refraction of Light (MCQ) Q2 Modified</u>

A ray of light is incident on one side of a rectangular glass block, shown in **Figure 2**, so that the angle of refraction is 40° in the glass. Draw the path of the light ray until it emerges out of the glass block, given the refractive index of the glass is 1.50.

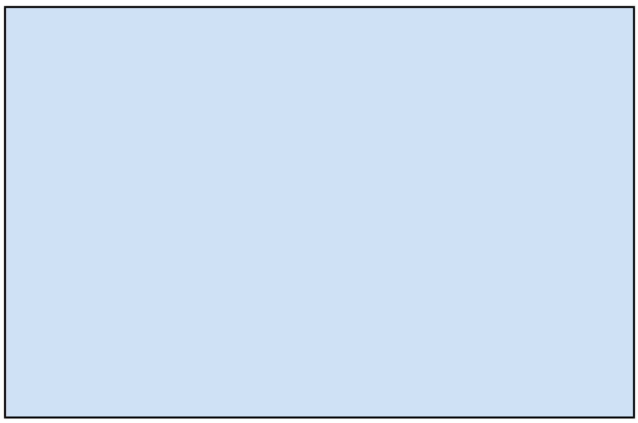


Figure 2

<u>Solution</u>

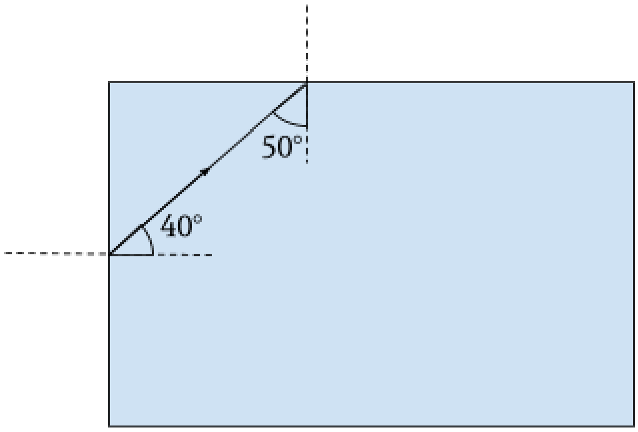
Let us first calculate the critical angle, θ_c from glass to air.

We solve for θ_c using $sin\ \theta_c = \frac{n_2}{n_1}$.

$sin\ \theta_c = \frac{1.00}{1.50}$

$\theta_c = 41.8°$

Now, let's start constructing the ray diagram. The information we know so far is:



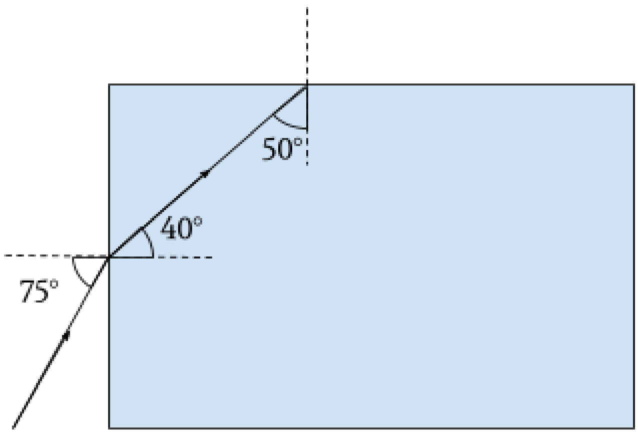
Let's calculate the angle of incidence of the initial ray, since we know the angle of refraction is 40°.

By **Snell's Law**, $n_1\ sin\ \theta_1 = n_2\ sin\ \theta_2$

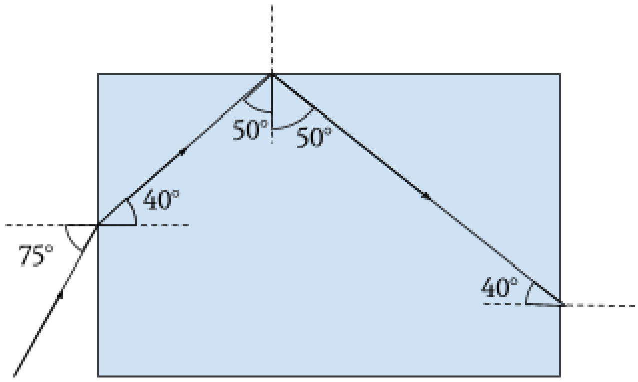
$1.00\ sin\ \theta_1 = 1.50\ sin\ 40°$

$\theta_1 = sin^{-1}(1.50\ sin\ 40°)$

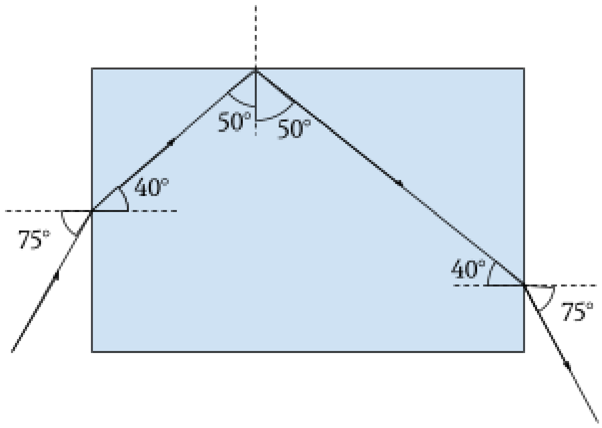
$= 75°$



Now, let's consider what happens when the ray reaches the edge of the glass block. Since $50° > \theta_c$, total internal reflection occurs instead of refraction, hence obtaining:



Now, using the result by **Snell's Law** just now, we can infer the angle of refraction is 75°.



And we are done.

14.7 Dispersion of Light

Light can be split into its 7 main constituent colours - Red, Orange, Yellow, Green, Blue, Indigo, Violet (i.e. the colours of the rainbow).

This **splitting** of light **into its constituent colours** is called **dispersion**.

14.7.1 Why Does Dispersion Occur?

[verified by Mr Yeem if its wrong its all Mr Yeem's fault]

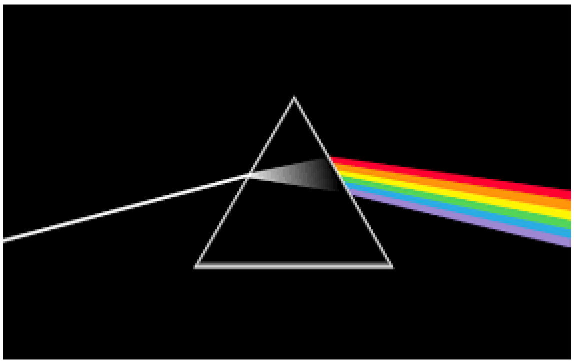
Different frequencies of light actually travel at slightly different speeds in a transparent medium, so they will refract by different amounts.

Higher frequency lights will tend to travel **slightly more slowly** than lower frequency light in the same medium (apart from vacuum, where all electromagnetic waves have a speed of c, 3.0×10^8 m/s).

Since red light moves faster, mediums have a **smaller refractive index,** n, for red light (in comparison to violet light), as described by $n = \frac{c}{v}$, since c is constant and v is bigger.

Hence, red light experiences **less bending** (i.e. refracts with a smaller angle of refraction) than violet light.

This causes the different colours of light to split out of a prism as such:



This process, **dispersion**, along with **refraction**, is what allows rainbows to form.

Chapter 15: Light III - Lenses

15.1 Concave and Convex Lens

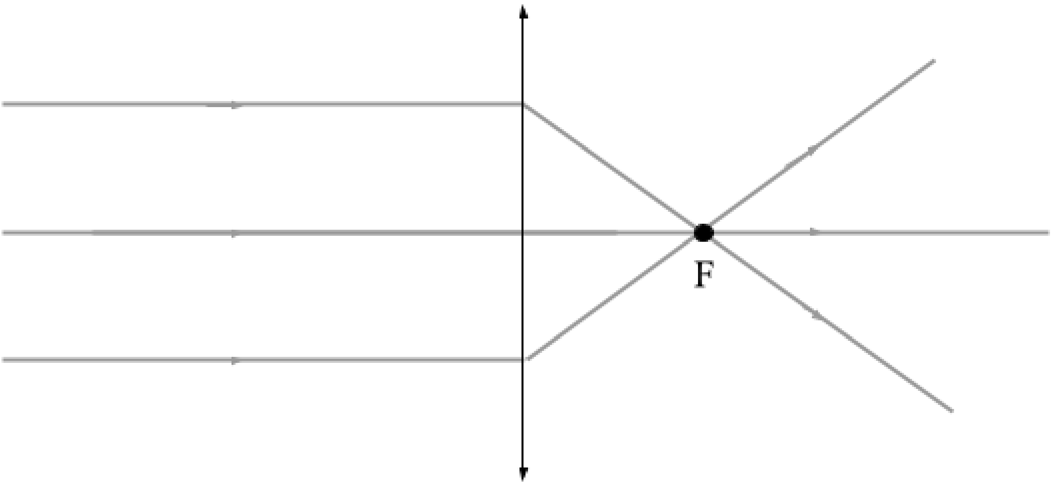
There are two types of lens - concave (diverging) and convex (converging) lens.

Con**cave** (diverging) Lens   Convex (converging) Lens

Tip: *A way to memorise Concave/Convex is that a concave lens looks like a **cave** (or you can remember that it **caves** inwards).*

15.2 Focal Point of Convex Lens

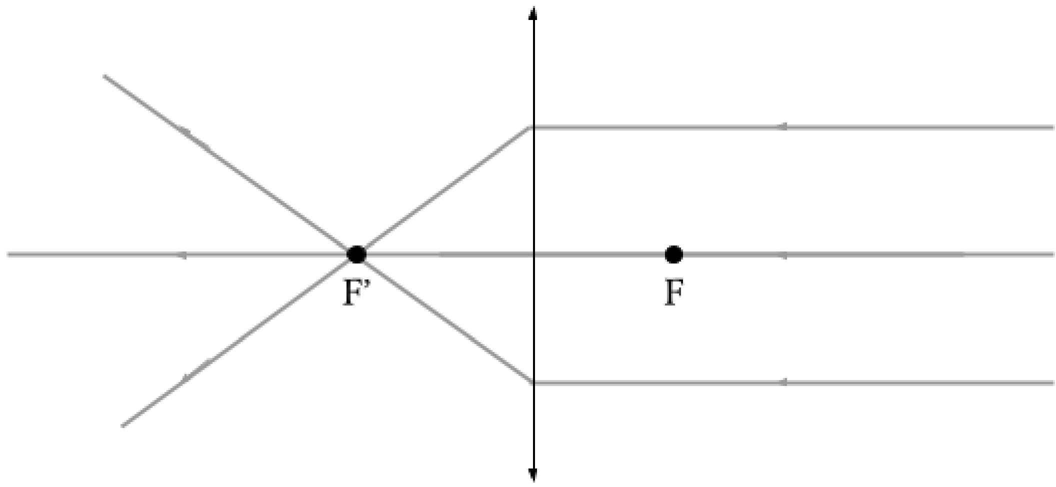
To find the focal point of a convex lens, we can shine parallel rays of light at it.



When parallel rays are shone onto a convex lens, all the rays will refract to meet at a certain point, F, which is known as a **focal point** of the lens.

Note: We denote a converging lens with a double-headed arrow.

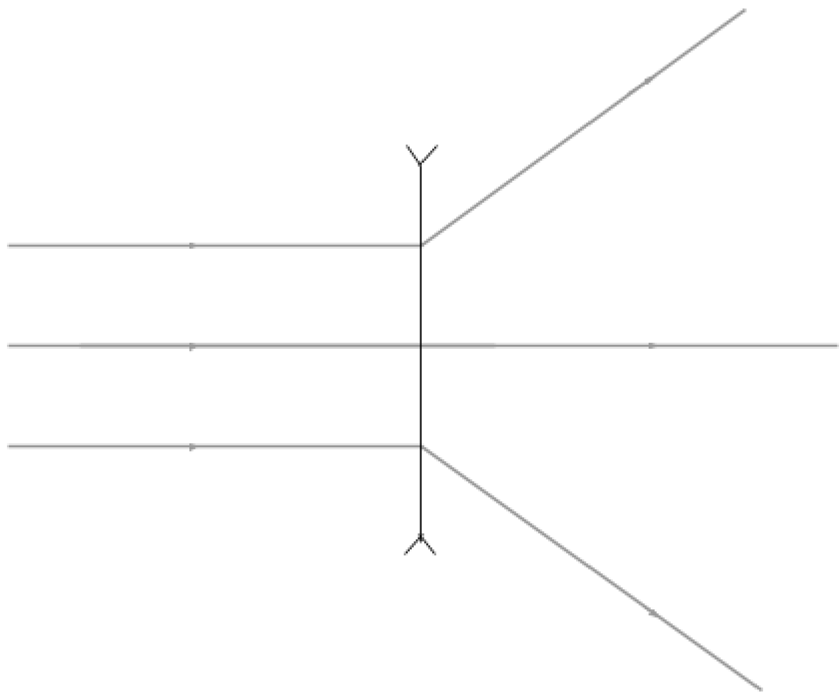
However, there is actually another focal point, F' if the light is coming from the other side of the lens, as shown below.

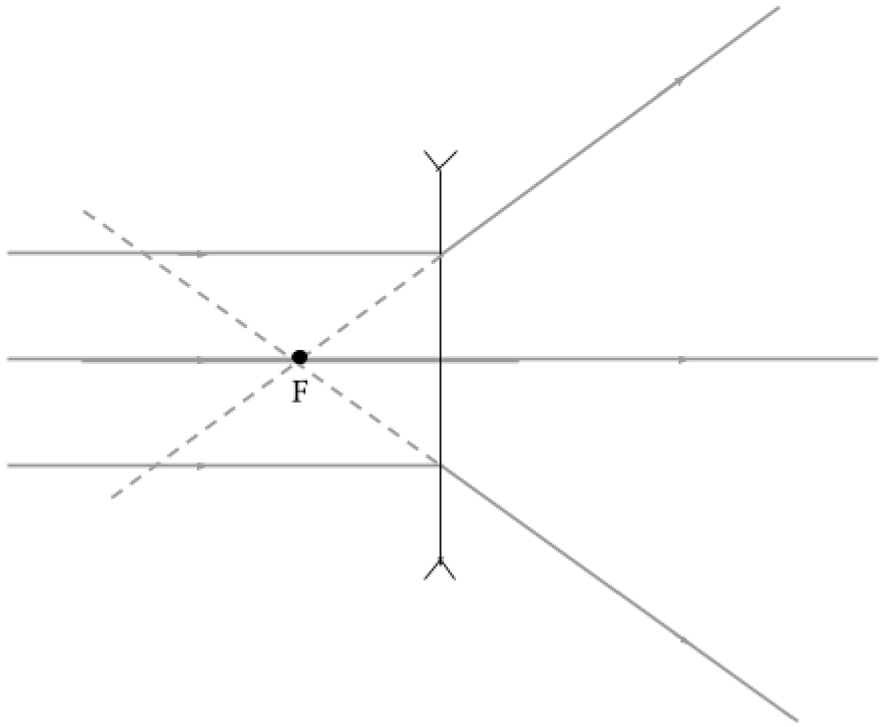


The two focal points are equidistant from the lens.

15.3 Focal Point of Concave Lens

To find the focal point of a concave lens, we do a similar procedure, first shining parallel beams of light at the lens.





As shown above, we then extend the three beams of light, and the intersection point is our focal point. However, do remember that there will be another focal point on the opposite side, equidistant to the lens.

The focal length of a convex or concave lens is then just the **distance between the lens and the focal points**. Take note that the focal point is **always on the optic axis**.

15.4 Ray Tracing

Ray tracing is dependent on 3 rays, which I will cover later, called the **principal rays.**

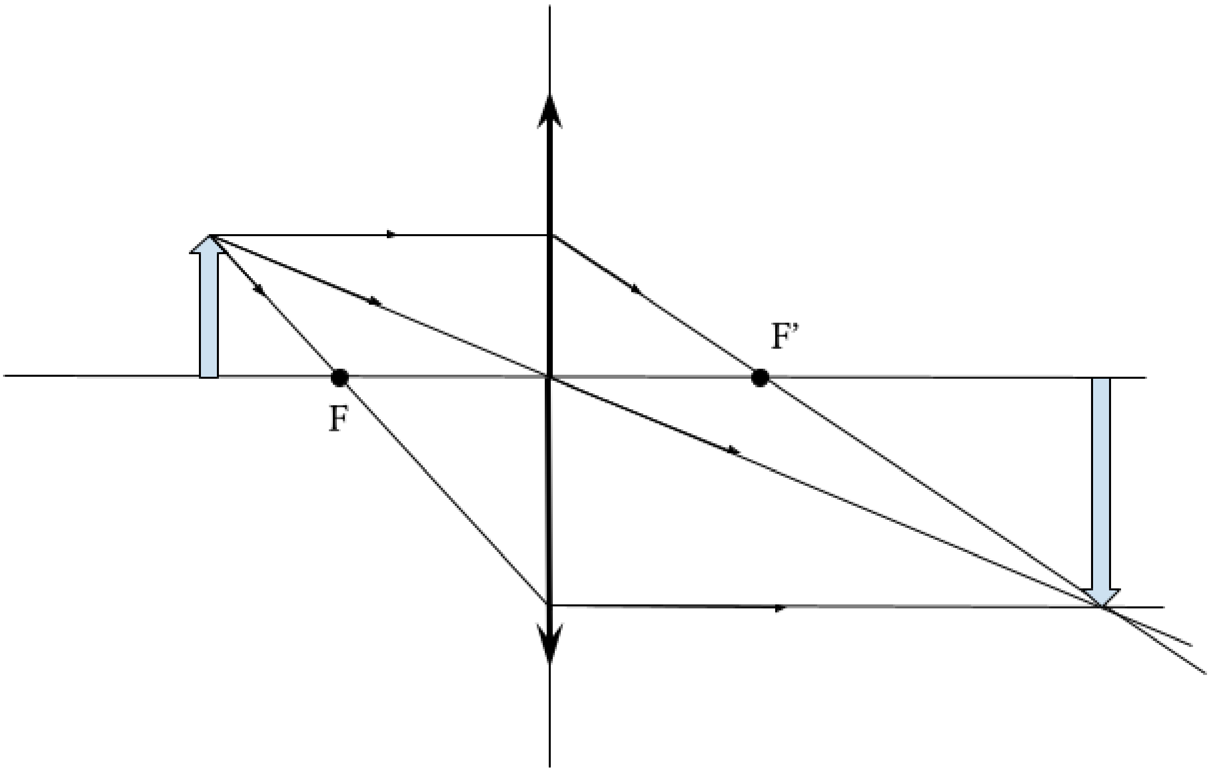
The first principal ray goes parallel to the **optic axis**, then refracts at the lens to meet the **focal point** on the other side, and then extends in a straight line.

The second principal ray goes through the **origin** and is mainly unaffected by refraction, passing through the lens in a straight line.

The third principal ray goes through the **focal point**, then refracts at the lens and continues in a straight line parallel to the **optic axis**.

We can split this into 3 cases, based on the object distance, x_o (i.e. distance between object and lens), and the focal length of the lens, f.

15.4.1 Case 1: $x_o > f$



Here is how we find the image (on the right) of the object (on the left) with a distance greater than the focal length.

As mentioned, we use the 3 principal rays.

The first principal ray is the ray that goes **parallel to the optic axis** (i.e. the axis perpendicular to the lens), then hits the lens and refracts to **pass through the focal point** on the other side.

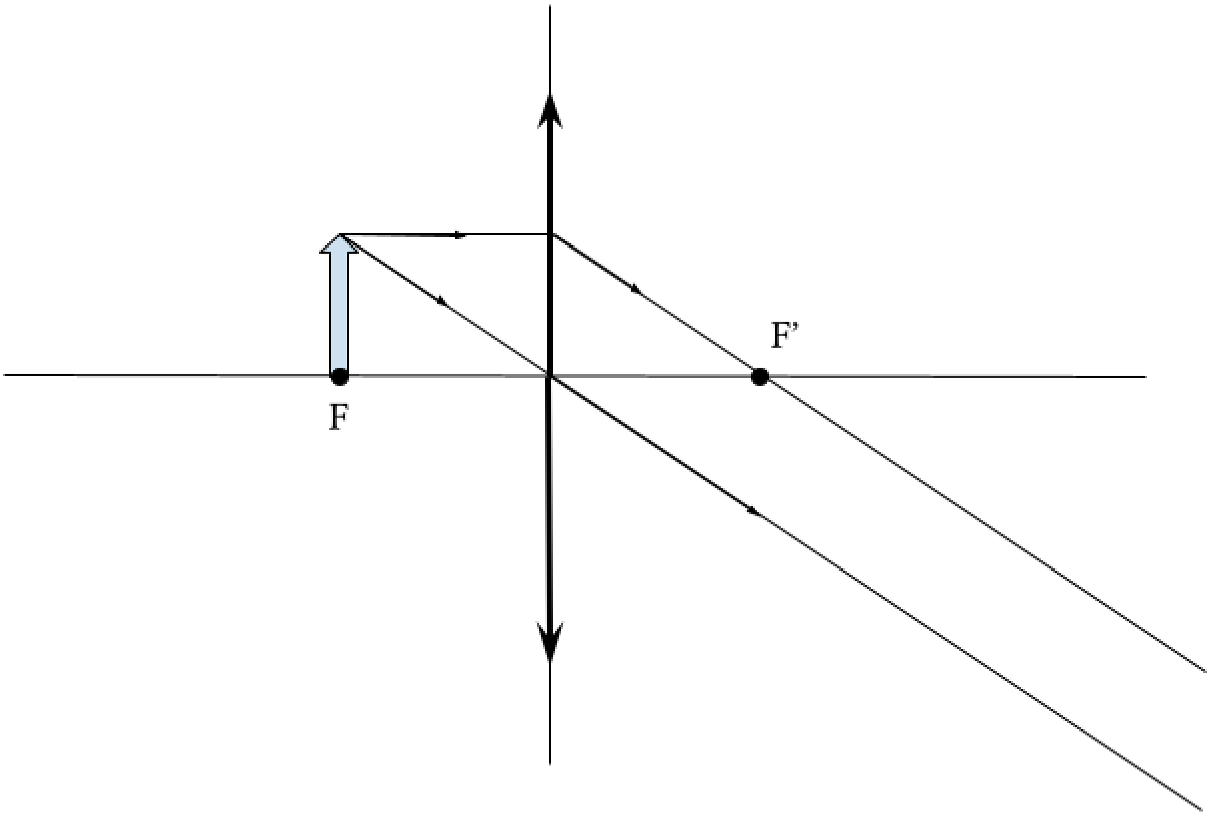
The second principal ray is the ray that **passes through the centre of the lens** (intersection between the lens and optic axis), and is **unaffected by refraction**.

The last principal ray is the ray that **passes through the first focal point**, then hits the lens and refracts to go **parallel to the optic axis**.

When the three principal rays meet at a point, that point is the tip of the image.

We can then denote the image with an arrow.

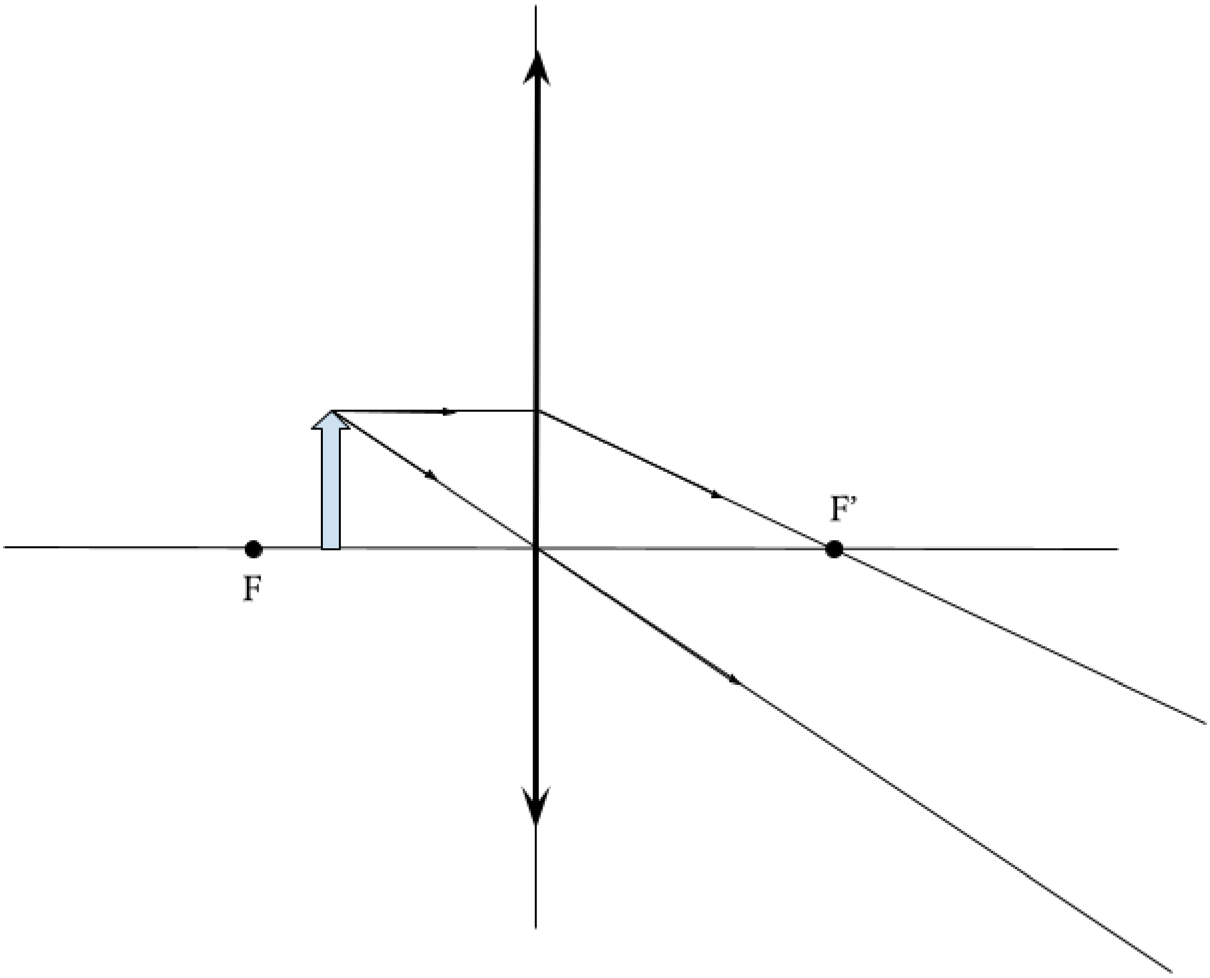
15.4.2 Case 2: $x_o = f$



For this special case, we can only construct two of the principal rays, and we can clearly see that these two rays are then parallel.

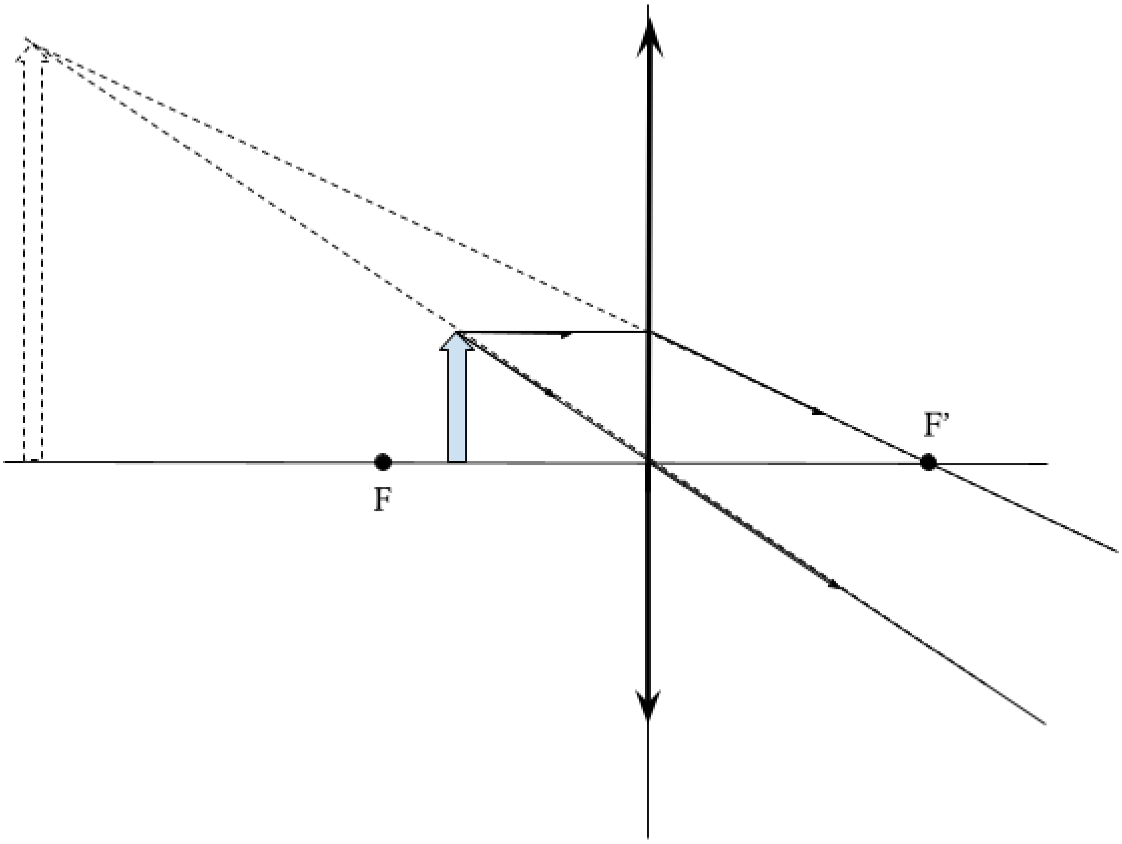
When these rays are parallel, they will never meet and hence an **image doesn't form**, or we say the **image is at infinity**.

15.4.2 Case 3: $x_o < f$

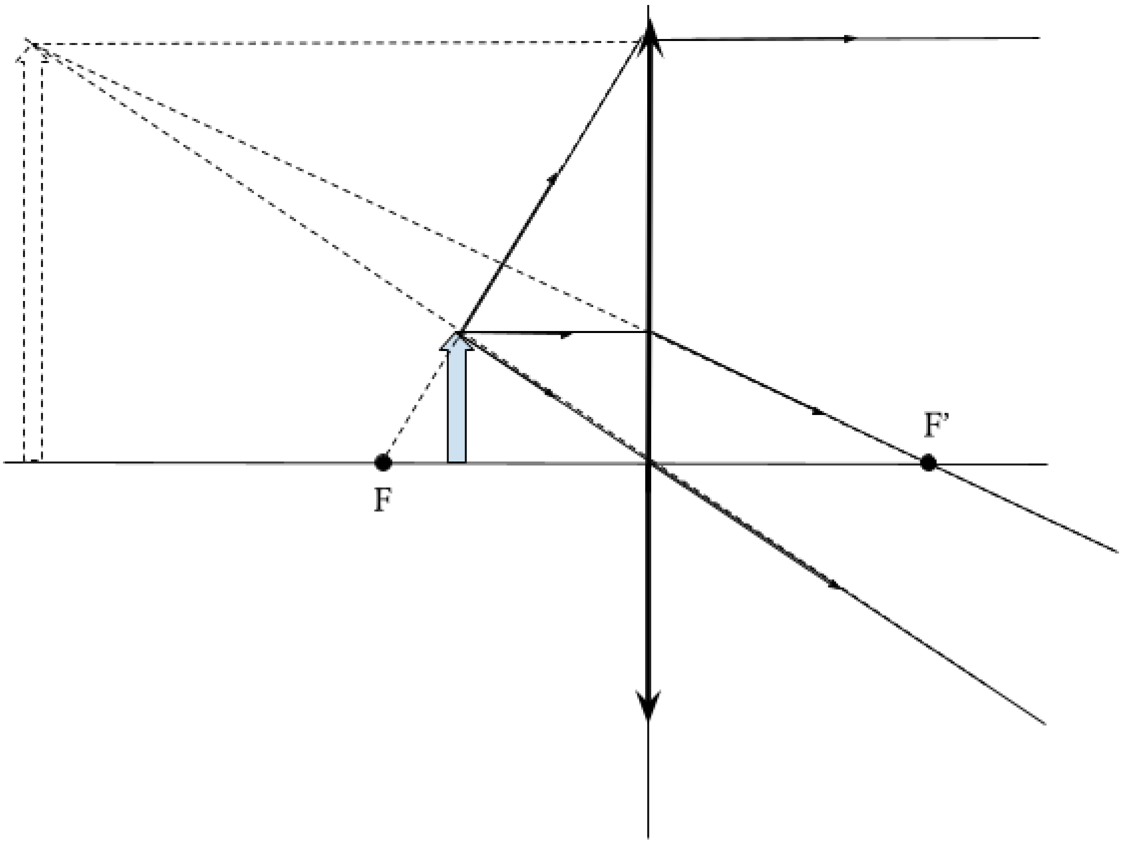


We can first construct two principal rays as such. However, they don't seem to intersect… or do they?

Well, it becomes more clear when we extend these rays, making sure to use dotted lines.



We can now extend the third principal ray, from F, to the arrow, using a dotted line, then extend it to the lens using a solid line.



Now, we see that an image does form, but since the rays were extended, the image is not real. It is **virtual**. Speaking of, let's summarise the properties of convex lens images.

Here are properties of Convex Lens Images:

x_o, Object Distance	Image Size	Image Characteristics
$x_o > 2f$	Diminished (Smaller)	Inverted, opposite side, real
$x_o = 2f$	Same Size	Inverted, opposite side, real
$2f > x_o > f$	Magnified (Larger)	Inverted, opposite side, real
$x_o = f$	Image at Infinity (No Image Formed)	
$x_o < f$	Magnified	Upright, same side, virtual

15.5 Lens Equation

We can express the focal length of a lens f, object distance x_o, and image distance x_i using the following equation, known as the **Lens Equation**:

$$\frac{1}{f} = \frac{1}{x_o} + \frac{1}{x_i}$$

Note: Some people might know this equation as $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$, as taught by Mr Yeem (uwu); Don't worry, it's just a simple different naming of variables.

15.6 Magnification

The magnification, m, of an object through a **convex** lens is given by:

$$m = \frac{h_i}{h_o} = -\frac{x_i}{x_o}$$

Where:

- m is the magnification;
- h_i is the image height;
- h_o is the object height;
- x_i is the image distance; and
- x_o is the object distance.

Note: Some people might know this equation as $m = -\frac{v}{u}$, as taught by Mr Yeem (uwu); Don't worry; again, it's just a simple different naming of variables.

Note that when an image is inverted (i.e. flipped top-bottom), its height, h_i is negative, but u always takes the absolute value (i.e. the positive value).
FYI: This is because distance simply refers to magnitude, and does not have direction.

Hence, we can also conclude that when an image is inverted (i.e. real), $m < 0$, whereas when an image is upright (i.e. virtual), $m > 0$.

Credits

Some suitable revision questions are included in this set of notes for the reader to revise and practise on.

Here is the list of example questions used by this set of notes:

Course Packs

PC1131 Semester 1 Course Pack, Chapter 2, Page 10, Example 1
PC1131 Semester 1 Course Pack, Chapter 7, Page 57, Example 7
PC1131 Semester 1 Course Pack, Chapter 7, Page 59, Example 10 (b) Modified
PC1131 Semester 2 Course Pack Pages 9 - 53

Remedial Worksheets

PC1131 Remedial WS 2, Question 4
PC1131 Remedial WS 3, Question 6
PC1131 Remedial WS 3, Question 9 (a)

In-Class Assignments

PC1131 ICA 1, Question 5 (a)
PC1131 ICA 2, Question 4 (c)
PC1131 ICA 2, Question 4 (d)
PC1131 ICA 7, Question 1
PC1131 ICA 7, Question 2

PC1131 Common Test 1 Revision Package

Question 2
Question 6
Question 9 (c) Modified
Question 10 (d)

PC1131 Semester 1 Examination Revision Package

Question 2

Question 15

Common Test

PC1131 Common Test 1 Modified Question

Pictorial Sources

https://www.quora.com/What-color-does-blue-and-red-make
https://www.quora.com/Why-is-a-glass-prism-so-good-at-splitting-light-into-different-colors-compared-to-other-3D-shapes-like-a-cube-or-sphere

Thank you for reading this set of notes!

Good luck for all your exams!

❤️

~A tired LQ