ATARNotes

Physics Units 3&4

ATARNotes September Lecture Series

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AIM OF THE DAY

- **Today's goal:**
  - Practice questions from VCAA Exams that were hard
  - Show how to approach harder questions

- Why aren't we doing content summaries?
  - At this point in the year, summarising through practice questions is more effective for most students to make sure you have the knowledge and skills you need

HOW TO ANSWER QUESTIONS IN PHYSICS

Calculation answers:

- **ALWAYS WRITE THE FORMULA YOU ARE USING**
- Then substitute the numbers in
- Solve for your answer

$$a = \frac{v^2}{r}$$

$$= \frac{(7.7 \times 10^3)^2}{(6760 \times 10^3)}$$

$$= 8.8 \text{ m s}^{-2}$$

HOW TO ANSWER QUESTIONS IN PHYSICS

Worded answers:

- Always put it in dot points – be concise
- General structure – this may vary depending on the question
  1. Explain the **theory** related to the question
  2. Put the theory in **context** to the question
  3. Final statement if necessary

Eg. Explain why the normal force and weight force are not an example of Newton's 3rd Law where an object is at rest on the surface of the Earth.

- Newton's 3rd Law states that $F_{A\ on\ B} = -F_{B\ on\ A}$ where object A applies a force on object B. These forces must be acting on different objects.
- The weight force is a result of the Earth's gravitational attraction on the object whereas the normal force is a result of the Earth's surface pushing the object up
- As the normal force and weight force act on the same object, the normal force and weight force cannot be an example of Newton's third law

PROJECTILE MOTION

Key points of projectile motion where the object is in the air and under the influence of gravity:

- The only force acting on the projectile/object is gravity (excluding air resistance)
- The horizontal and vertical velocities are independent of each other
- The horizontal velocity is constant $v = \frac{x}{t}$ or $x = vt$
- The vertical velocity changes due to gravity – but the acceleration is constant (a = (-)9.8 ms^{-2} on the surface of the Earth)
    - Hence any of the constant acceleration formulae are applicable

NEWTON'S 3 LAWS

Newton's 3 Laws:

1. An object will remain at rest/travel with a constant velocity if the net force acting on the object is zero.
2. When a non-zero net force acts on an object, the object will accelerate ($\Sigma F = ma$)
3. If object A exerts a force on object B, object B will exert an equal and opposite force on object A ($F_{A\ on\ B} = -F_{B\ on\ A}$)
   note that these forces act on different objects

   The two members of an action/reaction pair act on two *different* objects.

Motion

Question 4 (2 marks)

Liesel, a student of yoga, sits on the floor in the lotus pose, as shown in Figure 4. The action force, F_g, on Liesel due to gravity is 500 N down.

Figure 4

Identify and explain what the reaction force is to the action force, F_g, shown in Figure 4.

Question 4

Mark	0	1	2	Average
%	90	2	8	0.2

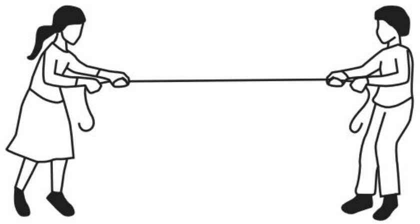
The correct response was to demonstrate Newton's third law and state that if the action force is the gravitational force on Liesel due to the Earth, then: 'The reaction force is the gravitational force of Liesel on the Earth'. This is the force of Liesel pulling up on Earth, not Earth pushing up on Liesel.

This question was not well done. The most common error was to confuse Newton's third law with situations involving balanced forces. The upwards force of the floor on Liesel is a normal force and balances the gravitational force, which is why Liesel is not accelerating. This is not a reaction force. Also of concern were

the high number of students who stated that the reaction force was the normal force. Newton's laws, particularly the first and third and the difference between them, were poorly understood.

Question 9

Two students pull on opposite ends of a rope, as shown in the diagram below. Each student pulls with a force of 400 N.



Which one of the following is closest to the magnitude of the force of the rope on each student?

A. 0 N

B. 400 N

C. 600 N

D. 800 N

2022 VCE

FORCES - TENSION

- It is just applying Newton's 2nd Law to the whole system (find acceleration) and then to an individual component

- General tips for when you get stuck on a force question:
  - **Draw a force diagram** and label the forces – will help sort things out in your brain
  - Find the **acceleration** by looking at the **system as a whole**
  - Find the **tension** by looking at **one component of the system** (usually the back)

Whenever I can do a tension question

THE NORMAL FORCE

- Apparent weight – describes how heavy someone feels
  - This is related to the normal force
  - If $F_N > F_g$, the person feels heavier normal
  - If $F_N < F_g$, the person feels lighter than normal
- Apparent weightlessness – occurs when $F_N = 0$ so that the person *feels* weightless
  - $v = \sqrt{gr}$ this formula can be used in circular motion when $F_N = 0$ N
- True weightlessness – occurs when $F_g = 0$ – only occurs in deep space where the gravitational field strength is 0 N kg^{-1} ($w = mg$)

SPRINGS

- One of the worst done topics on the exam
- It comes up pretty much every year
- Today, we will focus on an **oscillating spring** where the spring is hung from the ceiling and there is a mass attached to it
- Two perspectives when looking at springs:
  - **Force**
    - Force from the spring
    - Weight force
  - **Energy**
    - All three types: U_g, U_s and E_k

OSCILLATING SPRINGS

- Let's discuss what happens in a spring at 3 different points of its oscillation in terms of energy and forces

$$U_g = mgh$$

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

$$U_s = \frac{1}{2}kx^2$$

Top:

- Energy
  - U_g = maximum (equals total)
  - E_k = 0 J
  - U_s = 0 J
- Forces
  - F_g = constant
  - F_s = 0 N

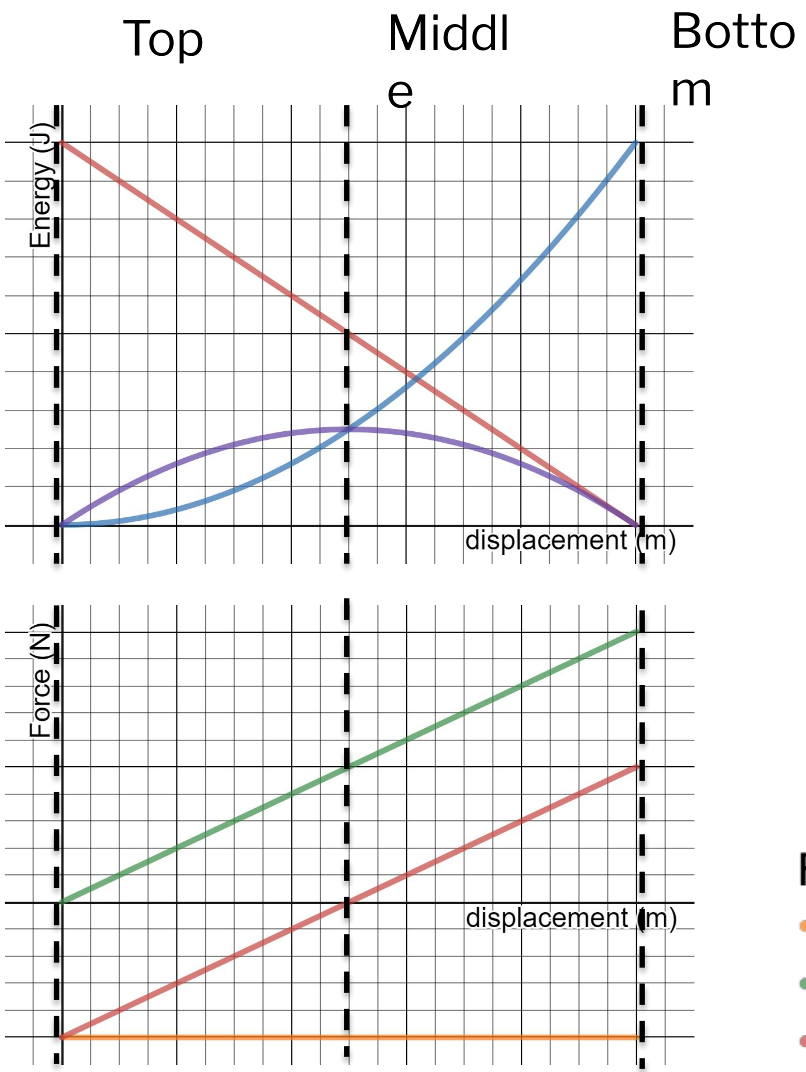
Middle:

- Energy
  - U_g = half total
  - E_k = maximum
  - $U_s = \frac{1}{2}kx^2$
- Forces
  - F_g = constant
  - $F_s = F_g$

Bottom:

- Energy
  - U_g = 0 J
  - E_k = 0 J
  - U_s = maximum (equals total)
- Forces
  - F_g = constant
  - F_s = maximum

OSCILLATING SPRINGS



Energy/displacement graph:

- Red = gravitational energy ($U_g = mgh$)
- Blue = spring energy ($U_s = \frac{1}{2}kx^2$)
- Purple = kinetic energy ($E_k = \frac{1}{2}mv^2$)

Connected between net force and kinetic energy
Net force = 0 N no acceleration maximum velocity maximum kinetic energy

Force/displacement graph:

- Orange = weight force
- Green = spring force ($F = -kx$)
- Red = net force

Motion

b. With four masses on the spring, the students release it from its unstretched length, as shown in Figure 4b.

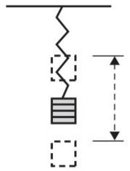
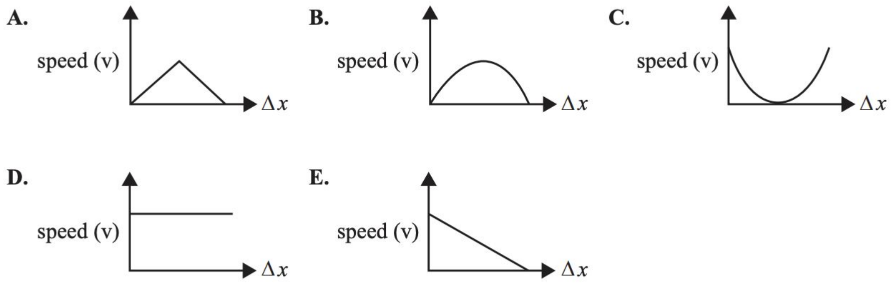


Figure 4b

Which one of the following graphs (**A.–E.**) best shows the speed as a function of extension Δx as the mass moves from top to bottom? Explain your answer. 2 marks



Question 13a.

Marks	0	1	2	3	Average
%	67	2	1	30	1

Motion

Question 13 (7 marks)

Pat and Robin hang a mass of 2.00 kg on the end of a spring with spring constant $k = 20.0\ \text{N m}^{-1}$.

They hold the mass at the unstretched length of the spring and release it, allowing it to fall, as shown in Figure 11.

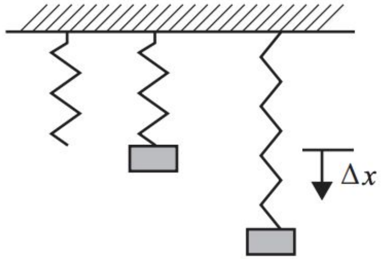


Figure 11

a. Determine how far the spring stretches until the mass comes momentarily to rest at the bottom. Show your working. 3 marks

Question 13a.

Marks	0	1	2	3	Average
%	67	2	1	30	1

PROPERTIES OF CIRCULAR MOTION

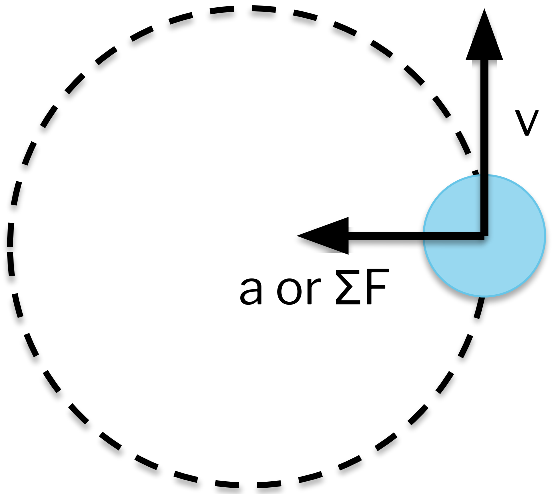
- Properties of circular motion:
  - Uniform circular motion – the speed of the ball is the same
  - Centripetal acceleration – the acceleration is towards the centre of the circle

$$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$$

  - Centripetal force – the net force acting on the object in circular motion that acts towards the centre

$$\Sigma F = ma = \frac{mv^2}{r} = \frac{4\pi^2 mr}{T^2}$$

  - The velocity is tangential to the circular path
  - The centripetal acceleration/force is always perpendicular to the velocity

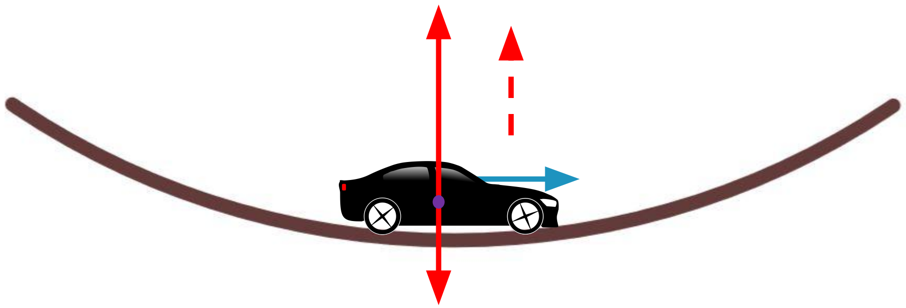


HORIZONTAL CIRCULAR MOTION

- Circular motion that occurs on a horizontal plane
- **Properties**:
  - The **speed** of the object is **constant**
  - The velocity of the object is always changing

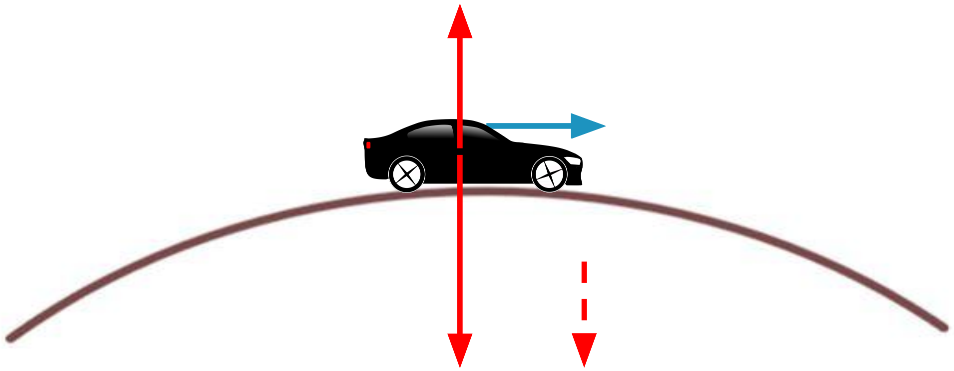
VERTICAL CIRCULAR MOTION

Remember that this is NOT uniform circular motion – think energy transformations



Bottom of the circle:

- Net force is upwards
- Normal force is greater than the weight force



Top of the circle:

- Net force is downwards
- The normal force is smaller than the weight force

Motion

Question 9 (10 marks)

Abbie and Brian are about to go on their first loop-the-loop roller-coaster ride. As competent Physics students, they are working out if they will have enough speed at the top of the loop to remain in contact with the track while they are upside down at point C, shown in Figure 9. The radius of the loop CB is *r*.

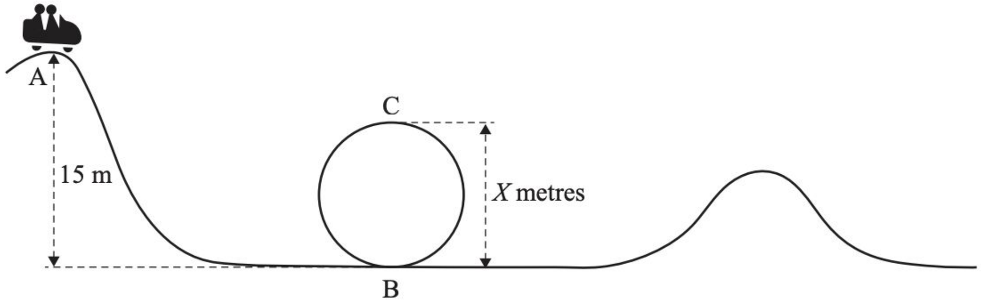


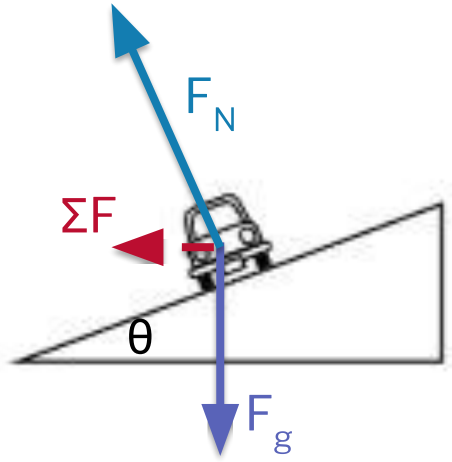
Figure 9

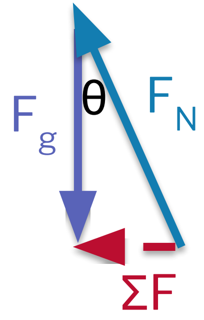
The highest point of the roller-coaster (point A) is 15 m above point B and the car starts at rest from point A. Assume that there is negligible friction between the car and the track.

b. By considering the forces acting on the car, show that the condition for the car to just remain in contact with the track at point C is given by $\frac{v^2}{r} = g$. Show your working. 2 marks

CIRCULAR MOTION BANKED TRACKS

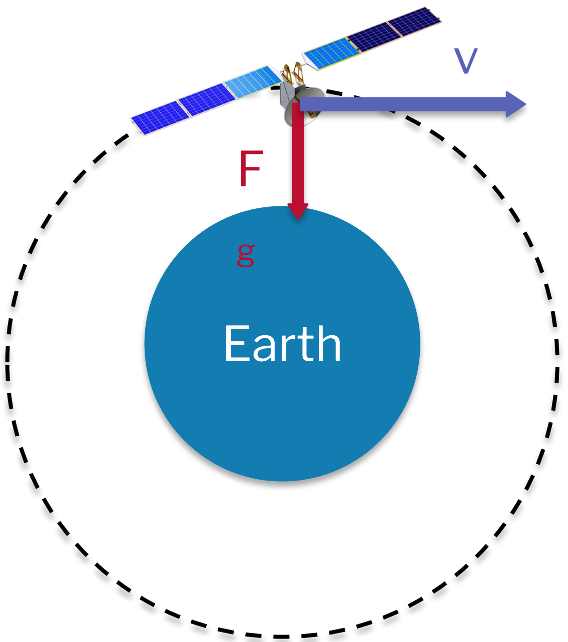
- This describes circular motion that occurs on an inclined plane
- **Design speed** – the speed an object travels at so that friction is not needed to keep it on the track $tan\theta = \frac{v^2}{gr}$
- Note: the **net force** is towards the **centre** and not down the plane (like an inclined plane)





CIRCULAR MOTION - GRAVITY

- The **only** force acting on a satellite is its **weight force**
  - This acts as the **centripetal force** □ circular motion
  - All satellites are in **free fall** – this occurs when the only force acting on the object is the weight force
  - This means that **no normal force** acts on the object □ **apparent weightlessness** occurs
- Also note: because the force acting on the satellite is perpendicular to its motion, no work is done on it



CIRCULAR MOTION - GRAVITY

- **Formulae:**
  - As the only force acting on the satellite is the gravitational force,

$$\Sigma F = ma$$

$$mg = mg$$

$$g = a$$

For acceleration:

$$g = \frac{GM}{r^2} = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2} = a$$

For net force:

$$mg = \frac{GMm}{r^2} = \frac{mv^2}{r} = \frac{4\pi^2 mr}{T^2} = ma = \Sigma F$$

Fields

Question 2 (9 marks)

There are over 400 geostationary satellites above Earth in circular orbits. The period of orbit is one day (86 400 s). Each geostationary satellite remains stationary in relation to a fixed point on the equator. Figure 2 shows an example of a geostationary satellite that is in orbit relative to a fixed point, X, on the equator.

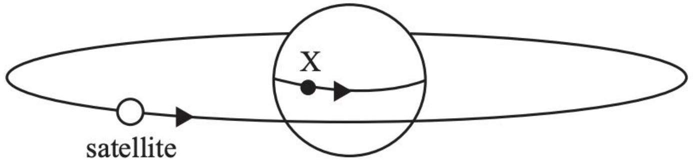
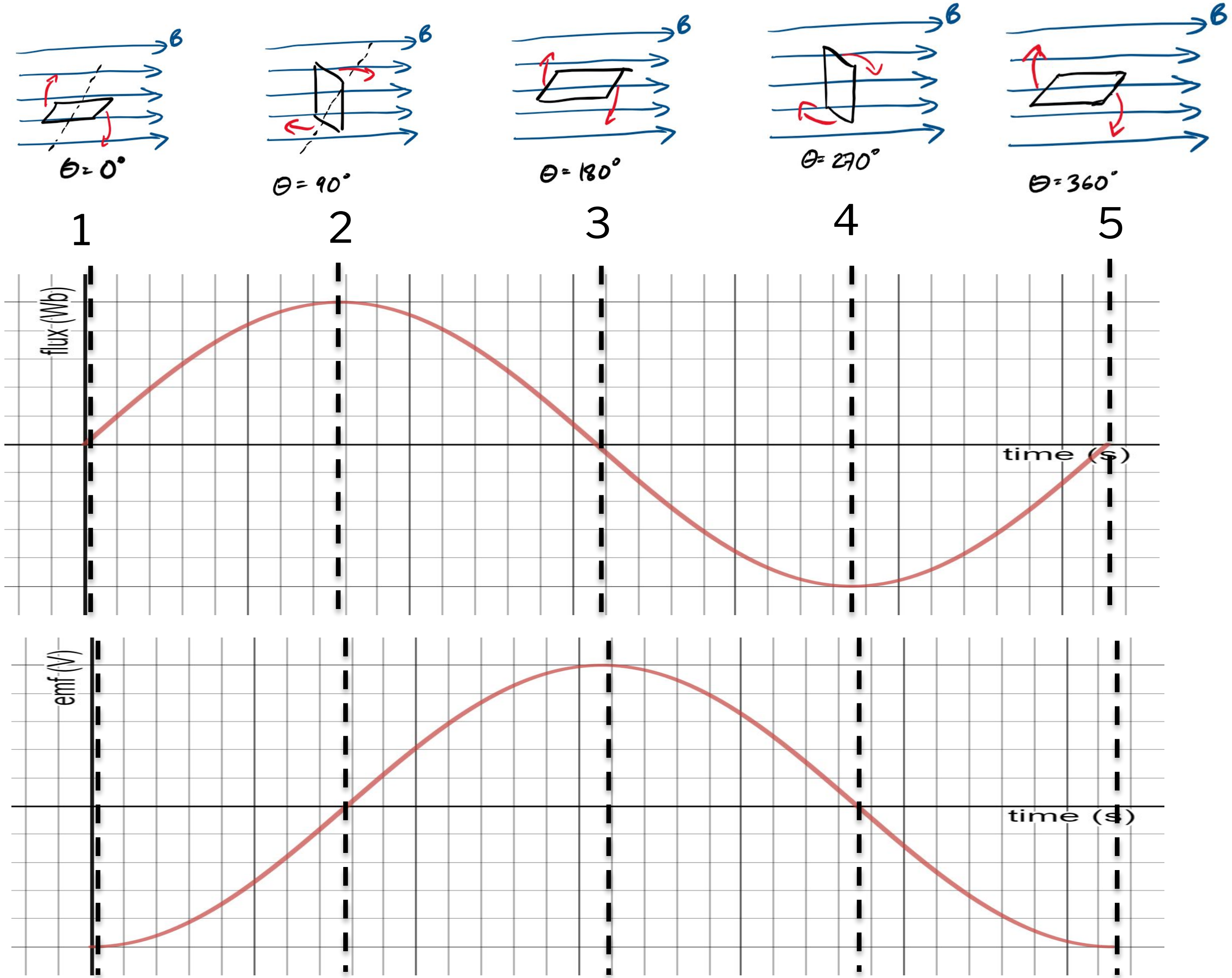


Figure 2

b. Using $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}, $M_E = 5.98 \times 10^{24}$ kg and $R_E = 6.37 \times 10^6$ m, show that the altitude of a geostationary satellite must be equal to 3.59×10^7 m. 4 marks

- Draw out force diagram (from the centre)
- Gravity only force in projectile motion and orbital motion
- Newton's 3 laws
- Oscillating Vs Static Spring

GRAPHS FOR GENERATORS (SLIP RINGS)



Note that the **emf** graph shape is the negative gradient of the **flux** graph as:

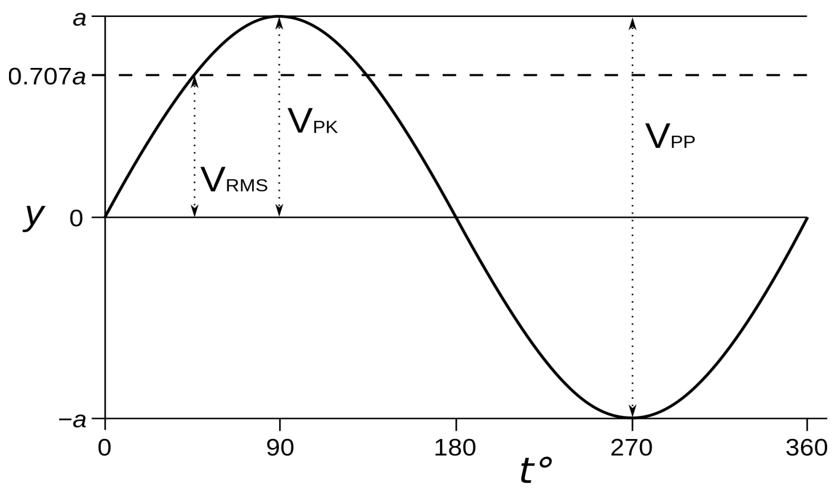
$$\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t}$$

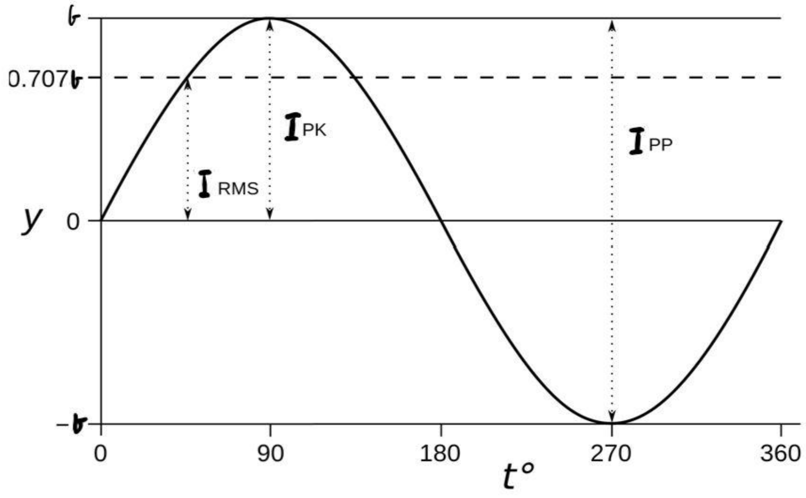
(Faraday's Law)

RMS VOLTAGE AND CURRENT

- RMS voltage/current is the DC voltage/current it would take to produce the same average power as the AC voltage/current.
- The RMS voltage/current is similar to "average voltage/current" but **they are different things**
- Peak voltage/current – measured from the x-axis to the peak
- Peak-to-peak voltage/current – measured from the peak to the trough
- RMS (root mean square) voltage/current - use the following formulae

$$V_{RMS} = \frac{V_{peak}}{\sqrt{2}} \qquad I_{RMS} = \frac{I_{peak}}{\sqrt{2}}$$





VCAA 2016 QUESTION 17

Question 17

Samira and Mark construct a simple alternator, as shown in Figure 21.

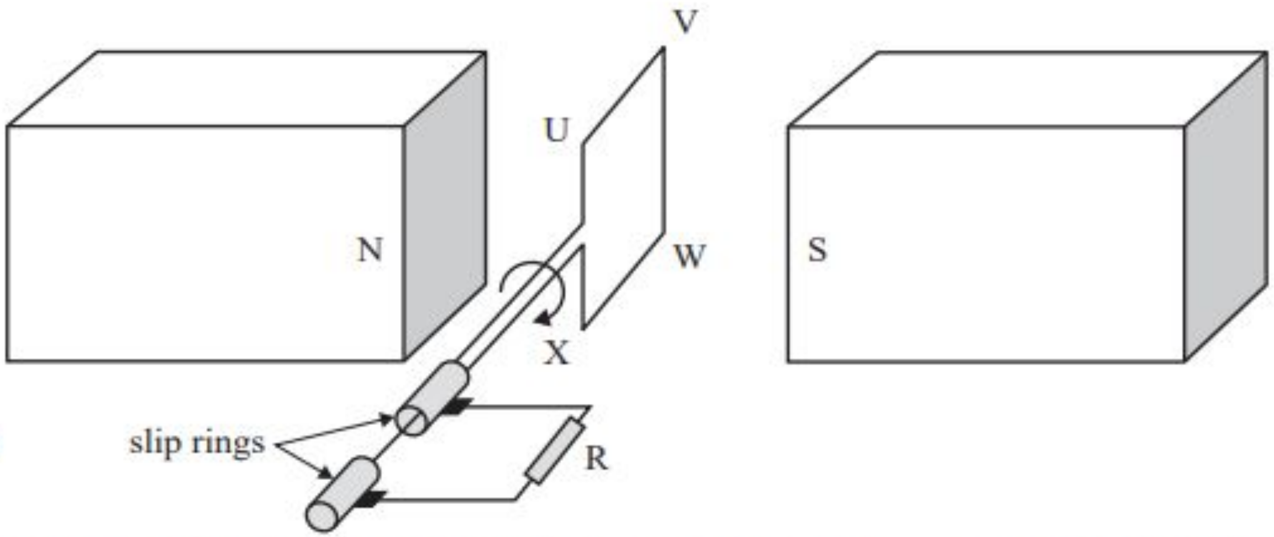


Figure 21

Describe the orientation(s) of the rotating coil when the magnitude of the emf is at a maximum. Give reasons for your answer. 2 marks

Question 17

Marks	0	1	2	Average
%	64	21	15	0.5

LENZ'S LAW

- **The actual definition of Lenz's Law:**
  - "any current induced in a loop will be in the direction so that the flux it creates will oppose the change in the flux that produced it"
- **Breaking down this definition:**
  - Lenz's law is used to determine the direction of the current created when there is a change in flux induces emf induces current
  - The aim of the current is to create a flux that opposes the flux that induced it

LENZ'S LAW

- Using Lenz's Law:

1. **Describing the initial change in flux**
   - Must include a **direction** and whether the flux is **increasing/decreasing**
2. **Figuring out the opposing flux created by the current**
   - An opposing flux will be changing **ONE OF the direction or increasing/decreasing**
     - To make life easier, try to ensure that the **opposing flux** uses the word **increasing** – this is important for the 3rd step
3. **Figuring out the direction of the current from the opposing flux**
   - This is the reason having "increasing" in the opposing flux is important
   - We use the **(reverse) right hand grip** rule to determine the **direction of the current**

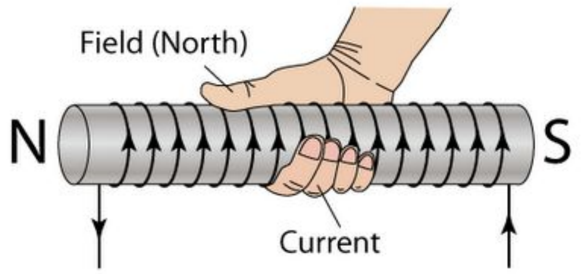
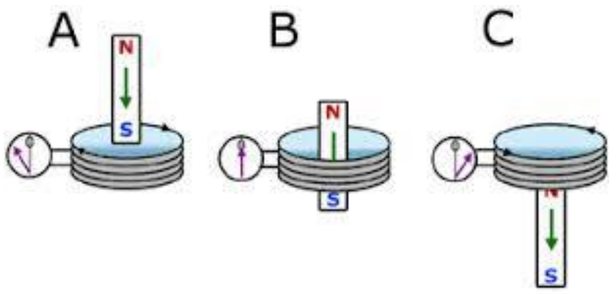


Photo credits:
https://www.miniphysics.com/ss-magnetic-field-due-to-current-in-a-solenoid.html



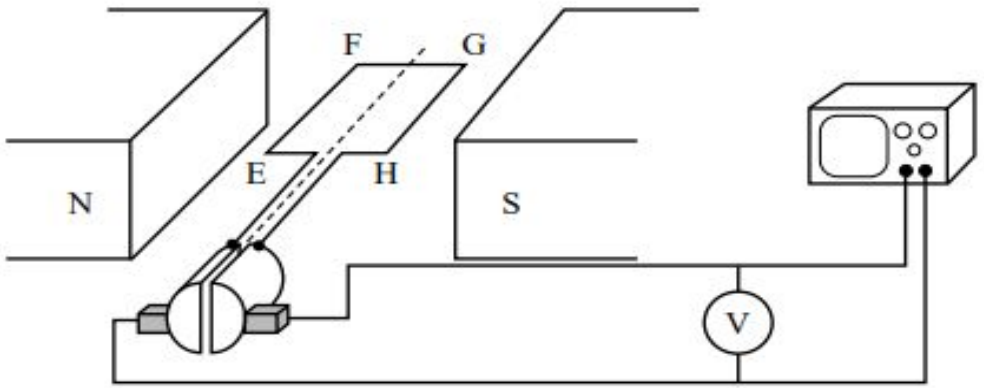
VCAA 2015 QUESTION 12

A model is set up as a DC generator, with the output connected to a voltmeter and oscilloscope via a commutator, as shown in Figure 13, with a coil of side length 4.0 cm and 10 turns, and a uniform magnetic field of 2.0×10^{-3} tesla.

The shaft is rotated by hand.

(it's a square coil)

Figure 13



The shaft and coil make two complete revolutions per second.

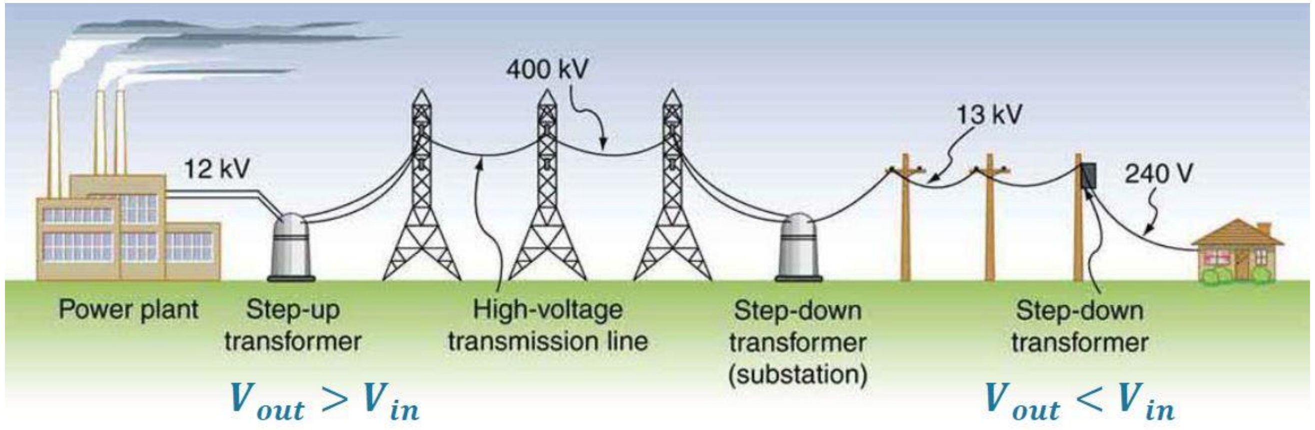
Calculate the magnitude of the average voltage as shown on the voltmeter during one-quarter revolution. Show your working. 3 marks

Marks	0	1	2	3	Average
%	40	20	7	33	1.3

POWER LOSS ALONG TRANSMISSION LINES

The process of electricity generation:

1. Power plant – electricity is generated
2. Step up transformer (increase V, decrease I)
3. Transmission lines ($P_{Loss} = I^2 R_{cables}$) – reduce I, reduce P_{loss}
    - Note that current is constant in the transmission lines
4. Step down transformer (decrease V, increase I)
5. Households for use – need a smaller voltage for appropriate use



VCAA 2011 EXAM 2 QUESTION 14

Question 14

Some townspeople are concerned about the high voltages, and propose that the same power could be transmitted more safely at a lower transmission voltage.

Explain clearly why this proposal would increase power losses in the transmission process.

Question 14

Marks	0	1	2	3	Average
%	22	14	35	30	1.7

For a given amount of power to be transmitted, by reducing the voltage the current would be increased. This would result in a greater power loss proportional to the current squared.

Many students simply copied information from their A4 sheet of notes, explaining how increasing the voltage reduces power losses. This did not address the question asked. A common misconception was that the resistance of the transmission lines would vary simply by changing the supply voltage. Others argued incorrectly that, according to Ohm's law, decreasing the voltage would increase the current.

Fields

$P_{loss} = I^2R$

$V = IR$

$P = VI$

5. In the system set out in the diagram below, there are 2 V of voltage and 4 W of power across the globe. There are two transformers set up where the ratio of primary coils to the secondary coils in T_1 and T_2 are 1:10 and 10:1 respectively.

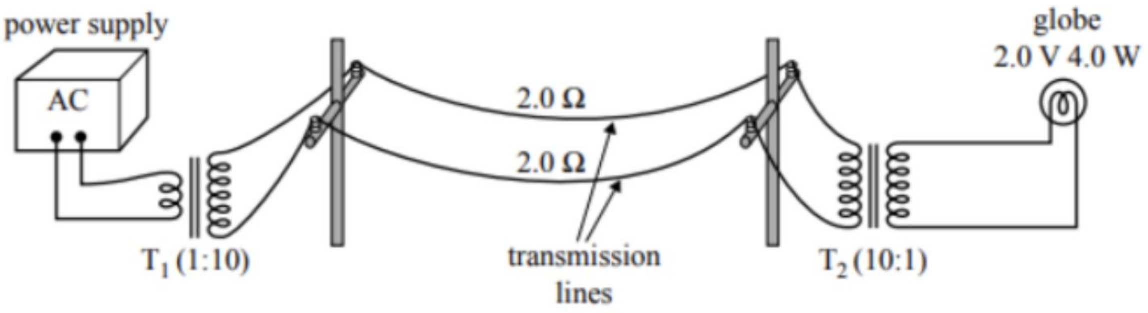


Image sourced from VCAA 2015 Physics Exam 2
http://www.vcaa.vic.edu.au/Documents/exams/physics/2015/2015physics-amd-w.pdf

Calculate the power loss in the transmission lines

f. Describe a real situation that this model could represent. Explain why the higher transmission voltage is used in terms of power losses you calculated in Alan and Becky's model. 4 marks

Question 5 (6 marks)
A model electrical transmission system shown in Figure 4 is created in a physics laboratory. The globe requires a minimum of 3.6 V to operate brightly.

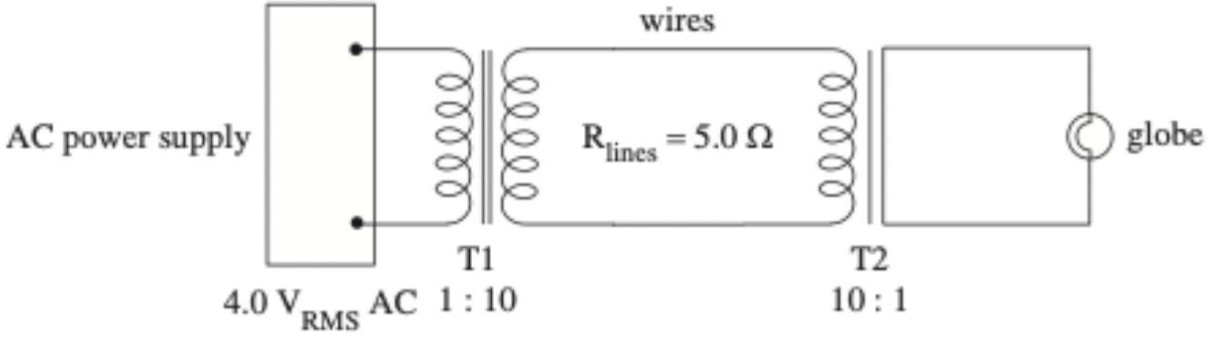


Figure 4

The students use two transformers, T1 and T2, with ratios of 1:10 and 10:1 respectively, and a $4.0\ V_{RMS}$ AC power supply. The transformers are assumed to be ideal. The students use a light globe that will operate brightly as long as a minimum voltage of 3.6 V is supplied to it. The wires of the model transmission lines have a total resistance of 5.0 Ω. The students measure the current in these wires to be 1.0 A.

a. Determine the magnitude of the power that is available to the globe. Show your working. 3 marks

b. State whether the globe will operate brightly. Provide a calculation to support your answer. 3 marks

- RMS Vs Peak-to-Peak
- Power loss proportional to I^2
- Step up/down transformer used to reduce power loss and **ONLY** operate on **AC** power
- Induced current will be in the direction so the flux it creates will oppose the change in the flux that produced it
- Flux vs EMF graph

Time for :

Q AND A

TIME DILATION

- Time is **relative** and it depends on your frame of reference

- The equation for time dilation links time measurements from one inertial frame of reference to the time measured in another.

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

...where

- t_0 is the proper time. This is the time measured from the reference frame where two events occur at the same position in space.
- t is the dilated time. This is the time measured from the reference frame where two events occur at different positions.
- Note that t and t_0 can be any unit of time as long as they are the same

LENGTH CONTRACTION

As objects get faster, we observe their length to contract

$$L = L_0\sqrt{1-\frac{v^2}{c^2}} = \frac{L_0}{\gamma}$$

Where

- L is the contracted length – measured in the frame of reference not stationary relative to the object
- L_0 is the proper length – measured in the frame of reference stationary relative to the object

RELATIVISTIC MASS

The equation for relativistic mass is written as:

$$m = \gamma m_0$$

- Where
  - m is the relativistic mass
  - γ is gamma
  - m_0 is rest mass (the mass observed when the **mass is at rest relative to the observer**)

- Hence the relativistic mass is always greater than the rest mass

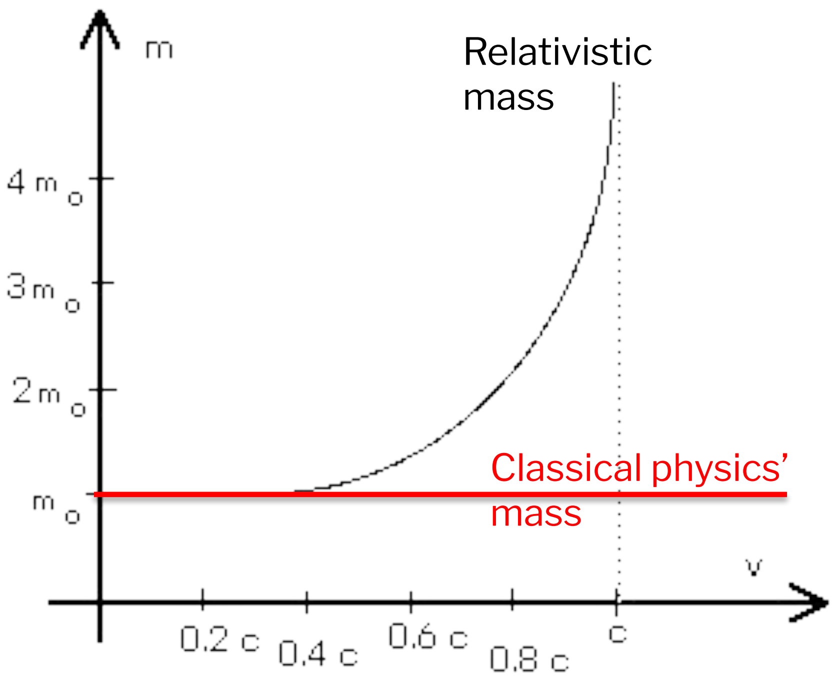
THE COSMIC SPEED LIMIT

- Special Relativity shows that as the speed of the body approaches the speed of light, the mass of the object approaches infinity

$$m = \gamma m_0$$

- Newton's Second Law, $\Sigma F = ma$, shows us that if the mass increases to infinity, an infinite amount of force will be required to accelerate the object to the speed of light – which is impossible

- **This is why no object can travel faster than the speed of light.**



Relativity

Use the following information to answer Questions 1 and 2.

Anna and Barry have identical quartz clocks that use the precise period of vibration of quartz crystals to determine time. Barry and his clock are on Earth. Anna accompanies her clock on a rocket travelling at constant high velocity, *v*, past Earth and towards a space lab (which is stationary relative to Earth), as shown in Figure 1.

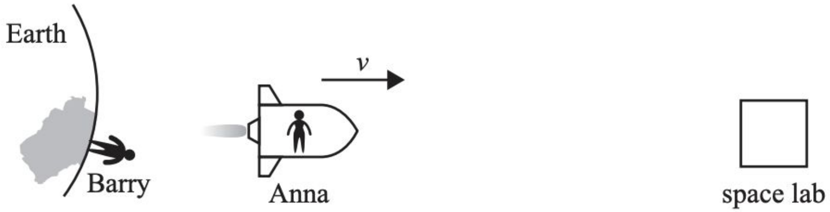


Figure 1

Question 1

Which one of the following statements correctly describes the behaviour of these two clocks?

A. The period of vibration in Anna's clock (as observed by Anna) will be shorter than the period of vibration in Barry's clock (as observed by Barry).

B. The period of vibration in Anna's clock (as observed by Anna) will be longer than the period of vibration in Barry's clock (as observed by Barry).

C. The period of vibration in Anna's clock (as observed by Anna) will be the same as the period of vibration in Barry's clock (as observed by Barry).

D. Only the time on Barry's clock is reliable because it is in a frame that is not moving.

Relativity

2021 q10

Question 10 (4 marks)

A new spaceship that can travel at $0.7c$ has been constructed on Earth. A technician is observing the spaceship travelling past in space at $0.7c$, as shown in Figure 10. The technician notices that the length of the spaceship does not match the measurement taken when the spaceship was stationary in a laboratory, but its width matches the measurement taken in the laboratory.

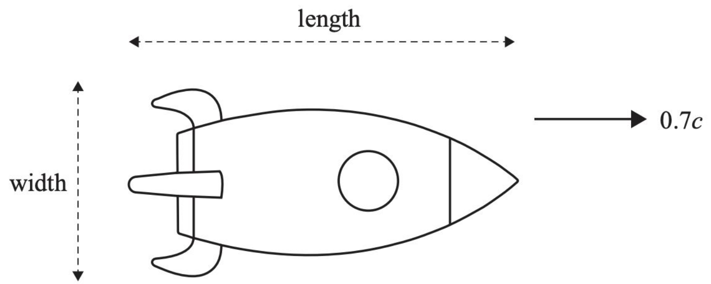


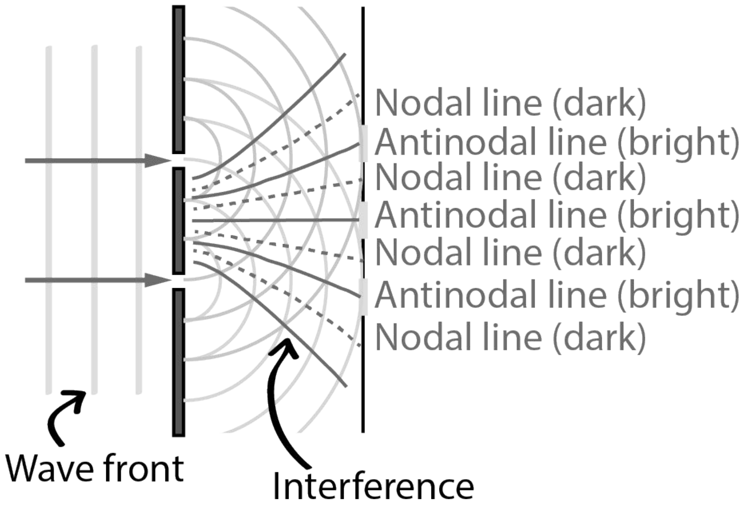
Figure 10

a. Explain, in terms of special relativity, why the technician notices there is a different measurement for the length of the spaceship, but not for the width of the spaceship. 2 marks

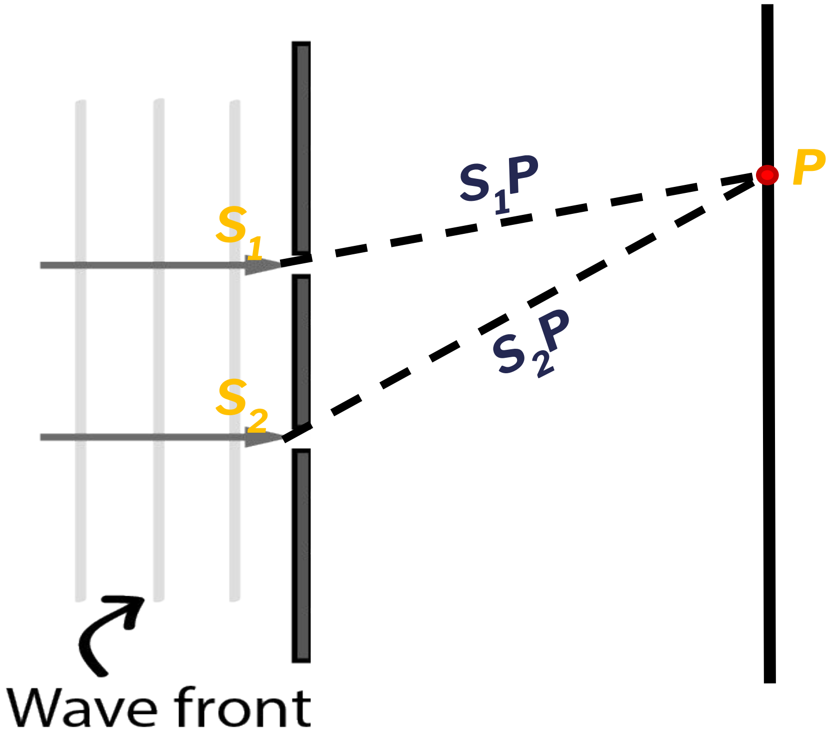
b. If the technician measures the spaceship to be 135 m long while travelling at a constant $0.7c$, what was the length of the spaceship when it was stationary on Earth? Show your working. 2 marks

YOUNG'S DSE

- What was the experiment:
  - Passing monochromatic light between two slits and onto a screen
- Results:
  - Evenly spaced alternating bright and dark bands
- Explanation:
  - Light diffracts at the slits and then they interfere with each other
  - When the path difference is $n\lambda$, constructive interference occurs (antinodal/maxima line)
  - When the path difference is $(n - \frac{1}{2})\lambda$, they waves are out of phase by ½λ, creating destructive interference (nodal/minima line)
- Use in exams:
  - Evidence that light is a wave (diffraction and interference)
  - Note that YDSE also works for all waves



INTERFERENCE PATTERNS



Recall the definition of path difference which is given by

$$p.d = |S_1P - S_2P|$$

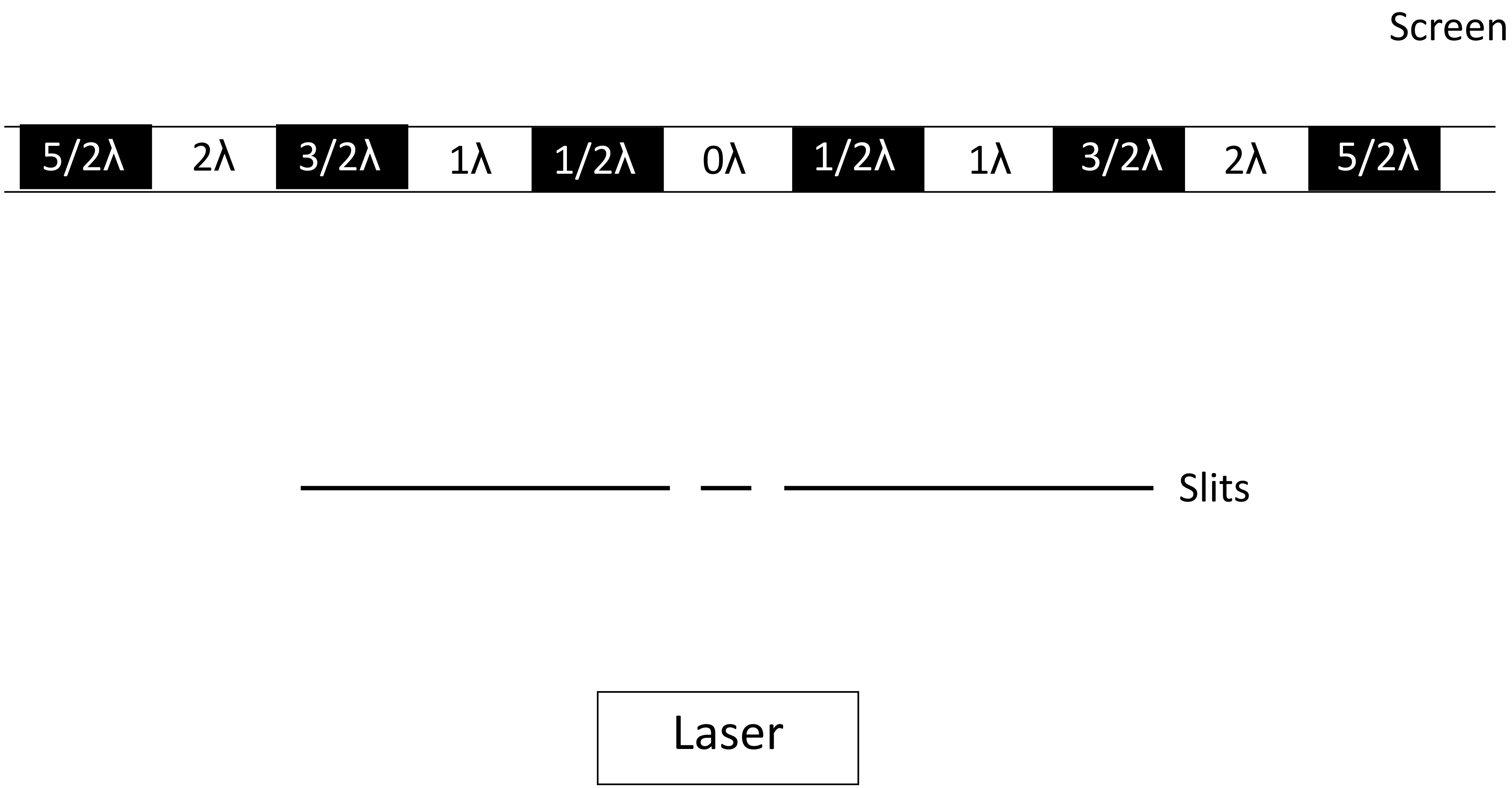
Constructive interference (high intensity):

$$pd = n\lambda$$

Destructive interference (low intensity):

$$pd = (n - \frac{1}{2})\lambda$$

YDSE AND PATH DIFFERENCE



VCAA 2015 QUESTION 17

Question 17 (4 marks)

Two students, Karina and Kim, are investigating double-slit interference. They have a 633 nm wavelength laser and a slide with two narrow slits. They set up their experimental arrangement as shown in Figure 18 and see a pattern of alternating bright and dark bands on their screen.

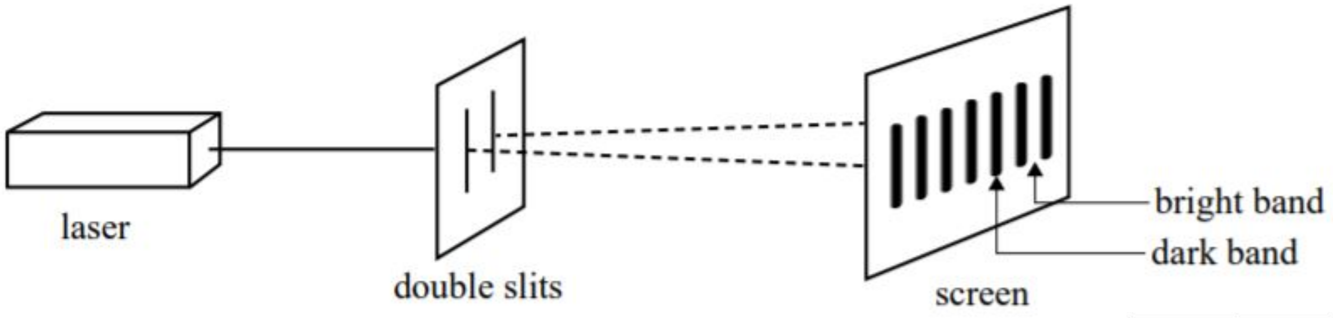


Figure 18

Marks	0	1	2	3	Average
%	21	14	27	38	1.8

a. Before they put the slide in place, they direct the laser beam onto the screen and mark the bright spot due to the laser on their screen. Kim believes that this point will be a dark band when the slide is put in place. Karina believes it will be a bright band.

Is this point a bright band or a dark band? Give a reason for your choice. 3 marks

VCAA 2014 QUESTION 19

Question 19 (3 marks)

A group of students carries out a two-slit interference experiment using light with a wavelength of 420 nm. The arrangement of the students' apparatus and the resulting interference pattern are shown in Figure 29.

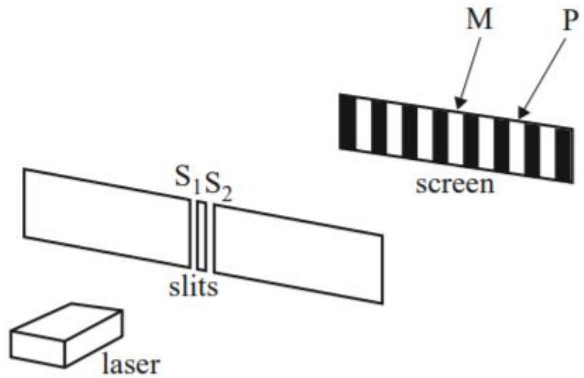
The point M on the screen is at the centre of the interference pattern. There is a bright band at point P on the screen. It is the second bright band to the right of M, as shown.

a. Calculate the path difference $S_1P - S_2P$. 1 mark

Question 19a.

Marks	0	1	Average
%	40	60	0.6

nm



b. The students repeat the experiment using light of a different wavelength. They find that, at the point P on the screen, there is now a **dark** band. It is the second dark band to the right of M.

Calculate the wavelength of this light. Show your working. 2 marks

Question 19b.

Marks	0	1	2	Average
%	53	1	46	0.9

nm

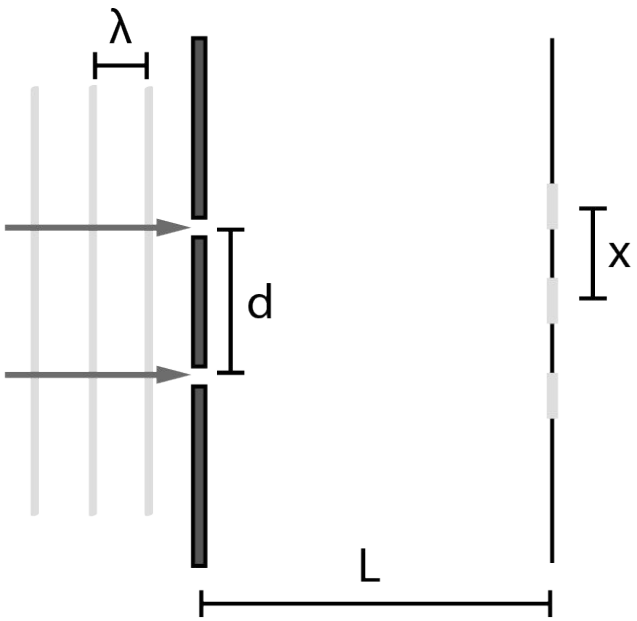
FRINGE SPACING

Fringe spacing – distance between consecutive bright (or dark) bands

$$\Delta x = \frac{\lambda L}{d}$$

Where

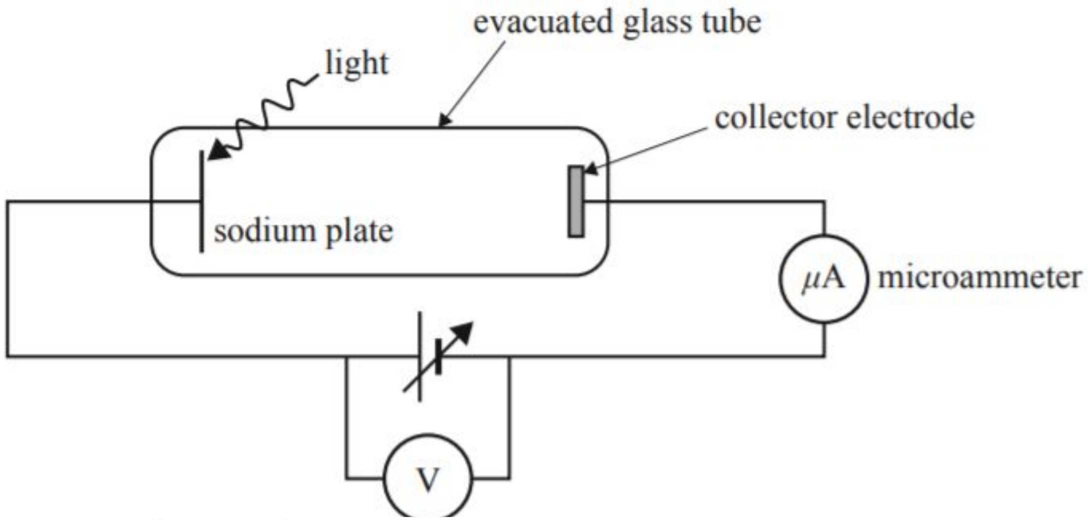
- Δx is the fringe spacing (m)
- λ is the wavelength (m)
- *L* is the distance between the screen and the slits (m)
- *d* is the distance between the slits in (m)

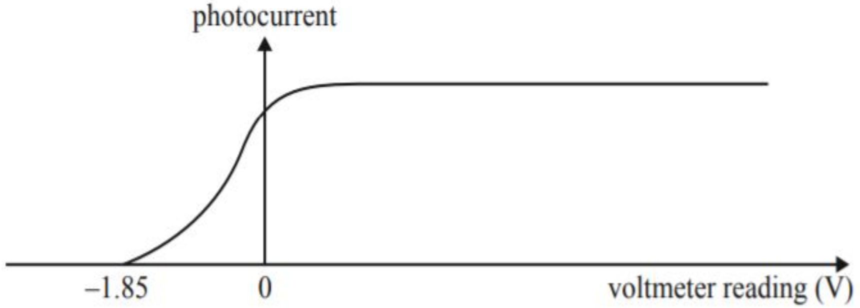


VCAA 2013 QUESTION 21

Question 21 (7 marks)

Students are investigating the photoelectric effect by shining monochromatic light with a frequency of 1.00×10^{15} Hz onto a sodium plate. Their apparatus is shown in Figure 26.



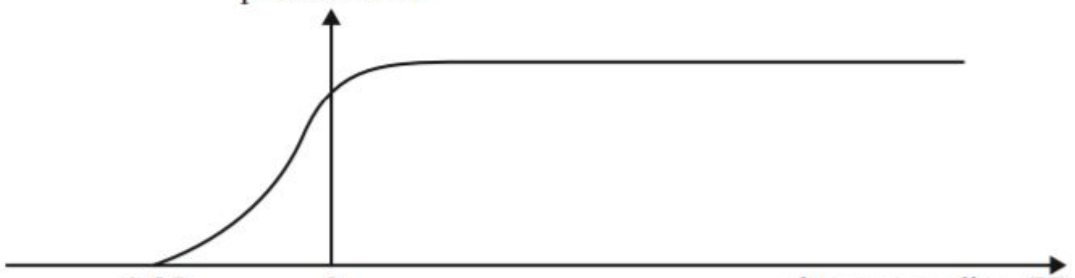


VCAA 2013 QUESTION 21

Question 21 (7 marks)

Students are investigating the photoelectric effect by shining monochromatic light with a frequency of 1.00×10^{15} Hz onto a sodium plate. Their apparatus is shown in Figure 26.

Figure 27 shows a graph of the relationship between the photocurrent and the reading on the voltmeter.



Question 21a.

Marks	0	1	Average
%	58	42	0.4

Question 21b.

Marks	0	1	2	Average
%	64	5	31	0.7

Question 21c.

Marks	0	1	2	Average
%	34	13	53	1.2

a. Use the information in the graph to calculate the maximum kinetic energy (in joules) of the photoelectrons. 1 mark

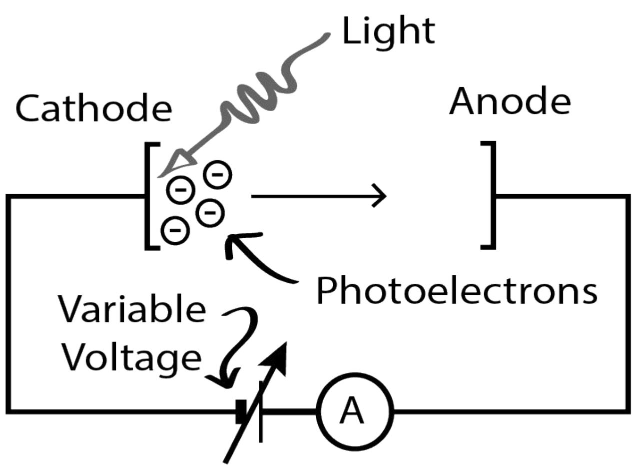
b. Calculate the work function (in eV) of sodium. 2 marks

c. The intensity of the light is now reduced and the experiment is repeated. The students obtain a new graph of photocurrent against voltage.

Sketch the new graph on Figure 27. 2 marks

PHOTOELECTRIC EFFECT

- **What was the experiment:**
  - Varying the intensity and frequency of incident monochromatic light shone on metal plate to eject electrons
- **Results:**
  1. There is a frequency called the threshold frequency, f_0, that below which, there will be no photoelectrons emitted.
  2. Above the threshold frequency, f_0, increasing the frequency increases the stopping voltage but not the current
  3. Increasing the intensity of light increases the current.
  4. Photoelectrons are released instantaneously.
- **Explanation:**
  - Light is a photon, not a wave
- **Use in exams:**
  - Evidence of light acting like a particle, rather than a wave



Terminology:

- Work function – minimum energy required to remove an electron
- Threshold frequency – minimum frequency of light needed to eject an electron

Related equations:

- $\phi = hf_0$ $\quad$ $ie.\ E = hf$
- $E_{k\ (max)} = hf - \phi$
  - This equation comes from $E_{light} = E_{k(max)} + \phi$ where $E_{light} = hf = \frac{hc}{\lambda}$
  - Hence, $E_{k(max)} = \frac{hc}{\lambda} - \phi$

PHOTOELECTRIC EFFECT

Question 17 (4 marks)
Figure 15 shows a circuit diagram for an experiment into the photoelectric effect.

For a light source of 500 nm, a stopping voltage of 1.7 V is just sufficient to ensure no current is recorded on the ammeter.

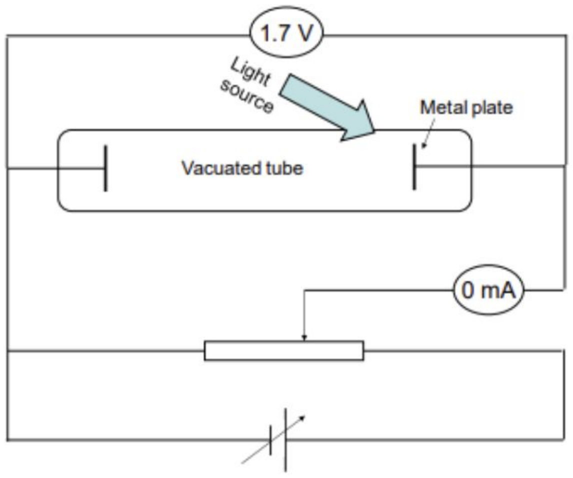


Figure 15

a. Determine the speed of the fastest electron as it is ejected from the metal surface. You must show your working. 2 marks

b. Determine the threshold frequency for the experiment. You must show your working. 2 marks

THE PHOTOELECTRIC EFFECT

Observations	Wave Model Predictions
1. There is a frequency called **the threshold frequency, f_0,** that below which, there will be **no photoelectrons emitted**.	1. **All frequencies of light** should eventually be able to emit photoelectrons ✗
2. Above the **threshold frequency, f_0**, increasing the frequency increases the **stopping voltage** but not the current	2. Above the **threshold frequency**, increasing the frequency increases the **current** ✗
3. Increasing the intensity of light increases **the number of photoelectrons released**.	3. Increasing the intensity of light increases **the kinetic energy of released photoelectrons** ✗
4. Photoelectrons are released **instantaneously**.	4. Photoelectrons are released with some time delay ✗

IMPACTS SUMMARY

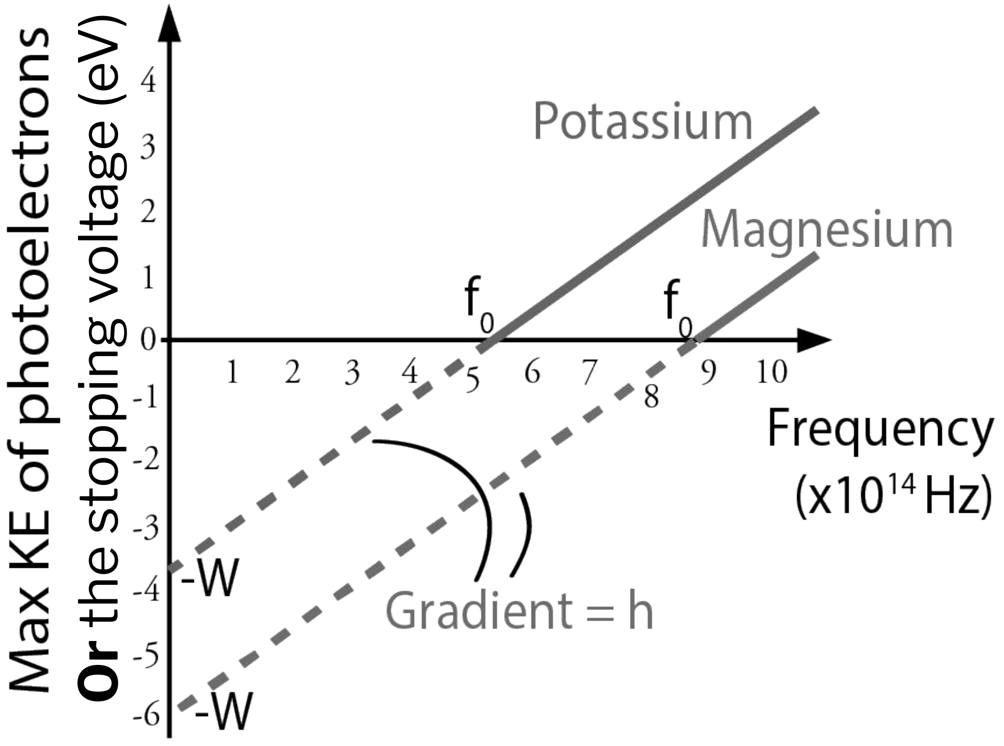
Independent Variable	Photon model	Wave model
Frequency of light	Related to energy. Impacts if photoelectrons are emitted and stopping voltage. Does not affect current	Should not affect if photoelectrons are emitted or not. Should affect the current.
Intensity of light	Related to number of photons emitted. Impacts current. Does not impact stopping voltage	Related to amplitude and energy. Impacts stopping voltage.

Related graphs: Max KE (or stopping voltage) vs. frequency

$$E_{k\ (max)} = hf - \phi$$

$$y = mx + c$$

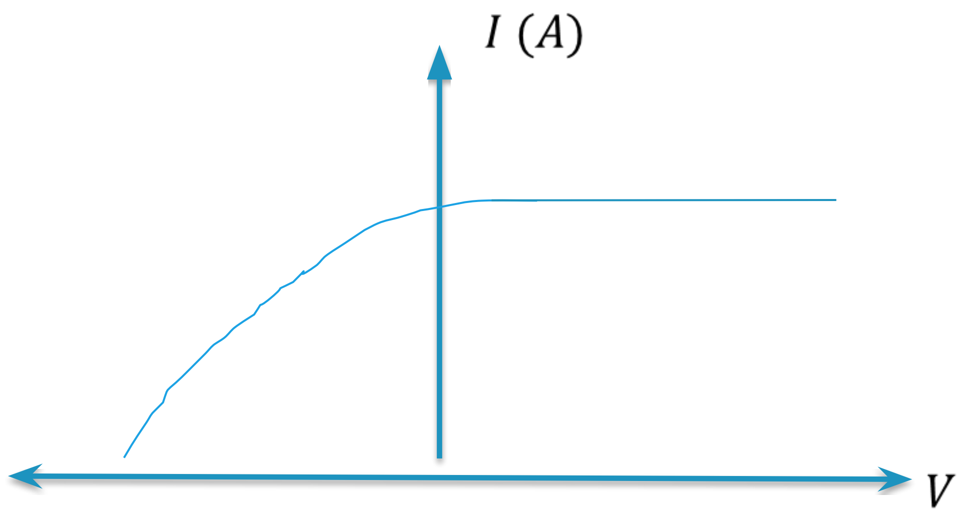
- **y-intercept** is the work function
- **x-intercept** is f_0 (threshold frequency)
- h is the **gradient** of the line
- *Note the dotted line below the threshold frequency and the axes label units*



PHOTOELECTRIC EFFECT

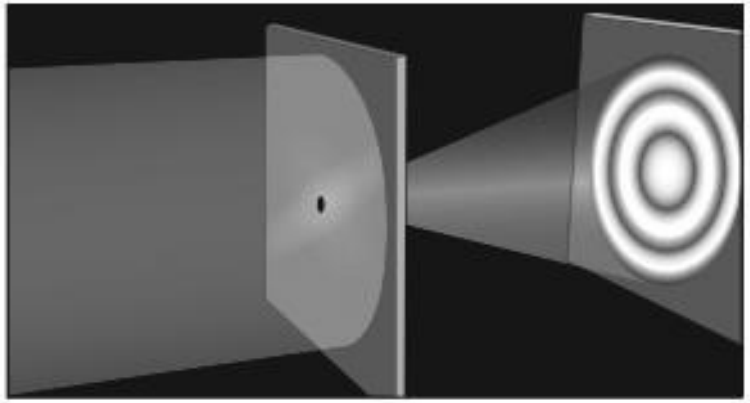
Related graphs: Current vs. Voltage graph

- The **x-intercept** is the stopping voltage as current = 0
  - The **x-intercept** is affected by **frequency** of the light (change in energy)
- The photocurrent reaches a maximum, constant value when there is a forward potential.
  - Maximum current is affected by **intensity**



ELECTRON DIFFRACTON

- What was the experiment:
  - Passing electrons through a slit
- Results:
  - Diffraction pattern is obtained
- Explanation:
  - Matter has a deBroglie wavelength ($\lambda = \frac{h}{p}$) associated with it, allowing the electrons to diffract
- Use in exams:
  - Evidence that of wave-particle duality



Note:

- If a particle and wave have the same momentum, they will have the same wavelength and create the same diffraction pattern
- The same DOES NOT apply for energy as $\lambda = \frac{hc}{E}$ for a wave and $\lambda = \frac{h}{\sqrt{2mE_k}}$ for a particle

Light as a wave and particle

2019 NHT Q11

Question 11 (6 marks)

Kym and Roger conduct an experiment to observe an electron diffraction pattern. 5000 eV electrons are projected through a diffracting grid and the resulting pattern is observed on a screen.

Kym and Roger want to calculate the wavelength of X-rays that would produce a similarly spaced diffraction pattern.

Kym says that they will need X-rays of 5000 eV.

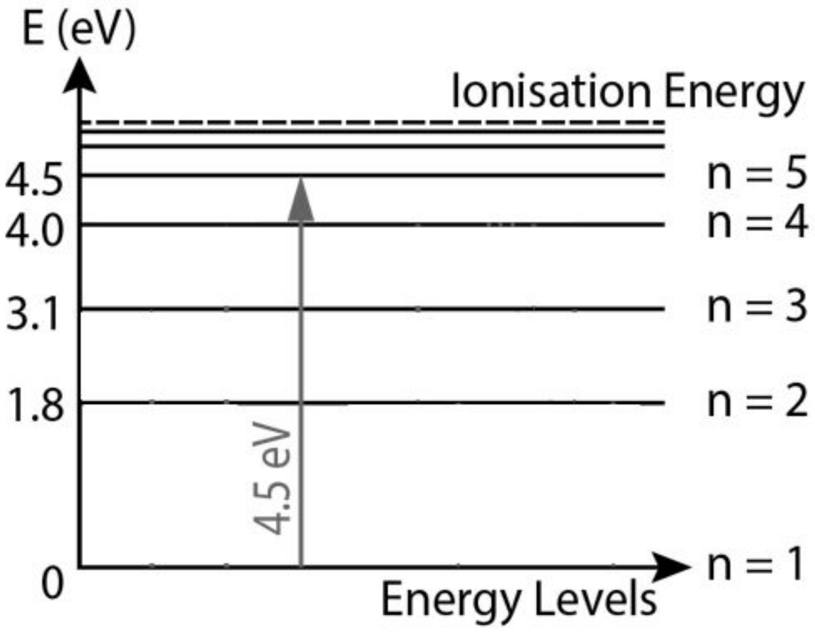
Roger says that X-rays of a different energy will be needed.

a. Explain why Roger is correct. 2 marks

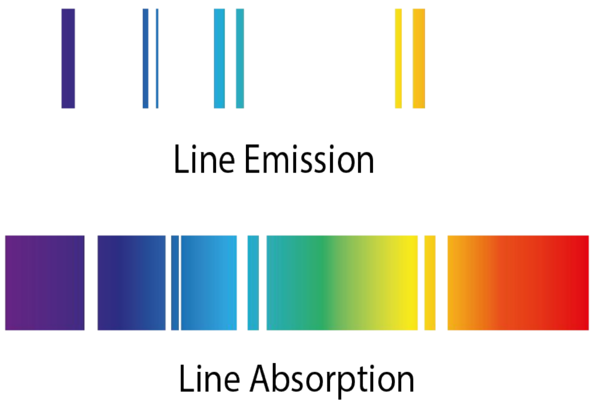
b. Showing each of the steps involved in your working, calculate the energy of X-rays that would be required to produce the similarly spaced diffraction pattern. 4 marks

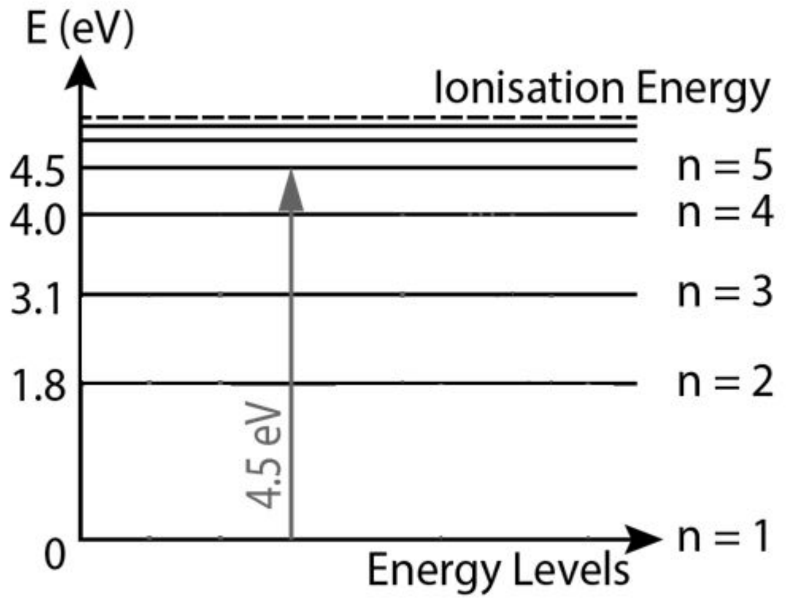
Energy Levels

- **Energy level diagrams** are one way we can represent the energy levels (orbits) or an atom
- Lines on the diagram represent the different orbits around an atom
- Allowed energy levels are labelled on the left-hand side of the diagram
- The distance between the lines is proportional to the energy difference
- Moving an electron **up** a energy-level diagram corresponds to **atomic absorption**
- Moving an electron **down** in an energy-level diagram corresponds to **atomic emission**



-
  - Although they appear the same below, normally there are **more spectral lines** in an **emission spectrum** than in an **absorption spectrum**
  - This is because there are more possible transitions *down*, from an excited energy state, than up, f





Light as a wave and particle

VCE 2016 Question 21

Question 21 (7 marks)

The visible spectrum of the hydrogen atom is observed to emit photons of energy 2.6 eV.

a. Calculate the wavelength of this emission spectral line.

The energy levels for the hydrogen atom are shown in Figure 25.

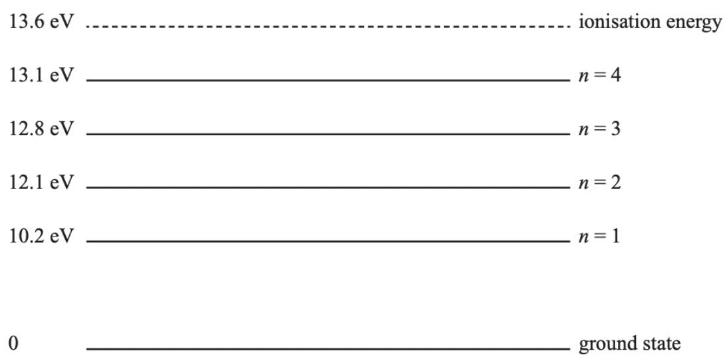


Figure 25
not to scale

b. Draw an arrow on Figure 25 to indicate the transition that could cause the spectral line calculated in **part a.** 2 marks

c. A hydrogen atom is excited to the 12.8 eV energy level.

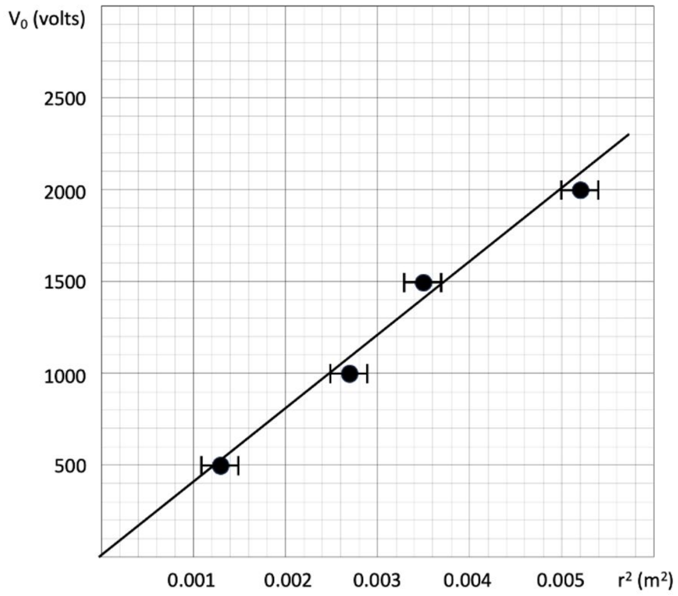
List the possible photon energies (in eV) that could be emitted as it returns to its ground state. 3 marks

Wellbeing

Final Graph Question

Question 17f.

Mark	0	1	2	3	4	5	6	7	Average
%	14	2	2	3	6	12	24	37	5.1



Just over one-third of students were able to draw this graph correctly. Of concern was the number of students who forced the line of best fit through the first and last points even though this left the point at (0.0035, 1500) completely off the line.

- Sacale
- Units
- Error bars X & Y axis
- Use the **ENTIRE** graph paper

Final Graph Question

During their practical investigation, some Physics students investigate the movement of a small rubber ball. The ball falls from a height of 1.00 m and rebounds to a height of 0.78 m. The students record the ball's vertical position versus time by using a smartphone's video feature and a metre rule scale.

The uncertainty in the ball's vertical position is ± 0.03 m. The results from the students' recorded data are plotted on the graph in Figure 21.

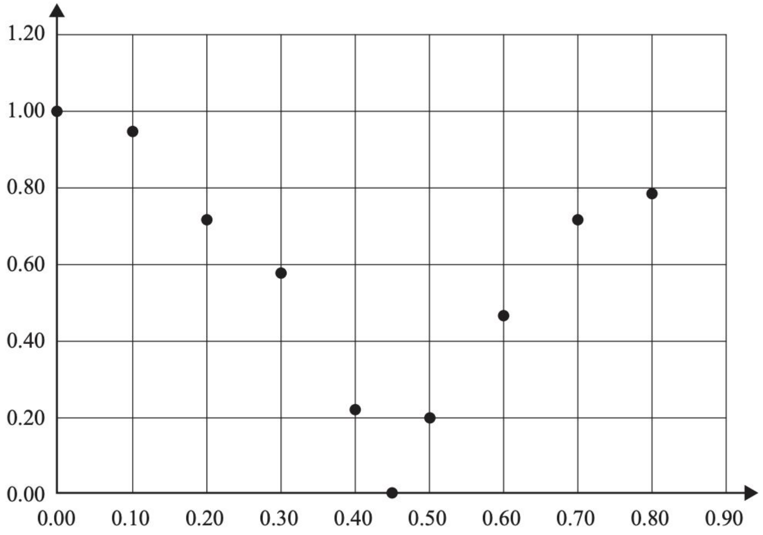


Figure 21

d. On the graph in Figure 21:

- label each axis and include units on each axis
- insert appropriate uncertainty bars for the height values on the graph, for the readings for the first four data points after the ball is released
- draw smooth curves of best fit. 5 marks

e. Estimate the speed of the ball at the instant of impact using an appropriate gradient of the graph in Figure 21. Use calculations to support your answer. 3 marks

- Time Dilation / Length contraction
  - Reference frames
- Wave Terminology
  - Node, Anti-node, Constructive / deconstructive interference, superimpose
  - Mechanical vs Transverse wave
- Photoelectric effect and particle model
- Double-split and wave model

Light as a wave and particle

- Make sure you know how to use your **scientific calculator**
- Make sure you know the **basic skills** like how to do algebra, rearrange vectors etc.
- Make sure you understand the **concepts along with the formulae**
- Print out the **formula sheet** and use it in class so you know where all the formulae are
- Make note of what things you want on your **cheat sheet** throughout the year – particularly any **derived formulae** or **concepts** you don't fully understand
- Make your **cheat sheet** well before the exam so you can practice using it during practice exams
- Do heaps of **practice questions**!!! Especially before SACs
  - Many people struggle with the worded questions in particular – practice these early on!!!
  - How you use the exams is more important than how many you do
- Northern Hemisphere Exams https://www.vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/NHT-past-exams/Pages/NHT-past-exams.aspx

CHEAT SHEETS

- Cheat sheets can be a good safety net if you forget anything
- Ultimately, the cheat sheet that will best serve you is one that is directly catered to YOU.
- In this sense, standard/commercial cheat sheets might not be the best thing you could use

- It is still recommended that you however include some or all of the following:
  - Key formulae not on the cheat sheet
  - Common written explanations
  - Anything else you're unconfident/iffy with
  - Don't waste space putting stuff you are confident with/know well on your cheat sheet

- $a = gsin\theta$ (ignoring friction)
  $\Sigma F = mgsin(\theta)$
  $F_N = mgcos(\theta)$
- $tan\theta = \frac{v^2}{gr}$
- $v = \sqrt{gr}$
- $I = F\Delta t = m\Delta v = \Delta p =$ area under a $F - t$ graph
- $v = c\sqrt{1 - \frac{1}{\gamma^2}}$
- $\lambda = \frac{2l}{n}, \quad f = \frac{nv}{2l}$
- $\lambda = \frac{4l}{n}, f = \frac{nv}{4l}$
- $\lambda = \frac{h}{\sqrt{2mE_k}}$

Wellbeing

REVISION

- Most of the work for physics at this point should be in the form of **practice exams**

- Another good idea is to go through the physics study design and go through, dot point by dot point, what you need to revise using the ‘traffic system’
  - Use a **green dot** to make a note of the things you’re confident with
  - Use a **yellow dot** to make a note of the things you’re iffy with
  - Use a **red dot** to make a note of the things you’re struggling with

Before the exam:

- When you're finished school, at least during the exam period, make sure you get **at least** 9 hours of sleep every night!
- Do NOT stay up the entire night before the exam and sleep early
- Eat healthy (a chocolate break won't hurt though)
- Take regular short breaks whilst you study and make time for actual breaks
- Make sure you keep perspective about the whole thing
- Make sure you talk to someone if you're struggling
- If you're feeling overwhelmed take a break
- Make sure you have a routine – wake up and sleep at regular times, eat at regular times, study at regular times
- Don't do practice exams the day before a morning exam or on the day of an afternoon exam, just read notes or do nothing

TRUST THAT YOU KNOW THE CONTENT!!!

During the exam:

- Skip questions if they're taking too long/too hard
- Do the questions that are easy first
- Double Check your work!!!!!!!! Edit – chances are that there is a mistake somewhere… FIND IT!
- Answer ALL of the questions – especially multiple choice – there is no excuse.
- Make sure you read the question CAREFULLY. Read. Every. Word.
- If there's something you can't do, don't panic; come back to it at the end

After the exam:

- Go home. Have food. Take a break. Sleep.
- Don't discuss answers after the exam – especially for worded questions; it can give you unnecessary stress
- Try to relax and forget about it

ATAR Notes

GOOD LUCK!