Hwa Chong Institution Examinations
Secondary 3 Integrated Programme

CANDIDATE NAME	

CLASS				REGISTER NUMBER		

HIGHER PHYSICS

SPECIMEN PAPER C

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and register number on all the work you hand in.
Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.
Write your answers in the spaces provided on the Question Paper.

Section B
Answer only **2 questions** out of the 3 questions.
Write your answers in the spaces provided on the Question Paper.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

The number of marks is given in brackets [ ] at the end of each question or part question.

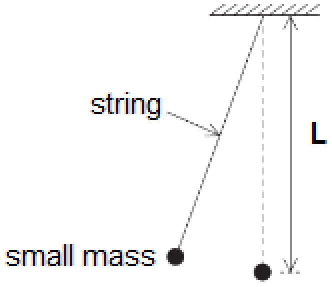
Take g to be exactly 10 m s^{-2} or 10 N kg^{-1} unless otherwise stated.

This document consists of **15** printed pages and **1** blank page.

Section A

Answer **all** the questions in the spaces provided.

1 A simple pendulum of length **L** consists of a small mass attached to the end of a light string.

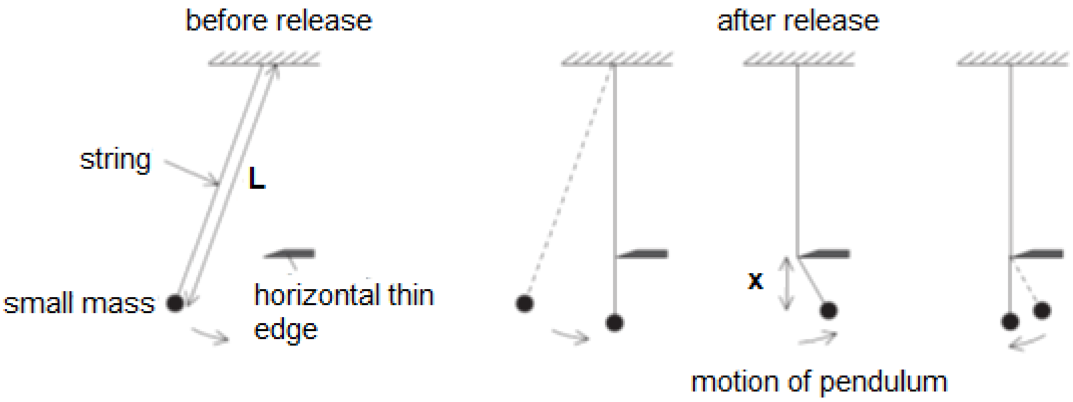


The time **T** taken for the mass to swing through one cycle is given by

$$\mathbf{T} = 2\pi\sqrt{\frac{\mathbf{L}}{\mathbf{g}}}$$

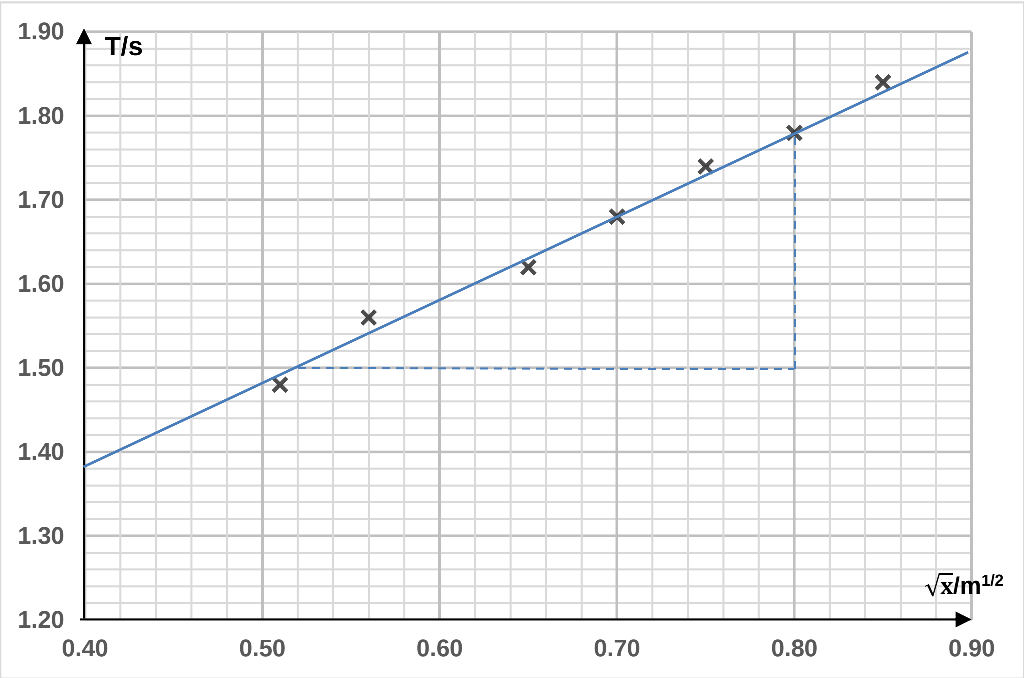
where **g** is the acceleration due to gravity.

The student modifies a simple pendulum of length **L** so that, after release, it swings for a quarter of a cycle before the string strikes a horizontal thin edge. For the next half cycle, the pendulum swings with a shorter length **x**. The string then leaves the horizontal thin edge to swing with its original length **L**.



The length **L** of the string is kept constant during the experiment. The vertical position of the horizontal thin edge is varied to change **x**.

With the data obtained from the investigation, the student plotted the graph of time period **T** against $\sqrt{\mathbf{x}}$. The plotted graph is shown below.



(a) On the graph, draw the best-fit line for the data.

Best fit straight line drawn

[1]

(b) Determine the value of ***x*** when **T** is 1.40 s.

When T = 1.40 s, $\sqrt{x}$ = 0.42 $m^{-1/2}$ [1]

x = 0.18 m [1]

x = [2]

(c) Explain why the time period for one complete oscillation of the pendulum is given by

$$\mathbf{T} = \frac{\pi}{\sqrt{g}}(\sqrt{L} + \sqrt{x})$$

As length of pendulum is still L m for half of the oscillation, the time for this half of oscillation is $\pi\sqrt{\frac{L}{g}}$. [1]

For another half oscillation, the length of the pendulum is x m, hence the time for this half of oscillation is $\pi\sqrt{\frac{x}{g}}$. [1]

Hence time for one complete oscillation is $\mathbf{T=\frac{\pi}{\sqrt{g}}\left(\sqrt{L}+\sqrt{x}\right)}$

[2]

(d) Determine **g** from the graph.

Determine gradient from graph [2]

(1.78 – 1.50)/(0.80-0.52) = 1.0

$\frac{\pi}{\sqrt{g}} = 1.0$

g = 9.9 m s^{-2} [1]

g = [3]

(e) Determine **L**.

Choose a point on the graph for substitute into equation [1]

Correct computation of L with unit [1]

When $\sqrt{x}$ is 0.80 $m^{-1/2}$, T = 1.78 s,

Hence 1.78 $= \frac{\pi}{\sqrt{9{,}9}}(\sqrt{L} + \sqrt{0.80})$

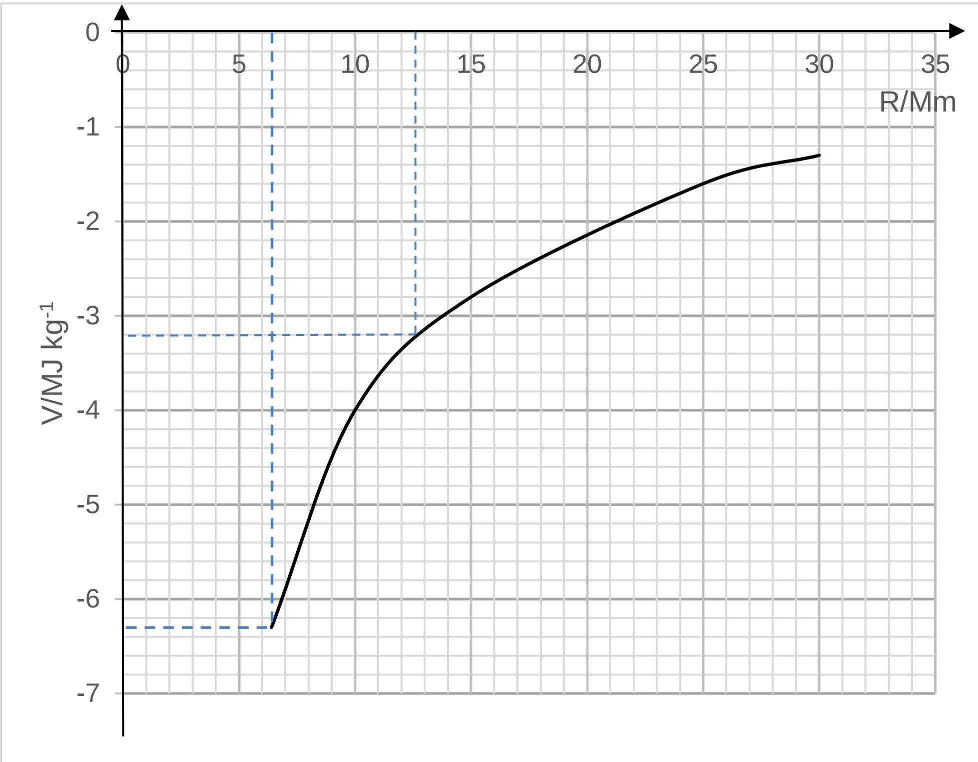
L = 0.79 m

L = [2]

2 Gravitational potential is the potential energy per unit mass at a point in a gravitational field.

$$\mathbf{V} = \frac{\text{potential energy}}{\text{mass}}$$

The below shows the variation of the gravitational potential V due to Earth with distance R from the centre of the Earth. The radius of the Earth is 6400 km.



(a) Use the graph to determine

(i) the gravitational potential at the surface of the Earth.

Gravitational potential = -6.3 MJ kg^{-1} [1] [1]

(ii) the increase in the potential energy of a 1200 kg satellite when it is raised from the surface of the Earth into a circular orbit of two times the radius of the Earth.

difference in gravitational potential = $V_{2R} - V_R$ = - 3.2 – (-6.3) [1]

= 3.1 MJ kg^{-1} [1]

Increase in potential energy = 3.1 x 1200 = 3700 MJ [1]

Increase in potential energy = [3]

(b) An object of mass **m** placed within the gravitational field of the Earth of mass **M** experiences a force **F** given by the equation

$$\mathbf{F} = \mathbf{G}\,\frac{\mathbf{m\,M}}{\mathbf{R}^2}$$

where **G** = 6.7×10^{-11} N m^2 kg^{-2} and **R** is the distance between object and the center of the Earth.

(i) Derive the expression of gravitational potential, **V**, in terms of G, M and R

$mg = F = GmM/R^2$ [1]

Work done by moving mass m through a distance R,
$mg*R = GmM/R$

Since gravitational potential V = work done per unit mass,
$V = gR$
$V = GM/R$ [1]

[2]

(ii) Calculate the gravitational field strength at a distance two times the radius of the Earth. The mass of the Earth is 5.97×10^{24} kg.

$g = GM/R^2 = (6.7 \times 10^{-11})(5.97 \times 10^{24})/(2 \times 6400 \times 10^3)^2$ [1]

$= 2.4$ N kg^{-1} [1]

Gravitational field strength = [2]

(iii) Explain how your result for part (b) (ii) is consistent with the fact that the gravitational field strength on the surface of the Earth is about 10 N kg^{-1}.

Since distance is twice as large as radius of Earth, gravitational field strength is four times smaller. [1]
Hence gravitational field strength on the surface of the earth is $4 \times 2.4 = 9.6$ N kg^{-1}. [1]

[2]

Section B

Answer **two out of the three questions** in this section.

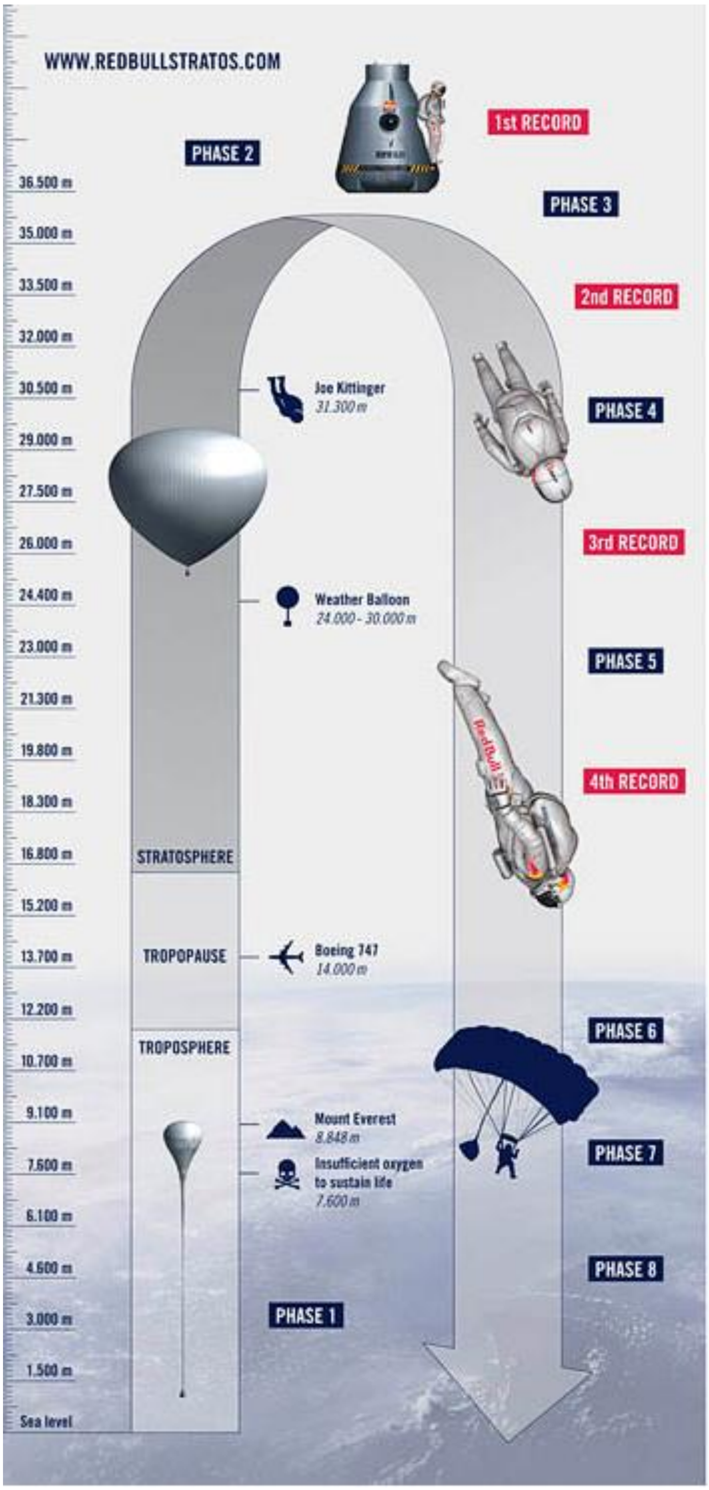
3 On 14 October 2012, Felix Baumgartner did a sky dive from a height of 36 km, in the upper atmosphere. He exceeded the speed of sound for parts of his dive and landed safety by parachute after freefalling for about 6 minutes. The figure below shows the phases of his daring act.

<u>Phase 2</u>

Balloon reaches the edge of space in less than 3 hours.

<u>Phase 1</u>

Balloon launches, carrying Felix in the capsule.



Picture from https://lovetime.fr/wp-content/uploads/2012/10/36855.jpg

<u>Phase 3</u>

At 36 km altitude, Felix jumps.

<u>Phase 4</u>

Felix breaks the speed of sound.

<u>Phase 5</u>

Free fall duration for about 6 minutes, reaching terminal velocity in this phase.

<u>Phase 6</u>

Felix deploys parachute at about 1500 m.

<u>Phase 7&8</u>

Felix lands approximately 10 minutes after parachute was deployed at constant velocity.

(a) The table below list some data at sea level and at 36 km altitude.

	Sea Level	36 km altitude
Temperature/ºC	15	-25
Atmospheric pressure/Pa	101 325	318
Air density/kg m^{-3}	1.225	0.00447

The volume of the balloon at 36 km in altitude was 8.22×10^5 m^3. What should be the volume of the balloon at sea level?

PV/T = constant

$(318)(8.22 \times 10^5)/(-25 + 273) = (101325)(V)/(15 + 273)$ [2]

$V = 3.0 \times 10^3$ m^3 [1]

OR

Mass of air at 36 km altitude = $(8.22 \times 10^5)(0.00447)$ kg [1]

Volume of air at sea level = $(8.22 \times 10^5)(0.00447)/ 1.225$

= 3.00×10^5 m^3 [1]

Volume of balloon = [2]

(b) Explain how jumping from 36 km allowed Baumgartner to reach a terminal velocity that is greater than the speed of sound.

At greater altitude, there is less air, hence less air resistance encountered. [1]

He experienced greater downward resultant force for a longer period of time, accelerate for a longer period of time. [1]

[2]

(d) Maximum velocity of 1342 km h^{-1} was achieved after 42 s of his jump. Calculate the mean resultant force which was acting on him during the 42 s if total mass of Baumgaetner and his gears was 120 kg.

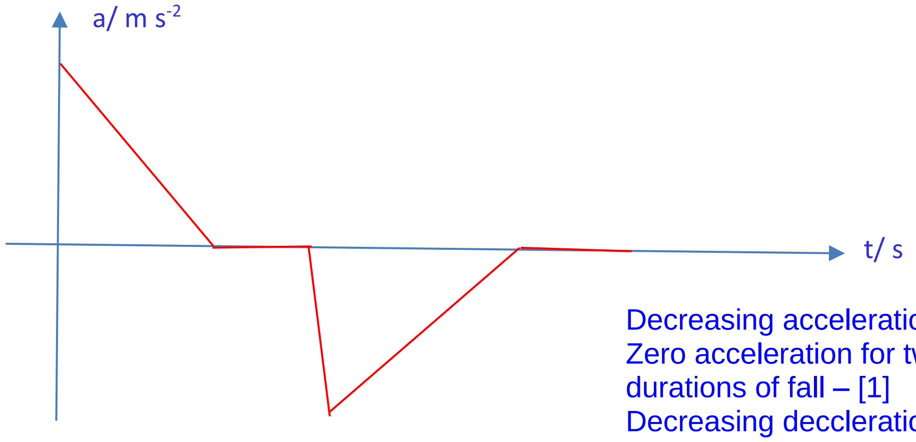
1342 km h^{-1} = 372.8 m s^{-1} [1]

F = ma = 120 x (372.8 – 0)/42 [1]

= 1.1 x 10^3 N

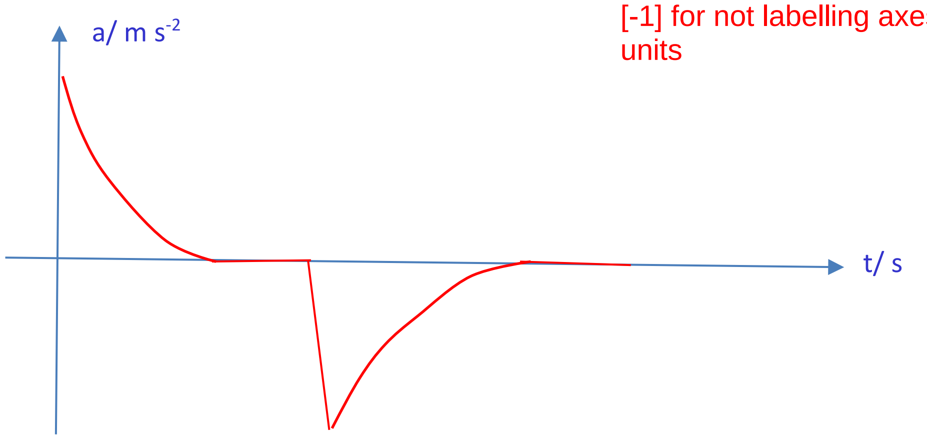
Mean resultant force = [3]

(c) Sketch a graph to show how acceleration varies with time when he first jumped off the capsule till he landed on the ground.



Decreasing acceleration – [1]
Zero acceleration for two durations of fall – [1]
Decreasing decclearation – [1]

[-1] for not labelling axes with units



[3]

4 Extreme hotness and coldness in a changing climate affect the stability of railroad tracks and can make them prone to buckling and lead to an increase in derailments. This problem has challenged engineers for many years.

Picture from https://qph.fs.quoracdn.net/main-qimg-f85b77b00b6020ef782665e4337c46d1-c

Liner expansion and contraction occur in the rail due to temperature rising and falling respectively.

A rail of length **L** that is free to move undergoes a temperature change of **ΔΘ**, its length would change by **x** given by the equation

$$x = L\alpha\, \Delta\Theta$$

where **α** is the material's coefficient of linear expansion.

However most rail are not able to move freely, so when expansion is prevented, the rail experiences a thermal stress **σ** given by the relation.

$$\sigma = E\epsilon$$

where **E** is the material's Young modulus and **ϵ** is the ratio of change in length to the original length.

(a) Determine the change of length for a stretch of steel rail of 580 km if temperature can range from -15 ºC in winter to 30 ºC in summer. The coefficient of linear expansion for steel is 1.15×10^{-5} ºC^{-1}.

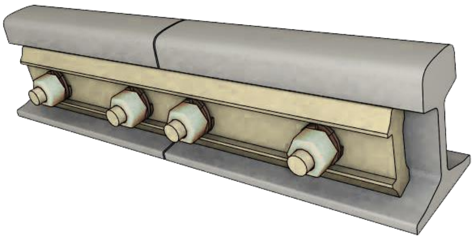
$x = L\alpha\, \Delta\Theta$

$= (580)(1.15 \times 10^{-5})(30 - (-15))$ [1]

$= 3.0 \times 10^{-1}$ km [1]

Change of length = [2]

(b) The standard procedure for preventing derailment due thermal expansion is to joint sections of rails with sliding fish-plated joints as shown in figure below.



Picture from
https://pwayblog.files.wordpress.com/2016/03/mechanical_rail_joint_track_superstructure_permanent_way_pway_cwr_crt_uk.png?w=640

(i) Explain why this procedure could work.

Having gaps allow rooms for expansion during hot weather [1] and friction between train and rail
as well as holding rail in place when it contracts during cold weather. [1]

[2]

(ii) Suggest a possible problem that is associated with this procedure.

Difficult to determine amount of gap to have. [1]

[1]

(iii) Explain why this procedure work better in Singapore as compared to New Zealand.

There is no extreme weather condition in Singapore [1]

Hence minimal expansion and contraction occurs in Singapore. [1]

[2]

(c) The force **F** exerted on the rail per unit cross sectional area **A** is the stress on the rail. Determine the force experience by the steel rail for each degree Celsius change in temperature if E = 2.10×10^{11} N m^{-2} and A = 7.67×10^{-3} m^2.

Thermal stress, $\sigma = E\epsilon$

Stress on rail F/A

$F/A = E\epsilon$

$= E\,(x/L)$ as $\boldsymbol{\epsilon}$ is the ratio of change in length to the original length

$= E\,\alpha\,\Delta\Theta$

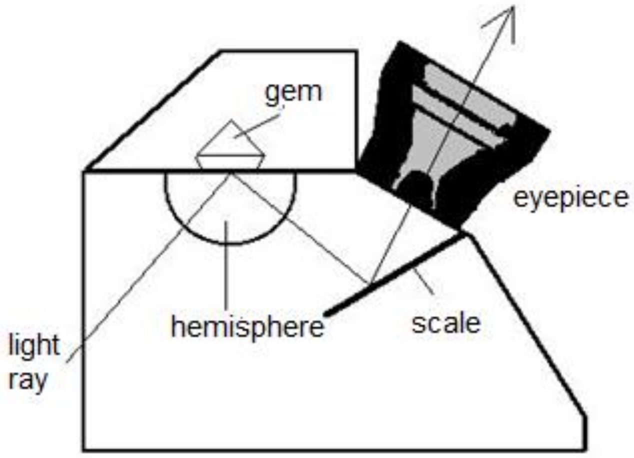
$F/\Delta\Theta = AE\,\alpha$ [1]

$= (7.67 \times 10^{-3})(2.10 \times 10^{11})(1.15 \times 10^{-5})$ [1]

$= 1.85 \times 10^{4}$ N $°C^{-1}$ [1]

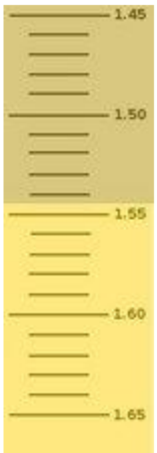
Force = [3]

5 A gem refractometer shown in the diagram below is an optical instrument that uses the critical angle of a gemstone to illuminate a calibrated scale. When viewed with a monochromatic light of wavelength 589 nm, dark and bright zones on the scale are observed at a boundary of the gemstone's refractive index.



Picture from https://i.pinimg.com/736x/8a/fd/21/8afd2153caed61cf7d6dc70b95103826--polish.jpg

(a) The following scale is observed through the eyepiece.



Picture from http://gemologyproject.com/wiki/images/thumb/d/df/Refractometerscale1.jpg/75px-Refractometerscale1.jpg

(i) Explain why there is a darker and lighter zone being observed.

If light hits the gem at angle less than critical angle of hemisphere and gem boundary, light is refracted into the gem, no light reached the scale, so dark region seen. [1]
If light hits the gem at angle greater than critical angle of hemisphere and gem boundary, light is total internally reflected, light reached the scale, so bright region seen. [1]

(ii) The refractive indices of some common gems are shown in the table.

Gem	Refractive index
Agate	1.535 - 1.539
Quartz	1.544 - 1.553
Opal	1.370 - 1.470
Turquoise	1.610 - 1.650

Identify the gem in the refractometer.

Gem is Quartz [1]

(iii) Explain the difference in observation of the scale if white light is used instead of monochromatic light.

Refractive index is dependent on wavelength of light [1]

The boundary between the bright and dark region will not be as distinct. [1]

(b) A contact liquid are used to create an optical contact between the hemisphere and the gemstone. The hemisphere and the contact liquid have similar refractive index of about 1.81.

(i) What is the critical angle of the gem with respect to the contact liquid?

n1sin <1 = n2sin <2

1.81 sin c = 1.545 sin 90º [1]

$c = 58.6^0$ [1]

(ii) Why do you think the contact liquid is necessary?

To have proper contact with the gem. If there is air between gem and hemisphere, critical angle would be difference and this would affect accuracy of the refractive index. [1]

(iii) State two limitations of the gem refractometer?

Cannot identify gemstone with refractive index more than 1.81/ limited by range of scale, can only identify gemstone from 1.45-1.65 [1]

Cannot be used to identify gemstone specifically; limited by precision of scale. [1]