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For Supervisor's use only

TOP SCHOLAR

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Scholarship 2009
Physics

2.00 pm Tuesday 17 November 2009
Time allowed: Three hours
Total marks: 48

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should answer ALL the questions in this booklet.

Write all your answers in this booklet.

For all 'describe' or 'explain' questions, the answers should be written or drawn clearly with all logic fully explained.

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For all 'describe' or 'explain' questions, the answers should be written or drawn clearly with all logic fully explained.

For all numerical answers, full working must be shown and the answer must be rounded to the correct number of significant figures and given with the correct SI unit.

Formulae you may find useful are given on page 2.

If you need more space for any answer, use the page(s) provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–22 in the correct order and that none of these pages is blank.

You are advised to spend approximately 30 minutes on each question.

You have three hours to complete this examination.

QUESTION ONE: ELECTRON STEW (8 marks)

Permittivity of free space = 8.85×10^{-12} F m^{-1}
Dielectric constant of air = 1.00
Charge on the electron = 1.60×10^{-19} C

Js

kg m^{-2} s^{-1} Js $\frac{n\lambda}{2}\lambda = 2\pi r$

(a) The Bohr model of the atom is based on several assumptions.

circular orbit. standing wave.

State these assumptions and discuss their significance.

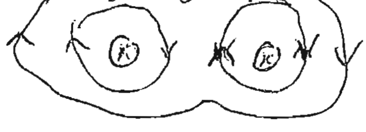
One of the assumptions is that the angular momentum of electrons is quantised ~~nmce~~ they are always integral multiple of $\frac{h}{2\pi}$. This is significant because electrons in fact form standing waves around the atom & the ~~m~~ circumference of the orbit is always an integral multiple of $\frac{1}{2}\lambda$. The other assumption is that the ~~p~~ orbit of electrons are circular which also helps the explanation of the standing wave pattern. The standing wave pattern illustrates the particular nature of electrons. Also the quantised angular momentum means that electrons do not spiral into the nucleus & that energy levels in the atom itself is quantised so this is able to explain the emission & absorption spectrum. i.e. only certain levels are stable & electrons absorb energy of these levels.

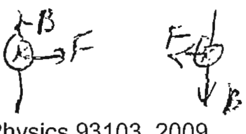
(b) Electrons repel each other. Two wires carrying parallel currents attract each other. Therefore currents in wires cannot be due to the motion of electrons.

false. magnetic force > electric force. wires & electrons neutral!
magnetic forces can repel

Comment.

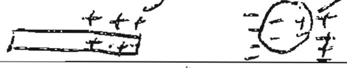
The currents in wires is in fact caused by the motion of the electrons. The force ~~of the~~ between wires cannot be caused by electrons, because there are both electrons & positive nuclei in wire, so there is no overall charge, +ive & -ive charges cancel out, there will not be net electric force between the wires. The force is not electric but magnetic. The movement of electrons current create ~~electric~~ field around the wires. The magnetic field of one current cuts the other wire at 90°, according to Fleming's left hand rule, there are attractive forces between the wires. Two ~~ch~~ wires carrying opposite charge in fact ~~attract~~ repel each other, so if the statement is right then this current is due to motion of electrons?





(c) Explain why there is a force of attraction between a charged rod and an uncharged, isolated metal sphere, and why this force increases when the sphere is earthed.

When a charged rod is brought near an uncharged isolated metal sphere, The electrons in the metal sphere move freely. eg if rod is positively charged, the free electrons are attracted & the side near the ~~sphere~~ rod has a negative charge, side away from rod a positive charged



If metal sphere is Earth, the positive charged is repelled out of the sphere, the metal sphere now has a net negative charge so the force of attraction increases. Both the end near the rod away from the rod is attracted to the rod, so overall force of attraction is greater.

$Q = CV$. $C = \frac{A\varepsilon_0}{d}$ $\frac{Q}{V} = \frac{A\varepsilon_0}{d}$ $\frac{Q}{A} = \frac{V\varepsilon_0}{d}$

(d) Calculate the average distance between the excess electrons on one plate of a parallel plate capacitor for which the plates are separated by 1.00 mm of air, and have a potential difference between them of 1.00×10^3 V.

$Q = CV$ $C = \frac{A\varepsilon_0\varepsilon_r}{d}$ $\therefore \frac{Q}{V} = \frac{A\varepsilon_0}{d}$ $\frac{Q}{A} = \frac{V\varepsilon_0}{d}$

charge per unit area $= \frac{10^3 V \times 8.85\times10^{-12} F m^{-1} \times 1.00}{0.001 m} = 8.85\times10^{-6} C m^{-2}$

$\therefore$ number of electrons per unit area $= \frac{8.85\times10^{-6} C m^{-2}}{1.6\times10^{-19} C} = 5.53\times10^{13} m^{-2}$ (3sf)

d

Area occupied by 1 electron $= \frac{1}{5.53\times10^{13} m^{-2}}$

$\therefore d = \sqrt{A} = \sqrt{\frac{1}{5.53\times10^{13} m^{-2}}} = 1.34\times10^{-7} m$ (3sf)

$\therefore d = \sqrt{A} = \sqrt{\frac{1}{5.53\times10^{13} m^{-2}}} = 1.31\times10 m$ (3sf)

QUESTION TWO: AC CIRCUITS (8 marks)

In an AC circuit, the RMS current and voltage are related to their peak values by the following two relations:

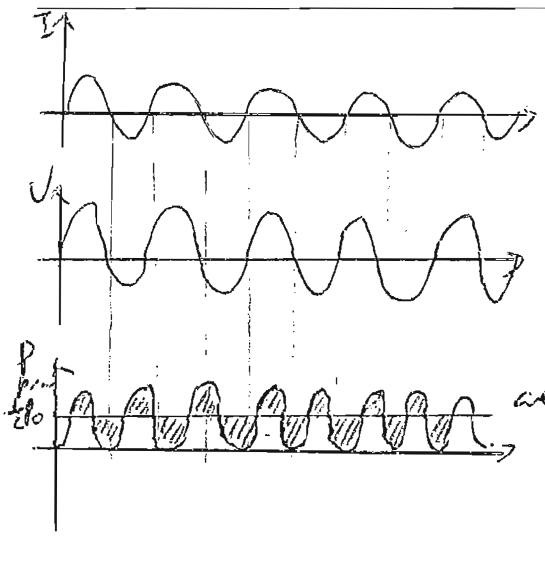
$$I_{\text{RMS}} = \frac{I_{\text{peak}}}{\sqrt{2}},\ V_{\text{RMS}} = \frac{V_{\text{peak}}}{\sqrt{2}}.$$

(a) Explain why RMS values are needed in AC electricity calculations, but not in DC.

Because in AC the current is constantly changing in magnitude & direction. RMS values are needed to represent the real/net equivalent current that gives the same power dissipated in a resistor for example. But in a DC with constant current, RMS value is essentially the same as the instantaneous value of current.

(b) Explain why the expressions connecting RMS and peak values for current and voltage include a factor $\sqrt{2}$.

~~In a sinusoidal AC field, the V & I are in phase.~~ RMS voltage & current are defined as the equivalent dc current & voltage that will give the same power dissipated through & across a resistor, $P=VI$, $P=IR^2$ $P=\frac{V^2}{R}$ they are all equivalent. In sinusoidal ac, $I=I_0\sin\omega t$, $V=V_0\sin\omega t$. $\therefore P=I_0^2R\sin^2\omega t$ $P=\frac{V_0^2}{R}\sin^2\omega t$ as shown in graph,
~~Average~~ $P_0=\frac{V_0^2}{R}=I_0^2R$, average $P=\frac{1}{2}P_0$.
$\therefore I_{rms}^2=\frac{1}{2}I_0^2$ $\therefore I_{rms}=\frac{I_0}{\sqrt{2}}$ $V_{rms}=\frac{V_0}{\sqrt{2}}$.

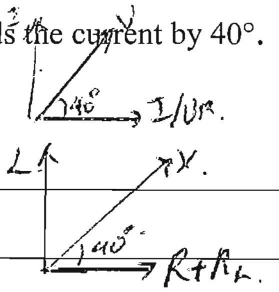


area shade above line = below line.

An AC electric motor can be considered to be an ideal inductor, L, in series with a resistance, R. The motor is connected in series to a load, represented by a resistance, $R_{load} = 120\ \Omega$, and a power supply. The power supply has a frequency $f = 50$ Hz and RMS voltage $V_{source} = 240$ V.

When the RMS current through the motor is 0.50 A, the supply voltage leads the current by 40°.

(c) (i) Find the resistance, R, of the motor.



Total impedance $X = \frac{V}{I} = \frac{240V}{0.50A} = 480\ \Omega$

$\therefore R + R_L = X \cos 40° = 368\ \Omega$ (3sf)

$R = 120\ \Omega \quad \therefore R_L = 368\ \Omega - 120\ \Omega = 248\ \Omega$

~~At~~ $X_L = 480 \sin 40° = 308.5\ \Omega$ (3sf) $X_L = L\omega \quad \therefore L = 0.982$ (3sf) H

(ii) What is the total power generated in the load and in the resistance of the motor when the current is 0.50 A? How much power is supplied to the circuit? Discuss your answers to these questions using physical principles.

~~Use~~ $P_{supply} = VI = 240V \times 0.5A = 120W \quad P_{load} = 120\Omega \times (0.5A)^2 = 30W.$

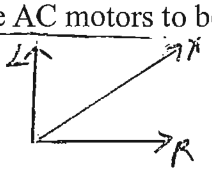
$P_{resistance\ of\ motor} = (0.5A)^2 \times 248\Omega = 61.9W$ (3sf)

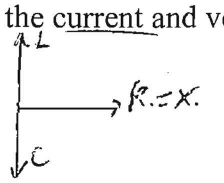
The total power output $= 30W + 61.9W = 91.9W$

Input ≠ output, energy is not only dissipated as heat in the resistance but also in the inductor, eg as heat caused by eddy current as magnetic flux change in the inductor, also as hysteresis loss as the magnetic domain change orientation when current changes direction. ~~Though~~.

(d) An energy supply company requires large AC motors to be run with the current and voltage in phase with each other.

Explain how this might be achieved.





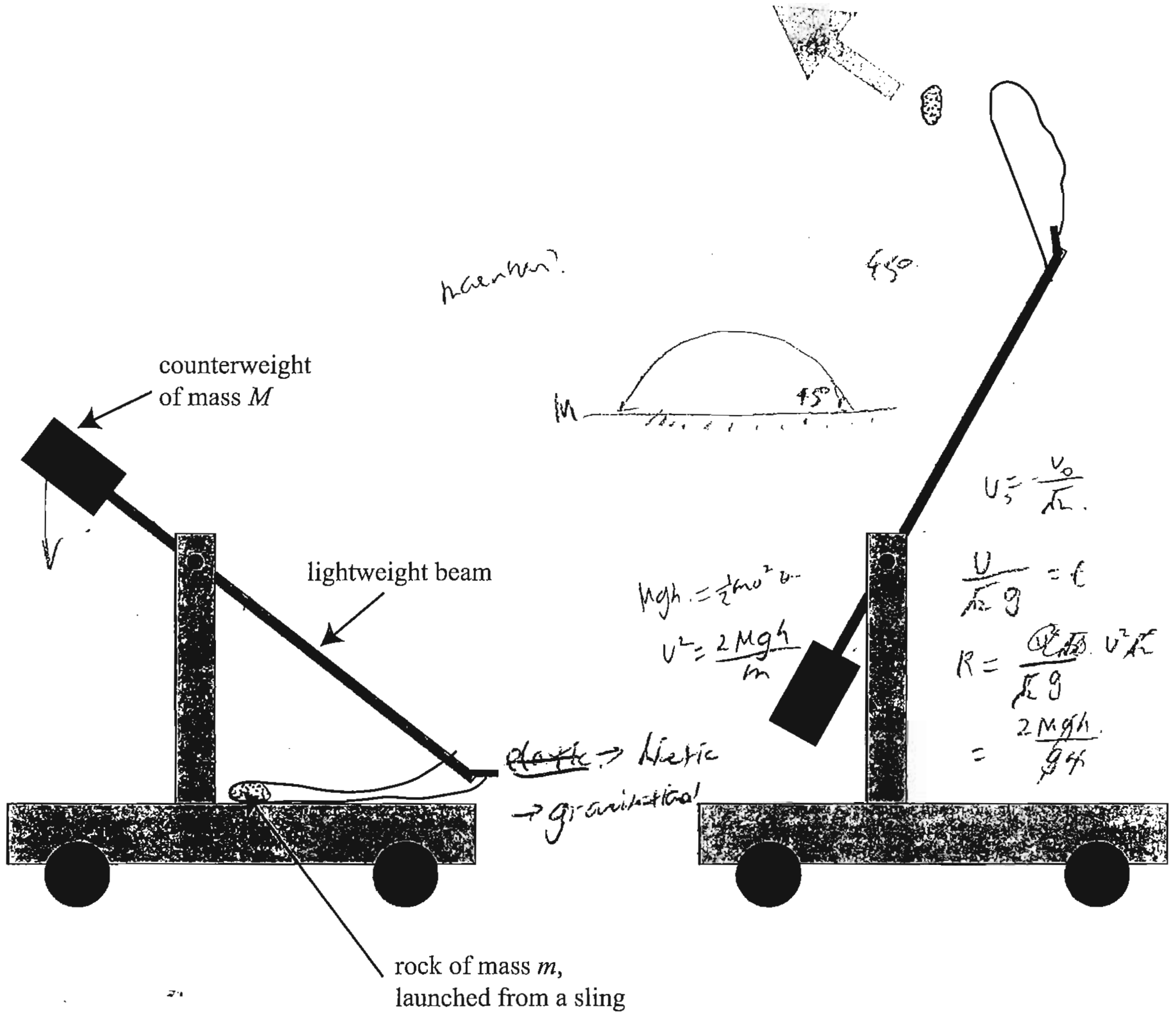
This can only be achieved by having a capacitor in series with the inductor. ~~Be~~ Because with only inductor & resistor the impedance & thus supply voltage will always be out of phase with current. Unless R is very big or L is very small which defeats the purpose of a motor. So a capacitor with same reactance as inductor can be used. $\omega L - \frac{1}{\omega C} = 0 \quad \therefore X = R$ current & voltage is in phase. $\therefore \frac{1}{\omega C} = 308.5\Omega$

$\therefore C = \frac{1}{308.5\Omega \times 2\pi \times 50Hz} = 1.03 \times 10^{-5}$ C (3sf)

QUESTION THREE: THE TREBUCHET (8 marks)

Acceleration due to gravity = 9.81 m s^{-2}

The trebuchet is a medieval weapon for hurling rocks at fortifications.



$g \to g$ 8.94

(a) State the energy changes that take place when the machine fires the rock.

~~Elastic potential energy of the sling changes first to kinetic energy of~~
~~Elastic potential energy of the sling changes first to kinetic energy of~~
~~the rock. The counter mass is lowered, its gravitational energy~~
~~decreases.~~ The gravitational potential energy of the counter-weight
is converted into gravitational energy of the rock at the instant it is
fired & its kinetic energy. Assuming there is no elastic potential energy in
the sling.

(b) Assuming that the rock is released from ground level, show that the theoretical maximum range is: Mh.

$R = 2\frac{M}{m}h$, where M = mass of counterweight
m = mass of rock
h = height counterweight falls

~~Gravit~~ Loss in gravitational potential energy of the counterweight = Mgh.
At the end of the projectile motion when rock is at ground level again,
The net change in its gravitational energy equals to zero. So all the
Ep of counterweight is converted to kinetic energy of rock.
$Mgh = \frac{1}{2}mv^2$. The range of projectile motion is maximum when angle
is 45° which means vertical component of velocity $= \frac{v}{\sqrt{2}}$ = horizontal component.
time taken for maximum height $t = \frac{v}{\sqrt{2}g}$ $\therefore R = 2t \times \frac{v}{\sqrt{2}} = \frac{v^2}{g}$
$v^2 = \frac{2Mgh}{m}$ $\therefore R = \frac{2Mgh}{mg} = 2\frac{M}{m}h$.

(c) The maximum range can be increased by mounting the trebuchet on wheels (rather than fixing it to the ground). CoM. energy work done against friction

Explain. ~~The trebuchet can be pushed with a horizontal velocity in the direction~~
~~when the trebuchet is fixed to the ground, the when counterweight is~~
~~pushed downwards, the trebuchet cannot move forward.~~
The trebuchet can be pushed in direction of the motion of the rock with
a velocity v before firing the rock, so the rock already has an
initial velocity in the horizontal direction, it already has kinetic
energy so the range will be larger than if the wheels are stationary.

(d) If a trebuchet with a maximum range of 100 m on Earth were taken to the Moon (where the gravitational field strength is one sixth of that on the surface of the Earth), what would be its range?

Earth.

Using physical principles, explain your answer.

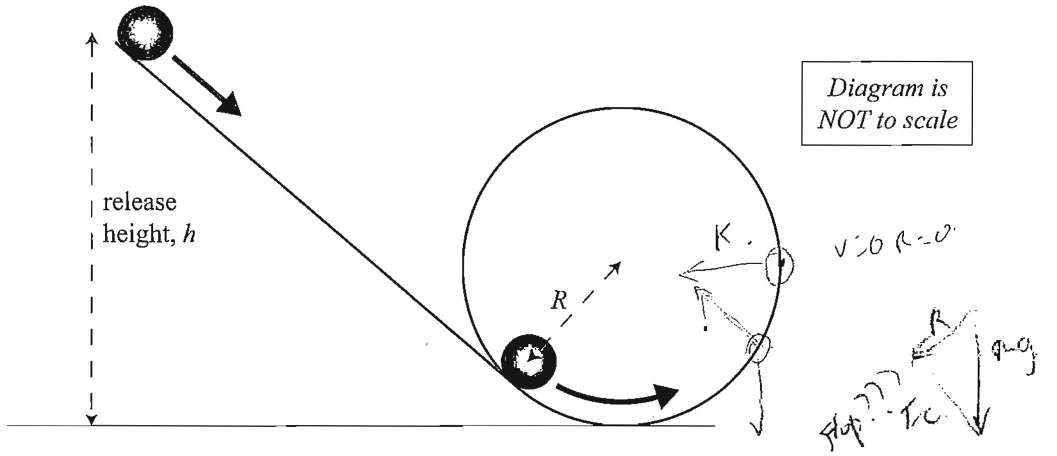
Moon.

The range will still be 100m, because ~~g~~ $g_m = \frac{1}{6}g$, so the gravitational
potential energy lost by counterweight as it falls is $\frac{1}{6}$ of original
value. So kinetic energy of the rock in projectile motion is less, but the
value of g is less, so the downward acceleration on the rock is less. The
range of the rock with same kinetic energy will be bigger on moon.
This effect cancels out, so range keeps the same.

QUESTION FOUR: LOOP THE LOOP (8 marks)

The rotational inertia of a solid sphere is $\frac{2}{5}mr^2$.

A ball of mass m rolls, without being slowed by friction, down a ramp leading to a vertical circular track. R is the distance from the centre of the track to the centre of mass of the ball. The radius of the ball, r, is much less than R.



(a) Explain what will happen to the ball for a release height, $h \le R$.

~~loss in gravitational potential energy = mgh.~~
~~At half way to top of the loop Ep = mgR in h ≤ R mgh ≤ mgR, the ball will not be able to loop the loop, it will fall back. Moreover, for the ball to loop the loop,~~
~~$mg = \frac{mv^2}{R}$ ∴ minimum $v = \sqrt{gR}$ Ek translational $= \frac{1}{2}mgR$~~
~~Ek rotational $= \frac{1}{2} \times \frac{2}{5} mr^2 \times \frac{gR}{r^2} = \frac{1}{5}mgR$~~ even if $h = R$, ball will not reach halfway ~~∴ even if h = R, the ball will not make~~
~~to the top~~ as its $v = 0$, which means centripetal force $= 0$, it would fall. So ~~If h ≤ R the ball will~~

(b) Show that the ball will "loop the loop" (stay in contact with the track for the full circle) if the ball is released from a height, $h \ge 2.7\,R$.

ball is released from a height, $h \ge 2.7\,R$. as $mg = \frac{mv^2}{R}$

At top of the loop, minimum $v = \sqrt{gR}$ $mg = \frac{mv^2}{R}$.

∴ translational Ek $= \frac{1}{2}mgR$ rotational Ek $= \frac{1}{5}mgR$. $\omega = \frac{v}{r}$.

The Ep at top relative to bottom of loop $= 2mgR$.

via Energy conservation

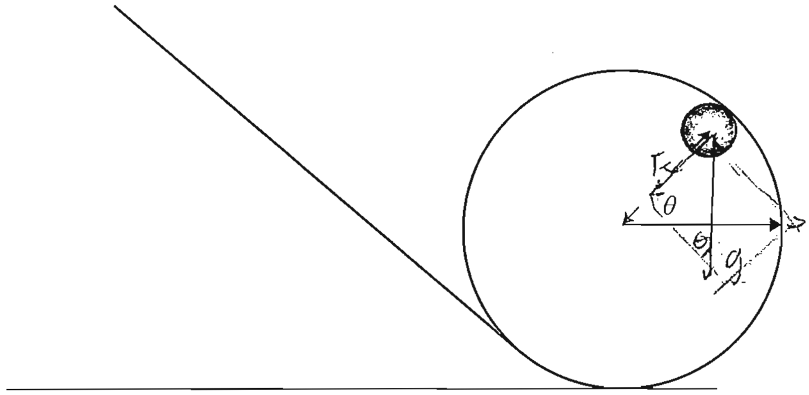
loss in Ep from h to bottom = gain in rotational & linear Ek + Ep at top

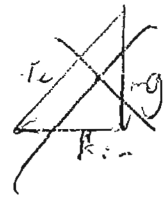
$\cancel{m}g h = 2\cancel{mg}R + 0.5\cancel{mg}R + 0.2\cancel{mg}R$

$h = 2.7R$ minimum

∴ for ball to loop the loop $h \ge 2.7R$.

(c) If the ball is released at a height greater than R but less than $2.7R$, it will lose contact with the track at an angle θ, as shown in the diagram below.





Derive an expression (in terms of θ) for the velocity of the ball at the time it loses contact with the track.

Explain your reasoning.

When the ball loses contact with the track, the contact force R between ball & track = 0. The only force acting on the ball is its gravitational force. The component of gravitational force in the direction towards centre of circle $F_c = mg\sin\theta$ as gravitational force is the only force to supply centripetal force. The ball to no longer move in a circle $\frac{mv^2}{r} = mg\sin\theta$. As gravitational force is smaller than required centripetal force to keep ball in circle.

$\therefore v = \sqrt{gr\sin\theta}$

(d) For a release height, $h \leq R$, the solid ball is replaced by a frictionless sliding block of the same mass and similar size. $h = R$ $h < R$.

mass and similar size. $h = R$ $h < R$.

Explain any similarities or differences from the motion for the rolling ball in part (a) of this question.

The ~~slide~~ block will reach the same height as the ball if h is the same & they will both oscillate backwards & forwards. However the translational velocity at every point is also oscillating because when $\theta = 0$ of the slide is greater than the ball.
Because for the ball $mgx = \frac{1}{2}mv^2 + \frac{2}{5}mv^2$ $\therefore v = \sqrt{\frac{gx}{0.7}}$
but for the slide rotational kinetic energy $= 0$
$\therefore mgx = \frac{1}{2}mv^2$ $v = \sqrt{2gx}$ $\therefore$ period of oscillation is larger.

QUESTION FIVE: DIFFRACTION (8 marks)

(a) When light is incident on a pair of slits (Young's slits), the light can undergo diffraction. The diffracted waves might then interfere with each other.

Explain what conditions are needed for diffraction and interference to take place.

For diffraction interference to take place the size of the slit or the obstacle needs to be comparable to the wavelength of the light used. The light sources need to be coherent meaning that they have constant phase difference. This ~~means~~ implies that frequency, speed & wavelength are all same. The amplitude of the waves need to be comparable. The waves must meet at a point. If they are polarised, they must be polarised in the same orientation. The separation of the slits also needs to be comparable to the wavelength of light used.

(b) The formulae $n\lambda = \frac{dx}{L}$ and $n\lambda = d\sin\theta$ can both be used in interference calculations.

What are the limitations on the use of these formulae?

The formula $n\lambda = \frac{dx}{L}$ assumes small angle where $\sin\theta = \tan\theta$ so it can only be used when fringe separation is small & distance to screen is large. They can both only be used for constructive interference maxima but not position of minima. They both assume that the parallel light rays from slits meet at a point. This is not true if distance to screen is not >> slit separation.

(c) Light of wavelength of 632 nm is incident on a double slit diffraction grating. The distance between the slits is 2.00×10^{-5} m. The diffraction pattern is observed on a screen at a distance of 1.20 m from the diffraction grating.
between the slits is 2.00×10^{-5} m. The diffraction pattern is observed on a screen at a distance of 1.20 m from the diffraction grating.

$0, \lambda, 2\lambda.$

Calculate how far the second order dark fringe is from the central maximum.

The second order dark fringe is 1.5λ out of phase with central maxima (1st order dark fringe being 0.5λ out of phase)

$\therefore 1.5 \times 632 \times 10^{-9}\,m = \frac{2.00 \times 10^{-5}\,m \times d}{1.20\,m}$

$d = 0.0569\,m$ (3sf) = 56.9 mm

(d) When a particular line spectrum is examined using a diffraction grating of 300 lines per mm with the light coming in along the normal, it is found that a line at 24.46° contains both red (640 to 750 nm) and blue/violet (360 to 490 nm) components.

Are there any other angles at which both red and blue/violet components are observed?

$n\lambda = d\sin\theta$. red $n = \frac{d\sin\theta}{\lambda} = \frac{\frac{0.001}{300} \times \sin 24.46^\circ}{640 \times 10^{-9} m} = 2.157$ (3sf) upper limit.

$n = \frac{\frac{0.001}{300} \times \sin 24.46^\circ}{750 \times 10^{-9} m} = 1.840$ (3sf) lower limit

So $n = 2$, it is the 2nd order maxima.

For violet light $n = \frac{\frac{0.001}{300} \times \sin 24.46^\circ}{360 \times 10^{-9} m} = 3.834$ (4sf) upper limit.

$n = \frac{\frac{0.001}{300} \times \sin 24.46^\circ}{490 \times 10^{-9} m} = 2.817$ (4sf) lower limit

$\therefore n = 3$, 3rd order maxima.

~~[illegible]~~ It will occur again for 4th order maxima

red $\therefore \sin\theta_2 = 2\sin\theta$ $\sin\theta = 2 \times \sin 24.46^\circ$ $\theta = 55.9^\circ$ (3sf)

Both red & violet components can also be observed when red is 1st order violet is 2nd order.

eg $1 \times 750 nm = 2 \times 375 nm$.

or $1 \times 720 nm = 2 \times 360 nm$ both of in range

$\therefore \sin\theta = \frac{1 \times 750 nm}{\frac{0.001 m}{300}}$ $\theta = 13.0^\circ$ or $\sin\theta = \frac{1 \times 720 nm}{\frac{0.001 m}{300}}$ $\theta = 12.5^\circ$ (3sf)

$\therefore 12.5 - 13.0^\circ$.

or 2nd order red 3rd order violet.

$\theta = 26.7^\circ - 25.6^\circ$

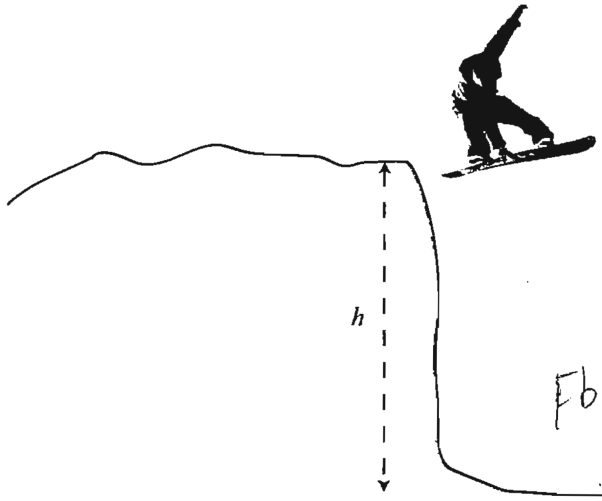
or 3rd order red 6th order violet

$\theta = 40.4^\circ - 42.5^\circ$

$\theta = 40.4^\circ - 42.5^\circ$

QUESTION SIX: SNOWBOARDING (8 marks)

A snowboarder of mass *m* rides over an icy ledge onto a horizontal surface below.
The snowboard leaves the ledge at 0 m s^{-1} in the vertical direction and at only a very small horizontal velocity.



$Fb = mgh + mgb$

(a) Assuming that the centre of mass drops by a distance *b* (through the bending of the knees) on impact, show that the average reaction force acting on the snowboarder is

$$F_R = mg\left(1+\frac{h}{b}\right)$$

Initial velocity is negligible ∴ $E_k = 0$ Loss in E_p in total $= mg(h+b)$

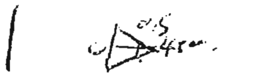
As the snowboarder is brought to stop, $E_k = 0$ again

∴ loss in E_p = work done by the force

As the snowboarder lands, its COM moves b metre to snow, so the land exerts upward force to him through a distance of b. ∴ if ground hadn't moved, COM b m

∴ $Fb = mg(h+b)$ ∴ $F_R = mg(\frac{h}{b}+1)$

(b) By using a height, h, of 3 m and a reasonable estimate of b, calculate the size of the average reaction force experienced by the snowboarder. Comment on how the actual force might differ from the average force.



Length of leg = 1m, suppose leg is bent at 45°

$b = 2 \times 0.5 \sin 45° = 0.707m \therefore b = 1m - 0.707m = 0.29m$ (2sf).

$\therefore F_R = \cancel{mg}\ 70kg \times 9.8 Nkg^{-1} \times (1 + \frac{3m}{0.29m}) = 7712 N$ (4sf)

The actual force will be smaller, because the snow is soft, so the snow boarder will sink in the snow, so distance the ground does work $> b$ $\therefore$ $\frac{h}{b}$ smaller F is smaller. The air resistance can be also taken into account so loss in $E_p < mg(h+b)$ $\therefore$ force is smaller. The snowboarder is very likely to slide when the very small ... taking into account, so she reach to, F is smaller.

(c) Show that the time to come to a stop is given by $t = b\sqrt{\frac{2}{gh}}$ and discuss the effect of landing on soft snow (a sample calculation is required).

$F = \frac{\Delta P}{\Delta t}$. p before landing $= mv$ $\qquad 4gh + 4gh. \quad gh + ... \quad g(h+b)$

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

On soft snow b = say 0.29m $\therefore$

$p = m\sqrt{2gh}$

$p = m\sqrt{2gh}$

$F = mg\frac{b+h}{b}$

$\frac{\sqrt{2gh}}{g(\frac{b+h}{b})} = b\sqrt{\frac{2}{g(h+b)}}$

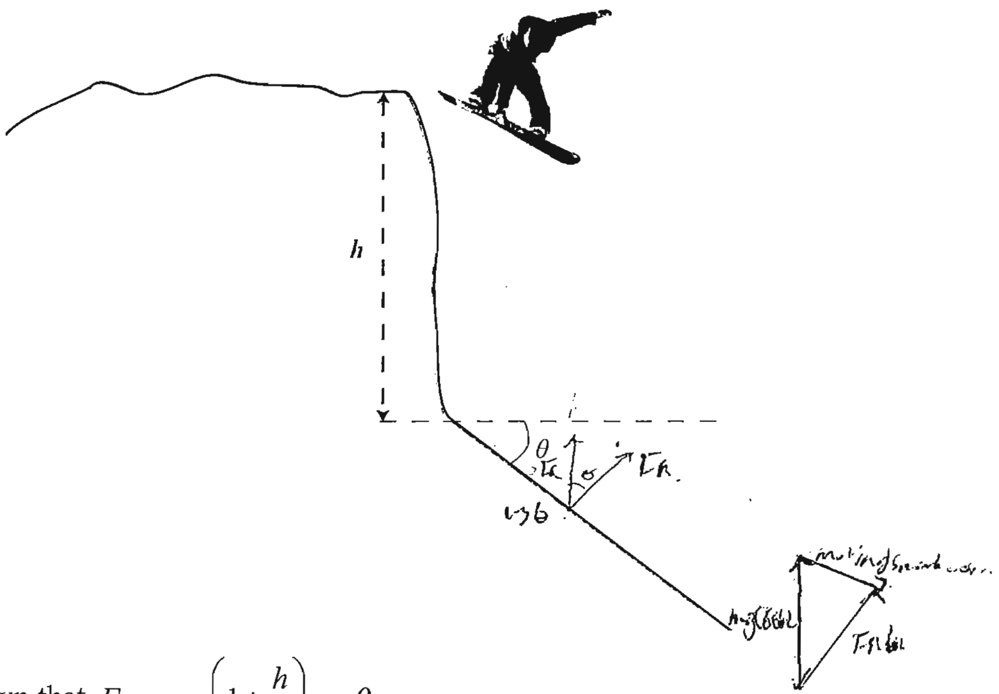
$\frac{}{g(\frac{b+h}{b})} = b\sqrt{\frac{}{g(h+b)}}$

$\therefore \Delta p = mg(\frac{b+h}{b}) \times \cancel{b} \sqrt{\frac{2}{gh}}$

$= m\sqrt{2g(b+h)}\ (b+h)$

Question Six (d) is on the following page.

(d) Having survived his first fall, the intrepid snowboarder makes sure his next fall is onto a surface sloping at angle θ to the horizontal, as shown.



It can be shown that $F_R = mg\left(1+\frac{h}{b}\right)\cos\theta$.

opposing gravitational force.

$\frac{F_R}{\cos\theta}$.

Explain, using physical principles, the effect of the slope on the force experienced by the snowboarder.

The force experienced by the snowboarder is reduced. As the angle θ increases. Consider the extreme case if $\theta = 90°$ $F_R = 0$ as the snowboarder is free falls freely. The reaction force acted by the surface of the slope is now at an angle to the vertical. ~~So the vertical force~~
~~that was thought [illegible] is now [illegible] $F_R = 0$ [illegible]~~
~~That was thought [illegible] is now [illegible] $F_R = 0$ [illegible]~~
F_R is now $\frac{F_R}{\cos\theta}$ instead of F_R.

(e) For snowboarders approaching the ledge with a non-zero velocity, the slope can be made so that the reaction force on landing is zero.

Discuss what shape of the slope would be required and why.

The shape of the slope needs to be parabolic because when the reaction force is zero, the only force on the snowboarder will be the gravitational force. It is just as if snowboarder is free falling in air, so a parabolic slope should be made.

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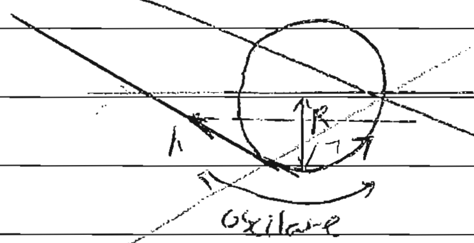
Extra paper for continuation of answers if required.
Clearly number the question.

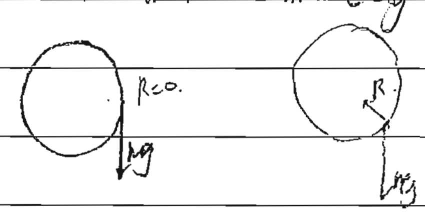
Question number	
4(a)	If $h \leq R$ ball will stop somewhere below the loop & ~~so~~ oscillate back to its starting place in a back & forth & so on. It will not lose contact with track as its weight supplies part of its centripetal force.



~~It will also be below the~~ Maximum height reached will also be below h, as some energy is needed as translation & rotational KE to keep ball in the circular loop.

3(a) The range will still be larger because less work is done against friction between the tehuchet & the ground, so more energy is available for the motion of the rock. Also the tehuchet can be considered as an isolated system if the person fires the rock stands in the tehuchet. The tehuchet recoils, but the centre of mass of the tehuchet & the rock must be still moving so the momentum of the rock will be more than if tehuchet is fixed.
momentum of the rock will be more than if tehuchet is fixed.

4(a) The loss in E_p at bottom of the ~~the~~ loop = mgh.
The gain in E_p at ~~top of the~~ maximum height reached = mgh.
$h \leq R$ i the ball will only reach at best halfway up the loop.



At the maximum height reached by the ball, $v = 0$ ∴ $F_c = 0$.

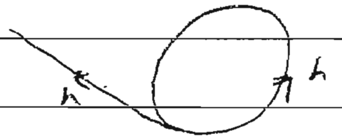
Extra paper for continuation of answers if required.
Clearly number the question.

Question number	

mg $\downarrow g$ $h < g$

There is no force in the direction of the centre of circle.
Only force acting on the ball will be the contact force with the track & the gravitational force on the ball. The contact force is always at 90° to the track.
Take the extreme case when $h = R$, the contact force between the loop & the ball $= 0$. the ball will fall vertically down so it is sliding on the track again
$\therefore$ the ball will oscillate between the starting point & a point on the loop where height above bottom $= h$, height of start.

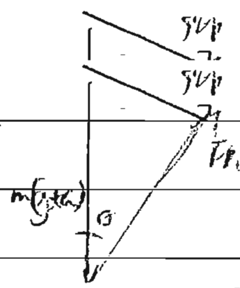
Seen



As at top of the oscillation $v = 0$ $\therefore$ $E_k = 0$
$\therefore mgh = mgh$
if $h \leq R$, the contact force will always be ≥ 0 when $v = 0$
$\therefore$ the ball will not come off the track.

6(d) ~~The force in vertical direction which does~~

6(d) The force in vertical direction which does work against the



$F_R = mg$ ... Since $F_R = mg\cos\theta$ so the reaction force is less.
Because the skateboarder continues to slide off so the ~~vel~~ decrease in vertical E_k is less, therefore ~~less~~ less work is needed to be done in the uphill direction to a certain ... The distance through which the ~~...~~ reaction force acts is now ~~...~~ also much, so the force is less.