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SUPERVISOR'S USE ONLY

TOP SCHOLAR

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Scholarship 2013
Physics

2.00 pm Friday 22 November 2013
Time allowed: Three hours
Total marks: 40

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.

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 room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–19 in the correct order and that none of these pages is blank.

You are advised to spend approximately 35 minutes on each question.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

The formulae below may be of use to you.

$F_g = \frac{GMm}{r^2}$ $F_c = \frac{mv^2}{r}$ $\Delta p = F\Delta t$ $\omega = 2\pi f$ $d = r\theta$ $v = r\omega$ $a = r\alpha$ $W = Fd$ $F_{net} = ma$ $p = mv$ $x_{COM} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$ $\omega = \frac{\Delta\theta}{\Delta t}$ $\alpha = \frac{\Delta\omega}{\Delta t}$ $L = I\omega$ $L = mvr$ $\tau = I\alpha$ $\tau = Fr$ $E_{K(ROT)} = \frac{1}{2}I\omega^2$ $E_{K(LIN)} = \frac{1}{2}mv^2$ $\Delta E_p = mgh$ $\omega_f = \omega_i + \alpha t$ $\omega_f^2 = \omega_i^2 + 2\alpha\theta$ $\theta = \frac{(\omega_i + \omega_f)t}{2}$ $\theta = \omega_i t + \frac{1}{2}\alpha t^2$	$T = 2\pi\sqrt{\frac{l}{g}}$ $T = 2\pi\sqrt{\frac{m}{k}}$ $E_p = \frac{1}{2}ky^2$ $F = -ky$ $a = -\omega^2 y$ $y = A\sin\omega t$ $y = A\cos\omega t$ $v = A\omega\cos\omega t$ $v = -A\omega\sin\omega t$ $a = -A\omega^2\sin\omega t$ $a = -A\omega^2\cos\omega t$ $\Delta E = Vq$ $P = VI$ $V = Ed$ $Q = CV$ $C_T = C_1 + C_2$ $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$ $E = \frac{1}{2}QV$ $C = \frac{\varepsilon_o\varepsilon_r A}{d}$ $\tau = RC$ $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ $R_T = R_1 + R_2$ $V = IR$ $F = BIL$	$\phi = BA$ $\varepsilon = -\frac{\Delta\phi}{\Delta t}$ $\varepsilon = -L\frac{\Delta I}{\Delta t}$ $\frac{N_p}{N_s} = \frac{V_p}{V_s}$ $E = \frac{1}{2}LI^2$ $\tau = \frac{L}{R}$ $I = I_{MAX}\sin\omega t$ $V = V_{MAX}\sin\omega t$ $I_{MAX} = \sqrt{2}\,I_{rms}$ $V_{MAX} = \sqrt{2}\,V_{rms}$ $X_C = \frac{1}{\omega C}$ $X_L = \omega L$ $V = IZ$ $f_0 = \frac{1}{2\pi\sqrt{LC}}$ $n\lambda = \frac{dx}{L}$ $n\lambda = d\sin\theta$ $f' = f\frac{V_W}{V_W \pm V_S}$ $E = hf$ $hf = \phi + E_K$ $E = \Delta mc^2$ $\frac{1}{\lambda} = R\left(\frac{1}{S^2} - \frac{1}{L^2}\right)$ $E_n = -\frac{hcR}{n^2}$ $v = f\lambda$ $f = \frac{1}{T}$

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You have three hours to complete this examination.

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QUESTION ONE: MODERN PHYSICS

(a) Albert Einstein and Niels Bohr provided explanations for the **photoelectric effect** and the **emission spectrum** of the hydrogen atom.

Explain in detail the key underlying physics of each explanation, and describe the fundamental physical connection between these two phenomena.

Bohr's model of the hydrogen atom assumes that electrons orbiting ~~a~~ hydrogen atom can only take on discrete and specific levels of angular momentum, this in turn means that orbital electrons can only have specific levels of energy, and when ~~passing~~ transitioning from one to another they do not pass through intervening energy levels. ~~When light hydrogen gas is bombarded with light at various frequencies, some of the photons will have the precise energy needed to cause the electron to~~ transition to a higher energy level. These ~~..~~ electro

When hydrogen atoms are excited, some electrons move to higher energy states, at random points ~~..~~ in time they will decay back to the lower energy state and emit ~~a~~ photon of the precise frequency denoting the difference between the initial and final energy levels of the electron. As the electrons energy levels are specific and discrete, so ~~.~~ too are the differences between them, and the photons emitted have only particular frequencies. These form the emission spectrum. ~~*~~

The photo electric effect occurs when a metal is bombarded with light, if the light has a sufficiently high frequency then when electrons absorb the photons they will ~~...~~ have enough (see back)

(b) With reference to the data below, explain how fission and fusion processes differ in their release of energy.

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Binding energies per nucleon:

Deuterium	$^{2}_{1}H$	= 1.12 MeV
Helium	$^{4}_{2}He$	= 7.08 MeV
Iron	$^{56}_{26}Fe$	= 8.79 MeV
Uranium	$^{238}_{92}U$	= 7.57 MeV

$1 eV = 1.6 \times 10^{-19}$ J

Binding energy per nucleon is the energy that must be supplied, per nucleon, in order to separate an atom into its component ~~p~~ protons and neutrons. When Deuterium atoms ~~d~~ fuse they form elements such as Helium ~~whi~~ with higher binding energies per nucleon (1.12 MeV compared to 7.08 MeV), and this difference in binding energy is equal to the energy released during the process, i.e. $4 \times (7.08 - 1.12) = 23.84$ MeV are released when two Deuterium atoms fuse to form Helium.

(c) Visible radiation with a continuous spectrum of wavelengths passes through hydrogen gas before passing through a diffraction grating. A series of dark lines (absorption spectrum) is produced in the resulting interference pattern.

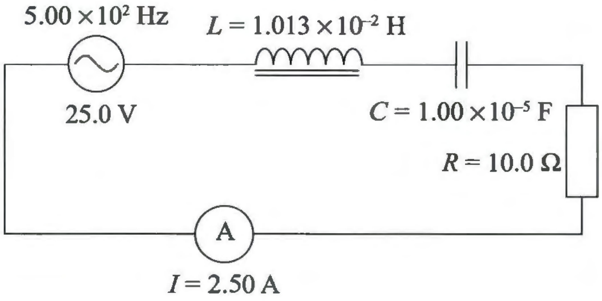
Explain, in detail, why this occurs.

~~As~~ Orbital electrons can only hold distinct energy levels, ~~they can only absorb~~ when ~~wavelengths of~~ photons of such a wavelength that their energy corresponds to the difference between two such levels impact an electron they are absorbed, and the electron moves to a higher energy level. Eventually it decays and the photon is re-emitted in a random direction. This absorbtion and random reemission results in a large drop in intensity at only these specific frequencies and causes the appearance of these dark lines. They are lines as only a particular frequency is absorbed.

QUESTION TWO: AC CIRCUIT THEORY

ASSESSOR'S USE ONLY

(a) The LCR circuit shown in the diagram is in resonance. The inductor and the capacitor are both ideal.



Show that the voltages at resonance across the inductor and the capacitor are both 79.6 V AND explain why voltages larger than the source voltage are created.

$\omega = 2\pi f = 1\times10^3 \pi$ Hz,

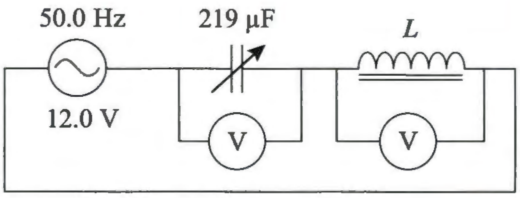
$X_C = \frac{1}{\omega C} = \frac{1}{1\times10^3\pi \times 1\times10^{-5}} = 31.8\ \Omega$, $X_L = \omega L = 10^3\pi \times 1.013\times10^{-2}$ H $= 31.84\ \Omega$

~~At resonance~~ $V_S = V_R$

$V_C = X_C \times A = 31.8\ \Omega \times 2.50\ A = 79.6\ V$, $V_L = X_L \times A = 31.84\ \Omega \times 2.50\ A = 79.6\ V$

Voltages larger than the supply voltage maybe created because ~~the volta~~ V_C and V_L are 180° out of phase, they only store power but do not dissipate it, they are able to supply large voltages which 'charges up' the 'opposite' component, as the voltages are in opposite directions. They cancel and the $V_S = V_R$, they supply the high voltages to each other. (see back).

(b) Two students, Ali and Sue, are trying to find the inductance of a coil. Using a 12.0 V, 50.0 Hz AC supply, Ali connects a variable capacitor, whose capacitance can be varied over the range of 100 to 300 μF, in series with the coil. Ali adjusts the variable capacitor until the voltages across it and the coil are exactly equal in magnitude. The value of the variable capacitor when this happens is 219 μF. Ali then uses the relation



$$f = \frac{1}{2\pi\sqrt{LC}}$$ to get a value of 46.3 mH for the inductance, L.

Show how Ali carried out his calculation, and explain what he has assumed about the coil.

$\frac{1}{f^2} = 4\pi^2 LC$, $L = \frac{1}{f^2 4\pi^2 C} = \frac{1}{(50.0\ Hz)^2 \times 4\pi^2 \times 219\times10^{-6}\ F}$

$= 0.0462\ 65\ H = 46.3$ mH

Ali has assumed that the coil is a perfect inductor, if not the voltage on the right voltmeter is $V_R + V_L$, he would be better off using an ammeter and varying the capacitance until the current reaches a maximum.

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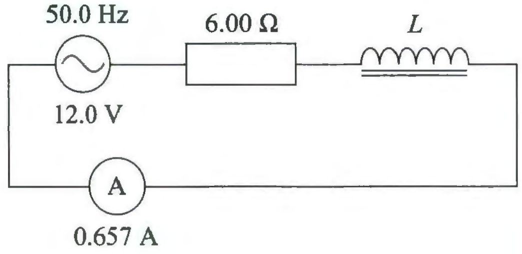
(c) Sue constructs a new circuit where she uses a 6.00 Ω resistor connected in series with the coil and an ideal AC ammeter. They are all connected in series to the same 12.0 Volt, 50.0 Hz AC supply.

Sue measures the RMS current to be 0.657 A.



Show that Sue needs to use the results from both circuits to determine that the true value of the inductance of the coil is 40.2 mH.

Let r be the internal resistance of L, let V_r be the voltage across it. Let R be the 6 Ω resistor

$Z = \frac{12V}{0.657A} = 18.265\Omega = \sqrt{X_L^2+(R+r)^2} = \sqrt{X_L^2+(8+r)^2}$

X_C in part b $= X_L + r$, $X_C = \frac{1}{2\pi f C} = 14.535\Omega$, $X_L + r = 14.535\Omega$

$333.61\Omega = X_L^2 + 64 + 16r + r^2$ $\quad X_L^2 = (14.535 - r)^2$

$269.61\Omega = 211.27 - 29.07r + r^2 + 16r + r^2$

$58.34\Omega = 2r^2 - 13r$, $r^2 - 6.5r - 29.17 = 0$,

form simultaneous equation requires X_C from part b, and Z from part c

$r = 9.55\ \Omega$, $X_L \approx 5\ \Omega$

$L = \frac{X_L}{2\pi f} = \frac{5}{2\pi \times 50} = 15.9\ mH$ does not match given value

see back

(d) A series LCR circuit has a resonant frequency of 1460 Hz. When set to another, higher frequency, the circuit has a capacitive reactance of 5.00 Ω and an inductive reactance of 28.0 Ω.

Calculate the values of the inductance and capacitance in the circuit.

$5.00\Omega = \frac{1}{\omega C}$, $28.0\Omega = \omega L$, $\omega = \frac{28.0}{L}$, $\omega = \frac{1}{5C}$, $\frac{28}{L} = \frac{1}{5C}$,

$L = 140C$. $\quad f = \frac{1}{2\pi\sqrt{LC}}$, $1460 = \frac{1}{2\pi\sqrt{140C^2}}$

$C = \sqrt{\frac{1}{140(2\pi 1460)^2}}$

$C = 9.21\ \mu F$, $L = 1.29\ mH$

7 (8)

QUESTION THREE: INTERFERENCE

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A pair of narrow parallel slits is illuminated by monochromatic light of wavelength 500 nm to produce Young's fringes on a screen.

Diagram not to scale.

(a) Explain the differences and similarities between the interference patterns produced by monochromatic illumination on a double slit and on a diffraction grating of the same slit separation.

The separation of fringes does not change, as this depends only on λ and the spacing d. With a diffraction grating ~~there are more dark~~ there is less partial interference due to the increased number of slits, the ~~se~~ bright fringes are brighter and ~~more~~ less broad. Further, more fringes will be visible at the edges than with a double slit.

Diagram not to scale.

The space between the slits and the screen is then completely filled with a block of transparent material for which the refractive index, n, is 1.6. Assume the refractive index is constant for all wavelengths.

$$\text{refractive index, } n = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in the material}} = \frac{c}{v_{\text{material}}}$$

(b) Describe and explain the changes that will take place in the pattern of the Young's fringes.

For bright fringes d $\sin\theta = n\lambda$, a refractive index of 1.6 indicates the light moves more slowly in the block, the value of λ falls, as d remains constant for any value of n $\sin\theta$ has to fall. Thus θ falls and the bright fringes move closer together.

$1.6t + d_1 = d_2$ $\quad d\theta = \lambda,\ \theta = \frac{\lambda}{d}$ $\quad \frac{t\cos\theta_1 \times 1.6}{c} + \frac{d_1\cos\theta_1}{c} = \frac{d_2\cos\theta_2}{c}$

ASSESSOR'S USE ONLY

The block of material is removed and a very thin slice of the transparent material from the block is used to cover the top slit, as shown in the diagram below. When this is done, the central maximum bright fringe (zeroth order) is observed to move up the screen.

Diagram not to scale.

(c) Explain why the pattern shifts up the screen.

In the material the light moves more slowly, but changes phase at the same rate (frequency is the same). At the central bright fringe the two diffracted beams must have travelled for the same time since diffraction took place to arrive in phase, as the top slit beam has a lower average speed this means this point will be closer to the top slit than to the bottom slit, and so the pattern moves up the screen.

(d) The slice of material has thickness, t, and the central maximum shifts up the screen to take the position originally held by the fifth order bright fringe produced when no material was between the slits and the screen.

$d\sin\theta = 5\lambda$ $\quad 5\lambda = \frac{dx}{L}$ $\quad x = \frac{5\lambda L}{d}$

Show that the thickness of the slice is less than or equal to 4.17×10^{-6} m.

with material $\frac{t\cos\theta_1 \times 1.6}{c} + \frac{x_1\cos\theta_1}{c} = \frac{x_2\cos\theta_2}{c}$ $\quad \cos\theta_1(t \times 1.6 + x_1) = \cos\theta_2(x_2)$

without $\frac{x_1\cos\theta_1}{c} = \frac{x_2\cos\theta_2}{c} + \frac{5 \times 10^{-7} \times 5}{c}$ ← phase difference $= 5\lambda$, converted to time

$x_1\cos\theta_1 = x_2\cos\theta_2 + 2.5 \times 10^{-6}$

$\cos\theta_1 \times t \times 1.6 = 2.5 \times 10^{-6}$ $\quad$ 5th order fringe, 5λ is path difference,

this is 2.5×10^{-6} m $= \left(\frac{2.5 \times 10^{-6}}{c}\right)$ seconds, material must slow down by that much over t, see back

(e) The monochromatic illumination is replaced by sunlight.

Explain how this will assist the experimenter to determine the position of the new central maximum bright fringe.

As the central maximum is no longer in the centre its position may be difficult to determine. But for sunlight the central bright fringe will be the only pure white one, as different wavelengths diffract different amounts and will elsewhere form separate fringes. The white one is 0th order.

8 (8)

QUESTION FOUR: WAVE MOTION

ASSESSOR'S USE ONLY

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

A cork floats on the surface of a pond across which a sinusoidal wave-train of wavelength 10 m and amplitude 0.20 m is travelling. The velocity, v, of waves of wavelength, λ, on a liquid surface is given by

$$v^2 = \frac{g\lambda}{2\pi} + \frac{2\pi\gamma}{\lambda\rho}$$

where ρ is the density (1.0 × 10^3 kg m^{-3} for water) and γ is the surface tension, which for water has the value 7.2 × 10^{-2} N m^{-1}.

(a) Show that the equation is dimensionally consistent.

$(ms^{-1})^2 = ms^{-2} \times m + \frac{Nm^{-1}}{kgm^{-3} \times m}$ $\quad$ $F=ma$ $\frac{F}{m}=a$

$m^2s^{-2} = m^2s^{-2} + Nm\,kg^{-1}$ $\quad$ $F=ma$, $\frac{F}{m}=a$, $\frac{N}{kg} = ms^{-2}$

$m^2s^{-2} = m^2s^{-2} + ms^{-2} \times m$

$m^2s^{-2} = m^2s^{-2} + m^2s^{-2}$, adding, same units, same as units on other side, so dimensionally correct

(b) Calculate the wave speed.

$v = \sqrt{\frac{9.81 \times 10}{2\pi} + \frac{2\pi \times 7.2 \times 10^{-2}}{10 \times 1 \times 10^3}}$ $= \cancel{3.95}$ $4.0\,ms^{-1}$ (2 s.f)

(c) Calculate the maximum speed of the cork as it rises and falls in the water.

$v = f\lambda$, $f = \frac{v}{\lambda} = \frac{4.0\,ms^{-1}}{10\,m} = 0.40\,Hz$

$w = 2\pi f = 2\pi \times 0.40\,Hz$

$V_{max} = Aw = 0.20m \times 2\pi \times 0.40\,Hz$

$= 0.50\ ms^{-1}$

Sea waves of wavelength 150 m and velocity of 15.3 m s^{-1} are heading North. A cruise ship is also travelling North at 8.0 m s^{-1}.

ASSESSOR'S USE ONLY

(d) Calculate the frequency of the ship's up and down movement.

Observed velocity of wave from cruiseship is
$15.3ms^{-1} - 8.0ms^{-1} = 7.3 ~~m~~ ms^{-1}$.
$v = f\lambda$, $f = \frac{v}{\lambda} = \frac{7.3ms^{-1}}{150m} = 0.049$ Hz (~~6~~2 s.f)
perceived distance isn't changed by movement of ship.
or, modifying formula for moving observer
$f' = f \frac{v_w - v_o}{v_w} = \frac{15.3}{150} \times \frac{15.3-8}{15.3} = 0.049$ Hz (2 s.f.)
same answer, so confirms

(e) The natural pitch period of the ship (the period of oscillation produced by pulling the front of a ship down in completely flat water) is about 8 s.

By considering the ship when it is travelling normal to the wavefront, explain why the ship must avoid certain speeds.

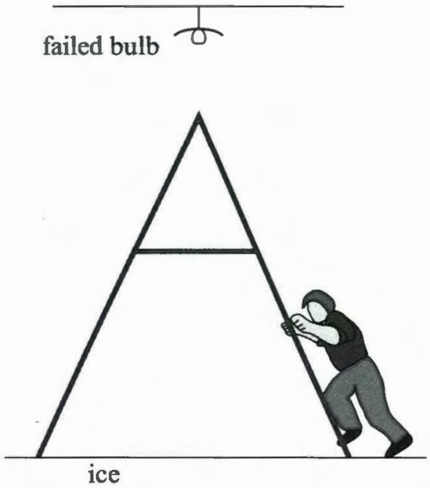
If the wave has a speed of 10.8 m s^{-1} and wavelength of 75 m, calculate the speeds that should be avoided.

$f = \frac{\Delta v}{\lambda}$, $T = \frac{1}{f}$, $T = \frac{\lambda}{\Delta v} = \frac{75m}{10.8ms^{-1} - x} = 8$
$x = 1.425 ms^{-1}$ produces a period of 8s,
as this is the natural pitch period there is little dampening, the amplitude of the pitch will grow until ~~a~~, it is so large the ship is damaged and slows, it could also ~~f~~risk throwing off cargo or crew members. At a velocity of $1.425ms^{-1}$ normal to wavefronts the supplied frequency is the ~~resonant~~ natural frequency, resonance ~~[illegible]~~ causes the build up of dangerous ~~[illegible]~~ oscillations.

QUESTION FIVE: THE A-FRAME LADDER

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

At the local ice rink one of the light bulbs has failed and must be replaced. A lightweight ladder is placed on the frictionless ice so that it is directly under the light bulb, and an electrician climbs the ladder to reach the bulb. Treat the ladder as having zero mass.



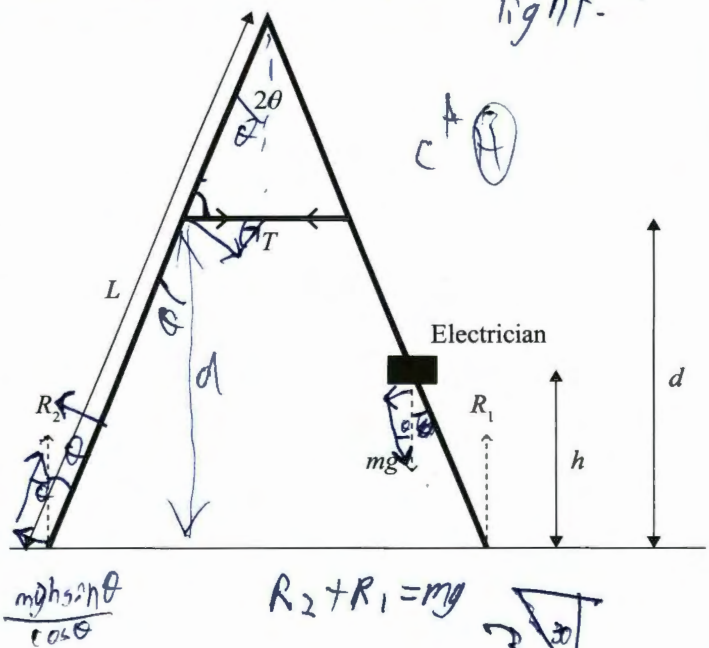
(a) For the initial position of the ladder and electrician shown in the diagram, the electrician will not be able to reach the light bulb.

Explain.

The ice is frictionless, it can exert no horizontal force on the ladder. The man and the ladder are a closed system, the initial momentum of the centre of mass is zero in the horizontal direction and this momentum is conserved. The ~~centr~~ centre of mass cannot move, and so as the man moves to the left climbing the ladder, the ladder slides to the right, ~~whenh~~ maintaining the centre of mass position. He cannot reach the light.

(b) With no friction acting on the base of the ladder, the only force preventing the collapse of the ladder is the tension, T, in the cross-tie bar.

The angle between the legs of the ladder is 2θ, and the reaction forces acting on these legs are shown in the diagram. The vertical distance to the cross-tie bar is d and the length of each leg is L. The mass of the electrician is m.



By taking moments about the top of the ladder, show that when the electrician is at a height, h, above the ground the tension in the cross-tie bar will be:

$$T = \frac{mgh\tan\theta}{2(L\cos\theta - d)}$$

Clockwise torque = anticlockwise torque.

for left strut, ~~$LR_2\sin\theta = \ldots = dT\cos\theta$~~

$LR_2\sin\theta =$ ~~$\ldots$~~ $T\cos\theta\left(L - \frac{d}{\cos\theta}\right) = T(L\cos\theta - d)$

for right: $T(L\cos\theta - d) + mg\sin\theta = LR_1\sin\theta$

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for right $T(L\cos\theta - d) + mg\sin\theta \times (L - \frac{h}{\cos\theta}) = LR_1\sin\theta$

$T(L\cos\theta - d) + mg\tan\theta L\cos\theta - mgh\tan\theta = LR_1\sin\theta$

add both $2T(L\cos\theta - d) + mgh\tan\theta(L\cos\theta - 1) = L\sin\theta(R_1 + R_2)$

Forces balanced too, $R_1 + R_2 = mg$, $\therefore = L\sin\theta\, mg = mgL\tan\theta\cos\theta$

$2T(L\cos\theta - d) = mgL\tan\theta\cos\theta - mgh\tan\theta(L\cos\theta - 1)$

$2T(L\cos\theta - d) = mgL\tan\theta\cos\theta - mgh\tan\theta L\cos\theta - (-mgh\tan\theta)$

$= mgh\tan\theta$

$2T(L\cos\theta - d) = mgh\tan\theta$

$T = \frac{mgh\tan\theta}{2(L\cos\theta - d)}$

(c) The angle, 2θ, between the legs of the ladder is 60°, and the cross-tie bar is one third the way down the leg.

(i) Calculate the maximum tension in the cross-tie bar when the electrician has a mass of 70 kg and the legs of the ladder are 3 m long.

$\theta = 30$, $d = 2\cos 30$, T max when h max, $h_{max} = 3\cos 30$

$T_{max} = \frac{70\text{kg} \times 9.81\text{ms}^{-1} \times 3\cos 30 \times \tan 30}{2 \times (3\cos 30 - 2\cos 30)} = 594.7\text{ N}$

$\approx 600\text{N}$ (1 s.f.)

(ii) Explain what effect increasing the angle will have on this maximum tension assuming the cross-tie bar remains fixed to the same points on the ladder.

Increasing the angle increases the outwards torques applied by R_1 and R_2, $LR_1\sin\theta$ and $LR_2\sin\theta$ respectively, this requires increased balancing torque from the tension force and so increases this maximum tension.

(d) Explain why it is important that the electrician climbs the ladder at a slow and steady speed.

If the electrition climbs at a rapid or unsteady pace then the force he exerts will vary above and below mg, this results in a varying applied torque and ~~rapdu~~ rapidly changing required tensions to balance the torque. The tension may be too high at one point and cause the crosstie bar to break.

Extra space if required.
Write the question number(s) if applicable.

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1a energy to depart the metal entirely, and are emitted as "photo electrons". Experimentation has shown that the energy of these photoelectrons depends only on the frequency of the bombarding light, not on the intensity, and so this further serves to demonstrate, just as the emissions spectra of hydrogen do, the ~~partical~~ particle nature of light.

Seen.

1b Thus we see that when fusion takes place energy is released as heavier atoms are formed with ~~higher~~ higher binding energies per nucleon.

Seen

However, Uranium has a lower binding energy per nucleon than some lighter atoms, such as iron. Uranium decays into lighter elements, also releasing energy in the process, assuming energy loss by beta-emission is negledgible, the decay of 4 atoms of uranium to ~~4~~ 17 atoms of iron 56 would yield $4 \times 238 \times (8.79 - 7.57) = 1161.44$ MeV.

2a ~~V~~ $V_s = Z A$, where Z is the total impedience of the circuit, $Z = \sqrt{(X_c - X_L)^2 + R^2}$, as it is the ~~geo~~ geometrical sum of the resistance and not reactance.

Seen

It follows that $V_s = \sqrt{(V_c - V_L)^2 + V_R^2}$, thus we can see that as long as $V_C \approx V_L$, V_c and V_L take

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on sufficiently close values, and as at resonance $V_C = V_L$ this is amply satisfied in the present case, there is nothing to prevent them ~~either~~ taking on values far in excess of V_S and the voltage equation still being satisfied. Thus $V_C = V_L$ may be greater than V_S in an AC circuit.

Seen

3d $v = \frac{d}{t}$, $d = vt$, $t = \frac{d}{v}$

$\frac{t}{c} = \frac{t}{\frac{c}{1.6}} + \frac{2.5\times10^{-6}}{c}$ $m = \frac{1.6t + 2.5\times10^{-6}}{c}$

$-0.6t = 2.5\times10^{-6}m$ (ignore negative as it is meaningless)

$t = \frac{2.5\times10^{-6}m}{0.6} = 9.1666\times10^{-6}m$

$= 4.17\times10^{-6}m$ (3 s.f.)

this assumes angle of diffraction is small so $t \approx t\cos\theta$, in fact $\cos\theta < 1$, so t must be equal to or less than $4.17\times10^{-6}m$ thick, depending on the spacing of the slits.

Seen

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

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2C $Z = \frac{12V}{0.657A} = 18.265\Omega = \sqrt{X_L^2 + (8+r)^2}$ derived ~~b~~ from infom in (c)

Seen.

from part b $X_C = \sqrt{X_L^2 + r^2} = 14.535\,\Omega$

$333.6 = X_L^2 + 64 + 16r + r^2$

$X_L^2 = 211.3 - r^2$

$333.6 = 211.3 - r^2 + 64 + 16r$

$58.3 = 16r$

$r = 3.64$