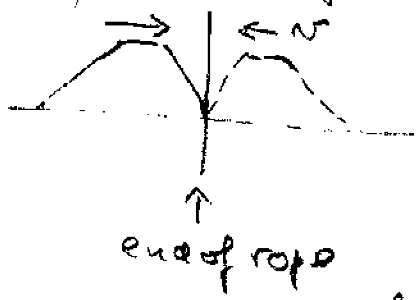
Physics 116, Winter 2007, OEVilches

Solution to final exam

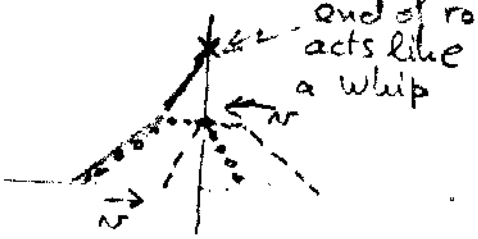
$\boxed{C}$ Q1. The rope does not move in the x-direction, so $v = 0$ m/s.

— o —

$\boxed{B}$ Q2. Look at rope and "image pulse" at two intervals when the pulse is at end of rope – Image pulse has same phase as real pulse.



at $t = 2$ s



at $t = 3$ s.

Vertical displacement is 0.2 m in 1 second

So $v = 0.2$ m/s.

— o —

$\boxed{B}$ Q3 – Picture above shows rope at $t = 3$ s

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$\boxed{D}$ Q4 – $f = \dfrac{n v_s}{2L} = \dfrac{4 \times 340\ \text{m/s}}{2 \times 4\ \text{m}} = 170$ Hz

— o —

$\boxed{C}$ Q5 – Fundamental frequency is $f_0 = \dfrac{v_s}{2L}$

Since $v_{s\,kr} < v_{sE}$ and length of pipe has not changed $f_{0kr} < f_{0E}$

— o —

$\boxed{E}$ Q6 – $db = 10 \log_{10} \dfrac{I}{I_{reference}} \Rightarrow 20 = 10 \log_{10} \dfrac{I}{10^{-6}\ \text{W/m}^2}$

$\dfrac{20}{10} = 2 = \log_{10} \dfrac{I}{10^{-6}} \Rightarrow I = 10^{2} \times 10^{-6}\ \frac{\text{W}}{\text{m}^2} = 10^{-4}\ \text{W/m}^2$

E Q7. Rider is moving towards source, so frequency heard goes up by Doppler effect. There are no beats (only one frequency) or interference (rider is at equal distance from each source)

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B Q8. Each source independently produces intensity I_0. The intensity is proportional to the amplitude of the wave squared. Since each source produces sound in phase with the other, the receiver gets twice the amplitude of the individual waves. So

$$I_0 = \text{Constant} \times E_0^2$$
$$I_{received} = \text{Constant} \times (2E_0)^2 = \text{constant} \times 4E_0^2 = 4I_0$$

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A Q9. Photons don't have a mass. Their $KE = pc = hf$
Sound waves can not be polarized because they are longitudinal waves

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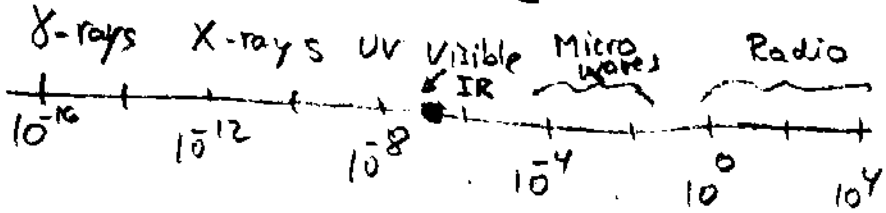
D Q10.



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E Q.11 $\frac{\text{Energy}}{\text{time}}$ = Power. Power through small hole is the intensity arriving at hole times area of hole.

$$P(\text{through hole}) = I_{10m} \times A_{hole} = \frac{P_{source}}{4\pi L^2} \cdot \pi R^2 =$$
$$= \frac{100\text{ Watts} \times (0.01m)^2}{4 \times (10m)^2} = 2.5 \times 10^{-5}\text{ Watts}$$

———o———

$\boxed{A}$ Q12. If source emits a power $P_{source} = P$, then Intensity at here is $\frac{P}{4\pi L^2} = I_{average}$

$$I_{average} = \frac{1}{2}\varepsilon_0 c E_0^2$$

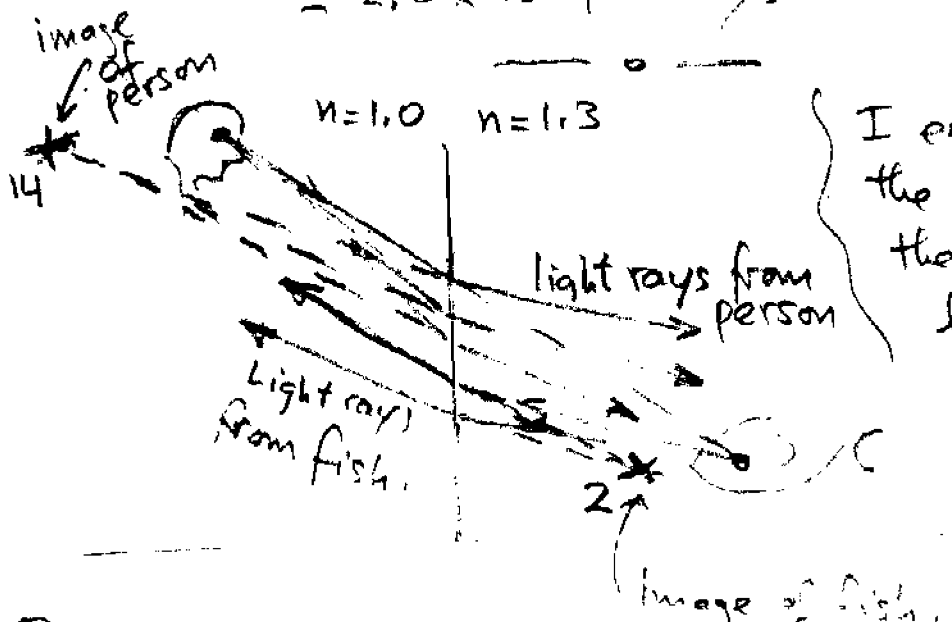
with E_0 the amplitude of the electric field.

Thus: $$E_0 = \left[\frac{2 I_{average}}{\varepsilon_0 c}\right]^{1/2} = \left[\frac{2P}{4\pi L^2}\right]^{1/2}$$

$\boxed{B}$ Q13. Number of photons per time $= \frac{\text{Power}}{\text{Energy of one photon}} =$

$$= \frac{10^{-4}\,\text{Watts}}{\frac{hc}{\lambda}} = \frac{10^{-4}\,\text{Watts} \times 5\times10^{-7}\,\text{m}}{6.635\times10^{-34}\,\text{J s} \times 3\times10^{8}\,\frac{\text{m}}{\text{s}}}$$

$$\cong 2.5\times10^{14}\ \text{photons/s}$$



I exagerated the slope of the eye to eye line.

$\boxed{B}$ Q14

$\boxed{E}$ Q15

$\boxed{A}$ Q16 – maxima at angles $\sin\theta_1 = \frac{m_1\lambda_1}{d} = \frac{m_1 \times 500}{2000}$

$$\sin\theta_2 = \frac{m_2\lambda_2}{d} = \frac{m_2 \times 600}{2000}$$

So λ_1 produces a smaller angle θ_1 than λ_2 (θ_2) and as m increases the angular separation also increases (the $\Delta\theta$ grows from $\approx 3°$ for $m=1$ to $15.6°$ for $m=3$) –

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$\boxed{B}$ Q.17 Only three orders are complete

$$m_1 = m_2 = 1, 2, 3$$

for $m_1 = 4$ there is a peak, but for $m_2 = 4$, $\sin\theta_2 > 1$

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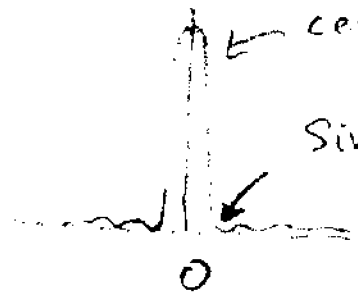
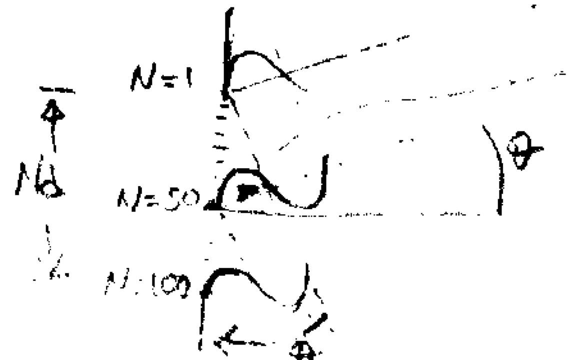
$\boxed{E}$ Q.18 –



$\sin\theta = \frac{\lambda}{100d}$ (slightly different for each wavelength



Diffraction grating with 100 slits

$\frac{Nd}{2}\sin\theta = \frac{\lambda}{2} \Rightarrow \sin\theta = \frac{\lambda}{Nd}$

There is a zero when difference in phase between slit 1 and slit 50 is half λ – Then output of slit 1 cancels with output of slit 50, Slit 2 with slit 51 – etc up to 49 and 100 cancelling –

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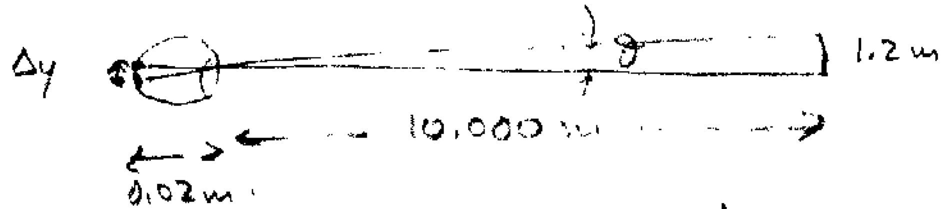
$\boxed{B}$ Q.19 – One can use very small angle approximation



$\tan\vartheta \simeq \vartheta \simeq \sin\vartheta \quad \dfrac{1.22\,\lambda}{d}$

So using similar triangles $\dfrac{1.2\text{ m}}{10^4\text{ m}} = \dfrac{\Delta y}{2\times10^{-2}\text{ m}} \Rightarrow \Delta y = 2.4\times10^{-6}\text{ m}$

— o —

$\boxed{D}$ Q.20 – Rayleigh's criteria says that two images may be resolved when the maximum intensity of image 1 falls in the first zero of intensity of image 2.

Brights overlap half way.

— o —

$\boxed{A}$ Q21 – The higher the temperature of the cavity the higher the frequency of the radiation emitted, and more radiation emitted (total intensity proportional to T^4]

— o —

$\boxed{C}$ Q.22

$\lambda_{peak} T =$ constant, so $\lambda_{sun} T_{sun} = \lambda_{3K} T_{3K}$

$\lambda_{peak\ sun}$ is in the visible $\simeq 500$ nm.

$\lambda_{3K} = \dfrac{T_{sun}}{T_{3K}}\lambda_{sun} = \dfrac{6000\text{K}}{3\text{K}}\, 500\text{ nm} = $

$\simeq 1\times10^{6}\text{ nm} \simeq 10^{-3}\text{ m}.$

— o —

$\boxed{B}$ Q23 1 electron × 100 Volts = 100 eV $\equiv 1.6\times10^{-17}$ Joules

— o —

[A] Q.24

$$\lambda_{photon} = \frac{hc}{E} = \frac{1.24\times10^{-6}\ eV\ m}{100\ eV} \cong 1.24\times10^{-8}\ m$$

$$\lambda_{electron} = \frac{h}{p} = \frac{h}{\sqrt{2m_e E}} = \frac{6.64\times10^{-34}\ J\ s}{\sqrt{9.11\times10^{-31}\ kg \times 2\times100\ eV\times1.6\times10^{-19}\ \frac{J}{eV}}}$$

$$= 1.2\times10^{-10}\ m$$

$$\lambda_{neutron} = \frac{h}{\sqrt{2m_n E}} = \frac{6.64\times10^{-34}\ J\ s}{\sqrt{1.67\times10^{-27}\ kg\times2\times100\ eV\times1.6\times10^{-19}\ \frac{J}{eV}}}$$

$$= 2.9\times10^{-12}\ m.$$

so $\lambda_{ph} < \lambda_e < \lambda_n$

[E] Q.25 – Einstein's equation $\frac{hc}{\lambda} = W_0 +$ Kinetic Energy of electrons

So $\frac{hc}{\lambda} = 3\ eV + 2\ eV = 5\ eV$

$$\lambda = \frac{hc}{5\ eV} = \frac{1.24\times10^{-6}\ eV\ m}{5\ eV} = 2.48\times10^{-7}\ m$$

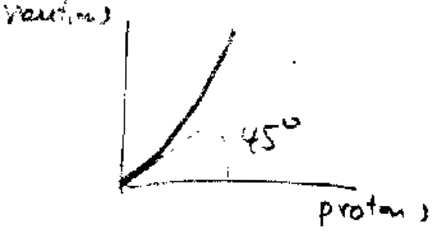
or 248.8 nm [same as in Exam III] ≅ 249 nm

[B] Q 26 – The $n=2$, $\ell=0$, $m_\ell=0$, $s=-\frac{1}{2}$ is the "ground state", or lowest energy state, for the third electron. It is not an excited state. The reason why electron is there is Pauli's exclusion principle, not two electrons can occupy the same quantum state

[E] Q 27 Shortest wavelength photon is the highest energy photon. And highest possible energy is for a transition from $n=\infty$ to $n=1$, $\Delta E = Z^2\times13.6\ eV\left[\frac{1}{1^2}-\frac{1}{\infty^2}\right] = 30^2\times13.6\ eV$

$= 12{,}240\ eV$

$\boxed{B}$ Q.28. Number of neutrons increases faster than number of protons to compensate for Coulomb repulsion between pair of protons



$\boxed{A}$ Q.29. Sequence is $\alpha \to \beta \to \beta \to \alpha$, with Z decreasing by 2 and A by 4 with α-particle emission, and Z increasing by 1 and A remaining constant with every β^- particle emission

$\boxed{E}$ Q.30. The counting rate is given by

$$\frac{\Delta N}{\Delta t} = \frac{0.693}{T_{1/2}} N$$

So

$$100 \frac{\text{decays}}{\text{day}} = \frac{0.693}{140\,\text{days}} N_0 \leftarrow t=0$$

$$\frac{\Delta N}{\Delta t} = \frac{0.693}{140\,\text{days}} \times N_0 e^{-\frac{0.693 \times 70\,\text{days}}{140\,\text{days}}}$$

Taking ratios

$$\frac{\frac{\Delta N}{\Delta t}}{100 \frac{\text{decays}}{\text{day}}} = e^{-\frac{0.693 \times 70\,\text{days}}{140\,\text{days}}} = 0.707$$

or about 71 %.

This problem could be answered by "guessing" since the activity will be reduced to 50% by $T_{1/2}$, and the time given is shorter than $T_{1/2}$.