(1) Physics-1 final exam solutions (Optics Part)

(11)(a) A diffracting grating has a large number of slits because -

[2] (i) Resolving power of a grating is $R = \frac{\lambda}{\Delta\lambda} = mN$ for m^{th} order spectrum, N = no. of lines. So more lines = closer lines can be better resolved.

(ii) Angular Width of principal maxima $\boxed{\Delta\theta_m \simeq \frac{\lambda}{N d \cos\theta_m}}$

for m^{th} order, so lines are sharper (with less width) for larger N.

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(11)(b) $R = \frac{\lambda}{\Delta\lambda} = mN$, here $m = 1$, $\lambda = 589$ nm,

[1] $\Delta\lambda = 589.6 - 589.0 = 0.6$ nm

$\Rightarrow \frac{5890}{6} = N \Rightarrow N = 982 \simeq 1000$

So it needs $N \simeq 1000$ lines to just resolve these lines.

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(4) For a grating with normal incidence, principal maxima are given by $d \sin\theta_m = m\lambda$ $\Rightarrow$ for 1st & 2nd order principal maxima,

[1] $\frac{\sin\theta_1}{\sin\theta_2} = \frac{1}{2}$ Here, $\theta_1 = 32°$

$\Rightarrow \sin\theta_1 = 0.52 > 0.5$

$\Rightarrow \sin\theta_2 = \frac{0.52}{0.5} > 1$ which is not possible.

So option (iv) None of these is correct as there is no second order maximum.

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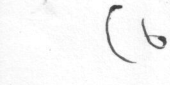
(12) Total width of central max = distance between first 2 minima on both sides of it. For single-slit Fraunhofer diffraction,

[3] The condition for minima is : $b \sin\theta_m = m\lambda$ $(m = 1, 2 \ldots)$

(b = slit width, m = m^{th} order minimum)

$\Rightarrow b \sin\theta_1 = \lambda$, $b \sin\theta_{-1} = -\lambda \Rightarrow \sin\theta_1 = \frac{\lambda}{b} = \frac{500 \text{ nm}}{0.2 \text{ mm}} = 2.5 \times 10^{-3}$



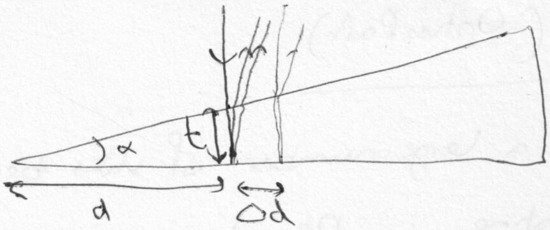
$\sin\theta_{-1} = -2.5 \times 10^{-3}$

$D >> b$, D = slit to screen distance $\Rightarrow \sin\theta_1 = \frac{y_1}{D} \Rightarrow y_1 = D \times 2.5 \times 10^{-3}$

$= 7.5 \times 10^{-3}$ m

$y_{-1} = -7.5 \times 10^{-3}$ m $\Rightarrow y_1 - y_{-1} = \boxed{0.015 \text{ m}}$

② (13)



$\mu_f = 1.5$

For a wedge-shaped film with normally incident light,

Optical path difference $\Delta = 2\mu_f t = m\lambda$ for dark fringes (since $\mu_f = 1.5 > \mu$ on both sides)

But wedge angle $\alpha = \frac{t}{d} \Rightarrow 2\mu_f \alpha d_m = m\lambda$, d = distance from wedge angle along the film. Distance between successive dark fringes is $\Delta d = d_{m+1} - d_m$,

[3]

$$2\mu_f \alpha d_{m+1} = (m+1)\lambda, \quad 2\mu_f \alpha d_m = m\lambda$$

$$\Rightarrow 2\mu_f \alpha \Delta d = \lambda$$

$$\text{or } \Delta d = \frac{\lambda}{2\mu_f \alpha} \quad \Rightarrow \alpha = \frac{\lambda}{2\mu_f \Delta d}$$

$\lambda = 500\text{ nm}$, $\mu_f = 1.5$, $\Delta d = 1/3\text{ cm}$

$$\Rightarrow \alpha = \frac{500 \times 10^{-9}\text{ m}}{2 \times 1.5 \times \frac{1}{3} \times 10^{-2}\text{ m}} = \boxed{5 \times 10^{-5}\text{ radians}}$$

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(5) (a) Peak power of pulse $= \dfrac{\text{energy}}{\text{width ~~time period~~ of pulse}}$

[2]

$$= \frac{0.5\text{ Joule}}{5 \times 10^{-9}\text{ s}} = \boxed{10^8\text{ Watt}}$$

(5) (b) Average power of laser $= \dfrac{\text{energy}}{\text{time period of pulse}}$

[1]

$$= \frac{0.5\text{ Joule}}{0.1\text{ s}} = \boxed{5\text{ Watt}}$$

(frequency of pulses $= 10\text{ Hz} \Rightarrow$ time period $= 0.1\text{ s}$)

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(1)

Physics - I Exam solutions (Thermodynamics part)

6 (a) (ii) (b) (iii) (c) (iii)

14 (a) For Z to be a thermodynamic property, its differential has to be exact i.e.

[1] if $dZ = M\,dx + N\,dy = \left(\frac{\partial Z}{\partial x}\right)_y dx + \left(\frac{\partial Z}{\partial y}\right)_x dy$

then we require $\left(\frac{\partial M}{\partial y}\right)_x = \left(\frac{\partial N}{\partial x}\right)_y$

This will give $\int_1^2 dZ = Z_2 - Z_1$ i.e. Z is a point function of only initial & final states & not a path function.

(14) (b) $dZ = P\,dV + V\,dP$

$\Rightarrow$ Here, $x = V$, $y = P$, $M = P$, $N = V$

[1] $\Rightarrow \left(\frac{\partial M}{\partial y}\right)_x = \left(\frac{\partial P}{\partial P}\right)_V = 1$ $\quad \left(\frac{\partial N}{\partial x}\right)_y = \left(\frac{\partial V}{\partial V}\right)_P = 1$

$\Rightarrow$ Above condition is satisfied & it is a property.

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(15) (a) The First law of thermodynamics states that for a cyclic process, the algebraic sum of ~~heat~~ energy transferred as heat across the boundary of the system = " " " " " work across boundary of the system.

[2] (i) Cyclic process - $\oint dQ = \oint dW$, where dQ & dW are elements of heat ~~work~~ & work transferred across boundary.

(ii) Any process - $\int_1^2 dE = \int_1^2 dQ - \int_1^2 dW$, where dE is element of change of energy of the system.

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[3] 15 (b) $P \propto \frac{1}{V}$ ie $PV =$ constant. $\quad P_1 = 500\ N/m^2 \quad V_1 = 0.2\ m^3$

$P_2 = 100\ N/m^2 \Rightarrow PV = P_1V_1$

$\ln 5 = 1.609$ Work done $= \int_1^2 P\,dV = P_1V_1 \int_1^2 \frac{dV}{V} = P_1V_1 \ln\frac{V_2}{V_1} = P_1V_1 \ln\frac{P_1}{P_2}$

$W = 500\ N/m^2 \times 0.2\ m^3 \times \ln 5 = \boxed{160.9\ J}$