Phy F110

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Errors

For N measurements of a quantity Q:
$\overline{Q} = \frac{1}{N}\sum Q_i$
Deviation $d = \sqrt{\frac{1}{N}\sum\left(Q_i - \overline{Q}\right)^2}$
Resultant measurement $Q = \overline{Q} \pm d$
Error $\Delta Q =$ **Standard error** $= d$
For a quantity $Q = Q(x, y, z)$, the general error is given as:

$$(\Delta Q)^2 = (\Delta Q_x)^2 + \left(\Delta Q_y^2\right)^2 + \left(\Delta Q_z^2\right)^2$$

Where $\Delta Q_x = \left(\frac{\partial Q}{\partial x}\right)\Delta x$ and so on for Q_y and Q_z
Combination of errors:

$$\begin{array}{ll}
Q = x \pm y & \Delta Q = \sqrt{(\Delta x)^2 + (\Delta x)^2} \\
Q = xy \text{ or } \frac{x}{y} & \left(\frac{\Delta Q}{\overline{Q}}\right) = \sqrt{\left(\frac{\Delta x}{\overline{x}}\right)^2 + \left(\frac{\Delta y}{\overline{y}}\right)^2} \\
Q = x^n & \left(\frac{\Delta Q}{\overline{Q}}\right) = n\frac{\Delta x}{\overline{x}} \\
Q = \ln x & \Delta Q = \frac{\Delta x}{\overline{x}} \\
Q = e^x & \frac{\Delta Q}{\overline{Q}} = \Delta x
\end{array}$$

Planck's constant

Boltzmann constant $(k) = 1.38 \cdot 10^{-23} J/K$
Planck's constant $= h$
$U(\nu)d\nu = \frac{8\pi h\nu^3}{c^3}\frac{1}{\left(e^{\frac{h\nu}{kT}} - 1\right)}d\nu$ (now, all relevant approximations can be made)
At a particular frequency ν, the photocurrent I_{ph} is approximated to be:

$$I_{\text{ph}} = \frac{8\pi h\nu^3}{c^3}e^{-\frac{h\nu}{kT}}$$

If we take the *natural logarithm* on both sides, the following is obtained:

$$\ln I_{\text{ph}} = -\frac{h\nu}{kT} + \text{constant}$$

Temperature dependence of resistance of tungsten filament:

$$R = R_0(1 + \alpha T + \beta T^2)$$

α, β being empirical constants used for calibration

EMI

$\varepsilon = -\frac{d\phi}{dt}$
Where $\varepsilon =$ EMF and $\phi =$ flux through the coil
$\omega_{\max} = 2\sqrt{\frac{Mgl}{I}}\sin\frac{\theta_0}{2}$
Here, $\sqrt{\frac{Mgl}{I}}$ is the *frequency* of oscillations, which can also be used to find the time period T
Considering R to be the radius of the arc (and $v_{\max}$ to be the maximum velocity of the arc), we get:

$$v_{\max} = R\omega_{\max} = \frac{4\pi R}{T}\sin\frac{\theta_0}{2}$$

After a bunch of approximations, it is concluded that $\varepsilon_{\max} \propto v_{\max}$ which is given a bit more precisely as:

$$\varepsilon_{\max} = -\frac{1}{R}\frac{d\phi}{d\theta}\bigg|_{\theta_{\max}} v_{\max}$$

Consider the pulse width of one oscillation to be τ and the time constant of the circuit to be RC. If:

- $RC < \tau \Longrightarrow$ Capacitor fully charged in one oscillation
- $RC > \tau \Longrightarrow$ Capacitor charges in multiple oscillations

Total charge delivered to capacitor after each swing $= q = \frac{\Delta\phi}{R}$
For a damped oscillation, the angular displacement is given as:

$$\theta_A(t) = \theta_{A_0}e^{-\frac{\omega_0 t}{2Q}}$$

Q being the **Quality factor** or strength of damping
$Q \propto \frac{1}{\text{Amount of damping}}$
In a plot of $\ln\theta_{An}$ vs. n, the equation is found to be:

$$\ln\theta_{An} = \ln\theta_{A0} - \frac{\pi}{Q}n$$

n being the number of oscillations

Newton's rings

Optical path difference for interfering waves $= 2\mu t$
Conditions for:

1. Constructive interference: $2t = m\lambda$
2. Destructive interference: $2t = m\left(m + \frac{1}{2}\right)$

Where $m \in \mathbb{Z}^+ \cup 0$.
Denoting the radius of the m^{th} order of the ring by r_m, the following can be proved after a bit of work:

$$r_m = \sqrt{m\lambda R}$$
$$r_m = \sqrt{\left(m + \frac{1}{2}\right)\lambda R}$$

for the **dark** and **bright** rings respectively. In the above results, R is the radius of the spherical surface and t is the thickness of the film
Diameter of m^{th} order ring $D_m = \sqrt{4m\lambda R}$

Diffraction grating

$a = (n-1)\Delta$
Single slit diffraction:
If the rays make an angle θ with the normal, the corresponding phase difference ϕ is given as $\phi = \frac{2m}{\lambda}\Delta\sin\theta$, Δ being the distance b/w consecutive points
Intensity distribution: $I = I_0\frac{\sin^2\beta}{\beta^2}$ where I_0 is the intensity at $\theta = 0$ and $\beta = \frac{\pi a\sin\theta}{\lambda}$
Minima: $a\sin\theta = m\lambda (m \neq 0)$
Maxima: $\tan\beta = \beta$
Double slit diffraction:
Similar as above, $\phi_1 = \frac{2\pi}{\lambda}d\sin\theta$
Intensity distribution: $I = 4I_0\frac{\sin^2\beta}{\beta^2}\cos^2\gamma$ where $\gamma = \frac{\phi_1}{2} = \frac{\pi}{\lambda}d\sin\theta$
Minima: $\gamma = (2n+1)\frac{\pi}{2} \Longrightarrow a\sin\theta = m\lambda$ where $m = (1, 2, 3\ldots)$
Maxima: $\gamma = n\pi \Longrightarrow d\sin\theta = n\lambda$ where $n = (0, 1, 2, \ldots)$
In all of the equations above, d represents the **distance** between the two point sources and a denotes the **width** of two parallel slits