Momentum (Linear Collisions):

momentum $\vec{p} = m\vec{v}$

impulse $\vec{J} = \vec{F}\Delta t = \Delta\vec{p} = m\vec{v}_2 - m\vec{v}_1$

$$m_1\vec{v}_1 + m_2\vec{v}_2 = m_1\vec{v}'_1 + m_2\vec{v}'_2$$

$$m_1\vec{v}_1 + m_2\vec{v}_2 = (m_1 + m_2)\vec{v}_{combined}$$

$$\vec{v}'_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)\vec{v}_1 + \left(\frac{2m_2}{m_1 + m_2}\right)\vec{v}_2$$

$$\vec{v}'_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)\vec{v}_2 + \left(\frac{2m_1}{m_1 + m_2}\right)\vec{v}_1$$

$\vec{v}'_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)\vec{v}_1$ $\quad$ $\vec{v}'_2 = \left(\frac{2m_1}{m_1 + m_2}\right)\vec{v}_1$

For elastic, head-on collisions with m_2 at rest ($v_2 = 0$)

Energy (Work):

$$\vec{F} = k\vec{x}$$

$$E_e = \frac{1}{2}k\vec{x}^2 \qquad \Delta d = \frac{\vec{v}_2\Delta t}{2}$$

$$\vec{x}^2 = \frac{m\vec{v}^2}{k} \qquad E_k = \frac{1}{2}m\vec{v}^2$$

$$w = \vec{F}\Delta\vec{d}\cos\theta \qquad v = \sqrt{\frac{2E_k}{m}}$$

$$w = \frac{1}{2}m\vec{v}^2$$

$$E_k = \frac{p^2}{2m}$$

$$\vec{F} = \frac{m\vec{v}_2}{\Delta t}$$

$$F_{Thrust} = v_{gas}\frac{\Delta m_{gas}}{\Delta t} \qquad r_{Schwarzschild} = \frac{2GM}{c^2}$$

$$\Delta E_g = -mg\Delta h \qquad F_G = \frac{GMm}{r_o^2} \qquad F_c = F_G$$

$r_{orbit} = r_{planet}$ + altitude (in m)

$$\Delta E_g = \left(-\frac{GMm}{r_2}\right) - \left(-\frac{GMm}{r_1}\right)$$

$$E_{g(Earth)} = \frac{-GM_Em}{r_{Earth}} \qquad E_{T(orbit)} = \frac{1}{2}E_g$$

$$g_{planet} = \frac{GM}{r_{planet}^2} \qquad E_{T(orbit)} = -\frac{1}{2}\frac{GM_{Earth}m_{satellite}}{r_{orbit}}$$

$$W = \Delta E = E_{T(orbit)} - E_{g(Earth)}$$

$$v_{escape} > \sqrt{\frac{2GM_{planet}}{r_{planet}}} \qquad v_{orbit} = \sqrt{\frac{GM_{planet}}{r_{orbit}}}$$

$$v_{launch} = \sqrt{GM\left(\frac{2}{r_E} - \frac{1}{r_o}\right)} \qquad T = \sqrt{\frac{4\pi^2 r^3}{GM_{planet}}}$$

$$T = \frac{2\pi r}{v_{orbit}} \qquad T = \frac{2\pi r^{3/2}}{\sqrt{GM_{planet}}} \qquad r = \sqrt[3]{\frac{T^2GM_{planet}}{4\pi^2}}$$

$$C_{sun} = \frac{GM_{sun}}{4\pi^2} = \frac{r^3}{T^2} \qquad C_{Earth} = \frac{GM_{Earth}}{4\pi^2} = \frac{r_{Moon}^3}{T_{Moon}^2}$$

Simple Harmonic Motion, Waves & Light:

$$f = \frac{1}{T} \qquad \frac{x}{a} = \frac{T^2}{4\pi^2} \qquad v = f\lambda \qquad f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

$$x = A\sin\frac{2\pi\ radians\ t}{T} \qquad T = 2\pi\sqrt{\frac{x}{a}} = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{l}{g}}$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1} \qquad \lambda = \Delta x\left(\frac{d}{L}\right) \qquad \frac{\Delta x}{L} = \frac{\lambda}{d}$$

$$n_1\sin\theta_1 = n_2\sin\theta_2 \qquad |P_nS_1 - P_nS_2| = \left(n - \frac{1}{2}\right)\lambda$$

$$\sin\theta_n = \left(n - \frac{1}{2}\right)\frac{\lambda}{d} = \frac{X_n}{L}$$

X_n = ⊥ distance to right bisector

L = distance from mid-point of sources to point or ⊥ distance from the midpoint between the slits to the screen

d = source separation

n = nodal line

$$\lambda = \left(\frac{X_n}{L}\right)\left(\frac{d}{n - \frac{1}{2}}\right)$$

$$d\sin\theta_m = m\lambda \qquad d\sin\theta_n = \left(n - \frac{1}{2}\right)\lambda$$

Constructive interference $\quad$ Destructive interference

$\sin\theta_n = \frac{n\lambda}{w} \quad \lambda = \frac{w\Delta y}{L}$	For dark fringes (single slit)
$\sin\theta_m = \frac{\left(m + \frac{1}{2}\right)\lambda}{w}$	For bright fringes (single slit)
$\sin\theta_m = \frac{m\lambda}{d}$	For bright spectral lines (gratings)
$\Delta x = L\left(\frac{\lambda}{2t}\right)$	For an air wedge
$c = f\lambda$	For all electromagnetic waves

Electromagnetism:

$$\vec{F}_e = \frac{kq_1q_2}{r^2} \qquad v = \frac{E_e}{q} \qquad F_M = qvB\sin\theta$$

$$F = IlB\sin\theta$$

$$\vec{\mathcal{E}} = \frac{kq_1}{r^2} \qquad V = \frac{kq_1}{r} \qquad B = \frac{F}{kIl\sin\theta}$$

$$\vec{\mathcal{E}} = \frac{\vec{F}_e}{q} \qquad v = \sqrt{\frac{2qV}{m}} \qquad B = \mu_0\left(\frac{I}{2\pi r}\right)$$

$$\vec{\mathcal{E}} = \frac{\Delta V}{r} \qquad \frac{q}{m} = \frac{\vec{\mathcal{E}}}{B^2r} \qquad B = \mu_0\left(\frac{NI}{L}\right)$$

$$\Delta E_e = q\Delta V \qquad E_e = \frac{kq_1q_2}{r} \qquad \sum B_{ll}\Delta l = \mu_0 I$$

$$F_{vertical} = q\vec{\mathcal{E}} = q\frac{V}{d} \qquad e\vec{\mathcal{E}} = mg$$

$$q = Ne \qquad B = k\frac{I}{r} \qquad V = \frac{mv^2}{2q} \qquad v = \frac{rBq}{m}$$

Matter-Energy Interface:

$$\Delta t_m = \frac{\Delta t_s}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$L_m = L_s\sqrt{1 - \frac{v^2}{c^2}}$$

$$p = \frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$E_{total} = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$E_{rest} = mc^2 \qquad E = hf$$

$$E_K = E_{photon} - W$$

$$E_K = hf - W$$

$$\lambda = \frac{h}{p} = \frac{h}{mv} \qquad p = \frac{h}{\lambda}$$

$$E_p = E_i - E_f \quad \text{emission}$$

$$E_p = E_f - E_i \quad \text{absorption}$$

$$E_n = \frac{-13.6}{n^2}eV$$

$$\Delta x\Delta p \geq \frac{h}{2\pi}$$

$$N = N_0\left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$$

$$A = A_0\left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$$

Electromagnetism Parallel Conductors

$$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

Constants:

$g = 9.80\ m/s^2$ or N/kg

$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$

$M_E = 5.98 \times 10^{24}$ kg

$r_E = 6.38 \times 10^6$ m

$k = 8.99 \times 10^9\ Nm^2/C^2$

$e = 1.6 \times 10^{-19}$ C

$\mu_o = 4\pi \times 10^{-7}$ Tm/A

$c = 3.00 \times 10^8$ m/s

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