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大学物理 之《光学》

一、质点运动学

① $|\int_a^b d\vec{r}| = |\vec{r}_b - \vec{r}_a|$ 位移模长 ② $\int_a^b |d\vec{r}| = S_{ab}$ 路程 ③ $\int_a^b d\vec{r} = \vec{r}_b - \vec{r}_a$

切向加速度 $a_t = \frac{dv}{dt}$. $a_n = \frac{v^2}{\rho}$; 极坐标 径向 $a_r = \frac{d^2r}{dt^2} - r\omega^2$. 横向 $a_\theta = r\frac{d^2\theta}{dt^2} + 2\frac{dr}{dt}\cdot\frac{d\theta}{dt}$

二、质点运动定律

三、机械能和功

保守力 $\oint \vec{F}\cdot d\vec{r} = 0$ $\vec{F} = -\nabla E_p = -(\frac{\partial}{\partial x}\vec{i} + \frac{\partial}{\partial y}\vec{j} + \frac{\partial}{\partial z}\vec{k})E_p$

四、动量和角动量

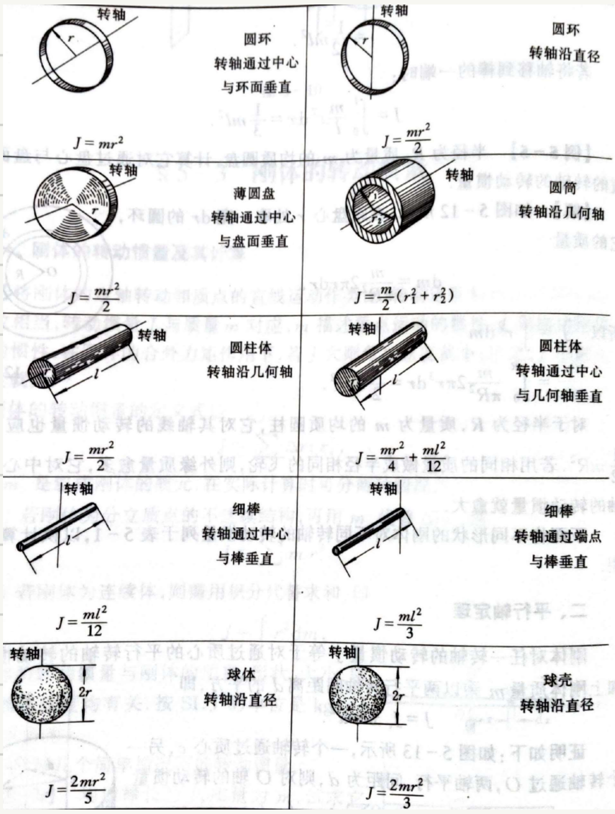
$e = \frac{v_2' - v_1'}{v_1 - v_2}$

$$\begin{cases} v_1' = v_1 - m_2\frac{(1+e)(v_1-v_2)}{m_1+m_2} \\ v_2' = v_2 + m_2\frac{(1+e)(v_1-v_2)}{m_1+m_2} \end{cases}$$

变质量 $F = m\frac{dv}{dt} + u\frac{dm}{dt}$

角动量 $\vec{L} = \vec{r}\times\vec{p}$ $\vec{M} = \vec{r}\times\vec{F} = \frac{d\vec{L}}{dt}$

五、刚体力学基础



$\vec{\alpha} = \frac{d^2\vec{\theta}}{dt^2}$ $\vec{a}_t = \vec{\alpha}\times\vec{r}$. $\vec{a}_n = \vec{\omega}\times(\vec{\omega}\times\vec{r})$

$J = \sum m_i r_i^2 = J_c + md^2$

$\vec{M} = J\vec{\alpha}$, $\vec{L} = J\vec{\omega}$, $M dt = L - L_0$

$E_k = \frac{1}{2}J\omega^2$, $A = \int M d\theta = E_k - E_{k0}$

进动 $\vec{M} = \vec{\omega}_p \times \vec{L}$. $\omega_p = \frac{M}{J\omega} = \frac{mgr}{J\omega}$

电扇 $P = M\omega$

六、振动力学基础

$x = A\cos(\omega t + \varphi)$. $\omega = \sqrt{\frac{k}{m}}$, $T = 2\pi\sqrt{\frac{m}{k}}$

$E_p = \frac{1}{2}kx^2$, $E_k = \frac{1}{2}mv^2$, $E = \frac{1}{2}kA^2$

同向同频 $x = A\cos(\omega t + \varphi)$ $A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos(\varphi_2 - \varphi_1)}$

*阻尼 $\tan\varphi = \frac{A_1\sin\varphi_1 + A_2\sin\varphi_2}{A_1\cos\varphi_1 + A_2\cos\varphi_2}$

七、狭义相对论基础

$\Delta t = \frac{\Delta t_0}{\sqrt{1-\frac{u^2}{c^2}}}$ $l = l_0\sqrt{1-\frac{u^2}{c^2}}$

$$\begin{cases} x' = \frac{x-ut}{\sqrt{1-\frac{u^2}{c^2}}}, & t' = \frac{t-\frac{u}{c^2}x}{\sqrt{1-\frac{u^2}{c^2}}} \\ x = \frac{x+ut}{\sqrt{1-\frac{u^2}{c^2}}}, & t = \frac{t+\frac{u}{c^2}x}{\sqrt{1-\frac{u^2}{c^2}}} \end{cases}$$

八、热力学平衡态

$pV = \nu RT$, $R = 8.31$

$p = nkT$, n: 分子数密度 $k = \frac{R}{N_A} = 1.38\times10^{-23}$

理想压强 $p = \frac{1}{3}nm\overline{v^2} = \frac{2}{3}n\bar{\varepsilon}_t$, 平均平动动能 $\bar{\varepsilon}_t = \frac{3}{2}kT$

平均动能: $\frac{3}{2}kT$, $\frac{5}{2}kT$, $3kT$ 内能 $E = \nu\frac{i}{2}RT$

九、热力学定律

过程	过程方程	吸收热量 Q	内能增量 ΔE	对外作功 A	摩尔热容 C_m
等体	$\frac{p}{T}=$恒量	$\frac{m}{M}C_{V,m}(T_2-T_1)$	$\frac{m}{M}C_{V,m}(T_2-T_1)$	0	$C_{V,m}=\frac{i}{2}R$
等压	$\frac{V}{T}=$恒量	$\frac{m}{M}C_{p,m}(T_2-T_1)$	$\frac{m}{M}C_{V,m}(T_2-T_1)$	$\frac{m}{M}R(T_2-T_1)$ 或 $p(V_2-V_1)$	$C_{p,m}=\frac{i+2}{2}R$ $=C_{V,m}+R$
等温	$pV=$恒量	$\frac{m}{M}RT\ln\frac{V_2}{V_1}$ 或$\frac{m}{M}RT\ln\frac{p_1}{p_2}$	0	$\frac{m}{M}RT\ln\frac{V_2}{V_1}$ 或$\frac{m}{M}RT\ln\frac{p_1}{p_2}$	∞
绝热	$pV^\gamma=$恒量 $V^{\gamma-1}T=$恒量 $p^{\gamma-1}T^{-\gamma}$ $=$恒量	0	$\frac{m}{M}C_{V,m}(T_2-T_1)$	$-\frac{m}{M}C_{V,m}(T_2-T_1)$ 或$\frac{p_1V_1-p_2V_2}{\gamma-1}$	0
多方	$pV^n=$恒量 $V^{n-1}T=$恒量 $p^{n-1}T^{-n}$ $=$恒量	$A+\Delta E$ 或 $\frac{m}{M}C_m(T_2-T_1)$	$\frac{m}{M}C_{V,m}(T_2-T_1)$	$\frac{p_1V_1-p_2V_2}{n-1}$	$C_m=\frac{(n-\gamma)R}{(n-1)(\gamma-1)}$ $=\frac{n-\gamma}{n-1}C_{V,m}$ $=C_{V,m}-\frac{R}{n-1}$

十七、机械波

软绳 $u=\sqrt{\frac{F}{\rho_l}}$

固体 $u=\sqrt{\frac{G}{\rho}}$横 $=\sqrt{\frac{Y}{\rho}}$纵

气体 $u=\sqrt{\frac{\gamma RT}{m}}$

波动方程 $\frac{dy^2}{dt^2}=u^2\frac{dy^2}{dx^2}$

能量密度 $\varepsilon_k=\frac{dE_k}{dV}$

$=\frac{1}{2}\rho\omega^2A^2\sin^2(\omega(t-\frac{x}{u})+\varphi)$

$\varepsilon_p=\frac{dE_p}{dV}=\frac{1}{2}\rho\omega^2A^2\sin^2(\ )$

$\varepsilon=\rho\omega^2A^2\sin^2(\ )$ $\quad\bar{\varepsilon}=\frac{1}{2}\rho\omega^2A^2$

能流密度 $J=\varepsilon u$ $\quad I=\bar{\varepsilon}u=\frac{1}{2}\rho\omega^2A^2u$(强度)

多普勒 $\nu=\frac{u\pm v_r\cos\alpha}{u\mp v_s\cos\beta}\nu_s$

相对论多普勒

红移 $1+z=(1+\frac{v}{c})\gamma=\frac{1-v\cos\theta/c}{\sqrt{1-\frac{v^2}{c^2}}}$ $\quad z\overset{\text{def}}{=}\frac{\lambda_o-\lambda_e}{\lambda_e}$ $\quad$ 引力红移 $1+z=\frac{1}{\sqrt{1-\frac{2GM}{rc^2}}}$

视超光速

$$AB = v\delta t$$
$$AC = v\delta t\cos\theta$$
$$BC = v\delta t\sin\theta$$
$$t_2-t_1=\delta t$$
$$t_1'=t_1+\frac{D_L+v\delta t\cos\theta}{c}$$
$$t_2'=t_2+\frac{D_L}{c}$$
$$\delta t'=t_2'-t_1'=t_2-t_1-\frac{v\delta t\cos\theta}{c}=\delta t-\frac{v\delta t\cos\theta}{c}=\delta t(1-\beta\cos\theta),\text{ where }\beta=\frac{v}{c}$$
$$\delta t=\frac{\delta t'}{1-\beta\cos\theta}$$
$$BC=D_L\sin\phi\approx\phi D_L=v\delta t\sin\theta\Rightarrow\phi D_L=v\sin\theta\frac{\delta t'}{1-\beta\cos\theta}$$

沿着路径 CB 的观测横向速度为 $v_T=\frac{\phi D_L}{\delta t'}=\frac{v\sin\theta}{1-\beta\cos\theta}$

$$\beta_T=\frac{v_T}{c}=\frac{\beta\sin\theta}{1-\beta\cos\theta}$$
$$\frac{\partial\beta_T}{\partial\theta}=\frac{\partial}{\partial\theta}\left[\frac{\beta\sin\theta}{1-\beta\cos\theta}\right]=\frac{\beta\cos\theta}{1-\beta\cos\theta}-\frac{(\beta\sin\theta)^2}{(1-\beta\cos\theta)^2}=0$$
$$\Rightarrow\beta\cos\theta(1-\beta\cos\theta)^2=(1-\beta\cos\theta)(\beta\sin\theta)^2$$