Institutt for fysikk 2016

Formelliste
TFY4115 Fysikk

Formlenes gyldighetsområde og de ulike symbolenes betydning antas å være kjent. Symbolbruk som i forelesningene.
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Fysiske konstanter:

$N_{\mathrm{A}} = 6,02 \cdot 10^{23}\,\mathrm{mol}^{-1}$ $\quad$ $\mathrm{u} = \frac{1}{12}\, m(^{12}\mathrm{C}) = \frac{10^{-3}\,\mathrm{kg/mol}}{N_{\mathrm{A}}} = 1,66 \cdot 10^{-27}\mathrm{kg}$

$k_{\mathrm{B}} = 1,38 \cdot 10^{-23}\,\mathrm{J/K}$ $\quad$ $R = N_{\mathrm{A}} k_{\mathrm{B}} = 8,31\,\mathrm{J\,mol^{-1}K^{-1}}$ $\quad$ $\sigma = 5,67 \cdot 10^{-8}\,\mathrm{Wm^{-2}K^{-4}}$

$c = 2,9979 \cdot 10^{8}\,\mathrm{m/s}$ $\quad$ $h = 6,63 \cdot 10^{-34}\,\mathrm{Js}$ $\quad$ $0°\mathrm{C} = 273\,\mathrm{K}$ $\quad$ $g = 9,81\,\mathrm{m/s^2}$

SI-enheter:

Fundamentale SI-enheter: meter (m) sekund (s) kilogram (kg) ampere (A) kelvin (K) mol

Noen avledede SI-enheter: $\mathrm{N = kg\,m/s^2}$ $\mathrm{Pa = N/m^2}$ $\mathrm{J = N\,m}$ $\mathrm{W = J/s}$ $\mathrm{rad = m/m = 1}$ $\mathrm{Hz = omdr/s}$

Varianter: $\mathrm{kWh = 3,6\,MJ}$ $\mathrm{m/s = 3,6\,km/h}$ $\mathrm{atm = 1,013 \cdot 10^5\,Pa = 1013\,hPa = 1013\,mb}$ $\mathrm{1\,cal = 4,19\,J}$

Dekadiske prefikser: $\mathrm{p} = 10^{-12}$ $\mathrm{n} = 10^{-9}$ $\mu = 10^{-6}$ $\mathrm{m} = 10^{-3}$ $\mathrm{h} = 10^{2}$ $\mathrm{k} = 10^{3}$ $\mathrm{M} = 10^{6}$ $\mathrm{G} = 10^{9}$ $\mathrm{T} = 10^{12}$

Klassisk mekanikk:

$\frac{\mathrm{d}\vec{p}}{\mathrm{d}t} = \vec{F}(\vec{r}, t)$ $\quad$ der $\quad$ $\vec{p}(\vec{r}, t) = m\vec{v} = m\dot{\vec{r}}$ $\quad$ $\vec{F} = m\vec{a}$

Konstant $\vec{a}$: $\vec{v} = \vec{v}_0 + \vec{a}t$ $\quad$ $\vec{r} = \vec{r}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$ $\quad$ $v^2 - v_0^2 = 2\vec{a} \cdot (\vec{r} - \vec{r}_0)$

Konstant $\vec{\alpha}$: $\omega = \omega_0 + \alpha t$ $\quad$ $\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$ $\quad$ $\omega^2 - \omega_0^2 = 2\alpha\,(\theta - \theta_0)$

Arbeid: $\mathrm{d}W = \vec{F} \cdot \mathrm{d}\vec{s}$ $\quad$ $W_{12} = \int_1^2 \vec{F} \cdot \mathrm{d}\vec{s}$ $\quad$ Kinetisk energi: $E_{\mathrm{k}} = \frac{1}{2}mv^2$

$E_{\mathrm{p}}(\vec{r})$ = potensiell energi (tyngde: mgh, fjær: $\frac{1}{2}kx^2$) $\quad$ $E = \frac{1}{2}m\vec{v}^2 + E_{\mathrm{p}}(\vec{r}) + \text{friksjonsarbeide} = \text{konstant}$

Konservativ kraft: $\vec{F} = -\vec{\nabla} E_{\mathrm{p}}(\vec{r})$ $\quad$ f.eks. $F_x = -\frac{\partial}{\partial x} E_{\mathrm{p}}(x, y, z)$ $\quad$ Hookes lov (fjær): $F_x = -kx$

Tørr friksjon: $|F_{\mathrm{f}}| \leq \mu_{\mathrm{s}}\, F_{\perp}$ eller $|F_{\mathrm{f}}| = \mu_{\mathrm{k}}\, F_{\perp}$ $\quad$ Våt friksjon: $\vec{F}_{\mathrm{f}} = -k_{\mathrm{f}}\vec{v}$ eller $\vec{F}_{\mathrm{f}} = -bv^2\,\hat{v}$

Kraftmoment (dreiemoment) om origo: $\vec{\tau} = \vec{r} \times \vec{F}$, $\quad$ Arbeid: $\mathrm{d}W = \tau \mathrm{d}\theta$

Betingelser for statisk likevekt: $\Sigma \vec{F}_i = \vec{0}$ $\quad$ $\Sigma \vec{\tau}_i = \vec{0}$, uansett valg av referansepunkt for $\vec{\tau}_i$

Massemiddelpunkt (tyngdepunkt): $\vec{R} = \frac{1}{M}\sum m_i \vec{r}_i \to \frac{1}{M}\int \vec{r}\,\mathrm{d}m$ $\quad$ $M = \sum m_i$

Kraftimpuls: $\int_{\Delta t} \vec{F}(t)\mathrm{d}t = m\Delta\vec{v}$ $\quad$ Alle støt: $\sum \vec{p}_i = \text{konstant}$ $\quad$ Elastisk støt: $\sum E_i = \text{konstant}$

Vinkelhastighet: $\vec{\omega} = \omega\,\hat{\mathbf{z}}$ $\quad$ $|\,\vec{\omega}\,| = \omega = \dot{\phi}$ $\quad$ Vinkelakselerasjon: $\vec{\alpha} = \mathrm{d}\vec{\omega}/\mathrm{d}t$ $\quad$ $\alpha = \mathrm{d}\omega/\mathrm{d}t = \ddot{\phi}$

Sirkelbev.: $v = r\omega$ $\quad$ Sentripetalaks.: $\vec{a} = -v\omega\,\hat{\mathbf{r}} = -\frac{v^2}{r}\,\hat{\mathbf{r}} = -r\omega^2\,\hat{\mathbf{r}}$ $\quad$ Baneaks.: $a_\theta = \frac{\mathrm{d}v}{\mathrm{d}t} = r\,\frac{\mathrm{d}\omega}{\mathrm{d}t} = r\,\alpha$

Spinn (dreieimpuls) og spinnsatsen: $\vec{L} = \vec{r} \times \vec{p}$ $\quad$ $\vec{\tau} = \frac{\mathrm{d}\vec{L}}{\mathrm{d}t}$, $\quad$ stive legemer: $\vec{L} = I\,\vec{\omega}$ $\quad$ $\vec{\tau} = I\,\frac{\mathrm{d}\vec{\omega}}{\mathrm{d}t}$

Spinn for rullende legeme: $\vec{L} = \vec{R}_{\mathrm{cm}} \times M\vec{V} + I_0\vec{\omega}$, $\quad$ Rotasjonsenergi: $E_{\mathrm{k,rot}} = \frac{1}{2}\,I\,\omega^2$,
der treghetsmoment $I \stackrel{\mathrm{def}}{=} \sum m_i r_i^2 \to \int r^2 \mathrm{d}m$ $\quad$ med r = avstanden fra m_i ($\mathrm{d}m$) til rotasjonsaksen.

Med aksen gjennom massemiddelpunktet: $I \to I_0$, og da gjelder:
kule: $I_0 = \frac{2}{5}\,MR^2$ $\quad$ kuleskall: $I_0 = \frac{2}{3}\,MR^2$ $\quad$ sylinder/skive: $I_0 = \frac{1}{2}MR^2$ $\quad$ åpen sylinder/ring: $I_0 = MR^2$
lang, tynn stav: $I_0 = \frac{1}{12}\,M\ell^2$ $\quad$ Parallellakseteoremet (Steiners sats): $I = I_0 + Mb^2$

Udempet svingning: $\ddot{x}+\omega_0^2 x=0$ $\quad T=\dfrac{2\pi}{\omega_0}$ $\quad f_0=\dfrac{1}{T}=\dfrac{\omega_0}{2\pi}$ $\quad$ Masse/fjær: $\omega_0=\sqrt{\dfrac{k}{m}}$

Tyngdependel: $\ddot{\theta}+\omega_0^2\sin\theta=0,\quad \text{der}\sin\theta\approx\theta$ $\quad$ Fysisk: $\omega_0=\sqrt{\dfrac{mgd}{I}}$ $\quad$ Matematisk: $\omega_0=\sqrt{\dfrac{g}{\ell}}$

Dempet svingning: $\ddot{x}+2\gamma\dot{x}+\omega_0^2x=0$ $\quad$ Masse/fjær: $\omega_0=\sqrt{k/m}$ $\quad \gamma=b/(2m)$

$\gamma<\omega_0$ Underkritisk dempet: $x(t)=A\,\mathrm{e}^{-\gamma t}\cos(\omega_\mathrm{d}t+\phi)$ med $\omega_\mathrm{d}=\sqrt{\omega_0^2-\gamma^2}$
$\gamma>\omega_0$ Overkritisk dempet: $x(t)=A\mathrm{e}^{-\gamma t}\mathrm{e}^{\alpha t}+B\mathrm{e}^{-\gamma t}\mathrm{e}^{-\alpha t}$ med $\alpha=\sqrt{\gamma^2-\omega_0^2}$,
$\gamma=\omega_0$ Kritisk dempet: $x(t)=(A+tB)\,\mathrm{e}^{-\gamma t}$

Tvungne svingninger: $\ddot{x}+2\gamma\dot{x}+\omega_0^2x=f_0\cos\omega t$, med (partikulær)løsning når $t\gg\gamma^{-1}$:

$$x(t)=x_0\cos(\omega t-\delta),\quad \text{der}\quad x_0(\omega)=\frac{f_0}{\sqrt{(\omega_0^2-\omega^2)^2+4\gamma^2\omega^2}}\qquad \tan\delta=\frac{2\gamma\omega}{\omega_0^2-\omega^2}$$

Termisk fysikk:

n= antall mol $\quad N=nN_\mathrm{A}$ = antall molekyler $\quad n_\mathrm{f}$ = antall frihetsgrader

$\alpha=\ell^{-1}\mathrm{d}\ell/\mathrm{d}T \qquad \beta=V^{-1}\mathrm{d}V/\mathrm{d}T$

$\Delta U=Q-W \qquad C=\frac{1}{n}\frac{đQ}{\mathrm{d}T} \qquad C'=\frac{1}{m}\frac{đQ}{\mathrm{d}T} \qquad L'_\mathrm{s}=\frac{đQ_\mathrm{s}}{\mathrm{d}m} \qquad L'_\mathrm{f}=\frac{đQ_\mathrm{f}}{\mathrm{d}m}$

$pV=nRT=Nk_\mathrm{B}T \qquad pV=N\,\frac{2}{3}\,\langle E_\mathrm{k}\rangle \qquad \langle E_\mathrm{k}\rangle=\frac{1}{2}m\left\langle v^2\right\rangle=\frac{3}{2}k_\mathrm{B}T \qquad W=p\Delta V \qquad W=\int_1^2 p\mathrm{d}V$

Ideell gass: $C_V=\frac{1}{2}n_\mathrm{f}R \qquad C_p=\frac{1}{2}(n_\mathrm{f}+2)R=C_V+R \qquad \gamma=\dfrac{C_p}{C_V}=\dfrac{n_\mathrm{f}+2}{n_\mathrm{f}} \qquad \mathrm{d}U=C_V\,n\,\mathrm{d}T$

Adiabat: $Q=0$ $\quad$ Ideell gass: $pV^\gamma=$ konst. $\quad TV^{\gamma-1}=$ konst. $\quad T^\gamma p^{1-\gamma}=$ konst.

Virkningsgrader for varmekraftmaskiner: $\eta=\dfrac{W}{Q_\mathrm{inn}}$ $\quad$ Carnot: $\eta_\mathrm{C}=1-\dfrac{T_\mathrm{L}}{T_\mathrm{H}}$ $\quad$ Otto: $\eta_\mathrm{O}=1-\dfrac{1}{r^{\gamma-1}}$

Effektfaktorer: Kjøleskap: $\eta_\mathrm{K}=\left|\dfrac{Q_\mathrm{inn}}{W}\right|\xrightarrow{\text{Carnot}}\dfrac{T_\mathrm{L}}{T_\mathrm{H}-T_\mathrm{L}}$ $\quad$ Varmepumpe: $\eta_\mathrm{V}=\left|\dfrac{Q_\mathrm{ut}}{W}\right|\xrightarrow{\text{Carnot}}\dfrac{T_\mathrm{H}}{T_\mathrm{H}-T_\mathrm{L}}$

Clausius: $\sum\dfrac{Q}{T}\leq 0 \qquad \oint\dfrac{đQ}{T}\leq 0$ $\quad$ Entropi: $\mathrm{d}S=\dfrac{đQ_\mathrm{rev}}{T} \qquad \Delta S_{12}=\displaystyle\int_1^2\frac{đQ_\mathrm{rev}}{T}$

1. og 2. hovedsetning: $\mathrm{d}U=đQ-đW=T\mathrm{d}S-p\mathrm{d}V$

Entropiendring $1\to 2$ i en ideell gass: $\Delta S_{12}=nC_V\ln\dfrac{T_2}{T_1}+nR\ln\dfrac{V_2}{V_1}$

Varmeledning: $\dot{Q}=\dfrac{\kappa\,A}{\ell}\Delta T=\dfrac{1}{R}\Delta T \qquad j_x=-\kappa\dfrac{\partial T}{\partial x} \qquad \vec{j}=-\kappa\vec{\nabla}T$ $\quad$ Varmeovergang: $j=\alpha\Delta T$

Stråling: $j_\mathrm{s}=e\sigma T^4=a\sigma T^4=(1-r)\sigma T^4$

Planck: $j_\mathrm{s}(T)=\displaystyle\int_0^\infty g(\lambda,T)\,\mathrm{d}\lambda$ $\quad$ der j_s's frekvensspekter $=g(\lambda,T)=\dfrac{\mathrm{d}j_\mathrm{s}}{\mathrm{d}\lambda}=2\pi hc^2\cdot\dfrac{\lambda^{-5}}{\exp\left(\frac{hc}{k_\mathrm{B}T\lambda}\right)-1}$

Wiens forskyvningslov: $\lambda_\mathrm{max}\,T=2898\,\mu\mathrm{m\,K}$