Institutt for fysikk 2011

Formelliste
TFY4115 Fysikk

Formlenes gyldighetsområde og de ulike symbolenes betydning antas å være kjent. Symbolbruk som i forelesningene. (2 sider) Siste rev.: 28.11.11(retta $\mathrm{d}U = C_V\, n\mathrm{d}T$) 2.12.11($\eta$ for virkn.grad)) 6.12.11(varmeovergang)

Fysiske konstanter:

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

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

$c = 2,9997 \cdot 10^{8}\,\mathrm{m/s}$ $\quad h = 6,63 \cdot 10^{-34}\,\mathrm{Js}$ $\quad 0°\mathrm{C} = 273\,\mathrm{K}$ $\quad g = 9,81\,\mathrm{m/s^2}$

SI-enheter:

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

Noen avledete SI-enheter : newton (N) pascal (Pa) joule (J) watt (W) hertz (Hz)

Varianter: kWh = 3,6 MJ m/s = 3,6 km/h ångstrøm = Å= 10^{-10} m atm = $1{,}013 \cdot 10^5$ Pa

Klassisk mekanikk:

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

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

Newtons gravitasjonslov: $\vec{F} = -G\frac{m_1 m_2}{r^2}\,\hat{\mathbf{r}}$ $\quad E_\mathrm{p}(r) = -G\frac{M}{r}m$ $\quad G = 6,673 \cdot 10^{-11}\,\mathrm{Nm^2/kg^2}$

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): $\vec{\tau} = (\vec{r} - \vec{r}_0) \times \vec{F}$, med $\vec{r}_0$ som valgt referansepunkt $\quad$ 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 $\vec{r}_0$ i $\vec{\tau}_i$

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

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: $\vec{L} = \vec{r} \times \vec{p}$ $\quad \vec{\tau} = \frac{\mathrm{d}}{\mathrm{d}t}\vec{L}$, $\quad$ stive legemer: $\vec{L} = I\,\vec{\omega}$ $\quad \vec{\tau} = I\,\frac{\mathrm{d}\vec{\omega}}{\mathrm{d}t}$

Rotasjonsenergi: $E_\mathrm{k,rot} = \frac{1}{2}\,I\,\omega^2$,
der treghetsmoment $I \stackrel{\mathrm{def}}{=} \sum m_i r_i^2 \rightarrow \int r^2\mathrm{d}m$ $\quad$ med r = avstanden fra m_i ($\mathrm{d}m$) til rotasjonsaksen.

Med aksen gjennom massemiddelpunktet: $I \rightarrow I_0$, 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: $\ddot{x} + \omega_0^2 x = 0$ $T = \dfrac{2\pi}{\omega_0}$ $f_0 = \dfrac{1}{T} = \dfrac{\omega_0}{2\pi}$ Masse/fjær: $\omega_0 = \sqrt{\dfrac{k}{m}}$

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

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

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

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

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

"Rakettlikningen": $m(t)\dfrac{\mathrm{d}\vec{v}}{\mathrm{d}t} = \vec{F}_\mathrm{Y} + \beta\vec{u}_\mathrm{ex}$ der $\beta = \dfrac{\mathrm{d}m}{\mathrm{d}t}$ og $\vec{u}_\mathrm{ex}$ = hast. utskutt masse relativ hovedmasse

Termisk fysikk:

n= antall mol $N = nN_\mathrm{A}$ = antall molekyler n_f = antall frihetsgrader

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

$\Delta U = Q - W$ $C = \frac{1}{n}\frac{đQ}{\mathrm{d}T}$ $C' = \frac{1}{m}\frac{đQ}{\mathrm{d}T}$

$pV = nRT = Nk_\mathrm{B}T$ $pV = N\,\frac{2}{3}\,\overline{E_\mathrm{K}}$ $\overline{E_\mathrm{K}} = \frac{1}{2}m\overline{v^2} = \frac{3}{2}k_\mathrm{B}T$ $W = p\Delta V$ $W = \int_1^2 p\mathrm{d}V$

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

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

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

Effektfaktorer: Kjøleskap: $\eta_\mathrm{K} = \left|\dfrac{Q_\mathrm{inn}}{W}\right| \xrightarrow{\text{Carnot}} \dfrac{T_\mathrm{L}}{T_\mathrm{H} - T_\mathrm{L}}$ 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: $\sum \dfrac{Q}{T} \leq 0$ $\oint \dfrac{đQ}{T} \leq 0$ Entropi: $\mathrm{d}S = \dfrac{đQ_\mathrm{rev}}{T}$ $\Delta S_{12} = \displaystyle\int_1^2 \dfrac{đQ_\mathrm{rev}}{T}$

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: $j_x = -\kappa\dfrac{\partial T}{\partial x}$ $\vec{j} = -\kappa\vec{\nabla}T$ Varmeovergang: $j = \alpha\Delta T$

Stråling: $j_s = e\sigma T^4 = a\sigma T^4 = (1 - r)\sigma T^4$ $j_s = \dfrac{c}{4}u(T)$

Planck: $u(T) = \displaystyle\int_0^\infty \eta(f, T)\mathrm{d}f$ der u's frekvensspekter $= \eta(f, T) = \dfrac{8\pi hf^3}{c^3}\cdot\dfrac{1}{\exp(hf/k_\mathrm{B}T) - 1}$