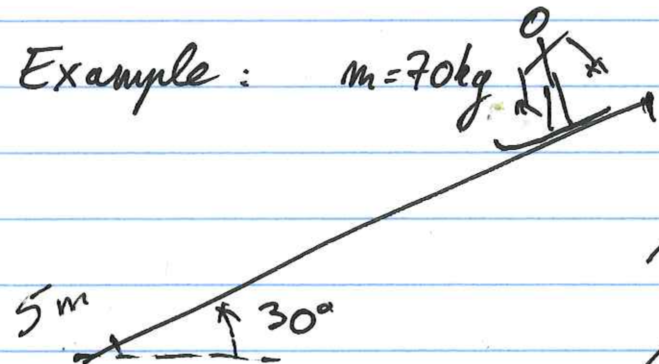
* Friction:

kinetic friction $f_k = \mu_k N$

static friction $0 \leq f_s \leq \mu_s N$

normal force ~~m~~ $N \neq$ weight W
not necessarily in same direction

* Example: $m = 70kg$



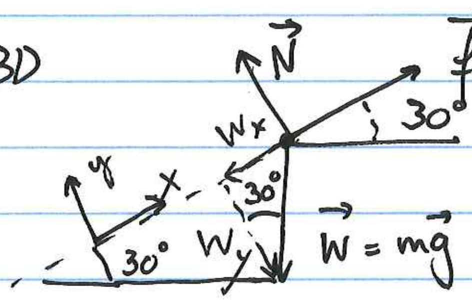
$V_0 = 0 m/s$

$\mu_{s, ice/wood} = 0.05$

$\mu_{k, ice/wood} = 0.03$

1) will the skier start moving?
2) what will be the velocity after skier has reached 5m?

FBD



$\vec{N}\,(0,\ N)$
$\vec{W}\,(-mg \sin 30°,\ -mg \cos 30°)$

$\vec{f}\,(f,\ 0)$

acceleration in y direction: $a_y = 0 \Rightarrow F_{net,y} = 0$

$N - mg \cos \underline{30°} = 0$

$\hookrightarrow \underline{N = 606\ N}$

if $a_x = 0$, what value for f_s do we need to have?

$a_x = 0 \Rightarrow F_{net,x} = 0$

$\hookrightarrow f_s - mg \sin 30° = 0$

$f_s = mg \sin 30° = 350\,N$

is $f_s < \mu_s N$? for $\mu_{s,\,ice/wood} = 0.05$

$\mu_s N = (0.05)(606N) \leq f_s$

for $\mu_{s,\,rubber/road} = 1$: $\mu_s N = 606N \geq f_s$

$a_x \neq 0 \rightarrow$ skier starts moving (1) ✓)

$F_{net,x} = f_k - mg \sin 30° = m a_x \neq 0$

$\hookrightarrow a_x = \dfrac{f_k - mg \sin 30°}{m} = \dfrac{\mu_k N - mg \sin 30°}{m}$

$= -4.7\,m/s^2 \quad < 0$

2) velocity after 5 m: $v^2 = v_0^2 + 2a_x(x - x_0)$

$x_0 = 0\,m \qquad a_x = -4.7\,m/s^2$

$x = -5\,m \qquad v_0 = 0\,m/s$

$v^2 = 2(-4.7\,m/s^2)(-5 - 0\,m) \Rightarrow v = -4.87\,m/s$

(down the slope)

* Elasticity & Hooke's law

change of the shape of an object under external force
deformation that is reversible

↳ Hooke's law is often valid

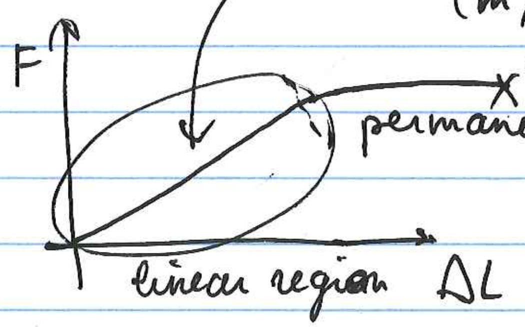
$$\underline{F} = k\,\underline{\Delta L},$$

force required (N)

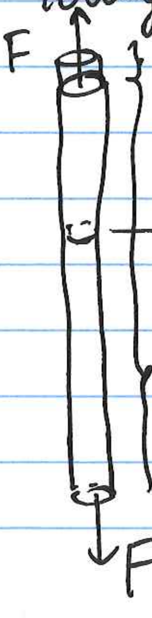
change in length (m)

Hooke's constant, specific to material $\left(\frac{N}{m}\right)$

how many windings does a spring have?
surface area of the cross section of the winding



* Young's modulus : only a property of the material



ΔL, change in length

A, cross sectional area

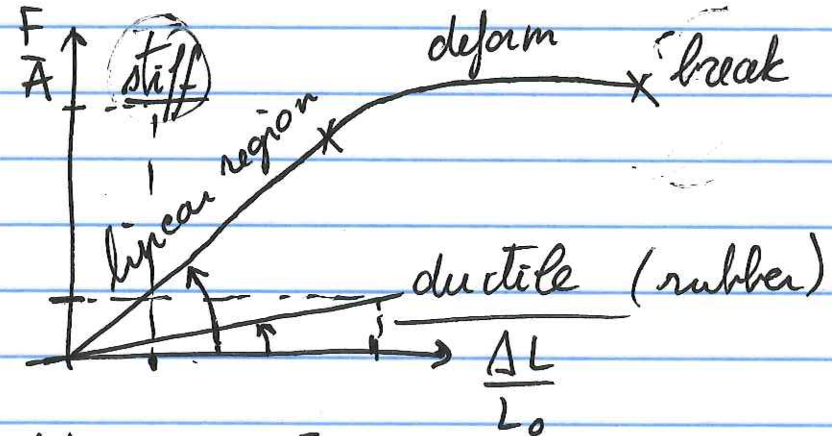
L_0, original length

$\Rightarrow F = k\Delta L$, with $k = \frac{AY}{L_0}$

$$\underbrace{\frac{F}{A}}_{\text{stress}\ \left(\frac{N}{m^2}\right)} = Y \underbrace{\frac{\Delta L}{L_0}}_{\text{strain (no units)}}$$

Y: Young's modulus $\left(\frac{N}{m^2}\right)$
↳ elastic

$$\underbrace{\frac{F}{A}}_{\text{stress}} = Y \underbrace{\frac{\Delta L}{L_0}}_{\text{strain}}$$



slope of $\underbrace{\frac{\Delta L}{L_0}}_{\text{strain}}$ versus $\underbrace{\frac{F}{A}}_{\text{stress}}$ graph $= Y$

* Femur : how much shorter does the femur get when you stand on it ?

$L_0 = 43\text{ cm} = 0.43\text{ m}$

$A = 8\text{ cm}^2 = 8\left(\frac{1}{100}\right)^2 \text{m}^2 = 8\times10^{-4}\text{ m}^2$

$Y_{bone} = 9\times10^9 \frac{N}{m^2}$

F half the weight, $m = 80\text{kg}$ $\quad \frac{F}{A} = Y\frac{\Delta L}{L_0}$

$$\Delta L = \frac{F}{A}\frac{L_0}{Y} = \frac{\frac{1}{2}(80\text{kg})(10\,^{m}/_{s^2})\cdot(0.43\text{m})}{(8\times10^{-4}\text{m}^2)\ (9\times10^9\frac{N}{m^2})}$$

$= 24\ \mu m$

Bone: compression: hydroxy apatite (crystals)
extension: collagen protein (strands)

↳ osteoporosis: larger mineral content in the bone
→ more brittle / stiff

children: smaller mineral content
→ more ductile / weaker