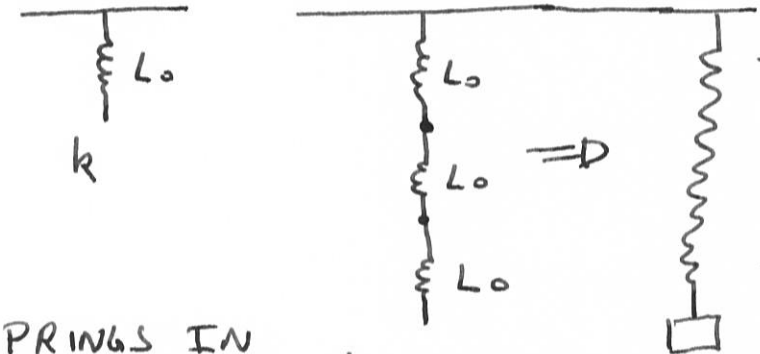
SPRINGS



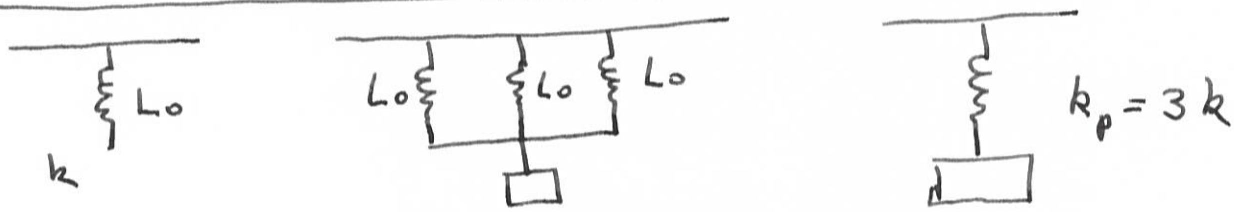
THIS LOOKS LIKE ONE SPRING WITH

$$k_s = \frac{1}{3} k$$

SPRINGS IN SERIES:

$$\boxed{k_s = \frac{1}{n_s} k}$$

LONGER SPRING of n_s identical springs is only $\frac{1}{n_s}$ as stiff as each of the shorter springs

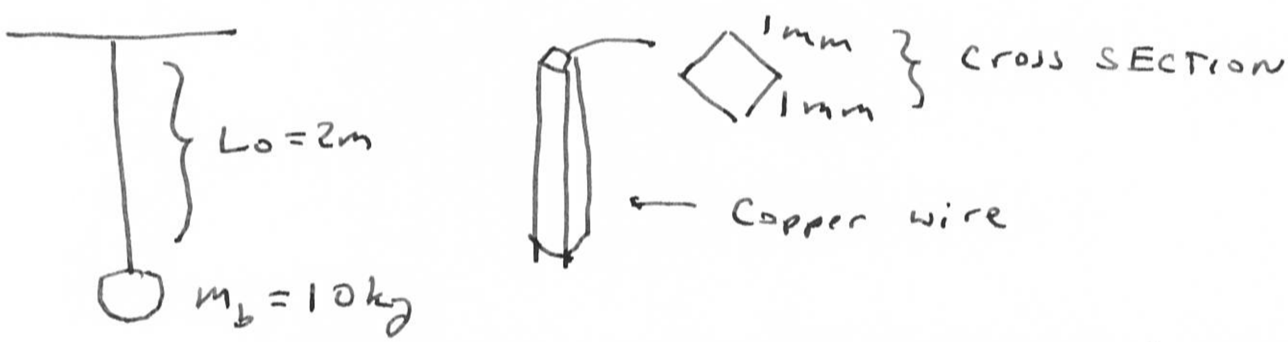


FORCE SHARED OVER 3 springs

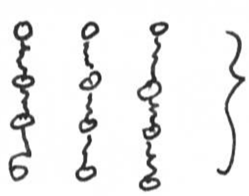
~~LONGE~~ PARALLEL COMBINATION OF n_p indentical springs results in a stiffer spring constant

$$\boxed{k_p = n_p k}$$

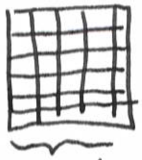
WE WILL APPLY THIS TO THE FOLLOWING PROBLEM



WE WILL TREAT ATOMS IN COPPER WIRE AS IF THEY WERE HELD TOGETHER BY SPRINGS.



Wire. We need to know number of Chains (n_p) and length of chain (n_s)



$L = n_a d$

$A = (n_a d)^2$ — ↑ Cross-section; ↖ atom size

n_a^2 = number of chains.

$n_a^2 = \dfrac{A}{d^2}$

$A = (10^{-3} m)^2 = 10^{-6} m^2$ $\quad d = 2.2 \times 10^{-10} m$ $\quad \boxed{n_p = 2 \times 10^{13}}$

$$n_p = n_a^2 = \frac{10^{-6} m^2}{(2.2 \times 10^{-10} m)^2} = 2 \times 10^{13}$$ } Number of chains in PARALLEL

$n_s \Rightarrow$ Length $\Rightarrow$ number of atoms

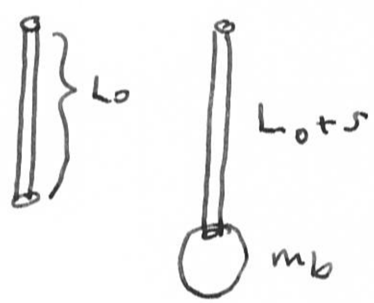
} $L = n_a d$

$$n_a = \frac{L_0}{d} = \frac{2m}{2 \times 10^{-10}} = 10^{10} \text{ atom}$$

$n_s \Rightarrow$ Number of springs in series. $\quad \boxed{n_s = 10^{10}}$

$n_s = n_a = 10^{10}$ chains (one for each atom)

WE STILL NEED k_{wire} $\quad \boxed{s = 1.5 \text{ mm}}$



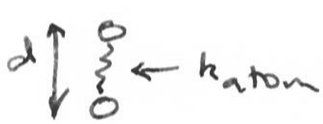
$F = k_{wire}(s)$

$\boxed{k_{wire} = 6.5 \times 10^4 N/m}$

$F = m_b g$
$= (10 kg)(9.8 m^2/s)$
$= 98 N$

Putting it all together

$$k_{wire} = \left(\frac{n_p}{n_s}\right) k_{atom} \Rightarrow k_{atom} = \left(\frac{n_s}{n_p}\right) k_{wire}$$



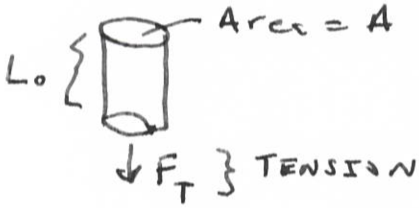
$$k_{atom} = \frac{10^{10}}{2 \times 10^{13}} \left[6.5 \times 10^4\right] N/m$$

$$\boxed{k_{atom} = 30 N/m}$$

↑ ROUGH ESTIMATE

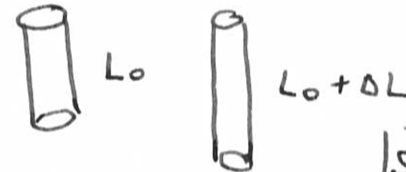
This is pretty large! ~~for an~~ AN ATOM HAS STIFF "SPRING" holding THE WIRE ~~[illegible]~~ Together!

STRESS, STRAIN, AND YOUNG'S MODULUS



$$\boxed{\text{STRESS} = F_T/A}$$

Note: A (the area) assumed NOT TO change.



[Normally $\Delta L \ll L_o$]

$$\boxed{\text{STRAIN} = \frac{\Delta L}{L_o}}$$

Young's modulus

STRESS ∝ STRAIN [STRESS BEHAVES LIKE STRAIN]

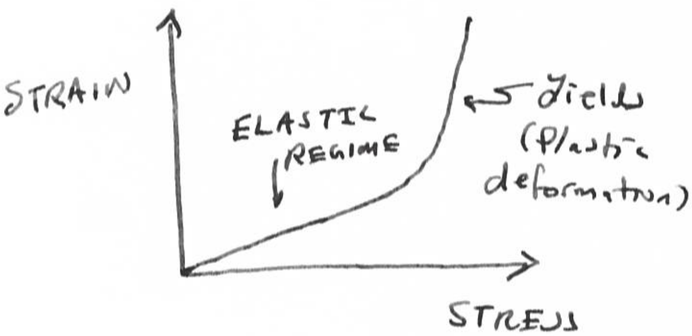
$$\boxed{\frac{F_T}{A} = Y \frac{\Delta L}{L_o}}$$

Y = Young's modulus

Note if A does not change (and L_o does not):

$$F_T = (AY/L_o)\,\Delta L = \frac{AY}{L_o} s \Rightarrow k_s s$$

$k_s \Rightarrow \frac{AY}{L_o}$ spring CONSTANT related to Young's modulus.

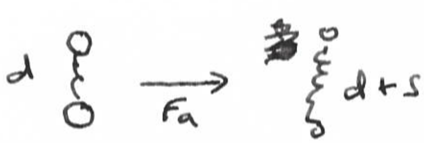


ELASTIC → WIRE OBEYS

$$\cancel{\frac{F_A}{A}} \quad \frac{F_T}{A} = Y \frac{\Delta L}{L_o}$$

Above a given stress → WIRE YIELDS → increases in length with small increase in force.

RELATING ATOM SPRINGS TO YOUNG'S MODULUS



$F_a = k_a s$ STRESS $\frac{F_a}{d^2} = \frac{k_a s}{d^2}$

STRAIN $= \frac{s}{d}$

$$\frac{F_a}{d^2} = \frac{k_a s}{d^2} = Y \frac{s}{d}$$

$$\boxed{Y = \frac{k_a}{d}}$$

PRETTY ROUGH ESTIMATE!

CHECK FOR COPPER

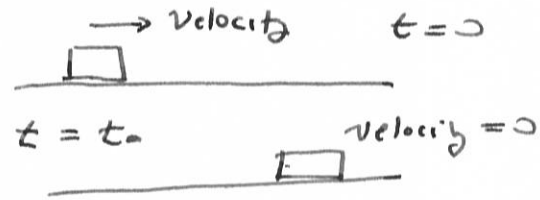
$k_a \approx 30\ N/m^2$ $\quad d \approx 2 \times 10^{-10}\ m$ $\quad \to 10^9\ N/m^2 = GPa$

$Y = \frac{k_a}{d} \approx \frac{30\ N/m}{2 \times 10^{-10}\ m} = \cancel{115}\ 150 \times 10^9\ N/m^2 = \underline{150\ GPa}$

FROM WEB $Y\ (Cu) = \underline{115\ GPa}$

FRICTION

SLIDING ⇒



An object sliding on surface will stop moving? Why? Changes momentum! MUST BE A <u>FORCE</u>!

WHAT IS THE FORCE?
** FRICTION **

Rough approximation

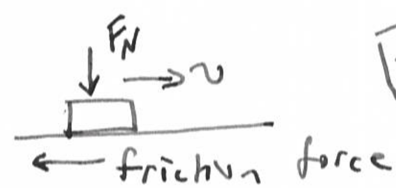
$f_{friction} \approx \mu_k F_N$

F_N = Normal force
μ_k = coefficient of $\boxed{\text{kinetic}}$ ~~friction~~ friction.
(sliding)

Direction of $f_{friction}$?

OPPOSITE TO THE MOTION.

$\boxed{F_N = -mg}$



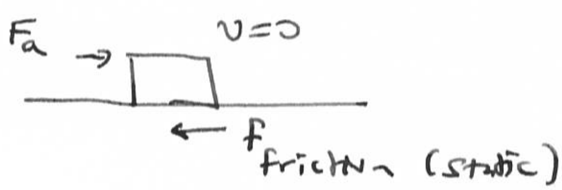
μ_k HAS NO UNITS!

$\mu_k \approx 0$ to 1.

$f_{fric} = \mu_k (mg)$

STATIC FRICTION

Apply F_a to STATIC ($v=0$) OBJECT. NOTHING HAPPENS!



$f_{friction\ (STATIC)} \leq \underbrace{\mu_s F_N}_{\text{MAX force before object moves}}$