Mon.	4.1-.5 Atomic nature of matter / springs	RE 4.a
Tues		EP 3, HW3: Ch 3 Pr's 42, 46, 58, 65, 72 & CP*
		RE 4.b
Wed.	4.6-.7, .9-.10 Stress, Strain, Young's Modulus, Compression, Sound	
	InStove: here noon; Science Poster Session: Hedco7pm~9pm	
Lab	L4: Young's Modulus & Speed of Sound (Read 4.11-.12)	RE 4.c laptop, smartphone…
Fri	4.11-.12; .14-.15 Sound in Solids, Analytical Solutions Quiz 3	
Mon.	4.8, .13 Friction and Buoyancy & Suction	RE 4.d
Tues.		EP 4, HW4: Ch 4 Pr's 46, 50, 81, 88 & CP
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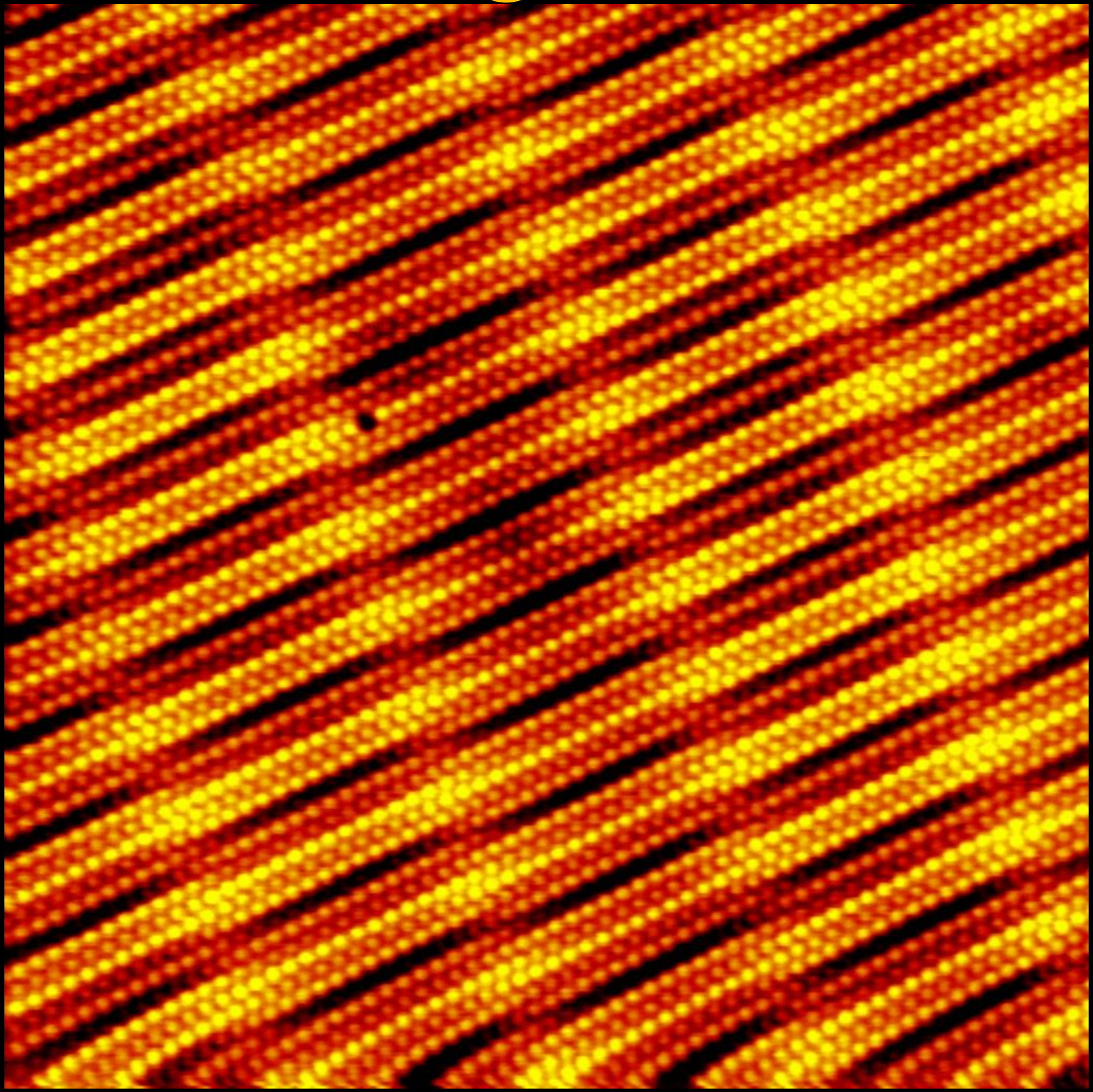
Fri.	Exam 1 (Ch 1-4)	

* Uses G = 6.7×10^{-11} N m^2/kg^2

The Atomic “hypothesis” (p. 139)

- All matter consists of atoms, whose typical radius is about 1×10^{-10}m
- Atoms attract each other when they are close to each other but not too close.
- Atoms repel each other when they get too close to each other.
- Atoms in solids, liquids, and gases keep moving even at very low temperatures.

Seeing atoms

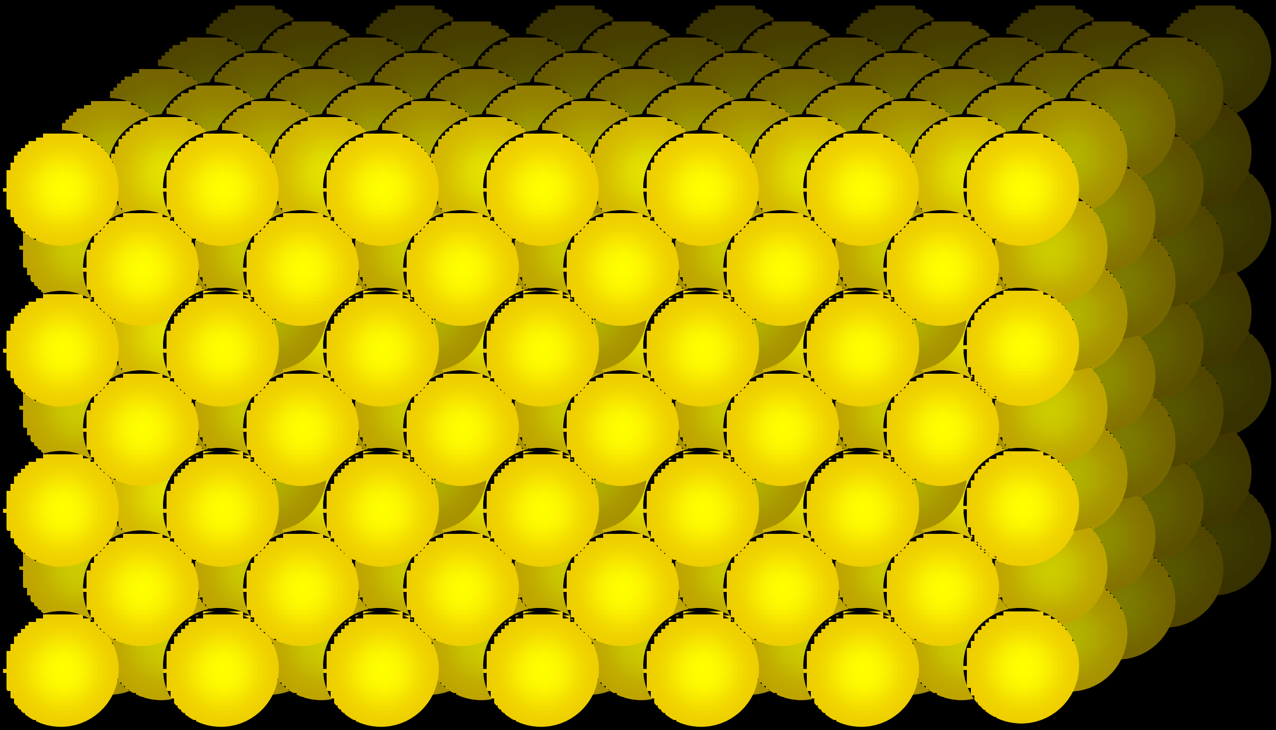


A 180×190 $Å^2$ Image of the Pt(001)-hex reconstructed surface taken with a custom Scanning Tunneling Microscope at Aarhus University's Scanning Probe Microscopy lab. The dark spot near the center is a single, missing atom.

Condensed Matter / Surface Science

Hex Reconstruction of Pt(001) Surface

- Platinum Crystal
  - Unit Cell
  - Bulk

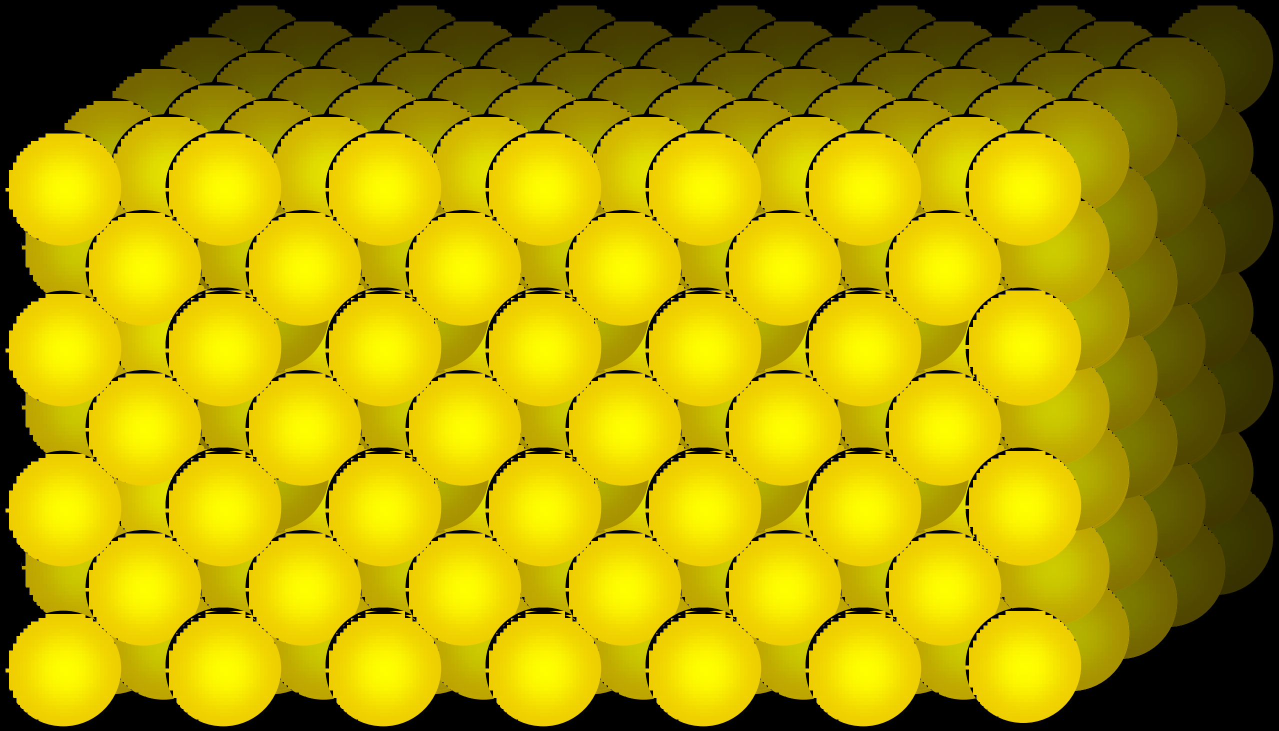


Condensed Matter / Surface Science

Hex Reconstruction of Pt(001) Surface

- Platinum Crystal
  - Unit Cell
  - Bulk
  - Cleaved (001) Surface
  - Reconstructed (001) Surface

?



Condensed Matter / Surface Science

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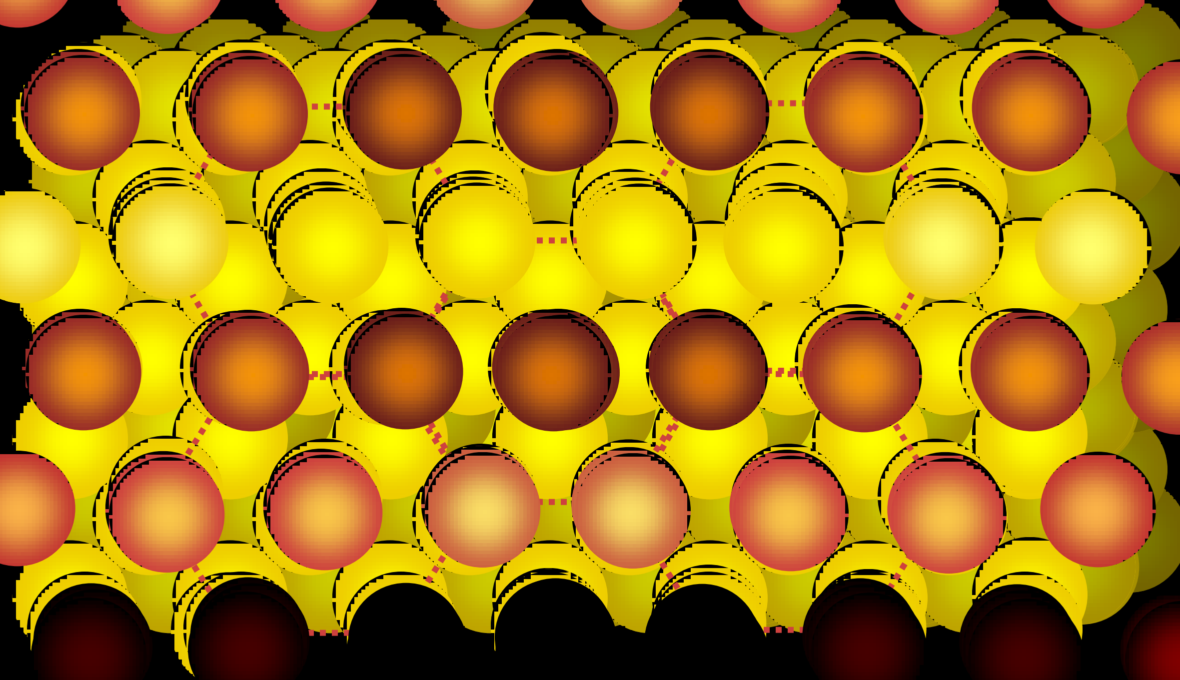
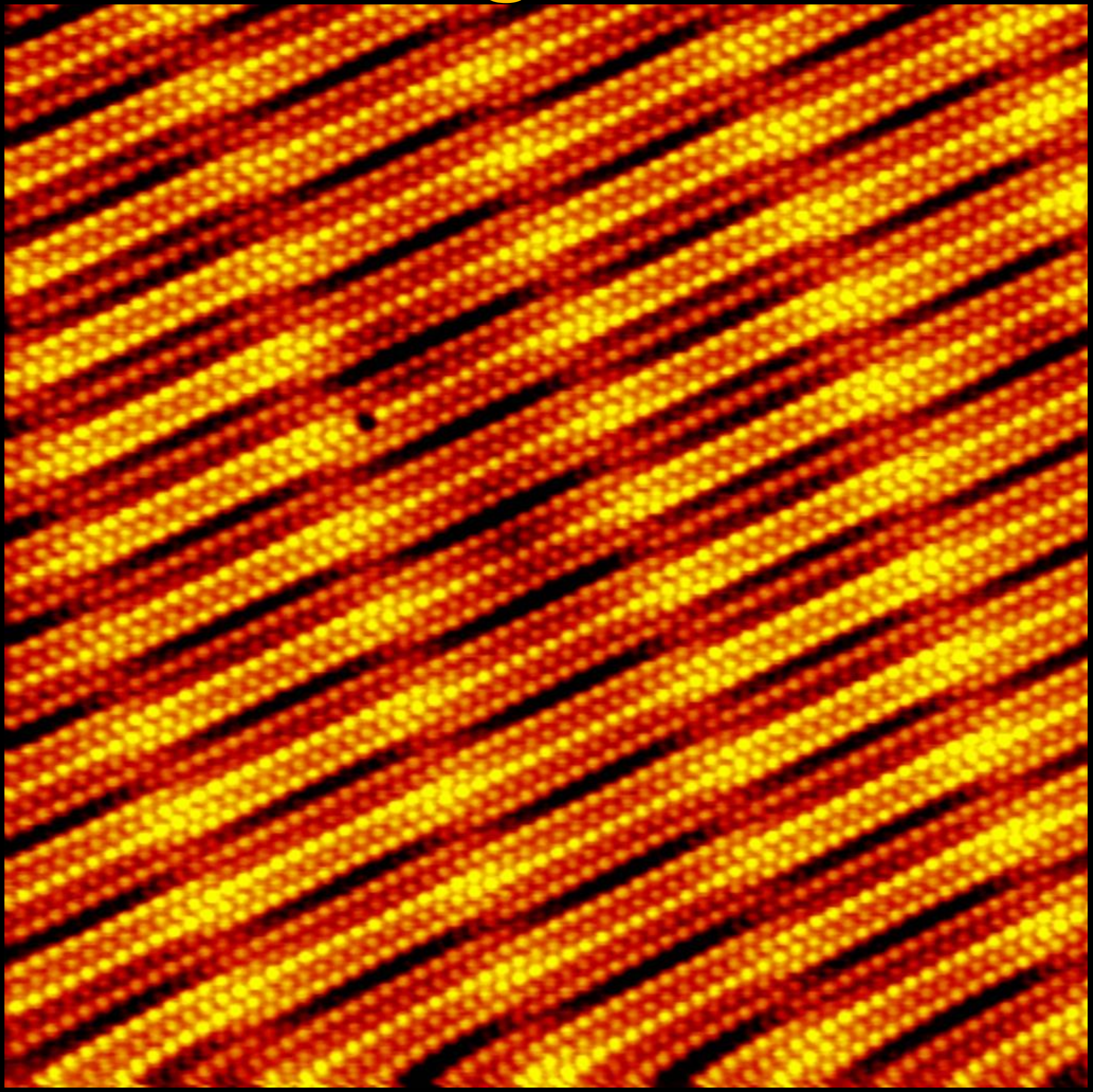
  - Bulk
  - Cleaved (001) ...urf...
  - Reconstructed (0... S...ce

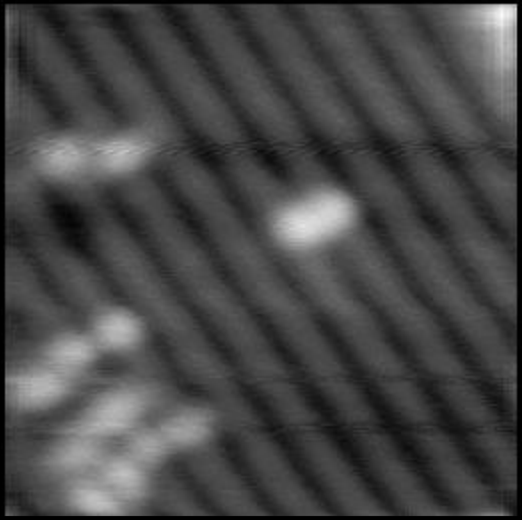


Seeing atoms

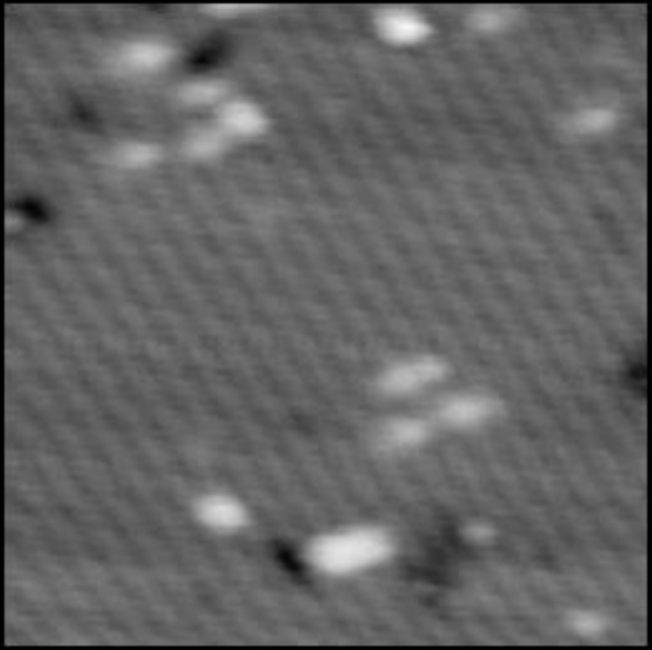


A 180×190 $Å^2$ Image of the Pt(001)-hex reconstructed surface taken with a custom Scanning Tunneling Microscope at Aarhus University's Scanning Probe Microscopy lab. The dark spot near the center is a single, missing atom.

Pair of atoms rotating

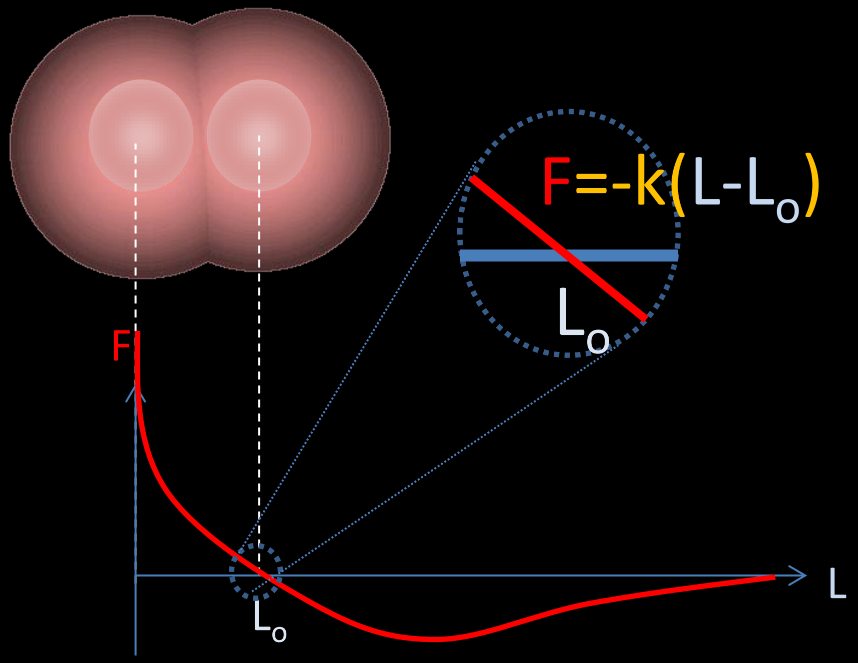


Pair of atoms traveling

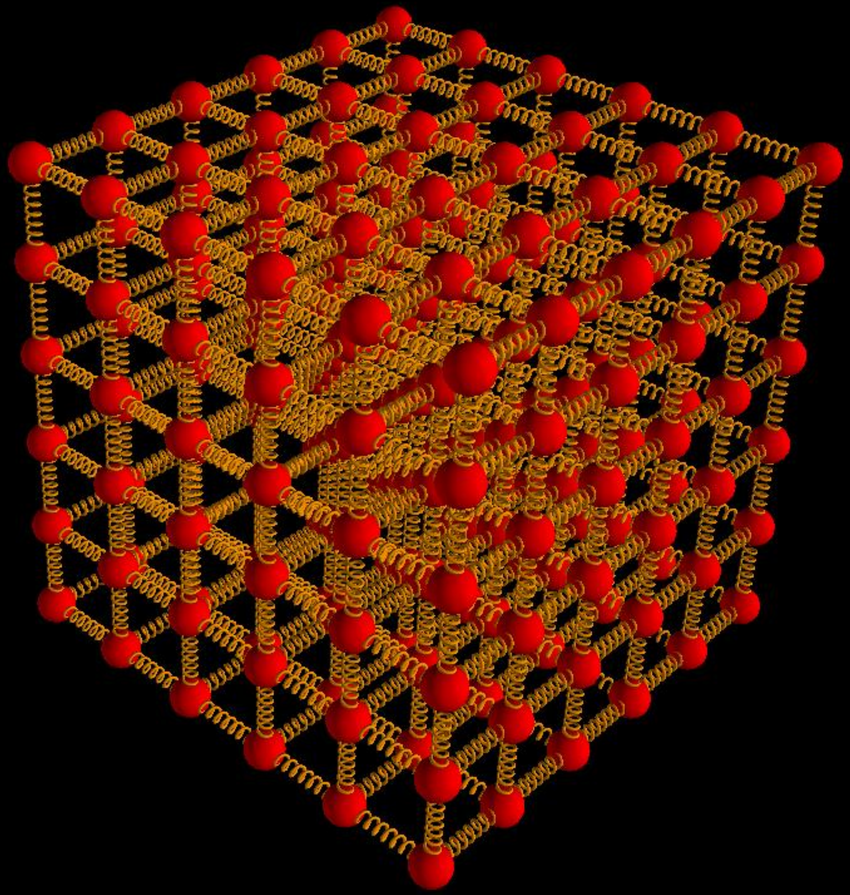


Ball-Spring Model

Molecule

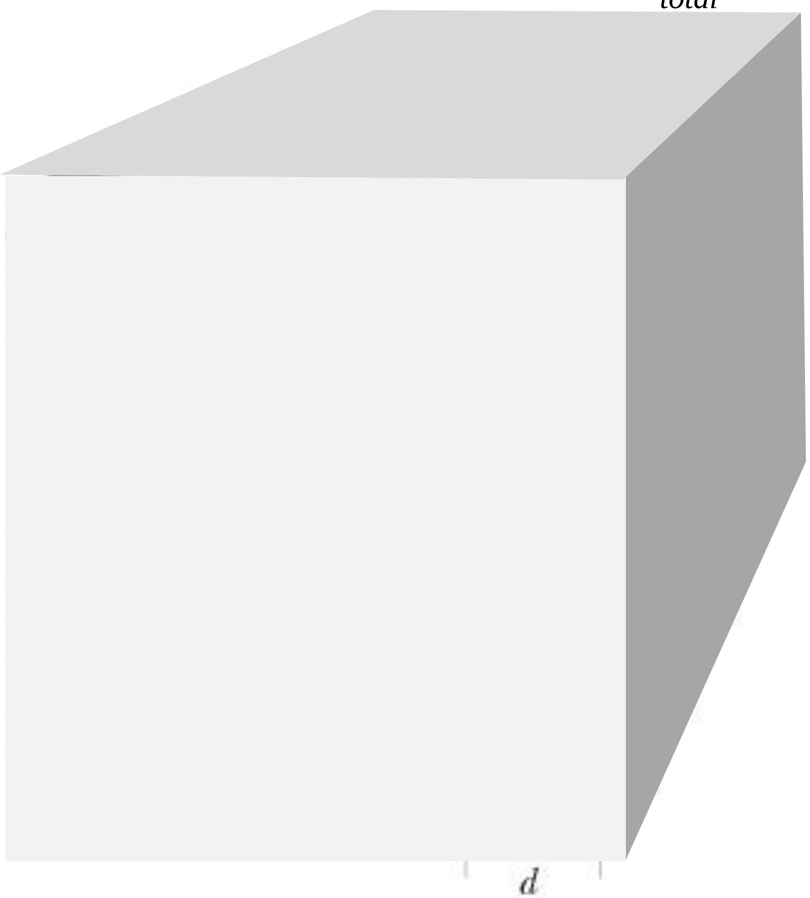


Solid



Atomic separation

$$\frac{M_{total}}{Vol_{total}} = density = \frac{m_{atom}}{Vol_{atom}} = \frac{m_{atom}}{d^3} \Rightarrow d = \left(\frac{m_{atom}}{density}\right)^{1/3}$$



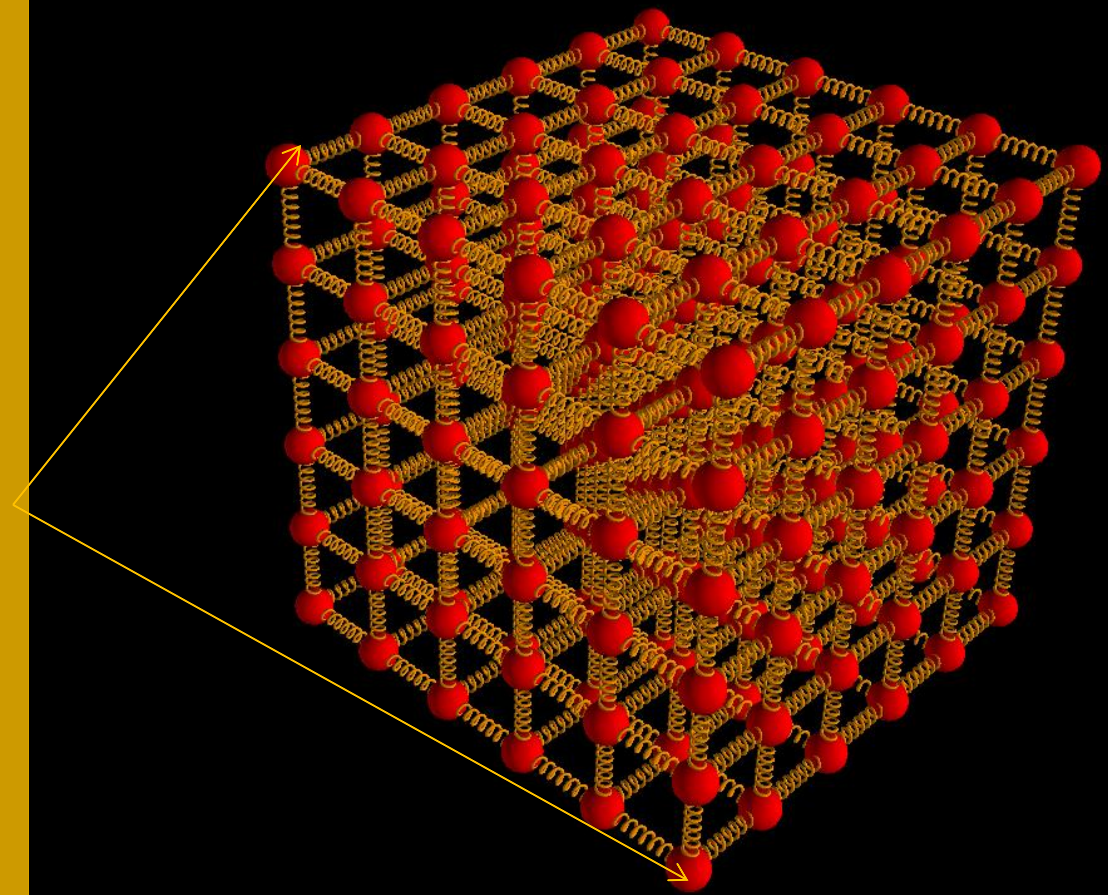
$$m_{atom} = a.m.u. * m_{nucleon} = a.m.u. * 1.7\times10^{-27}\,\text{kg}$$

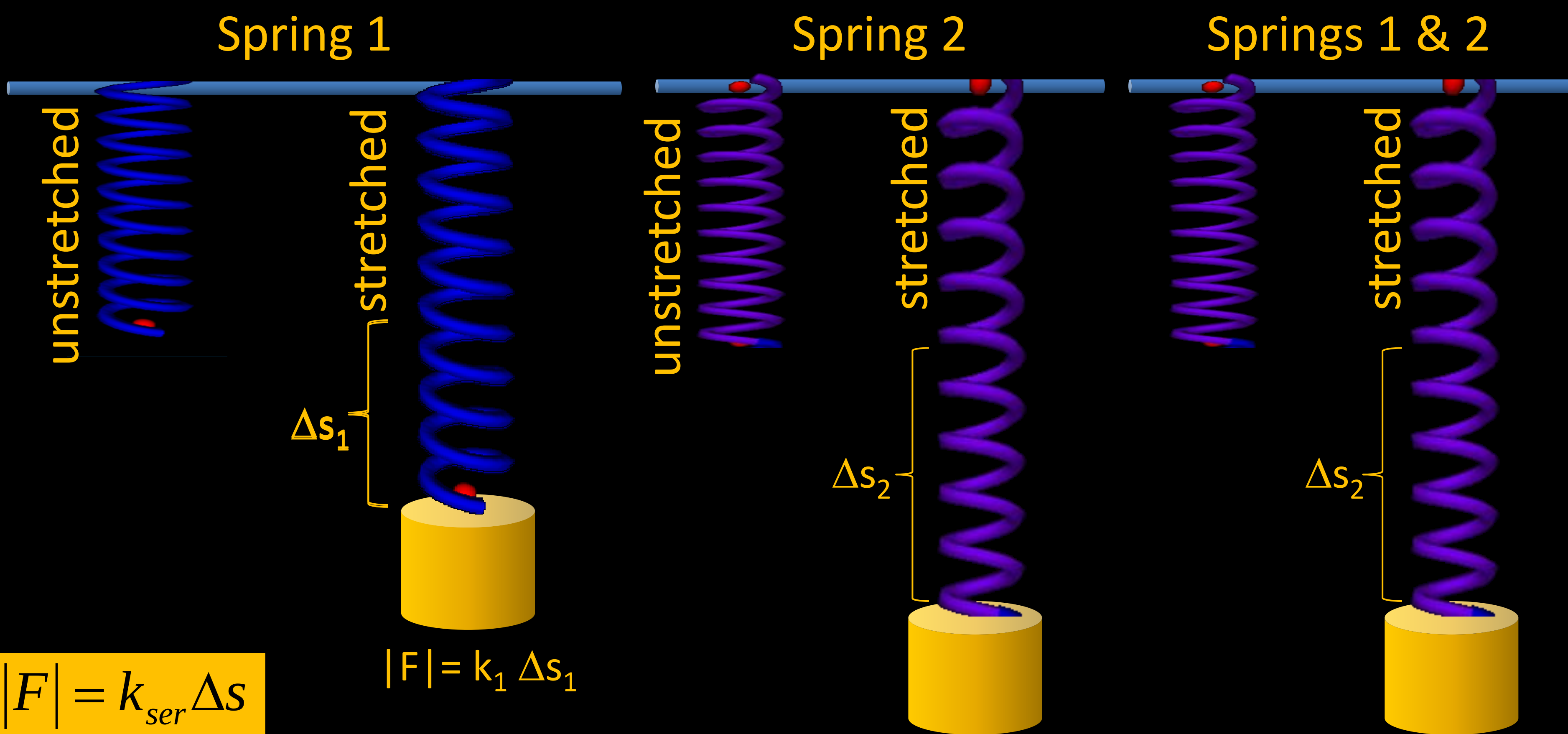
$$m_{atom} = a.m.u. * \left(\frac{1kmole}{6.02\times10^{26}\,atom}\right)$$

Example: separation of Si atoms

One mole of silicon (6×10^{23} atoms) has a mass of 28 grams. The density of silicon is 2.33 grams/cm^3. What is the typical separation of a silicon atoms (i.e., ~ their diameters) assuming their arranged cubically?

Wires as Masses on Parallel and Series Springs





$|F| = k_1\,\Delta s_1$

$|F| = k_2\,\Delta s_2$

Springs in Series

$$\left|F\right| = k_{ser}\Delta s$$

$$\left|F\right| = k_{ser}\left(\Delta s_1 + \Delta s_2\right)$$

$$\left|F\right| = k_{ser}\left(\frac{\left|F\right|}{k_1} + \frac{\left|F\right|}{k_2}\right)$$

$$1 = k_{ser}\left(\frac{1}{k_1} + \frac{1}{k_2}\right)$$

$$\left(\frac{1}{k_1} + \frac{1}{k_2}\right)^{-1} = k_{ser}$$

$|F| = k_{ser}\,\Delta s$

Q4.5.a: Springs in "series"

$$\left(\frac{1}{k_1}+\frac{1}{k_2}\right)^{-1}=k_{ser}$$

You hang a 1 kg mass from a spring, which stretches 0.4 m.

You link the spring end to end with another identical spring, and hang a 1 kg mass from the linked springs.

How much does this longer spring stretch?

a. 0.16 m
b. 0.2 m
c. 0.4 m
d. 0.8 m

Special case: ***Identical*** Springs in Series

$$k_{ser} = \left(\frac{1}{k_1} + \frac{1}{k_1}\right)^{-1}$$

$$k_{ser} = \frac{1}{\left(\frac{1}{k_1} + \frac{1}{k_1}\right)}$$

$$k_{ser} = \frac{1}{\frac{1}{k_1}(2)}$$

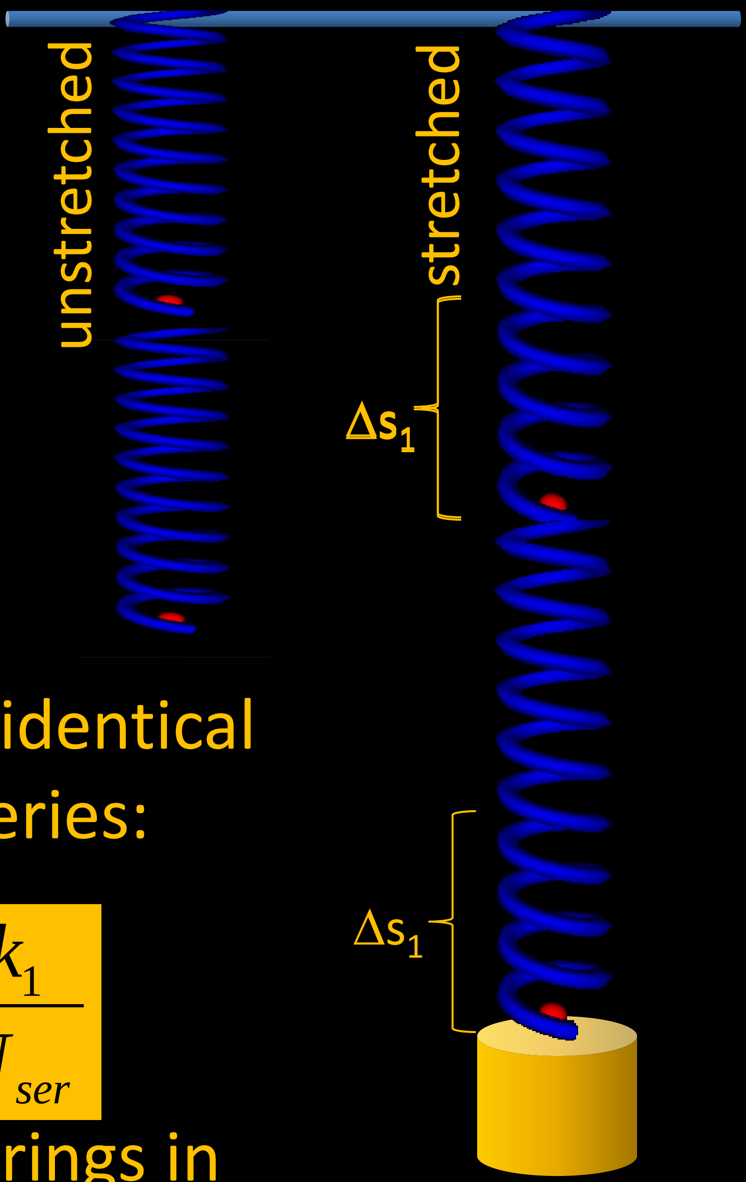
$$k_{ser} = \frac{k_1}{2}$$

If 3,4,…N_{ser} identical springs in series:

$$k_{ser} = \frac{k_1}{N_{ser}}$$

The more springs in series, the less stiff

Identical Springs 1&2



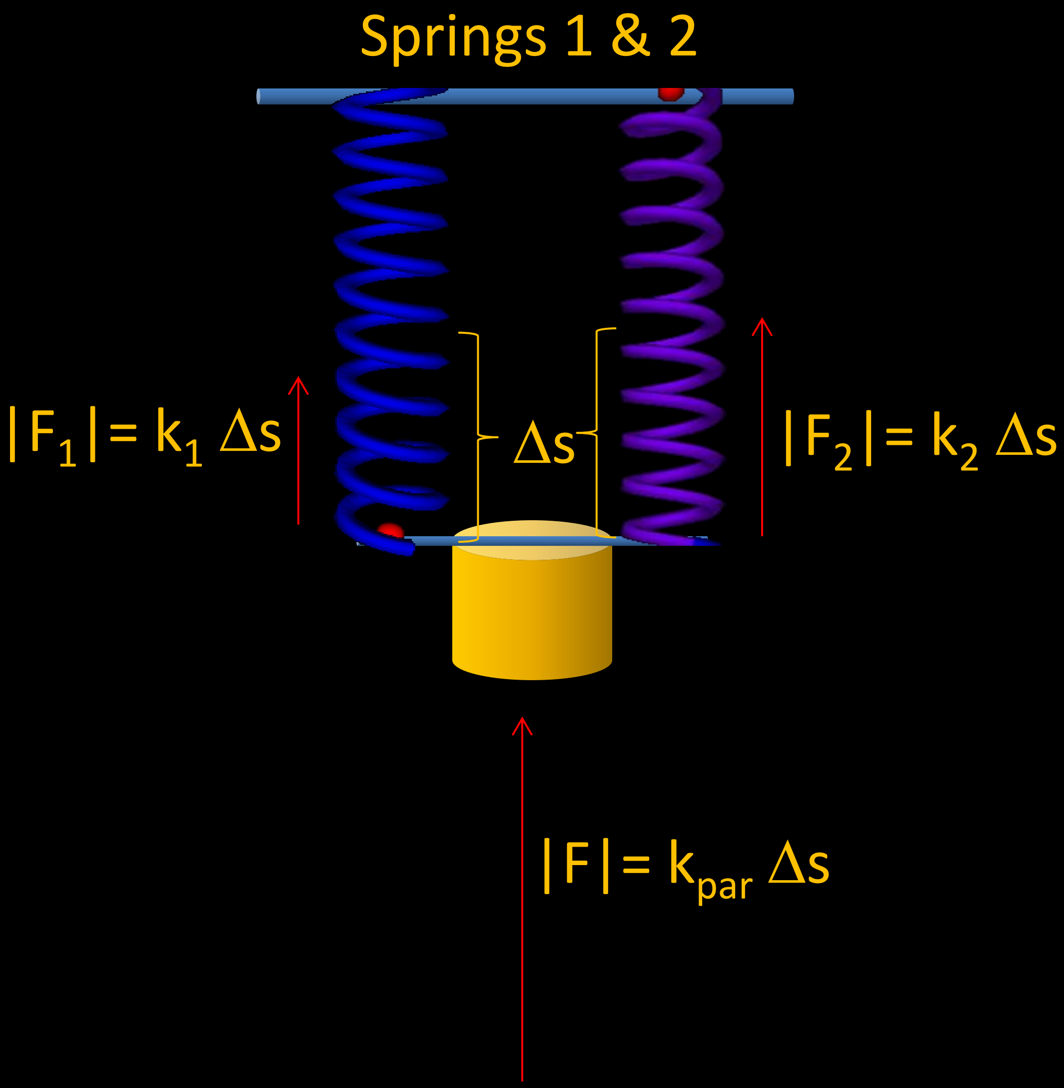
Q4.5.b: Springs in "series"

$$k_{ser} = \frac{k_1}{N_{ser}}$$

A short spring has a stiffness of 20 N/m. You link 4 of these springs end to end to make a longer spring. What is the stiffness of the longer spring?

a. 0.2 N/m
b. 5 N/m
c. 20 N/m
d. 80 N/m

Springs in Parallel



$$k_{par}\Delta s = |F|$$

$$k_{par}\Delta s = k_1\Delta s + k_2\Delta s$$

$$k_{par}\Delta s = (k_1 + k_2)\Delta s$$

$$k_{par} = (k_1 + k_2)$$

Special case: ***Identical***

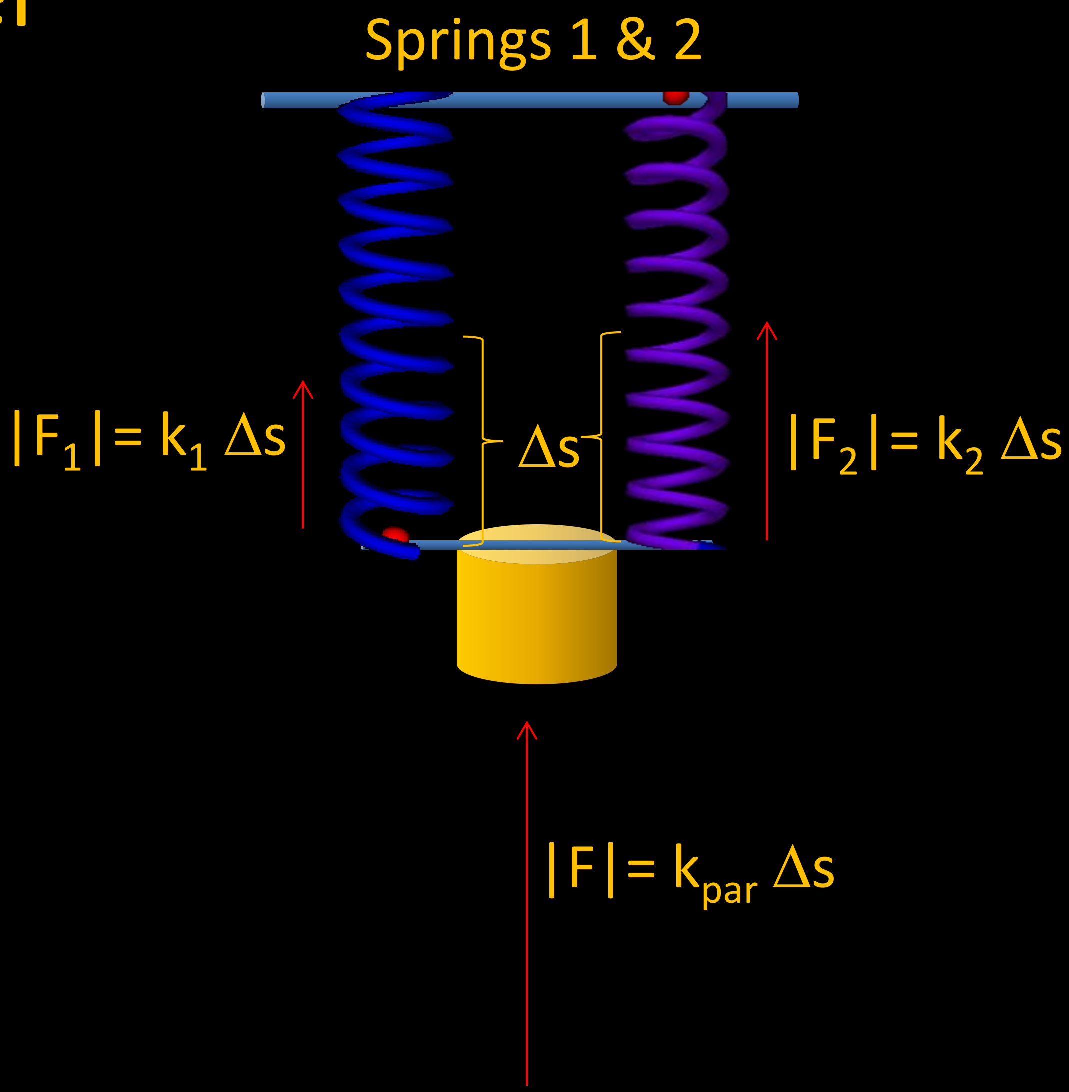
Springs in Parallel

$$k_{par} = (k_1 + k_1)$$

If 3,4,…N_{par} identical springs in parallel:

$$k_{par} = N_{par} k_1$$

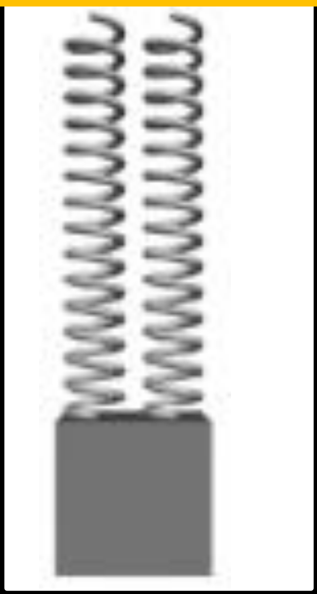
The more springs in parallel, the stiffer



Q4.5.c: Springs in "parallel"

$$k_{par} = (k_1 + k_2)$$

You hang a 1 kg mass from a spring, which stretches 0.4 m. You place a second identical spring beside the first, so the 1 kg mass is now supported by two springs.



How much does each spring stretch?

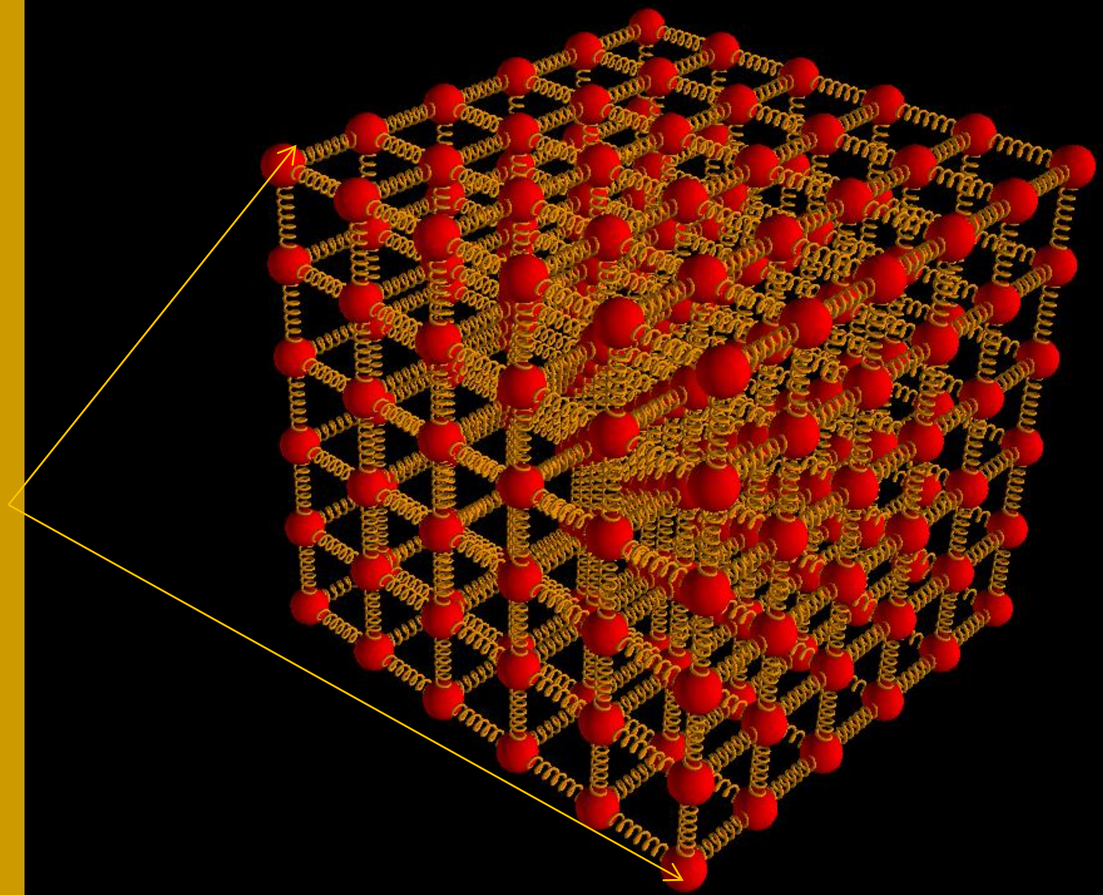
a. 0.2 m
b. 0.4 m
c. 0.5 m
d. 0.8 m

Q4.5.d: Springs in "parallel"

A short spring has a stiffness of 20 N/m. You use 4 of these springs side by side to support a mass. What is the stiffness of the 4 side-by-side springs, considered as one effective spring?

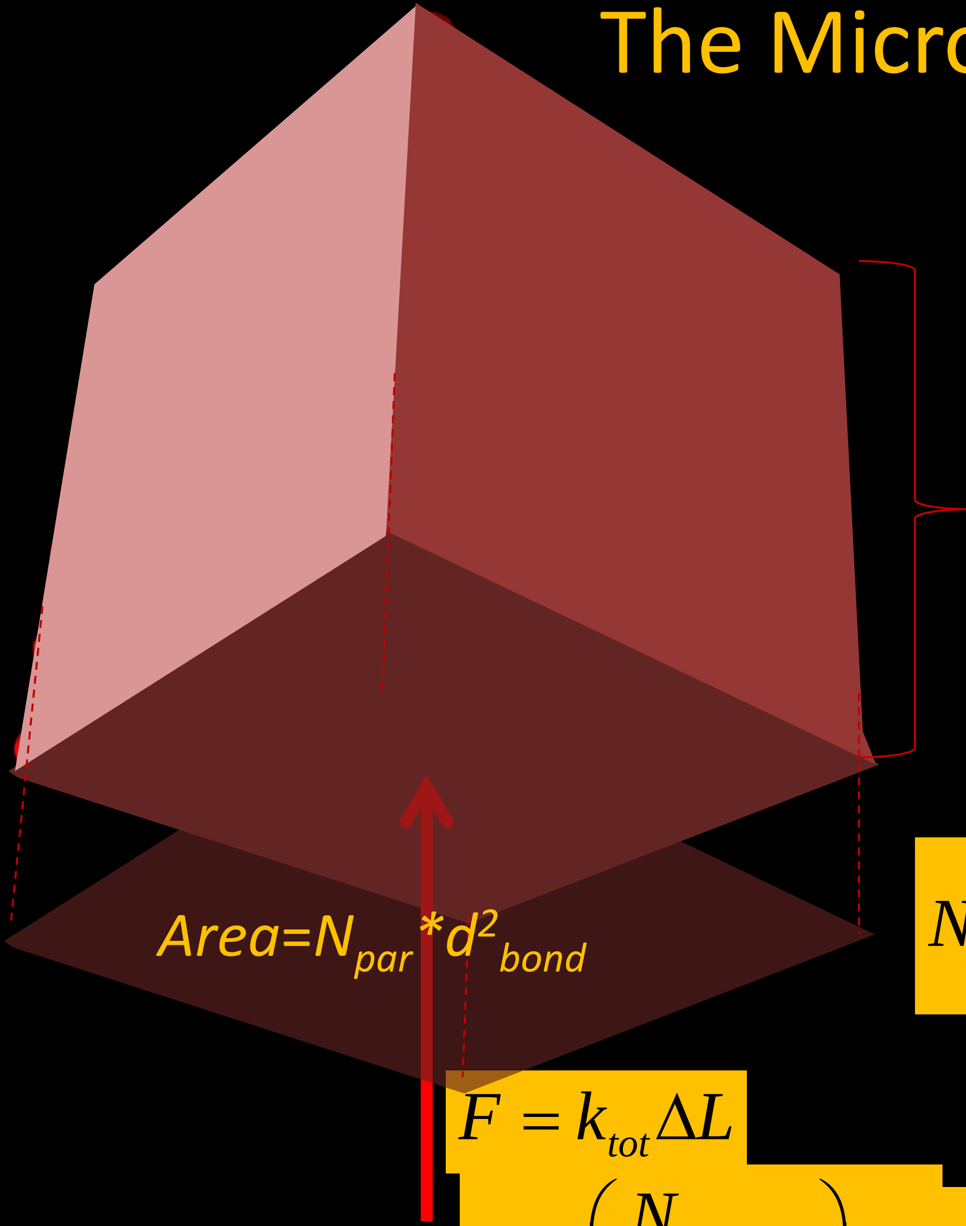
a. 0.2 N/m
b. 5 N/m
c. 20 N/m
d. 80 N/m

Wires as Masses on Identical Parallel and Series Springs



The Micro-Macro Connection:

Stiffness for springs in series *and* in Parallel



Length=N_{ser}*d_{bond}

$$N_{ser} = \frac{L}{d}$$

$$N_{par} = \frac{A}{d^2}$$

$$F = k_{tot}\Delta L$$

$$F = \left(\frac{N_{par}}{N_{ser}}k_1\right)\Delta L = \left(\frac{A}{d \cdot L}k_1\right)\Delta L$$

$$k_{total} = \left(\frac{A}{d \cdot L}k_1\right)$$

Q4.6.d: Wires

$$F = \left(\frac{A}{d \cdot L} k_1 \right) \Delta L$$

You hang a 10 kg mass from a copper wire, and the wire stretches by 8 mm.

Now you hang the same mass from a second copper wire, *whose cross-sectional area is half as large* (but whose length is the same).

What happens?

a) The second wire stretches 4 mm

b) The second wire stretches 8 mm

c) The second wire stretches 16 mm

$$F = \left(\frac{A}{d \cdot L} k_1 \right) \Delta L$$

Q4.6.e: Wires

You hang a 10 kg mass from a copper wire, and the wire stretches by 8 mm.

Now you hang the same mass from a second copper wire, *which is twice as long*, but has the same diameter.

What happens?

a) The second wire stretches 4 mm

b) The second wire stretches 8 mm

c) The second wire stretches 16 mm

Spring in Series & Parallel Rephrased
Stress, Strain, and Young's Modulus

$$F = k_{total}\Delta L$$

$$F = \left(k_{atomic}\left(\frac{A}{dL}\right)\right)\Delta L$$

From counting series and parallel

regroup

$$F = \left(\frac{k_{atomic}}{d}\right)\frac{A\Delta L}{L}$$

Microscopic details

Macroscopic measurables

$$Y \equiv \text{Young's Modulus}$$

$$F = Y\frac{A\Delta L}{L}$$

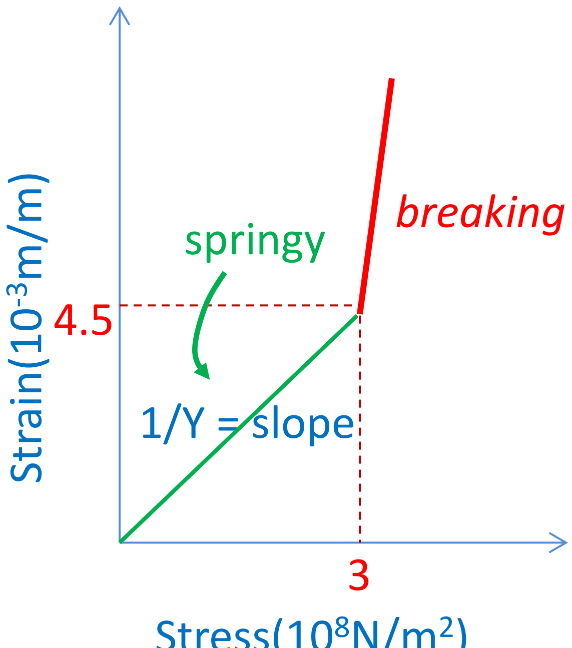
$$\left(\frac{F}{A}\right) = Y\left(\frac{\Delta L}{L}\right)$$

Stress

force transmitted per area (pressure)

Strain

stretch per length (fractional stretch)



Two wires with equal lengths are made of pure copper. The diameter of wire A is twice the diameter of wire B.

When 6 kg masses are hung on the wires, wire B stretches more than wire A.

Y = (F/A)/(DL/L)

You make careful measurements and compute Young's modulus for both wires. What do you find?

1) $Y_A > Y_B$

2) $Y_A = Y_B$

3) $Y_A < Y_B$

Example: You hang a heavy ball with a mass of 14 kg from a silver rod 2.6m long by 1.5 mm by 3.1mm. You measure a stretch of the rod, and find that the rod stretched 0.002898 m. Using these experimental data, what value of Young's modulus do you get?

Mon. Tues Wed. Lab Fri	4.1-.5 Atomic nature of matter / springs 4.6-.7, .9-.10 Stress, Strain, Young's Modulus, Compression, Sound *InStove: here noon; Science Poster Session: Hedco7pm~9pm* L4: Young's Modulus & Speed of Sound (Read 4.11-.12) 4.11-.12; .14-.15 Sound in Solids, Analytical Solutions Quiz 3	RE 4.a EP 3, HW3: Ch 3 Pr's 42, 46, 58, 65, 72 & CP* RE 4.b RE 4.c laptop, smartphone…
Mon. Tues. . . Fri.	4.8, .13 Friction and Buoyancy & Suction Exam 1 (Ch 1-4)	RE 4.d EP 4, HW4: Ch 4 Pr's 46, 50, 81, 88 & CP

* Uses $G = 6.7\times10^{-11}$ N m^2/kg^2