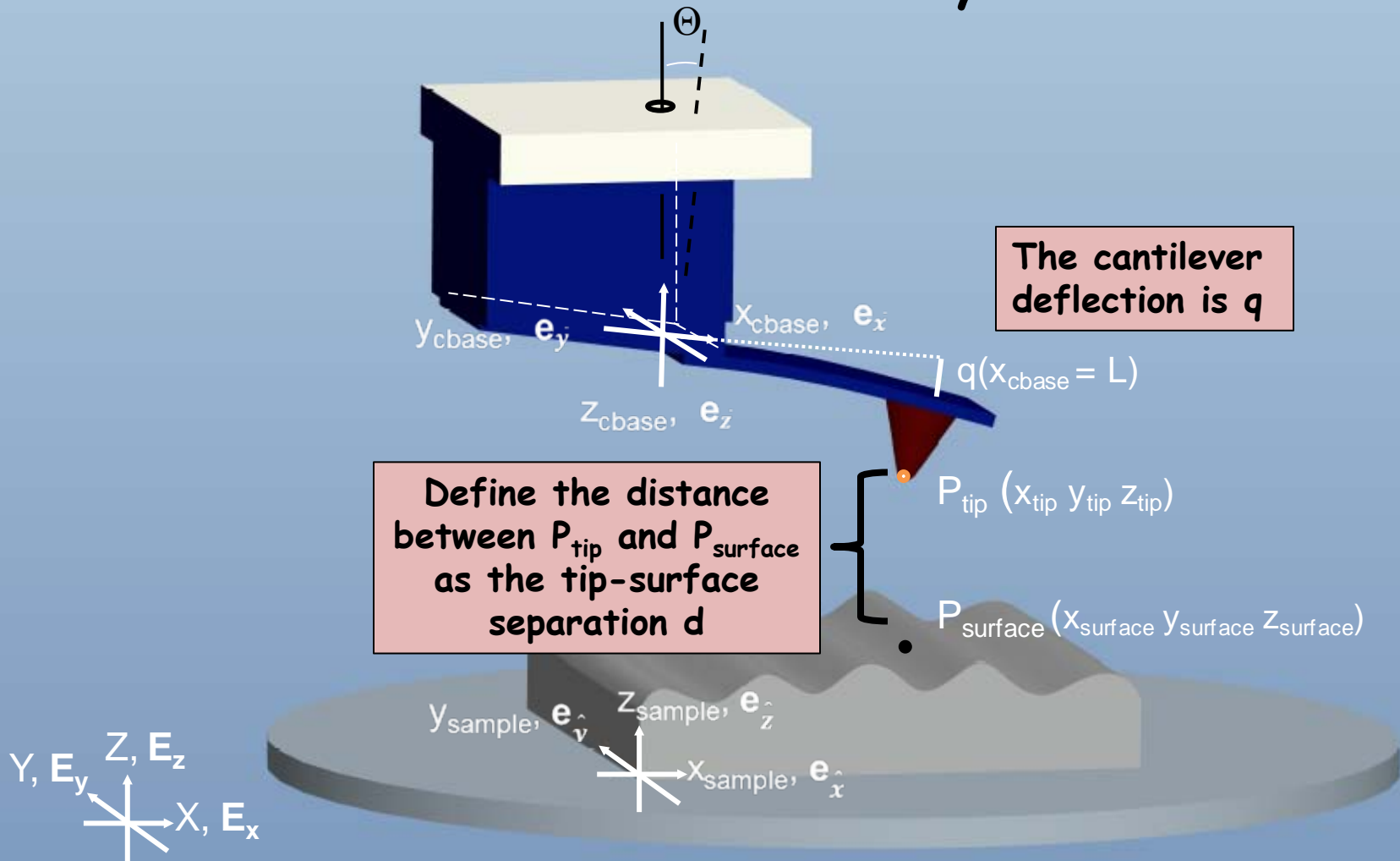# Lecture: P1_Wk4_L2

## The Approach Curve

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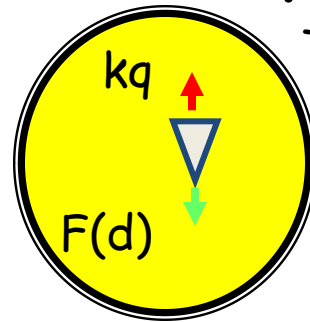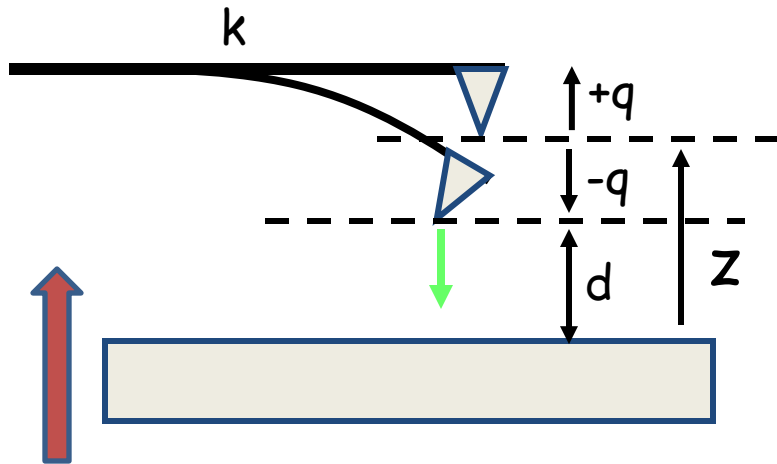
Purdue University

2012

# The AFM co-ordinate system



$\Theta$

The cantilever deflection is q

$y_{cbase}$, $\mathbf{e}_{\hat{y}}$     $\mathbf{e}_{\hat{x}}$     $X_{cbase}$, $\mathbf{e}_{\hat{x}}$

$q(x_{cbase} = L)$

$z_{cbase}$, $\mathbf{e}_{\hat{z}}$

Define the distance between $P_{tip}$ and $P_{surface}$ as the tip-surface separation d

$P_{tip}$ ($x_{tip}$ $y_{tip}$ $z_{tip}$)

$P_{surface}$ ($x_{surface}$ $y_{surface}$ $z_{surface}$)

$y_{sample}$, $\mathbf{e}_{\hat{y}}$     $z_{sample}$, $\mathbf{e}_{\hat{z}}$

$x_{sample}$, $\mathbf{e}_{\hat{x}}$

$Z$, $\mathbf{E_z}$

$Y$, $\mathbf{E_y}$

$X$, $\mathbf{E_x}$

# Measuring Force vs. z-displacement
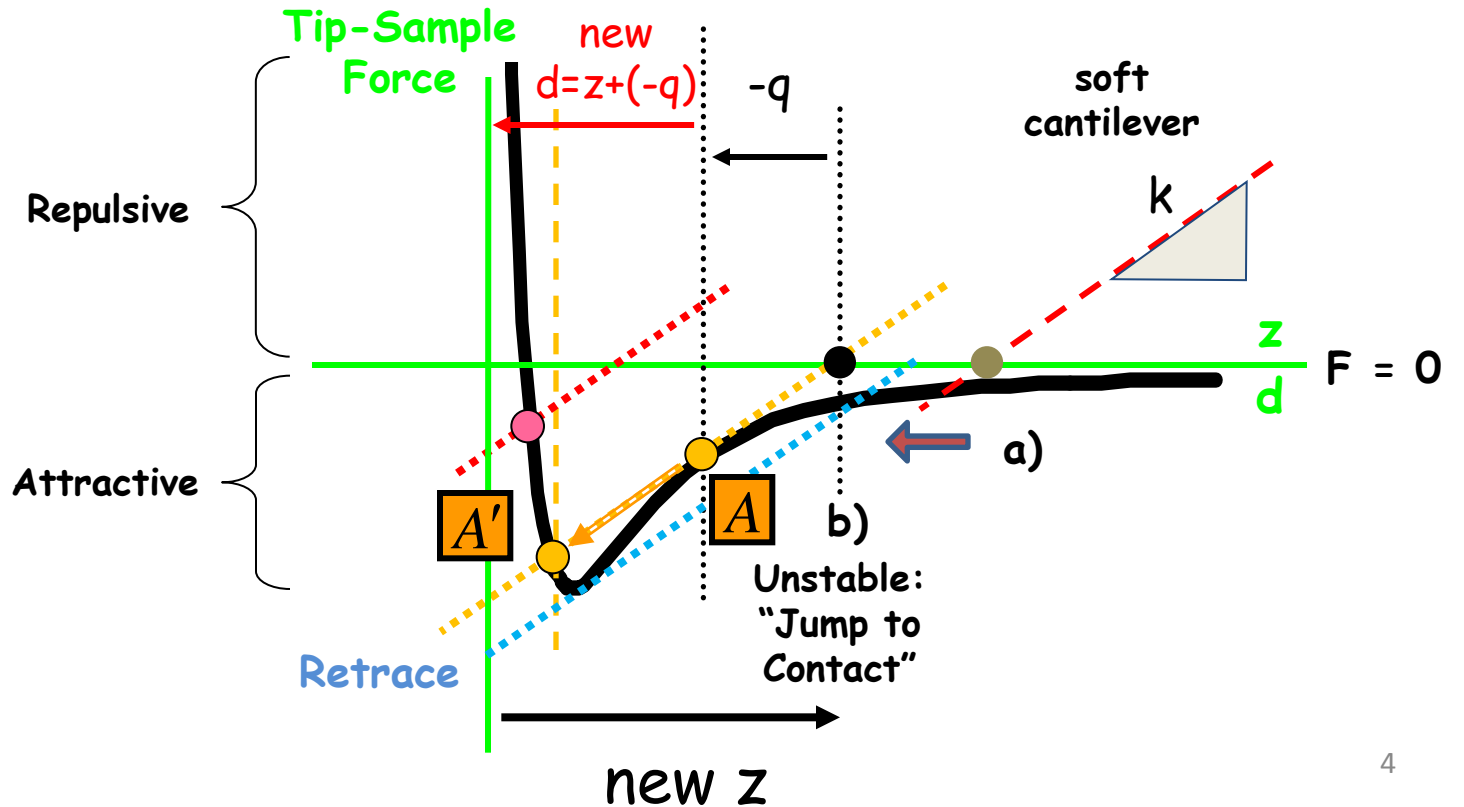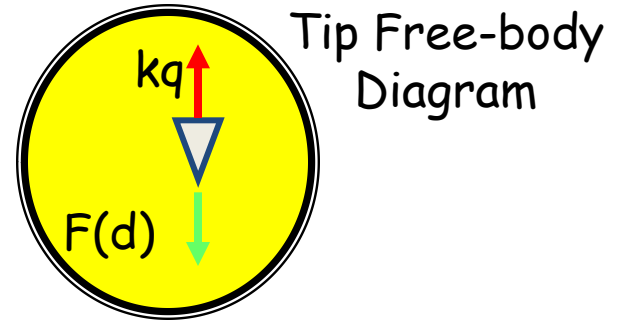
$k$

$+q$

$-q$

$d$

$z$

Tip Free-body Diagram

$kq$

$F(d)$

**Important:  Since z=0 is arbitrary (i.e. unknown), d=0 is not defined!**

**Tip-Sample Force**

$-q$

soft cantilever

$d=z+(-q)$

$k$

**Repulsive Force**
**d=z+q**

$z$

$d$

$F = 0$

**Attractive Force**
**d=z−q**

Set z

Measure F(d)

one click

P1_Wk4_L2

3

# Jump to Contact



Tip Free-body Diagram

$kq$

$F(d)$

Tip-Sample Force

new $d = z + (-q)$

$-q$

soft cantilever

$k$

Repulsive

Attractive

$F = 0$

$z$

$d$

$A'$

$A$

a)

b)

Unstable: "Jump to Contact"

Retrace

new z
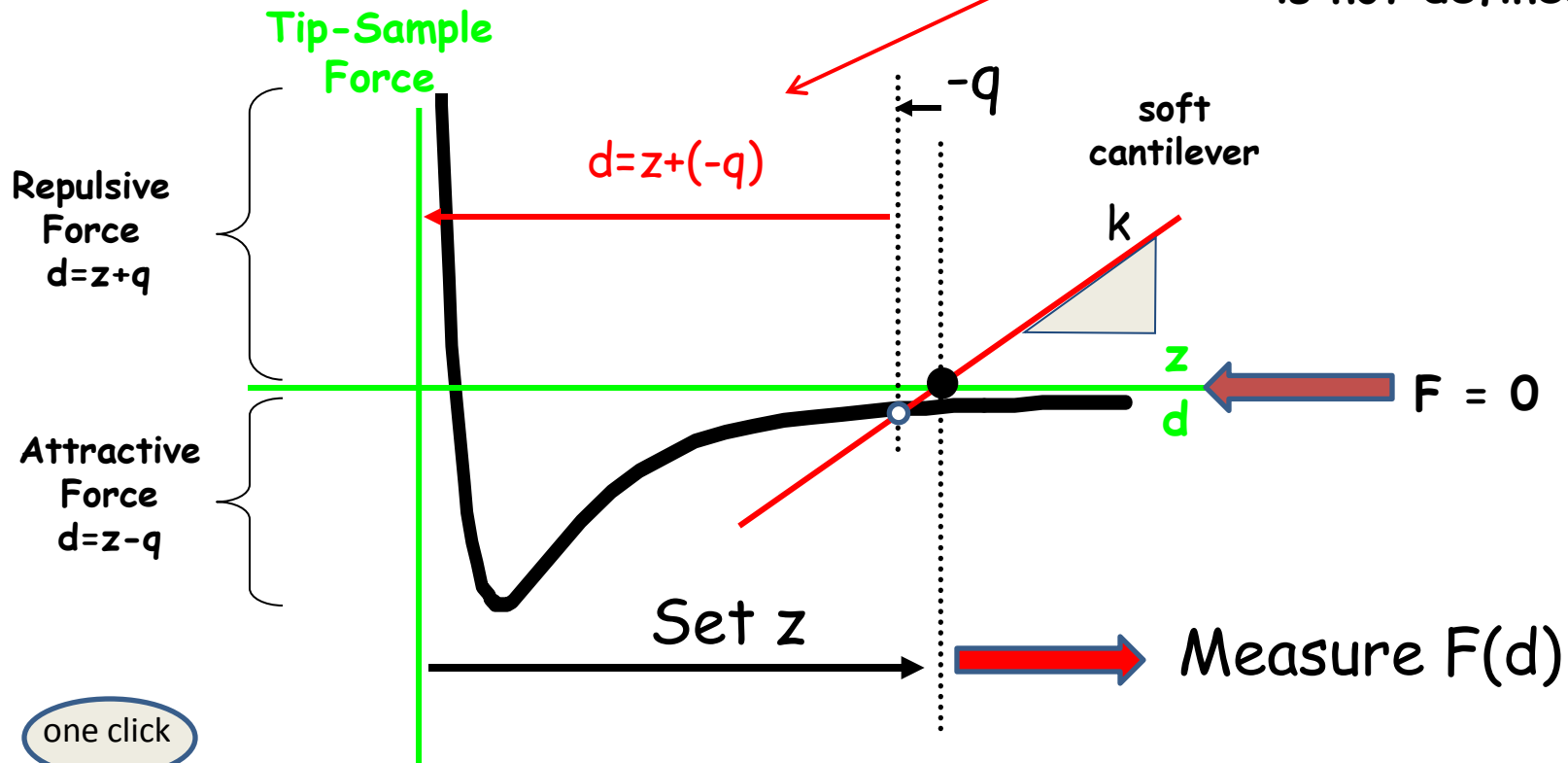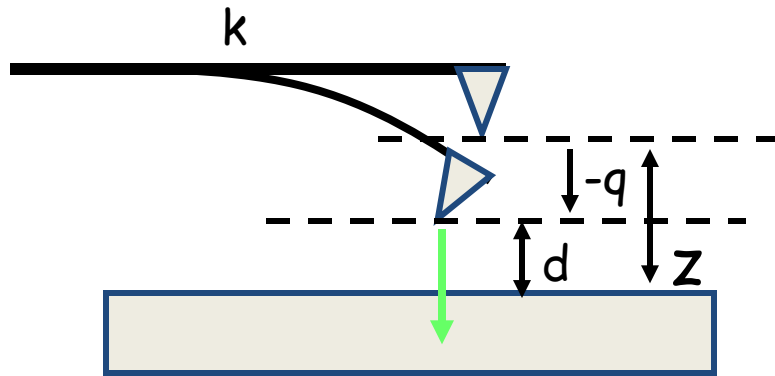
# Force vs. Separation Curve

**Tip-Sample Force**

soft cantilever

$k$

$z$

$d$

$f_{\text{set point}}$

$f_{\text{lift-off 2}}$

$f_{\text{jump 1}}$

$f_{\text{jump 2}}$

$f_{\text{lift-off 1}}$

**Retrace**

$F_{\text{adhesion}}$      $F_{\text{pull-off}}$

**Cantilever Force**

$f_{\text{set point}} = kq$

$z$

$f_{\text{lift-off 2}}$

$f_{\text{jump 1}}$

$f_{\text{jump 2}}$

$f_{\text{lift-off 1}}$

**Retrace**
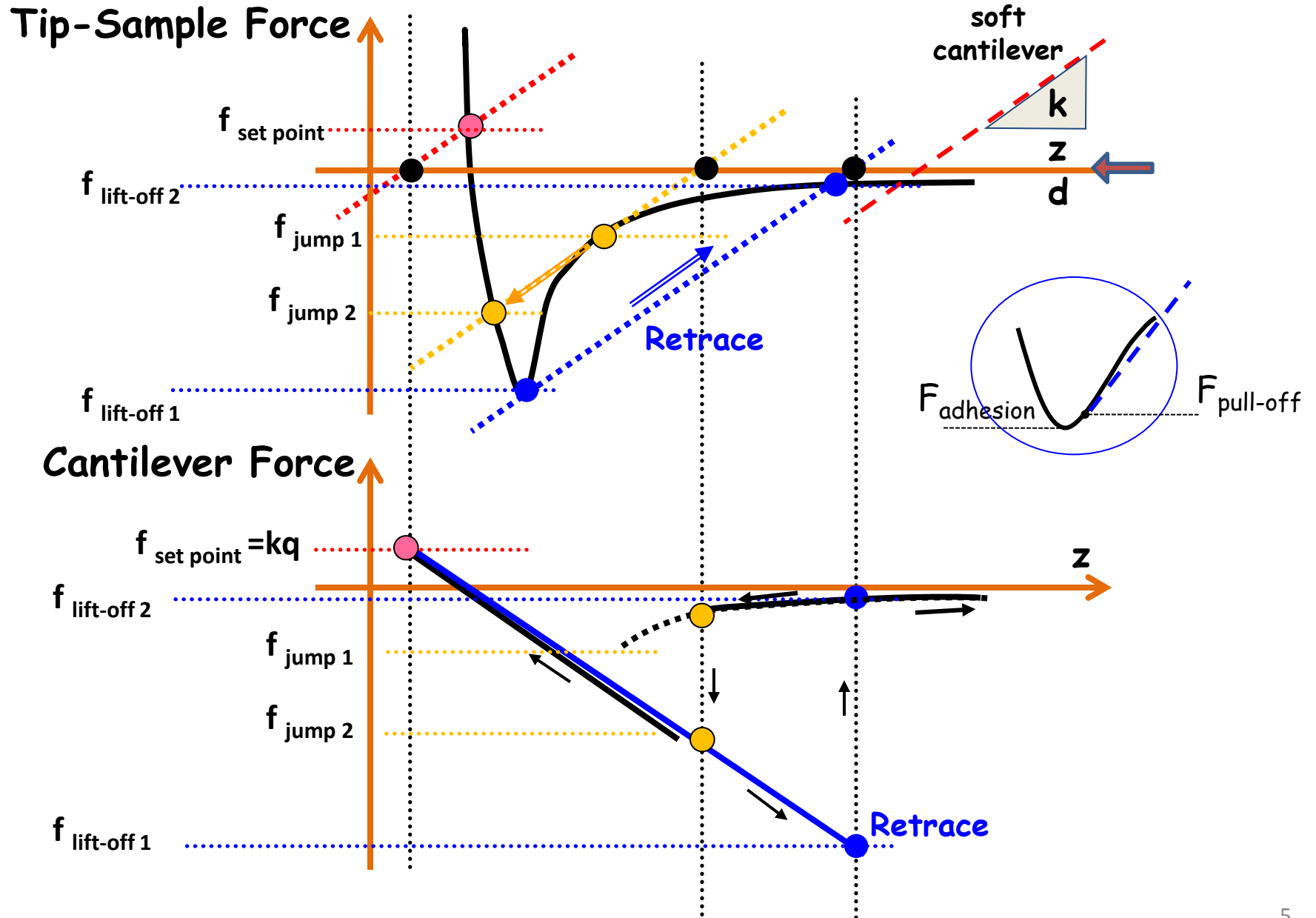
# The pull off force feature
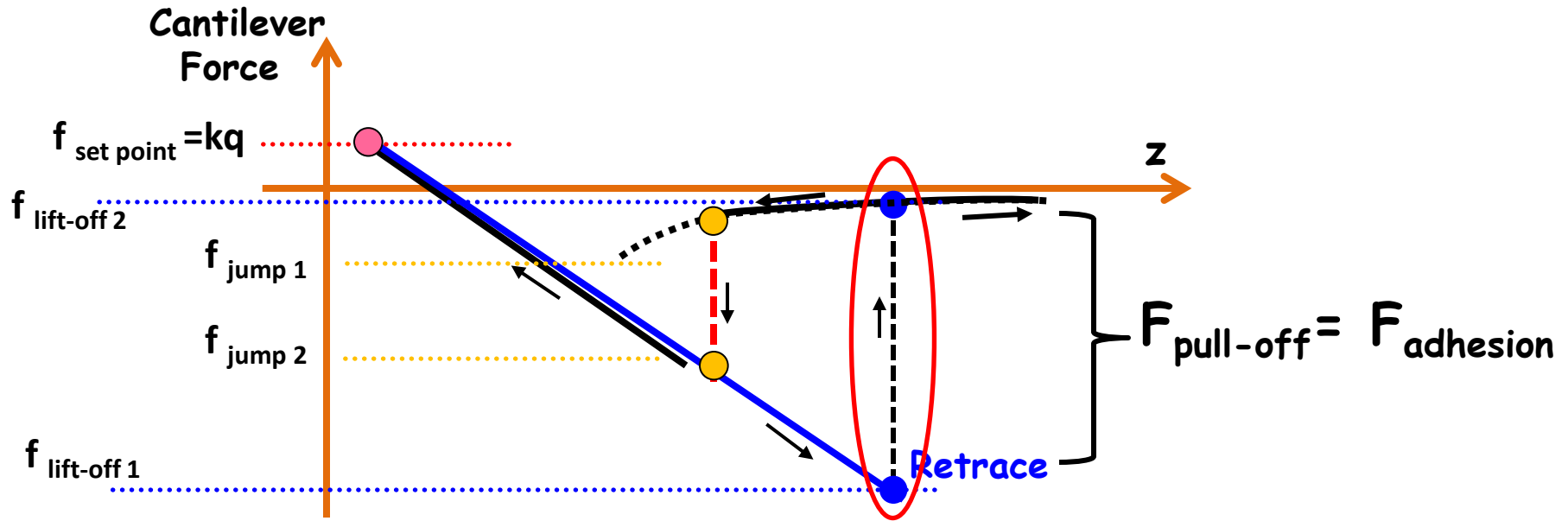


$$F_{pull-off} = f_{lift-off\,2} - f_{lift-off\,1}$$

$$F_{adhesion} = F_{electrostatic} + F_{vdW} + F_{capillary} + F_{chemcial} + ...$$

1. To understand $F_{pull-off}$, the tip-sample deformation, adhesion and contact area are required
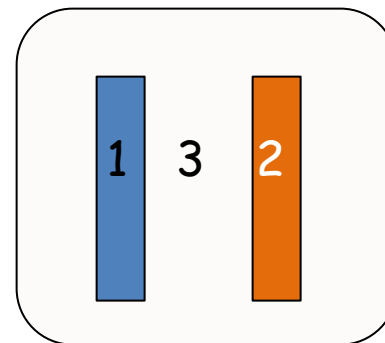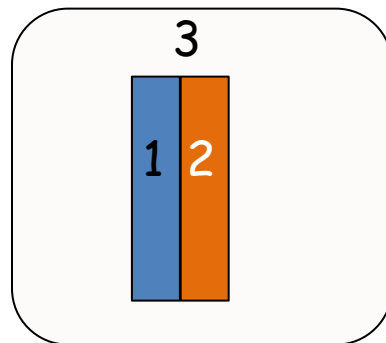2. **If** vdW forces dominate, then , e.g, the DMT model predicts

$$F_{adhesion}^{DMT} = 2\pi R_{tip} W_{132}$$

# Review: Adhesion and the DMT Model

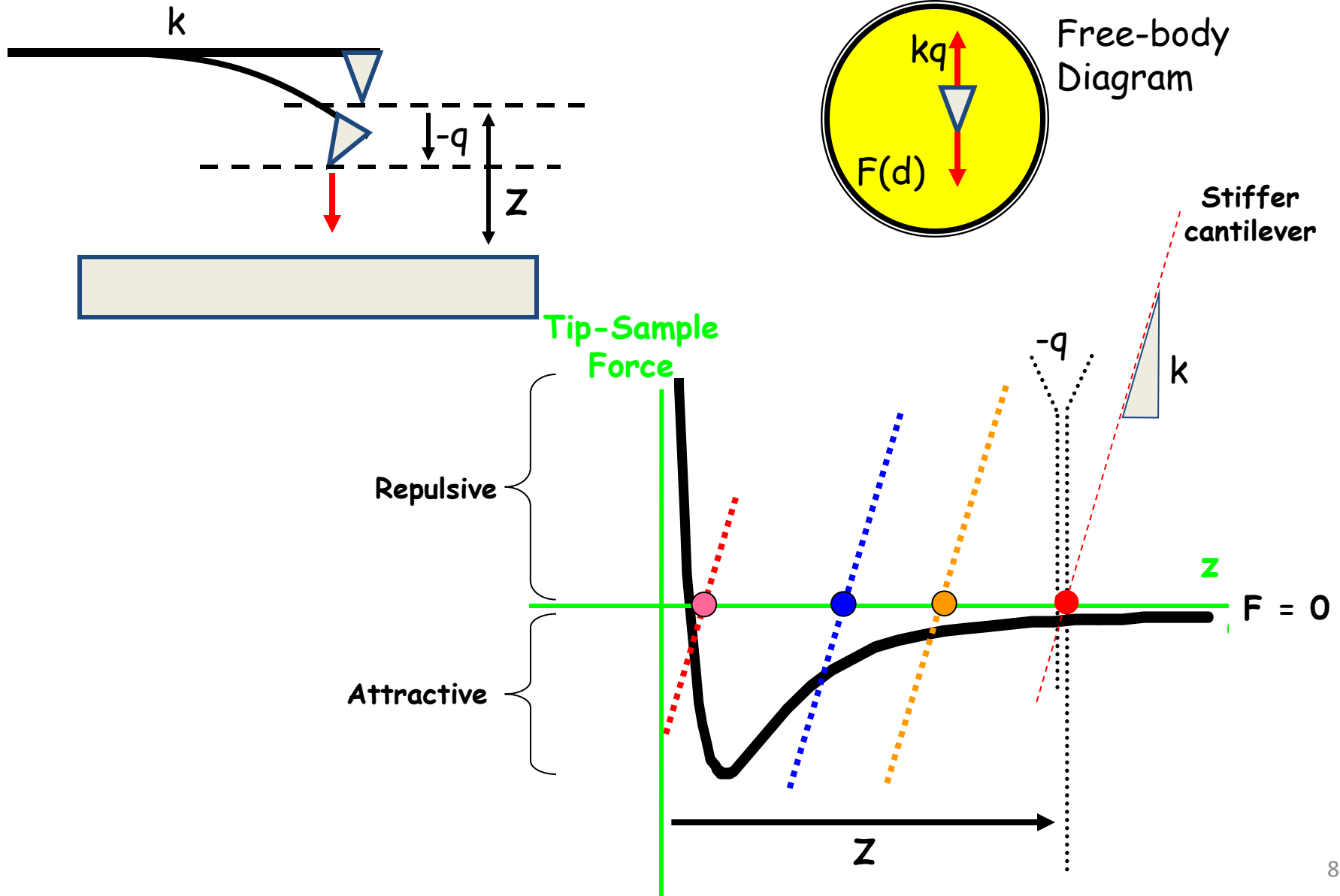$$F_{adhesion}^{DMT} = 2\pi R_{tip} W_{132}$$



1

3

2

$R_{tip}$

Contact radius, a

D=indentation

Before

After

3

1  2

1  3  2
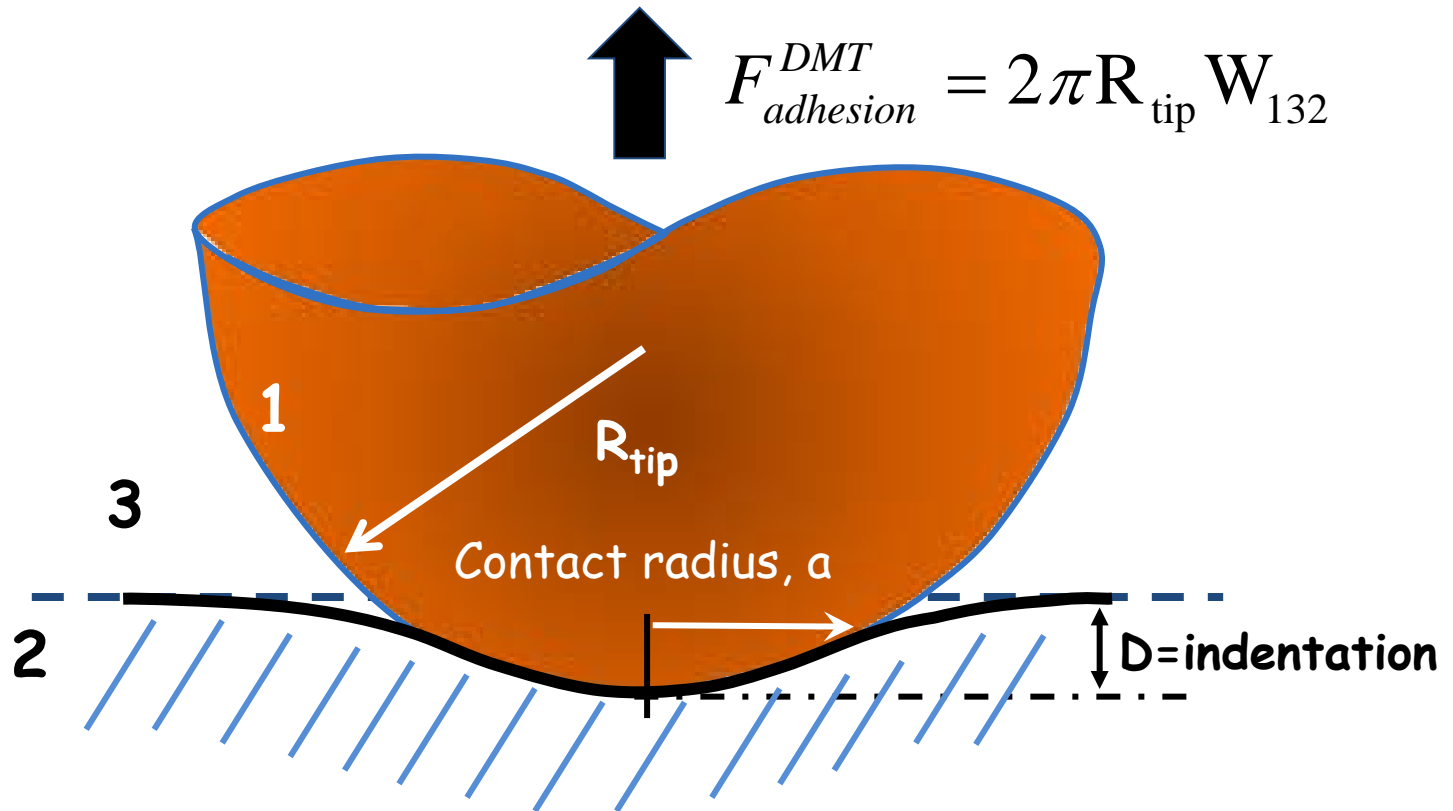
$$W_{132} = \gamma_{13} + \gamma_{23} - \gamma_{12}$$

# Stiffer Cantilever

k

$-q$

Z

kq

F(d)

Free-body
Diagram

Stiffer
cantilever
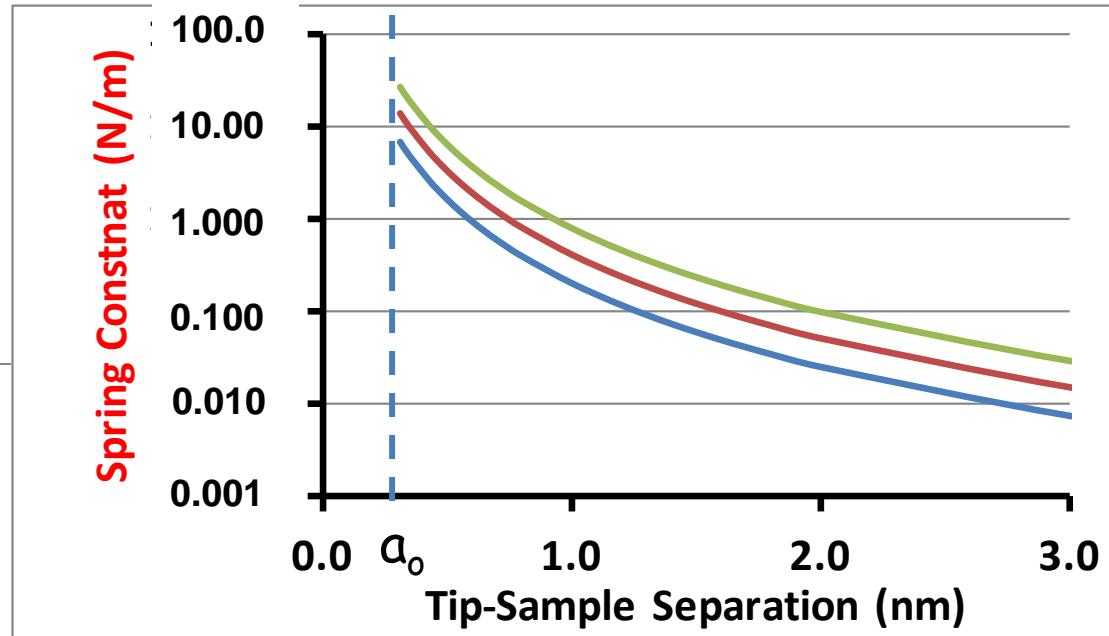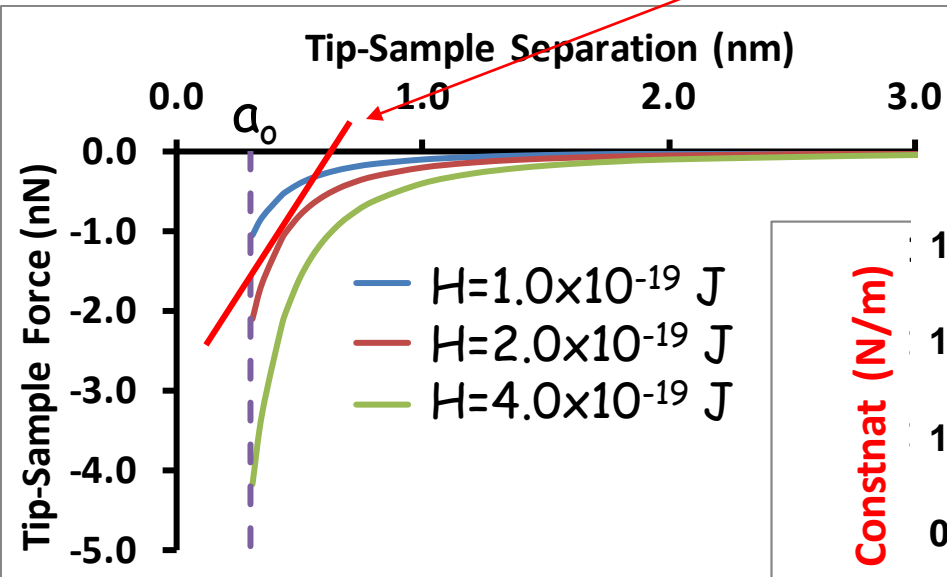
$-q$

k

Tip-Sample
Force

Repulsive

Attractive

z

F = 0

Z

# How Stiff of a Cantilever is Required?

$$F(d) = -\frac{HR}{6d^2}$$

$$slope(d) \simeq effective\ spring\ constant = \frac{HR}{3d^3}$$

$$Use\ R = 6\,nm$$

**Tip-Sample Separation (nm)**

Tip-Sample Force (nN)

H=1.0x10⁻¹⁹ J
H=2.0x10⁻¹⁹ J
H=4.0x10⁻¹⁹ J

Spring Constnat (N/m)

**Tip-Sample Separation (nm)**

However, stiffer cantilevers means loss of sensitivity

# The Sample Could Deform!



What the experiment controls

$z$

$R_{tip}$

$q_{tip}$

$d = z - (q_{tip} + q_{sample})$   Important in theory

$q_{sample}$

# Up Next: Jump to Contact