

## Last Time

- Some phenomena where short-circuits are important

## Diffusion in noncrystalline materials

- Gasses and liquids
  - Self-diffusion in metallic glasses
  - Interstitials in metallic glasses
  - Conformation of long-chain polymers
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## 3.21 Spring 2001: Lecture 21

### Diffusion in polymer melts

### Motion of Dislocations (KPIM Chapter 11)

- Forces on dislocations
  - Dislocation glide and climb
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### Dislocation motion

- Glide motion
  - plastic deformation of crystals at low temperature
  - movement of glissile interfaces at low temperature

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- Climb motion
  - contributes to high temperature deformation
  - results from operation of sources and sinks of vacancies

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## Forces on Dislocations

- external stresses
- osmotic force  $\vec{F} = \vec{F}_\sigma + \vec{F}_\mu + \vec{F}_\kappa$
- curvature force
- external stresses:
  - are given by the *Peach-Koehler equation*  $\vec{F}_\sigma = (\vec{b} \cdot \sigma) \times \vec{\xi}$
- osmotic force:
  - arises if nonequilibrium concentrations of point defects are present:
 
$$\vec{F}_\mu = (\vec{\xi} \times \vec{b}) \frac{kT}{\Omega} \ln \frac{N_v}{N^{e_q}}$$

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- curvature force:
    - line length can change if a curved dislocation moves  $\vec{F}_\kappa \approx \frac{\mu b^2}{R} \hat{n} = \mu b^2 \frac{d\vec{\xi}}{ds}$
  - Total force:  $\vec{F} = \vec{F}_\sigma + \vec{F}_\mu + \vec{F}_\kappa$

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## Screw dislocation glide

- Dislocation velocity  $v$  is limited by the sound velocity  $c$  in the material—essentially a relativistic effect
- Drag forces arise from
  - Sound emission

- Elastic dissipation
- Phonon and electron scattering
- Solute atom interactions

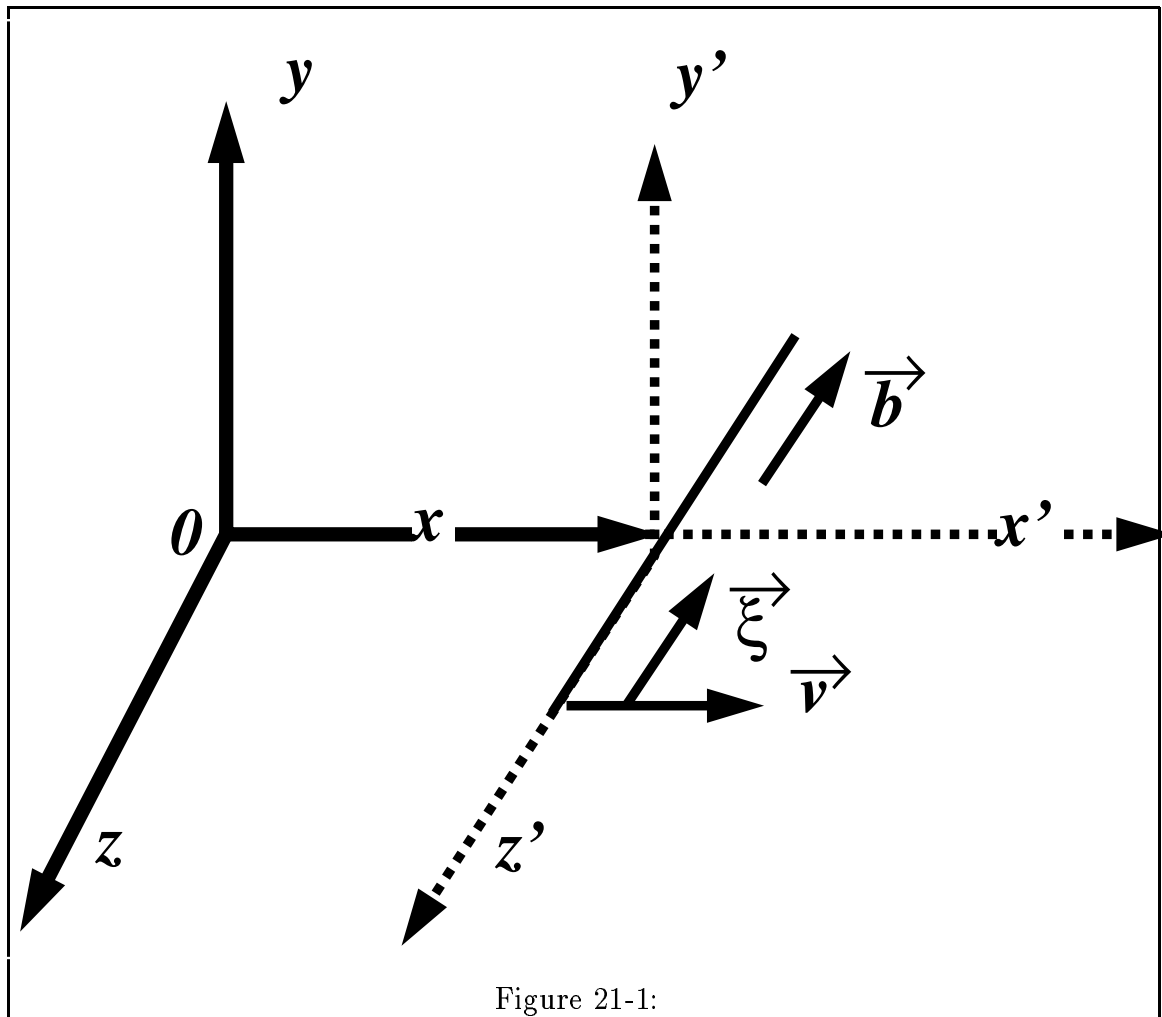


Figure 21-1:

### Experimental studies of dislocation motion

- Extensive studies of LiF in 1960's by Gilman and Johnson
- Velocities increase rapidly with increasing stress and appear to level off as they approach sound velocity

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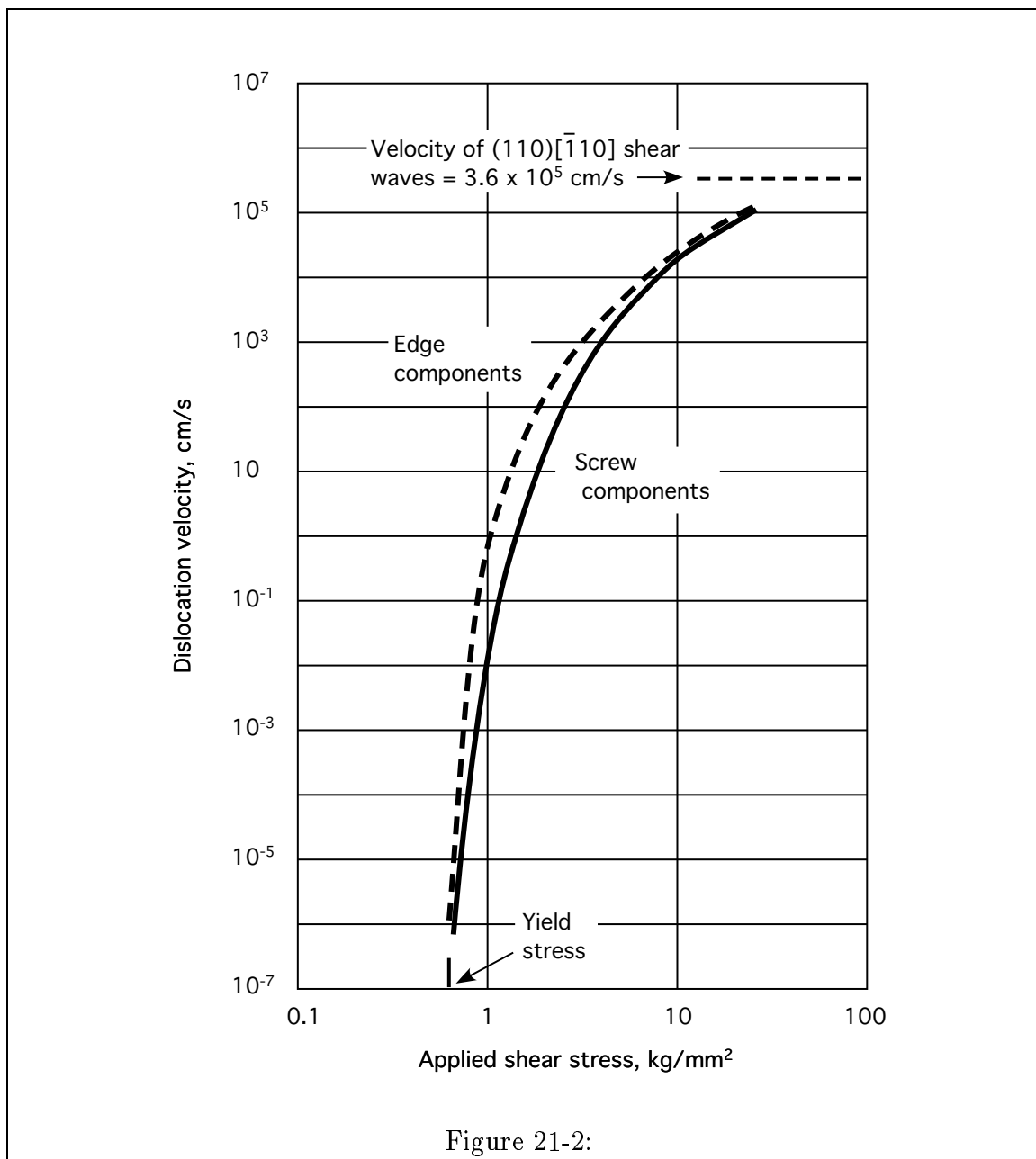


Figure 21-2:

## Dislocation climb

- Edge dislocations can absorb or emit vacancies by climbing
- *Jogs* are especially favorable sites for vacancy creation and destruction
  - A vacancy diffuses from within bulk and annihilates at a jog
  - B vacancy diffuses to dislocation core and attaches
  - C vacancy diffuses along core
  - D vacancy diffuses along core to jog and annihilates

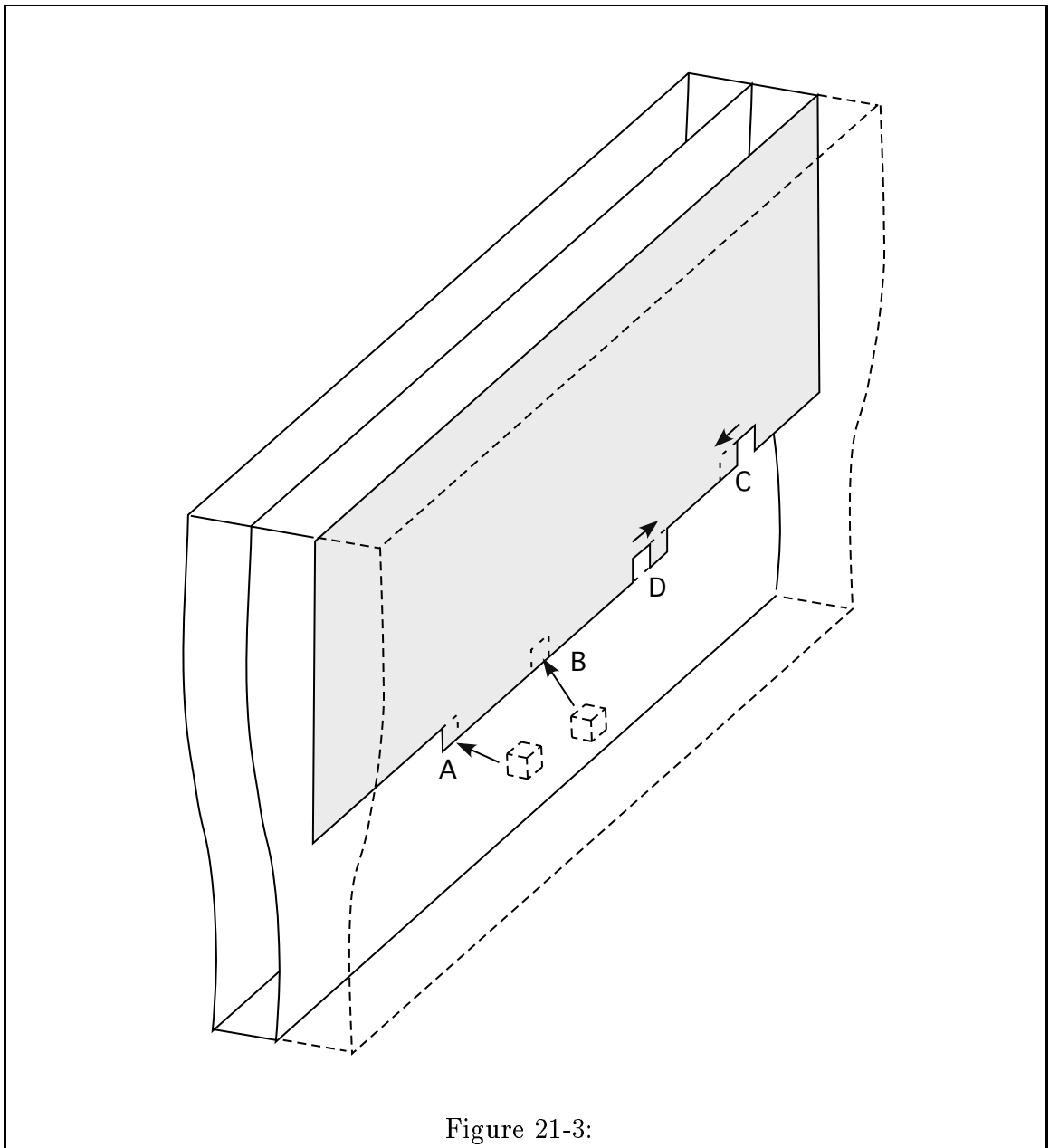
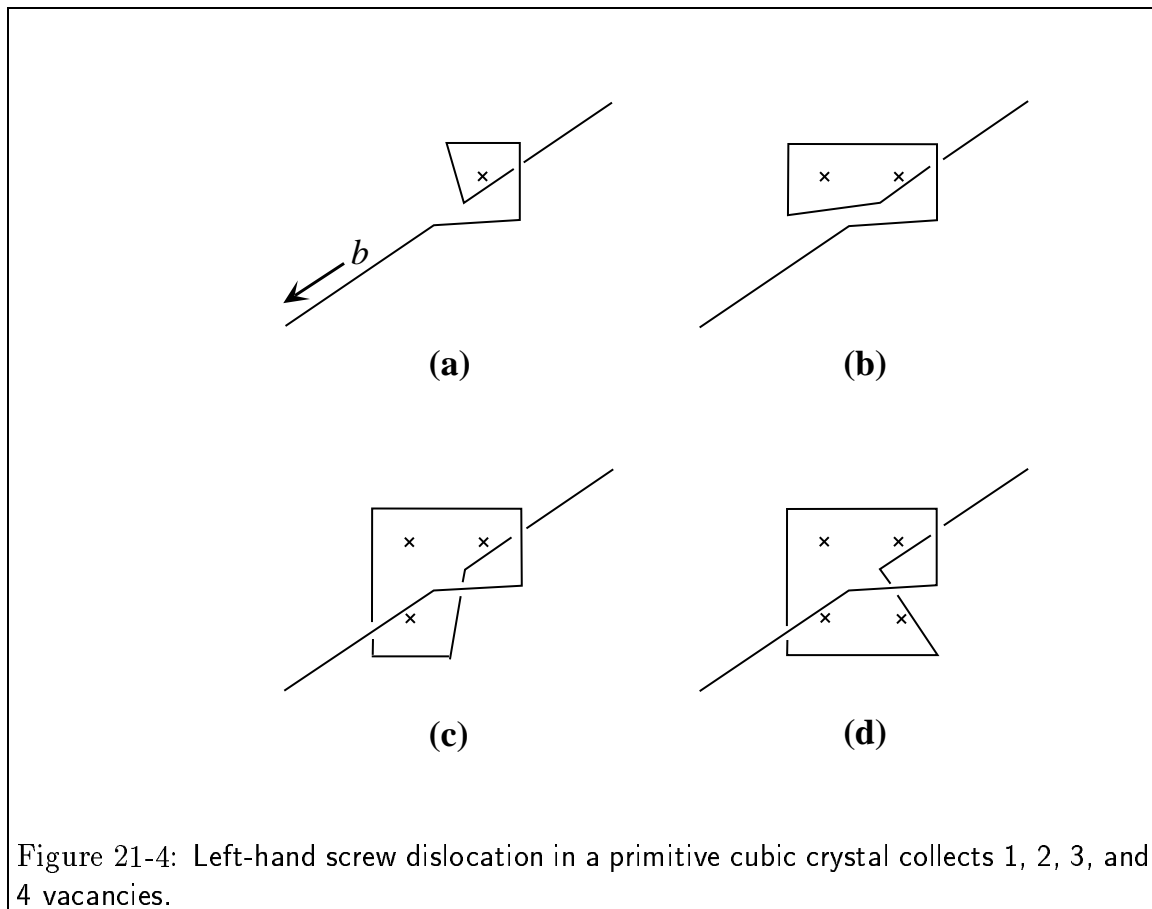


Figure 21-3:

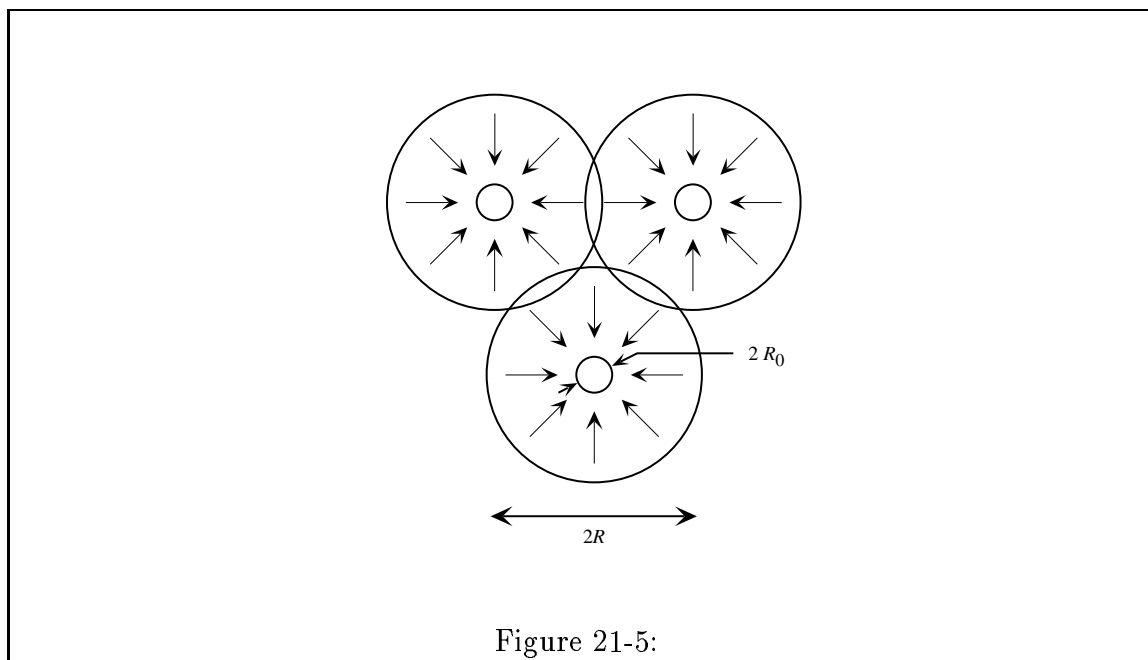
### Vacancy condensation on screw dislocations

- Formation of helical edge segments



## Vacancy condensation kinetics on edge dislocations

- Supersaturations can be relieved by diffusion of vacancies to dislocation cores



- Model as diffusion within finite cylinder of radius  $R$  where

$$\begin{aligned}
 R &= \sqrt{\pi \rho} \\
 c_\nu &= c_\nu^{eq} & R = r_0 & & t \geq 0 \\
 c_\nu &= c_\nu^0 & R_0 < r \leq R & & t = 0 \\
 \frac{\partial c}{\partial r} &= 0 & r = R & & t \geq 0
 \end{aligned}
 \tag{21-1}$$

- Approximate solution for fraction of excess vacancies remaining

$$f(t) = \exp(-\alpha_1 D_\nu t) \tag{21-2}$$

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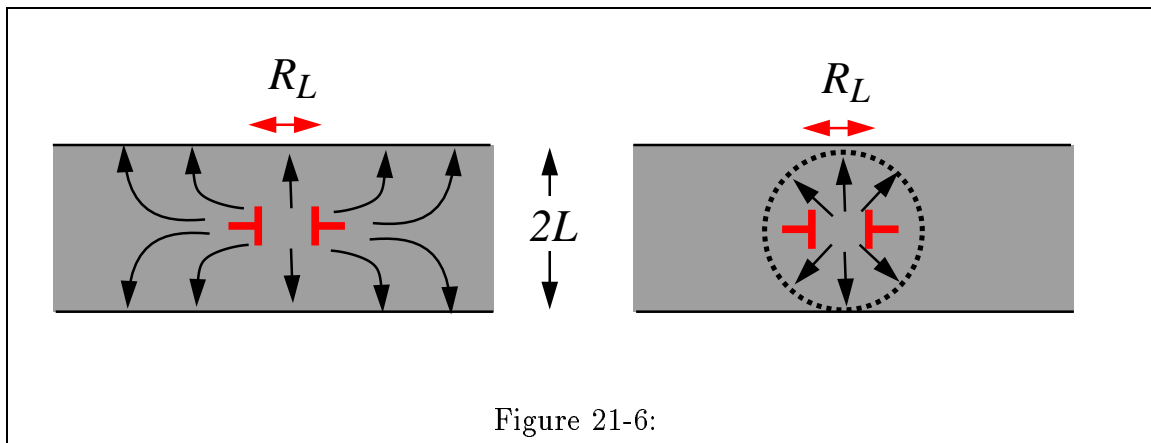
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## Shrinkage of prismatic dislocation loops by vacancy condensation

- Driving force for loop shrinkage is  $\Delta\mu$  between dislocation loop and free surface



- KPIM has a solution for the rate of decrease of loop radius adapted from electrostatics (Eq. 11.33)

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