EECS 106B/206B

Discussion 18

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Midterm Review: Thursday 1/4

- Manipulator Control
  - Lyapunov Stability
  - Impedance Control
- Grasping
  - Grasp Maps
  - Friction cone discretization, sampling
- Nonholonomic Motion Planning
  - Lie brackets vs Lie derivatives vs Lie algebras
  - Steering with Sinusoids
- Soft Robotics:
  - Material Properties
  - Rubber modeling (Gibbs Free energy, entropy, etc)
  - Embedded Sensing

Action Items

- Makeup Project Proposals due tonight
- Lab 3 due this Sunday
- HW 5 coming out this weekend
  - Project checkpoint
  - Some short problems
  - Paper reading/questions
- Lab 4 coming out soon

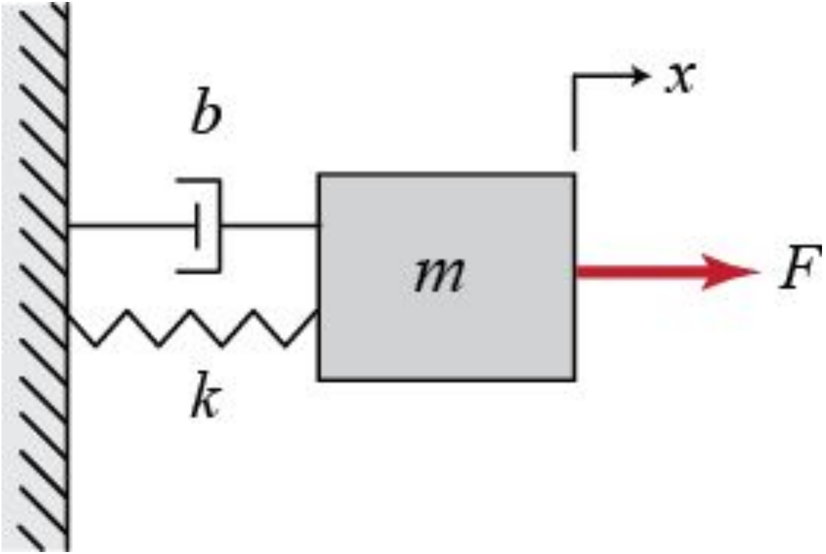
Semester Roadmap

- 4/2 and 4/4: Finish soft robotics
- 4/9: path planning
- 4/11: Guest Lecture: Hannah Stuart (underactuated hands)
- 4/16: Guest Lecture: Anca Dragan (path planning and CHOMP)
- 4/18: TBD (Techcrunch)
- 4/23 and 4/25: Project Progress Presentations
- 4/30: Guest Lecture: Sergey Levine (TBA)
- 5/02: Guest Lecture: Ken Goldberg (TBA)
- 5/10: Project Poster Session / Demo Day

Mechanics of Materials for Dummies

Mass-Spring-Damper Systems

- Canonical Mechanical Engineering System



Differential Equation

- Second-order System

Spring Force　　　Damping Fource

Applied Force　　　Movement of Mass

$$F(t) = kx(t) + M\frac{d^2x(t)}{dt^2} + k_d \cdot \frac{dx(t)}{dt}$$

Mass Spring Damper vs RLC Circuits

$$m\frac{d^2x}{dt^2} + c\frac{dx}{dt} + kx = F$$

$$L\frac{q^2x}{dt^2} + R\frac{dq}{dt} + \frac{1}{C}q = v$$

m = mass

c = damper

k = spring

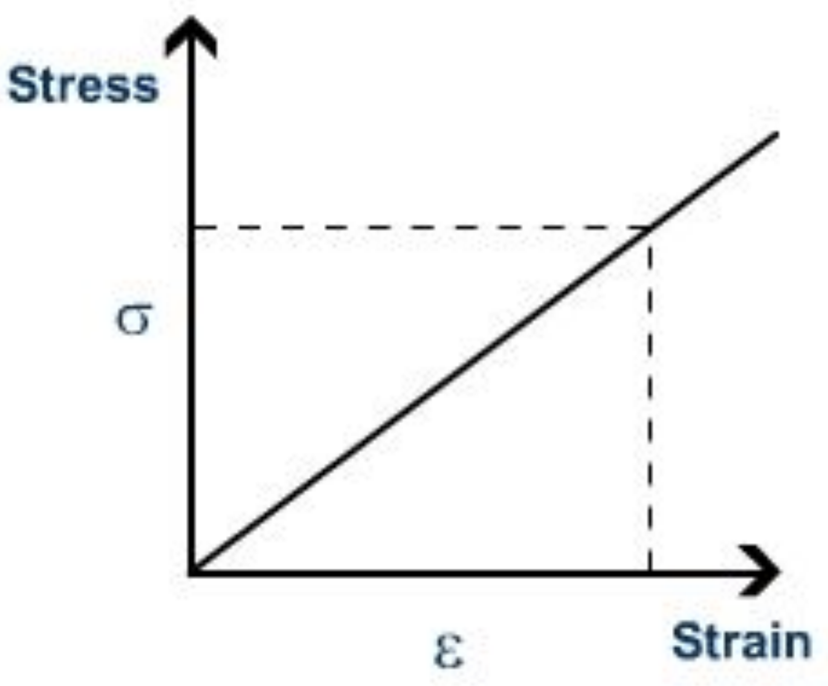
L = inductance => mass

R = resistance => damper

C = capacitance => inverse spring stiffness

Materials as Mass-Spring Damper Systems

- *Everything* is a spring.
- Sometimes things are dampers
- Ignore inertia (Why?)



Material deformation and failure

- Yield
- Fracture
- Fatigue

Stress = Force / Area

Strain = ΔL / L

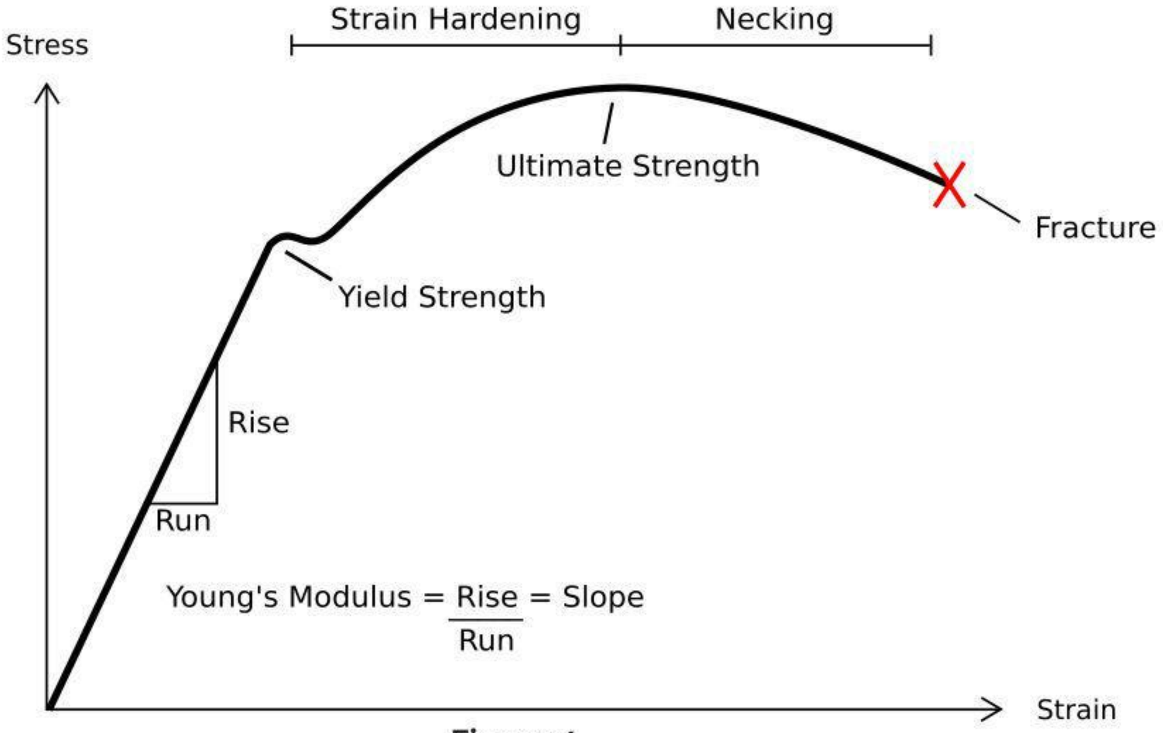
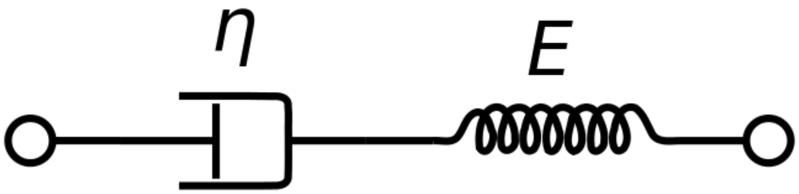


Figure 1

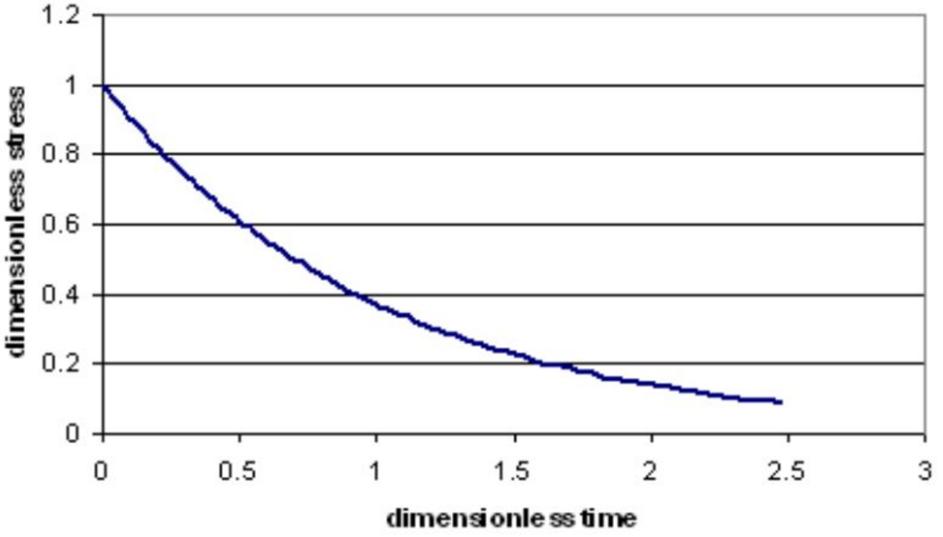
Dynamic Loading

- Now we consider *strain rate*
- Stress Relaxation: if held in a position, stress decreases over time
  - Old elastic waistband
- Creep: if held with a certain force, strain increases over time
  - Tire swing lengthens over time

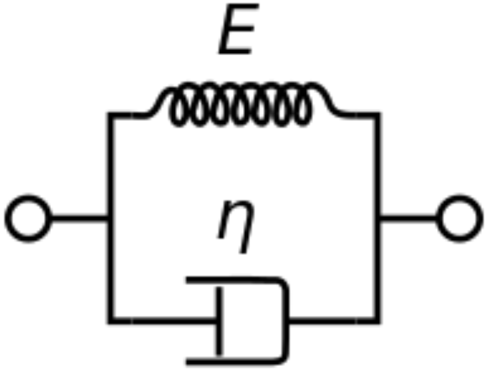
Maxwell Model: Stress Relaxation



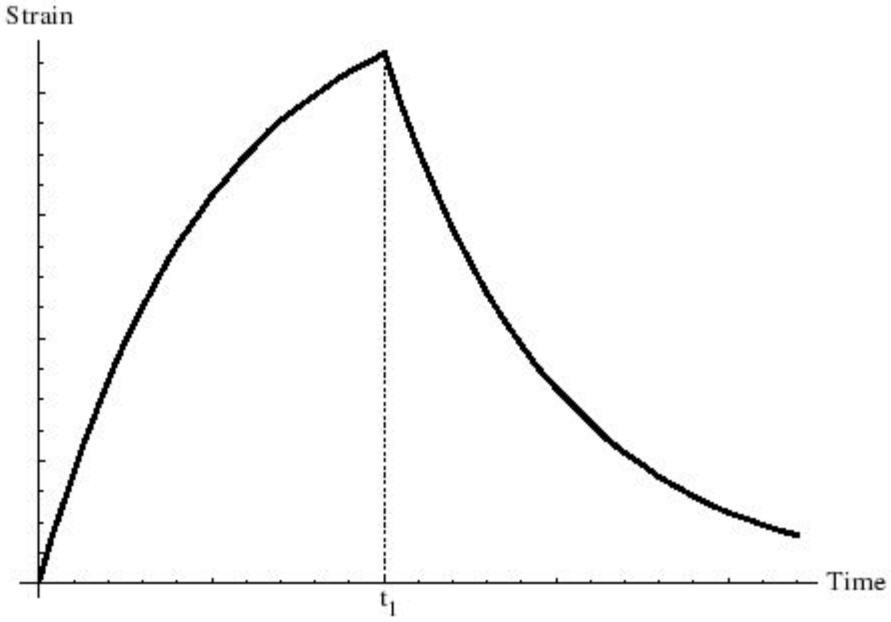
$$\frac{\dot{\sigma}}{E} + \frac{\sigma}{\eta} = \dot{\varepsilon}$$



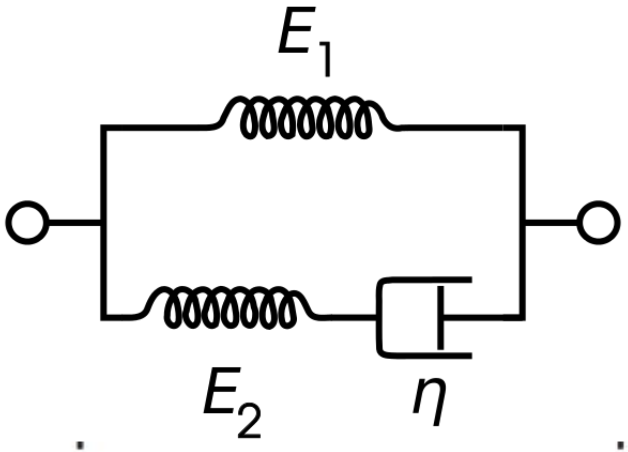
Kelvin-Voigt Model: Creep



$$\sigma(t) = E\varepsilon(t) + \eta\frac{d\varepsilon(t)}{dt}$$

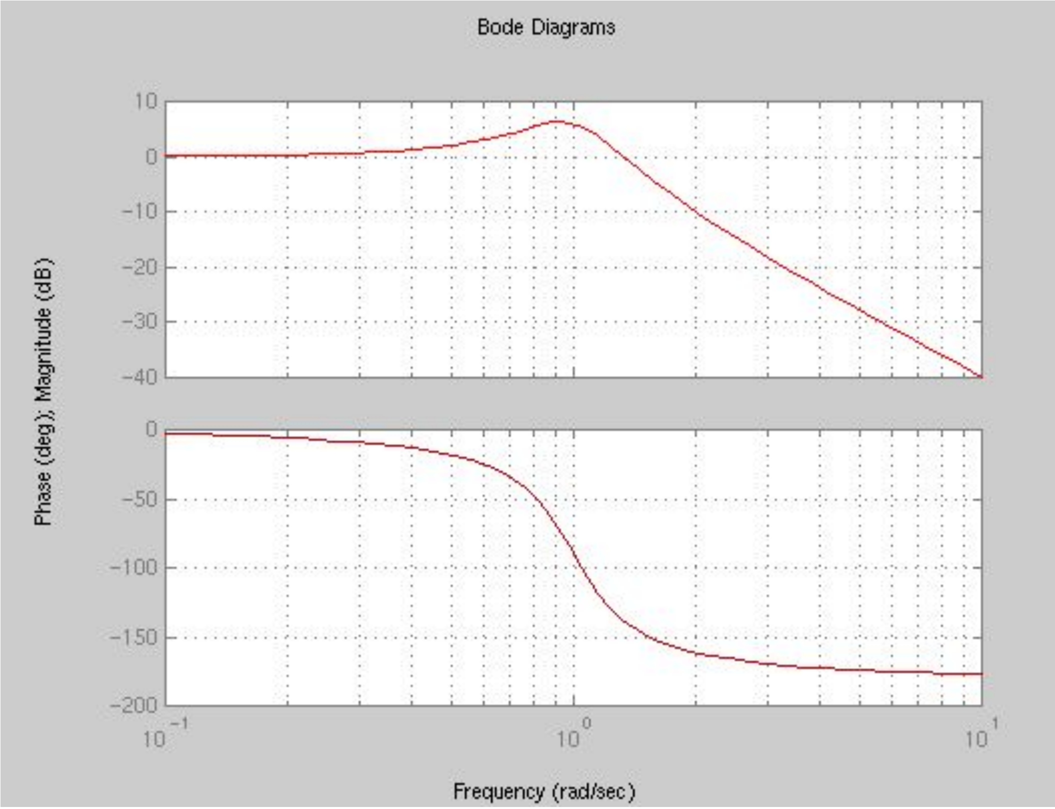


Standard Linear Solid Model: Both



$$\frac{d\varepsilon(t)}{dt} = (E_1 + E_2)^{-1} \cdot \left[\frac{d\sigma(t)}{dt} + \frac{E_2}{\eta}\sigma(t) - \frac{E_1 E_2}{\eta}\varepsilon(t) \right]$$

Cyclic Loading (underactuation):



Glossary of Terms

- Contact stress: stress between two small faces. Since contact area is very small, the surfaces deform together to increase contact area.
- Static analysis: there’s no motion, so just analyze with force/moment balances
- Dynamic analysis: Loads change over time, things are moving. You’ll need to analyze dynamic effects, like centripetal and coriolis forces
- Quasistatic analysis: Pretend that dynamic systems are static, so pretend things like coriolis and centripetal force are zero. Works well for slower motion
- Actuation: motion input to the system, from a motor, pneumatic actuator, etc