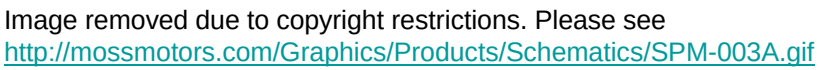
2.007 Design and Manufacturing I
Spring 2009

2.007 –Design and Manufacturing I

Belts, Chains, Cams, Bearings



Dan Frey

14 April 2009

- APO charity event
- Vote early, vote often
- I am currently in 3rd place – unacceptable!

2.007 Sponsor's Seminar

ExxonMobil

Taking on the world's toughest energy challenges.™

2.007 in Action!

Subsea Robotics in ExxonMobil's Offshore Operations

Meg Overstake and Peter Adornato
ExxonMobil Corporation

Thursday, April 23rd, 2009 7:00 PM

Extended Lab Hours

- From today until 1 May
- Monday through Friday 8AM to 6PM
- Continuous availability of lathes and mills
- Tuesday and Thursday 6:30-9:30PM
- One Saturday

An Important Message

- Although shop your are extended, we are not encouraging you to extend your hours
- Maintain a balanced approach
- Grading policies
- Last year’s seeding scores
- You are still expected to attend your assigned lab section times

Applications of Belts and Chains

Image from the Open Clip Art Library, http://openclipart.org

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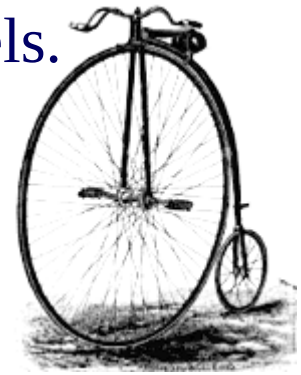
http://mossmotors.com/Graphics/Products/Schematics/SPM-003A.gif
http://mossmotors.com/Graphics/Products/Schematics/SPM-004.gif

Evolution of a Bicycle

1813 No pedals.

1840 Pedals added.

1845 Brakes appear. Large front wheels.

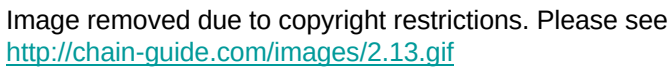


1884 Chain transmission.

1890 Pneumatic tires.

1897 The over-running clutch

Chains – Chordal Action NOT Conjugate Action



Two Kinds of Belts

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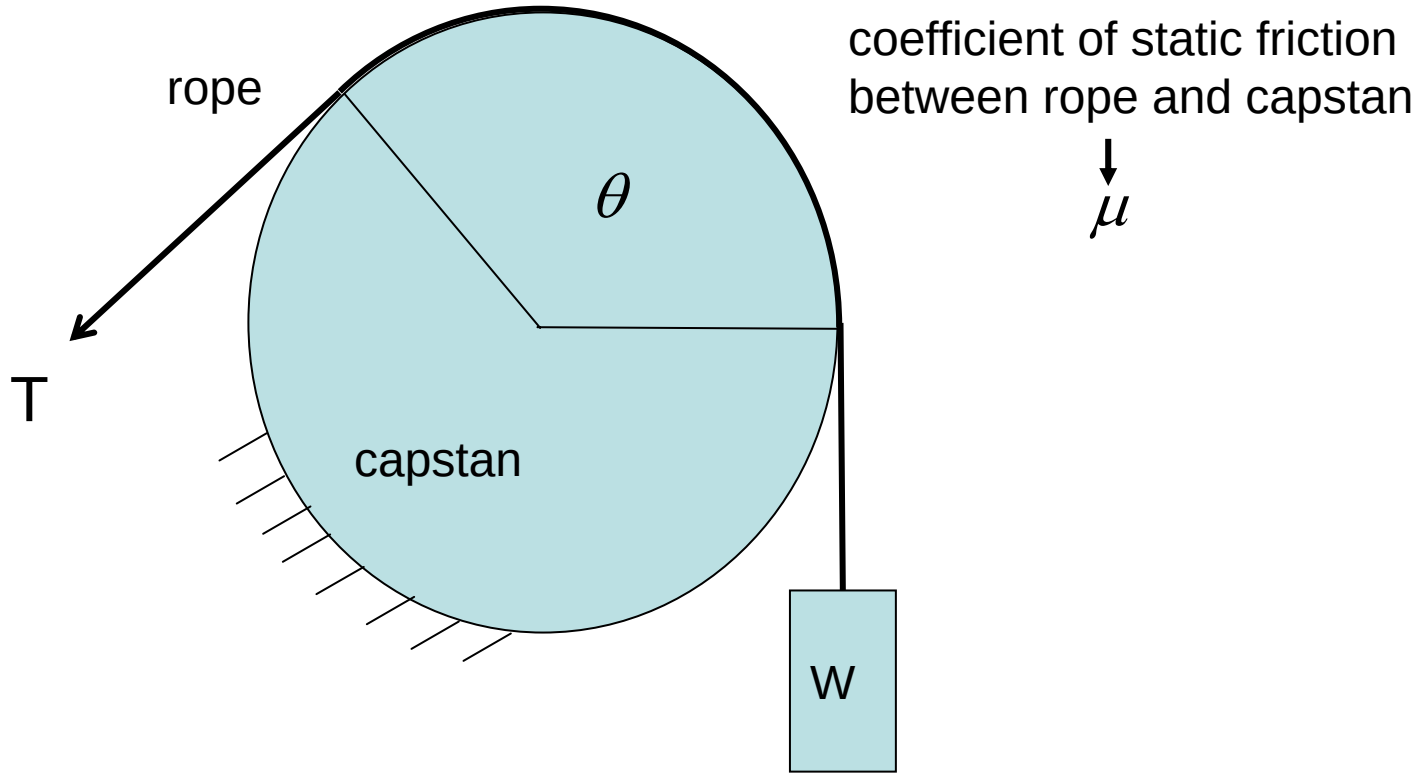
http://www.wmberg.com/catalog/catpage.aspx?url=pdf/B05A197.pdf
http://www.wmberg.com/catalog/catpage.aspx?url=pdf/B05A132.pdf

The Capstan Equation

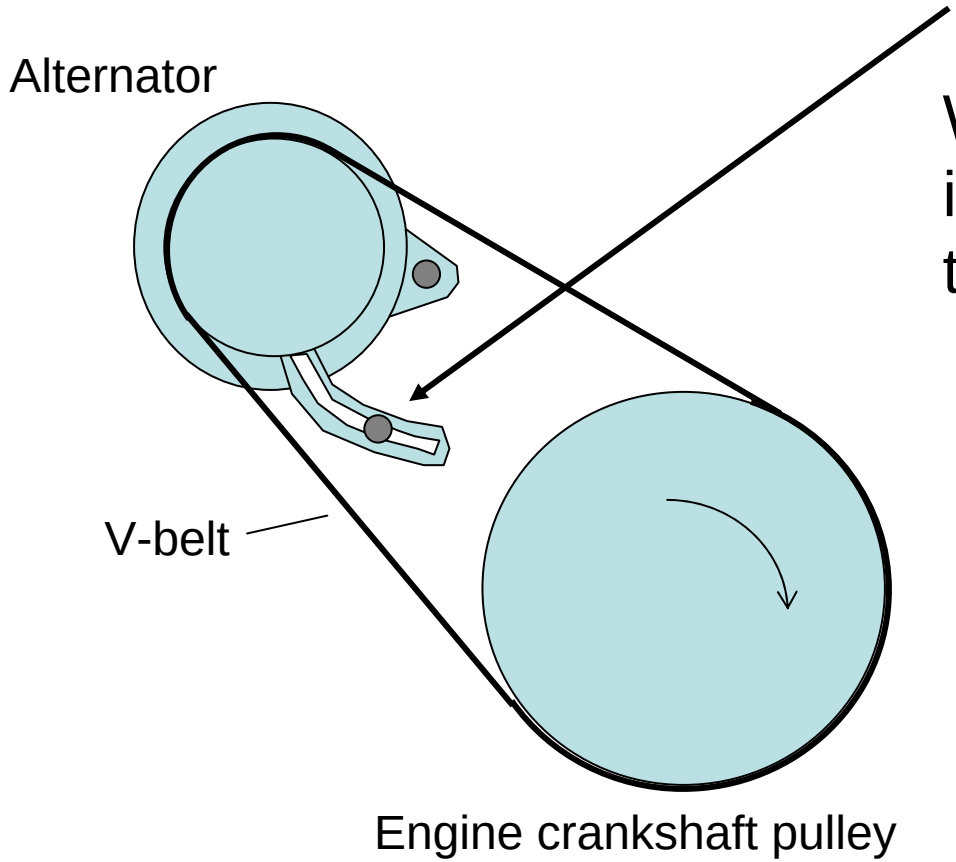


T=?

What is the smallest value of T that will keep the weight W from beginning to move downward?

A Belt Drive

Preload tension is set at P by pushing alternator up and then tightening this bolt



Which side of the V-belt is under greater tension?

Belts and Chains: The Big Picture

- What do belts and chain drives have in common?
- What do they have in common with gears?
- In what sort of applications is a belt desirable?
- In what sort of applications is a chain desirable?
- In what sort of applications is a gear better than either of them?

Definition of a Cam

Cam follower:
this one rotates,
some translate

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http://commons.wikimedia.org/wiki/File:Nockenwelle_ani.gif
http://en.wikipedia.org/wiki/Cam

Pushrod Cam

Image removed due to copyright restrictions. Please see http://static.howstuffworks.com/flash/camshaft-pushrod.swf

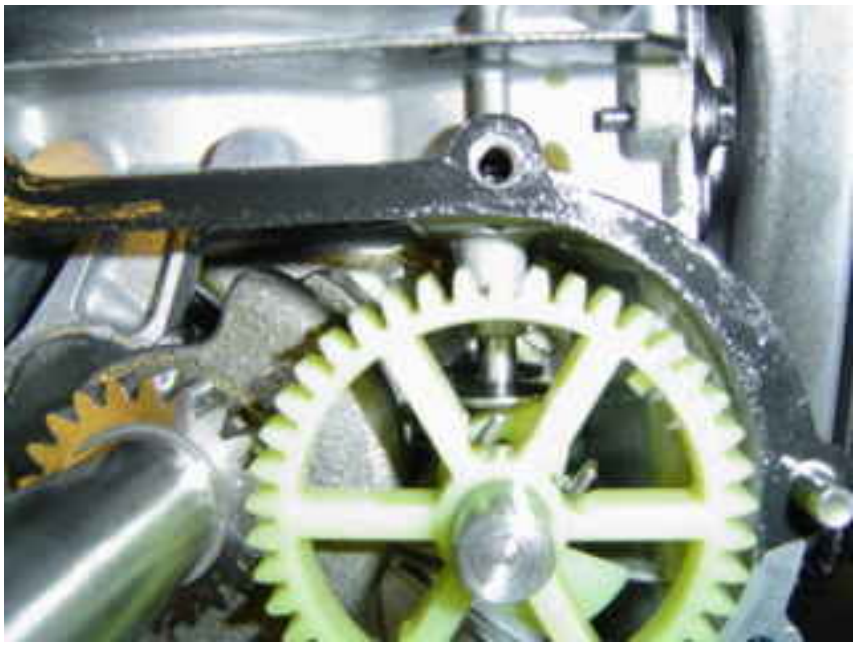
- Key advantage – cam shaft is mounted in the engine block and not in the cylinder head
- Note the pushrod is effectively a translating cam follower

Overhead Cam

Image removed due to copyright restrictions. Please see http://static.howstuffworks.com/flash/camshaft-sohc.swf

- Key advantage – dispense with pushrod and its elasticity, inertia, failure modes, etc.
- Note the rocker arm is a rotating cam follower (and essentially flat faced)

Cams in the Lawnmower Engine



Cams in Machine Tools

Screenshot of cam-controlled multispindle lathe removed due to copyright restrictions.

Cams in a Kinetic Sculpture

- As the cam rotates, information recorded on the cam is used to drive the pen writing “Go faster!”

Courtesy Arthur Ganson. Used with permission.

Roller Follower

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http://www.wmberg.com/catalog/catpage.aspx?url=pdf/B05C019.pdf

- Often, you can just have the cam slide on the follower
- This requires very good hardness of the cam and follower and excellent lubrication
- But, sometimes a roller followers is used
- Standard designs are available in catalogs

Closure of Cams

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http://www.camcoindex.com/images/facegroovecams.jpg
http://www.engr.colostate.edu/~dga/mech324/handouts/cam_stuff/Ducati_desmodromic_cam_animation.gif

- Force closure
  - Use a spring (usually) to ensure cam and follower are always in contact
  - Most common
  - Potential for lost contact w/ high acceleration
- Form closure
  - Geometry ensures closure
  - Groove
  - Conjugate cams

(aka Desmodromic)

http://members.chello.nl/~wgj.jansen/desmomovies.html

Axial Cams

- Motion of the follower is along the axis of the cam's rotation
- Face
  - Open

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- Barrel
  - A form closed axial cam

S V A J Diagrams

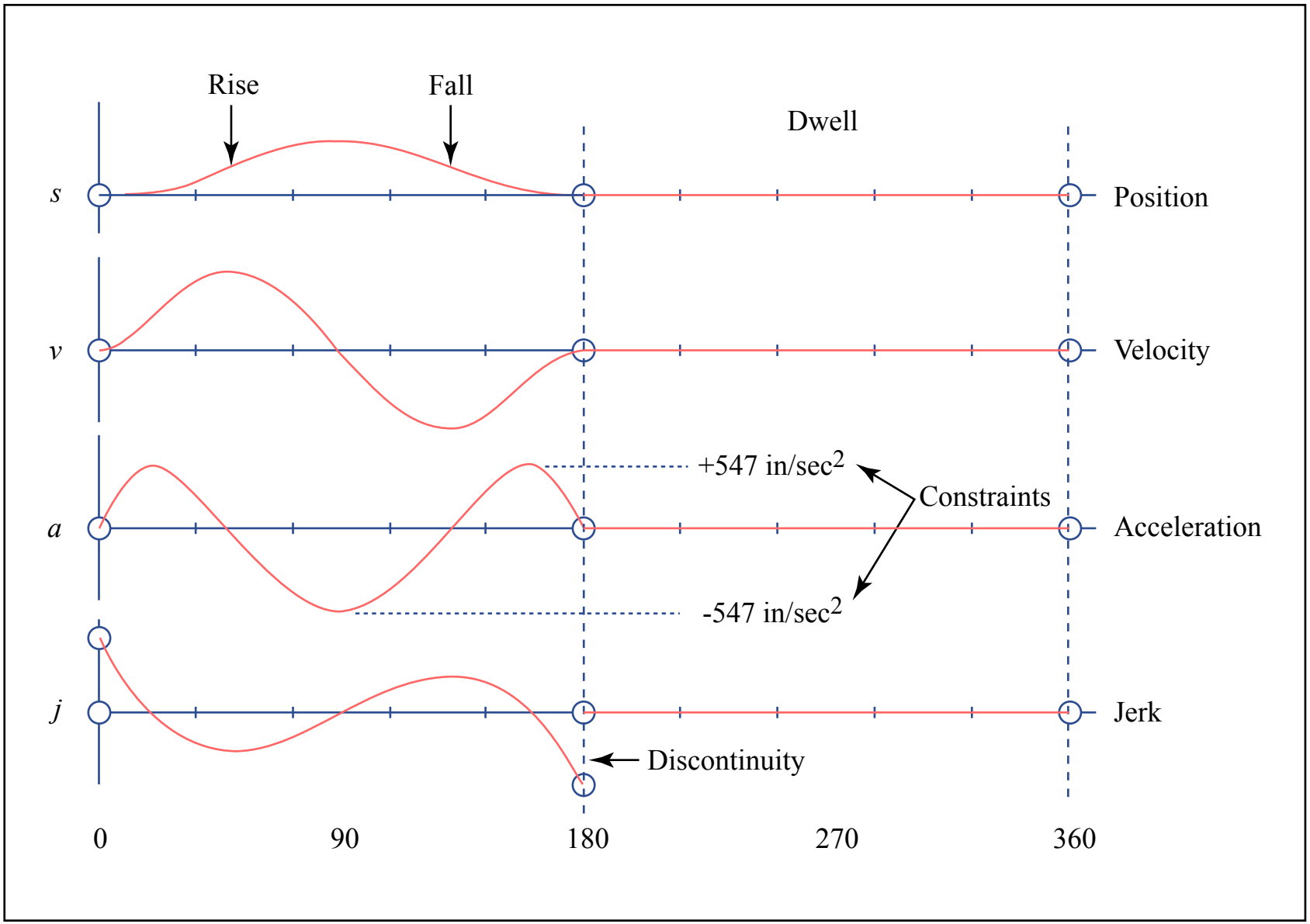
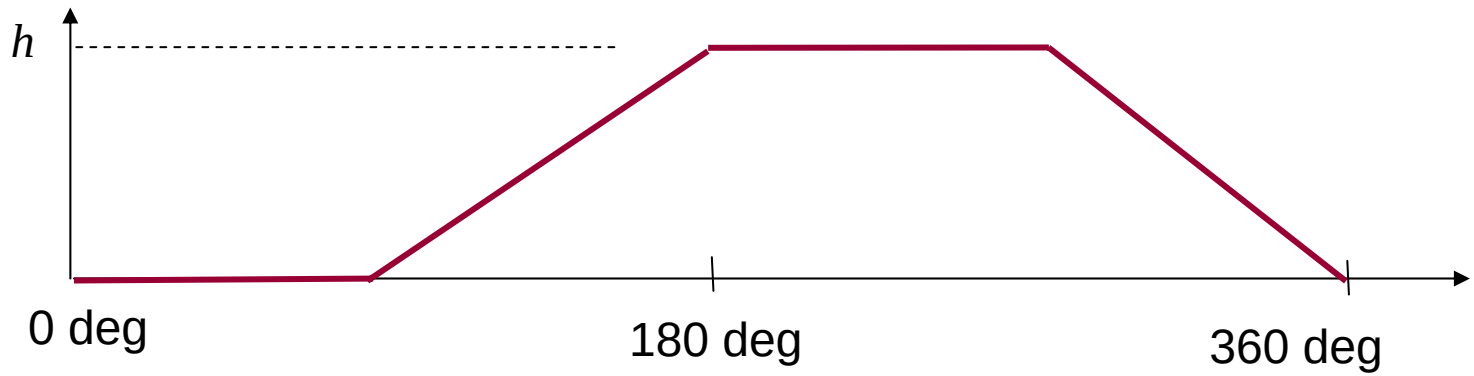


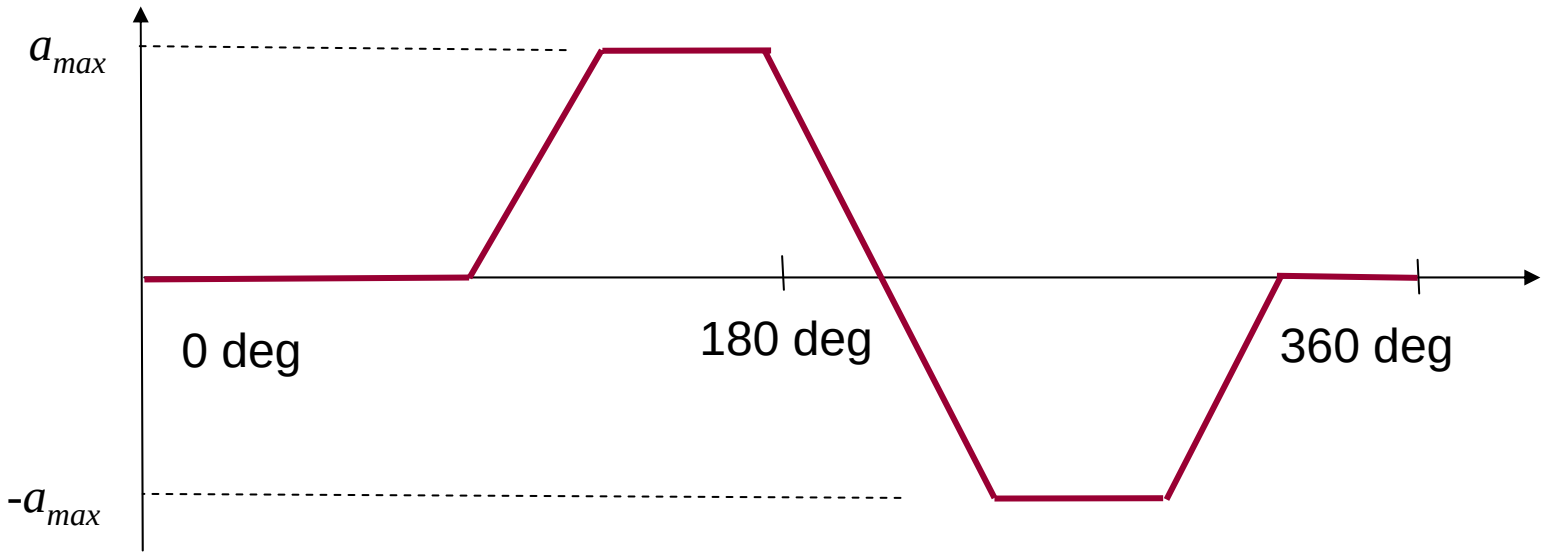
Figure by MIT OpenCourseWare.

- The following displacement curve is proposed for a cam device



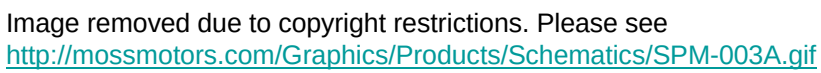
- Sketch the velocity and acceleration curves

- The following acceleration curve is proposed for a cam device



- Sketch the position, velocity and jerk curves

Journal Bearings



Journal Bearings

- Advantages (compared to rolling element bearings)
  - Require less space
  - Are quieter in operation
  - Are lower in cost
  - Greater Rigidity
  - Longer life
- Disadvantages (compared to rolling element bearings)
  - More friction therefore more power wasted
  - Stringent requirements on supply of lubricant
    - Must stay clean
    - Must not be interrupted
    - Temperature must be controlled

Early Experiment

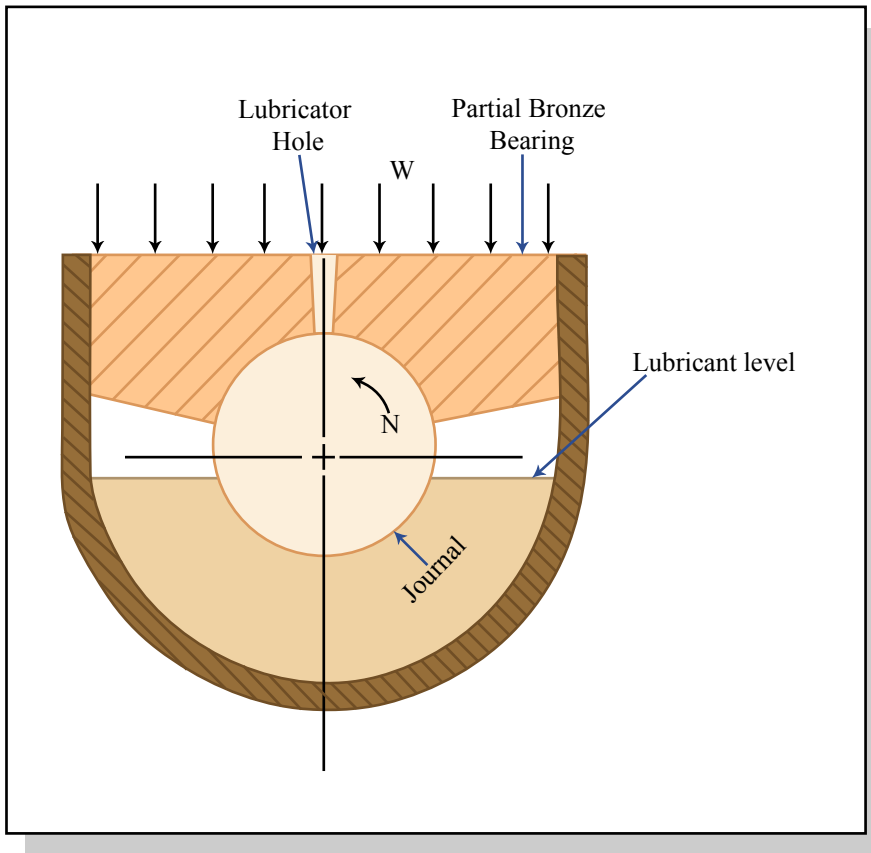
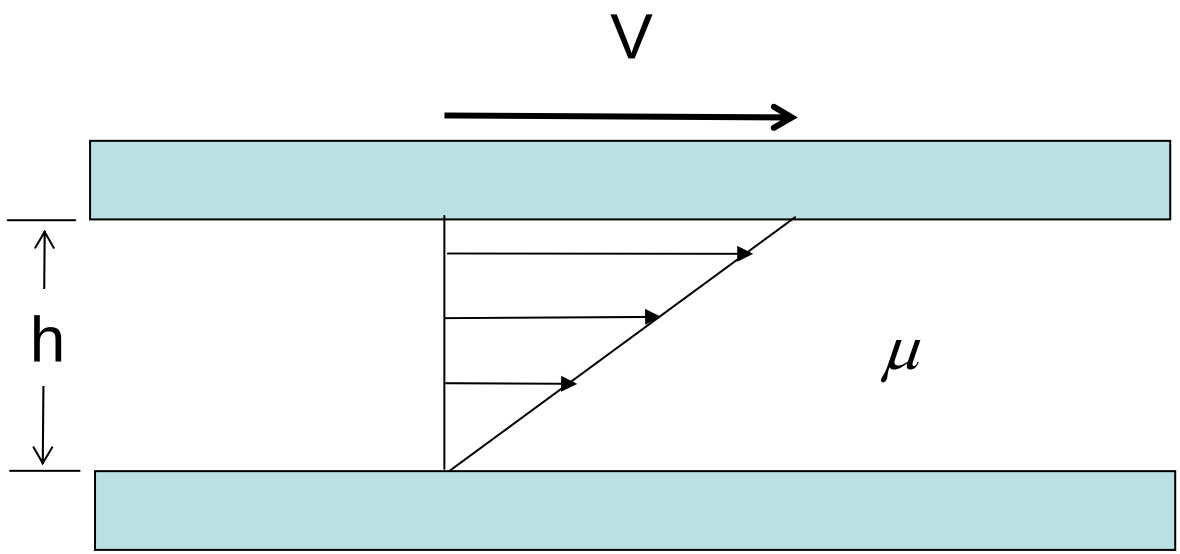


Figure by MIT OpenCourseWare.

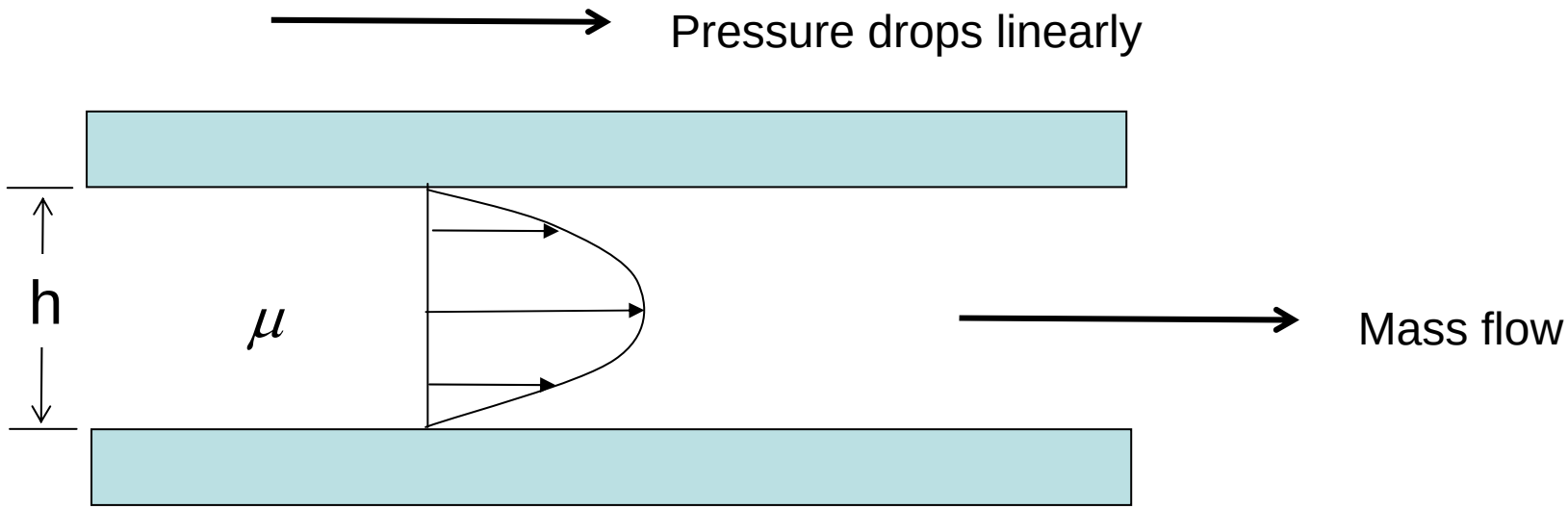
Say a railroad tank car creates the downward force W. The projected area of the partial bearing was A. Tower observed that the gauge pressure measured from the "lubricator hole" was about $2W/A$.

Tower, B., 1885, "First Report on Friction Experiments," *Proceedings of the Institute of Mechanical Engineers*, pp. 58-70.

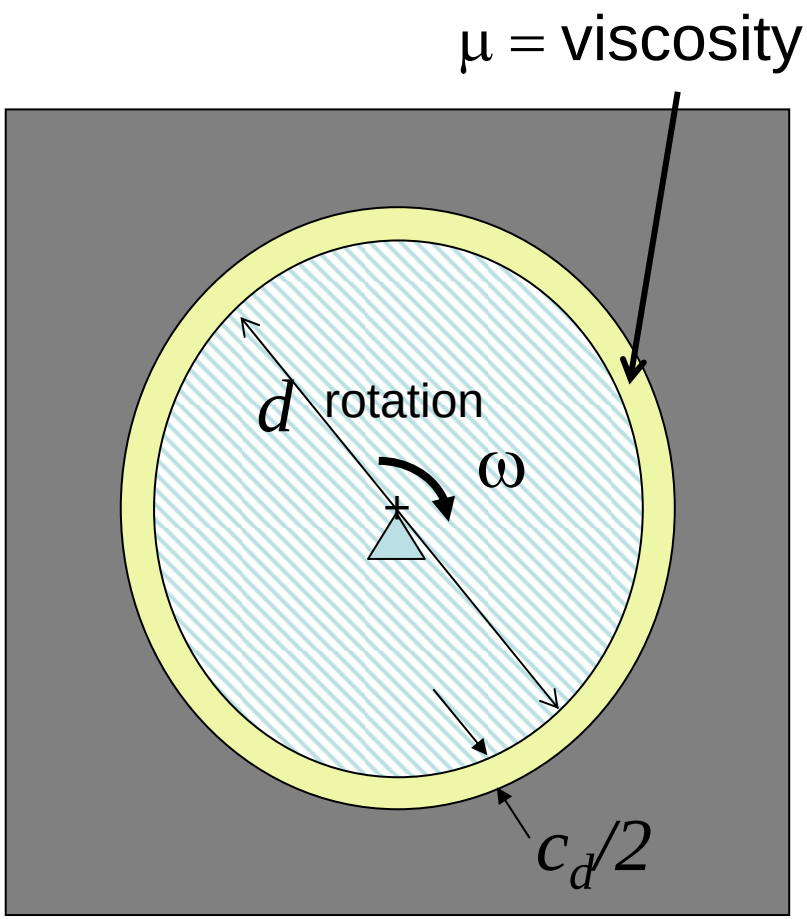
Couette Flow



Poiseuille Flow



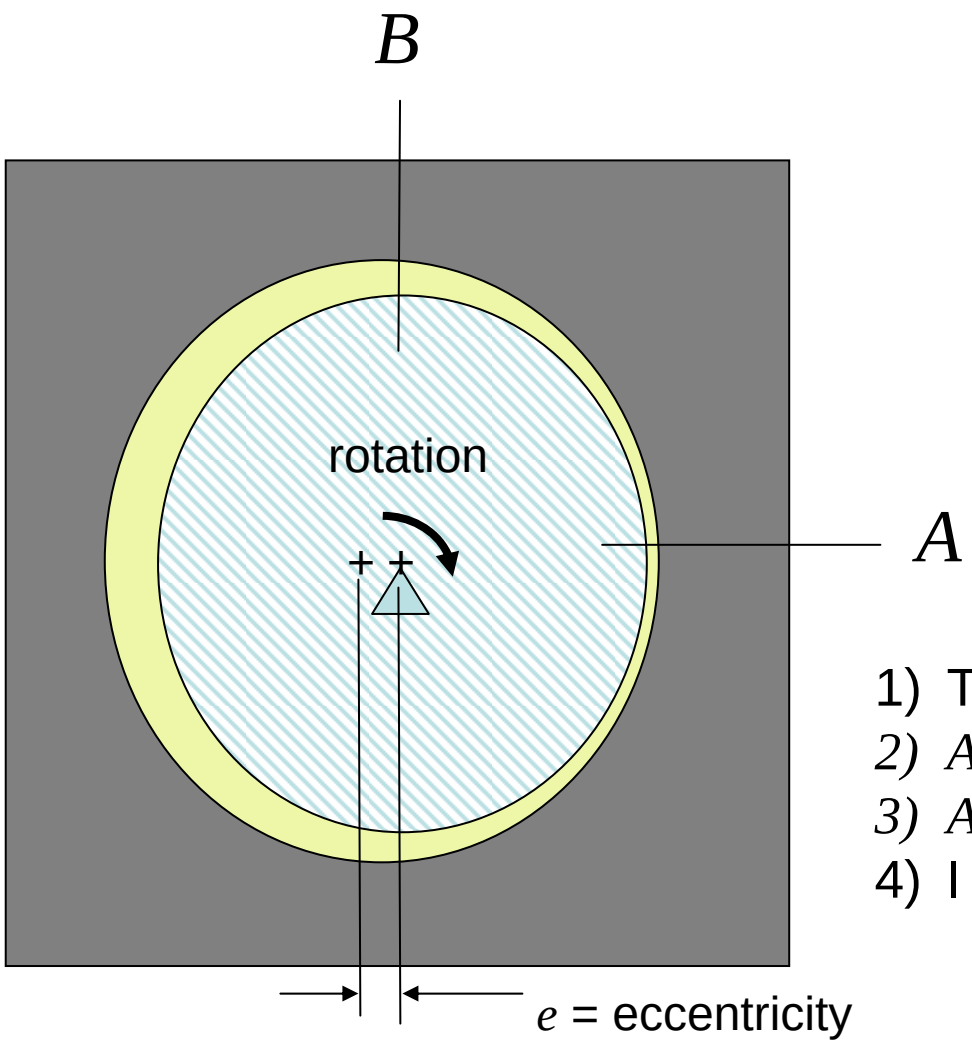
Journal Bearings



How does the torque applied to maintain a constant rotation rate depend on μ and c_d? (assume full film lubrication with a Newtonian fluid)

1) Linearly proportional to the product
2) Linearly proportional to the ratio
3) Some other dependence
4) I don't know

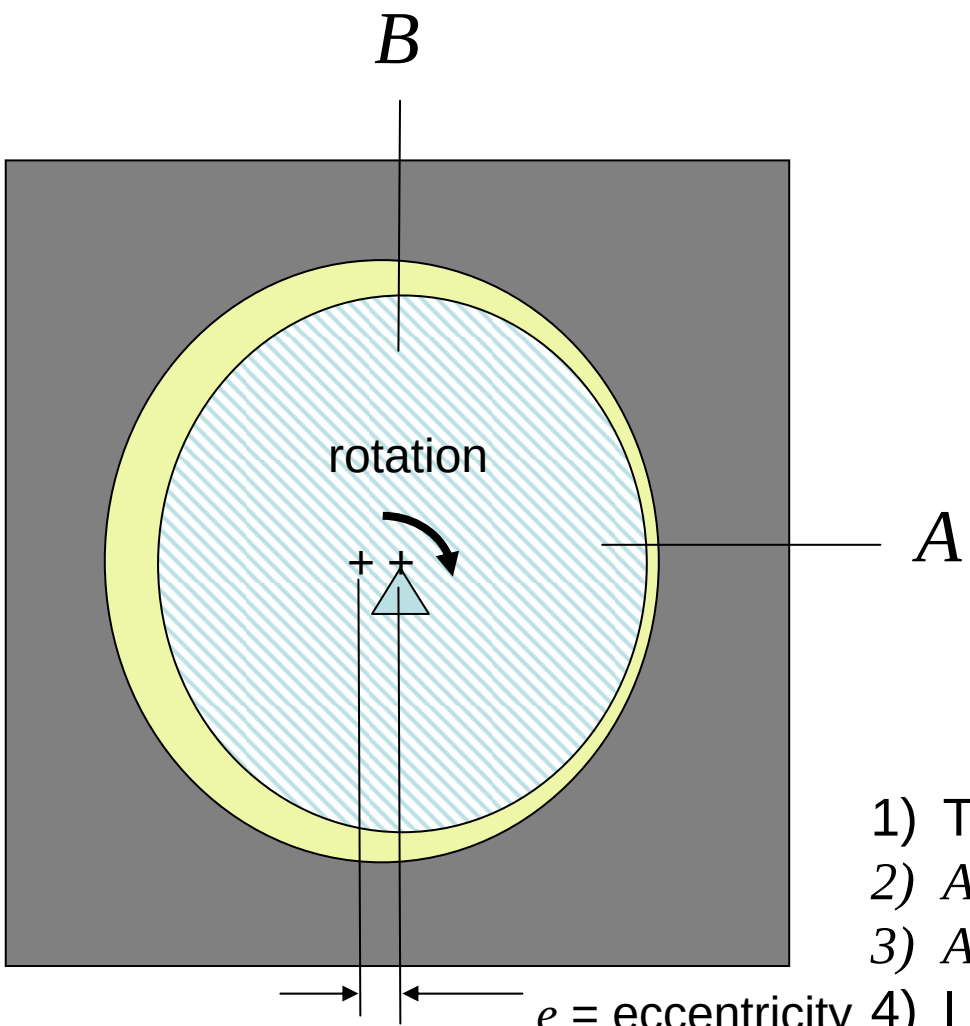
Journal Bearings



Which statement is true regarding the rate of fluid flow past line A and the fluid flow past line B?

1) They are essentially the same
2) $A < B$
3) $A > B$
4) I don't know

Journal Bearings

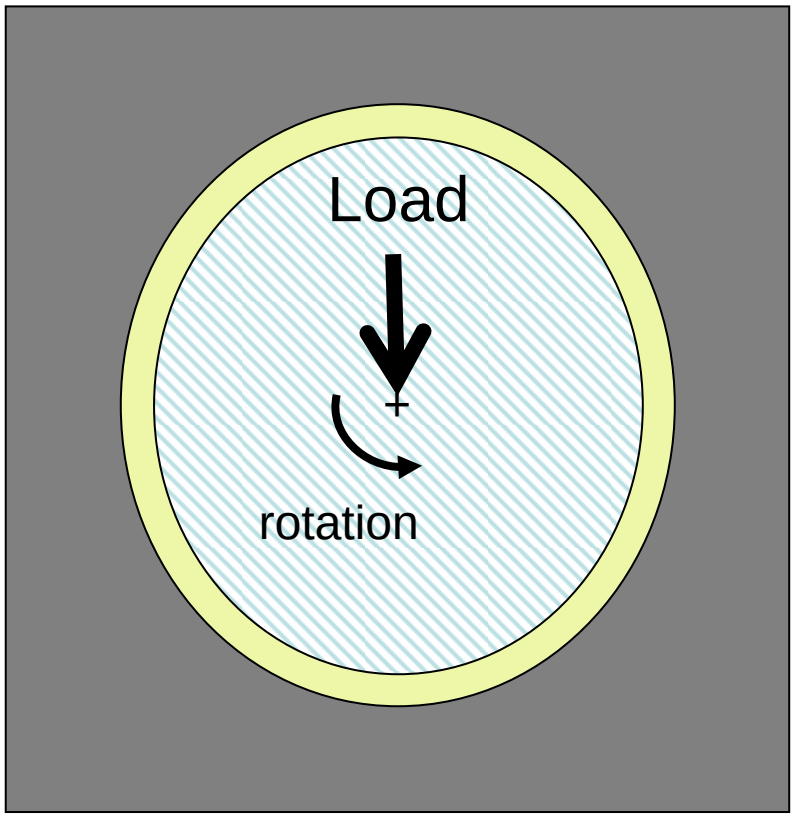


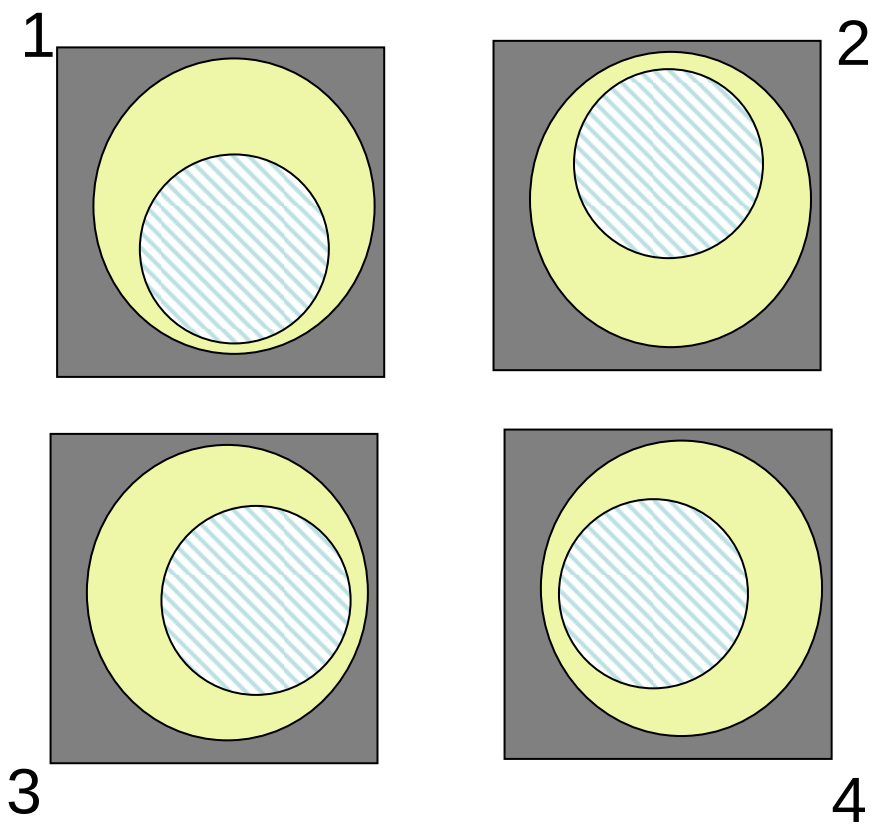
Which statement is true regarding the rate of fluid flow past line A and the fluid flow past line B <u>due to Couette flow only</u>?

1) They are essentially the same
2) $A < B$
3) $A > B$
4) I don't know

Concept Question

When the bearing is under load, what is the relative position of the shaft and block?





Rolling Element Bearings

- Low friction, especially with high starting torques

Self-aligning ball bearing	0.0010
Cylindrical roller bearing	0.0011
Thrust ball bearing	0.0013
Single row deep-groove bearing	0.0015
Tapered roller bearing	0.0018
Needle bearing	0.0045

Radial Ball Bearings

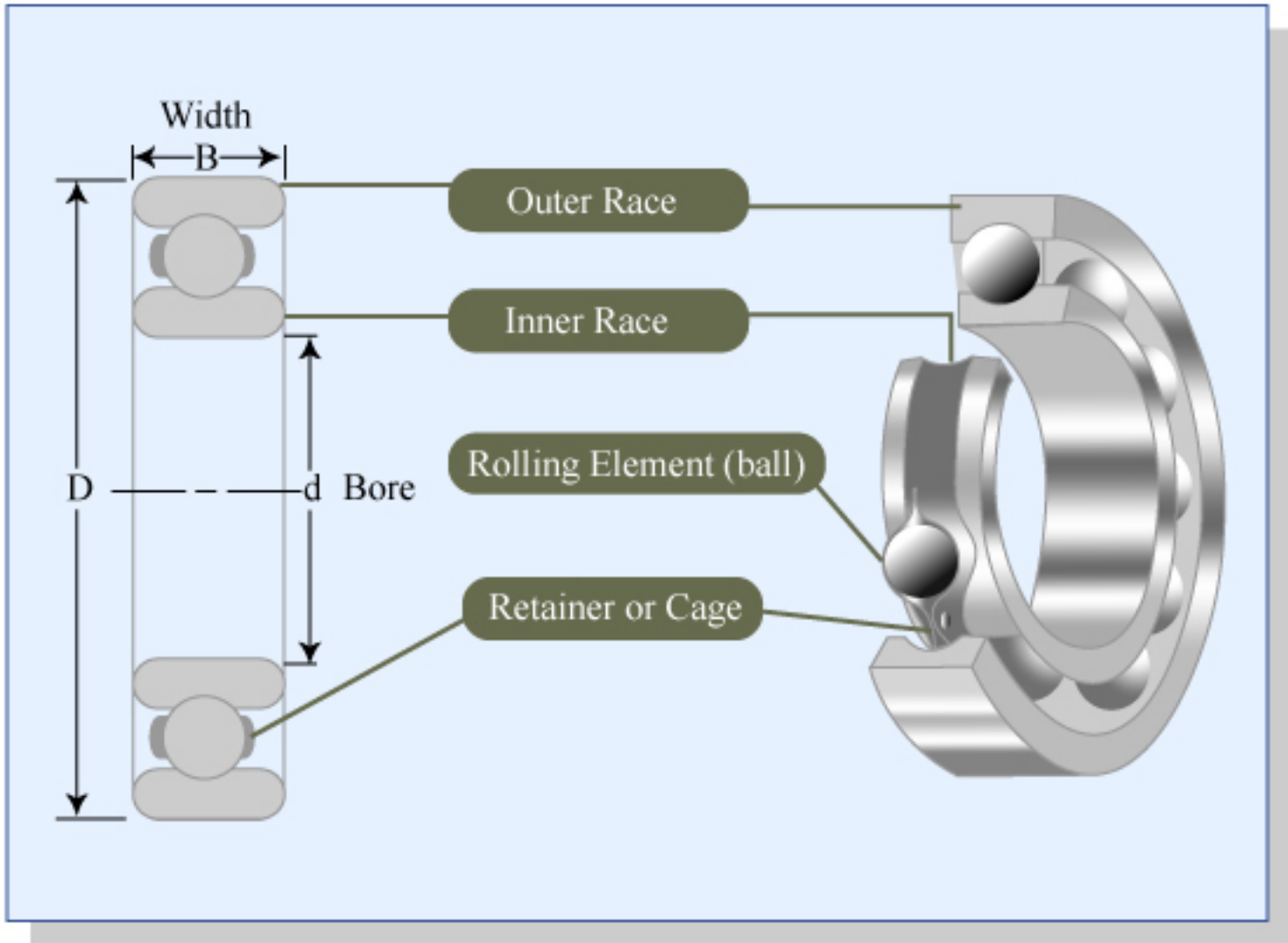


Figure by MIT OpenCourseWare.

Tapered Roller Bearings

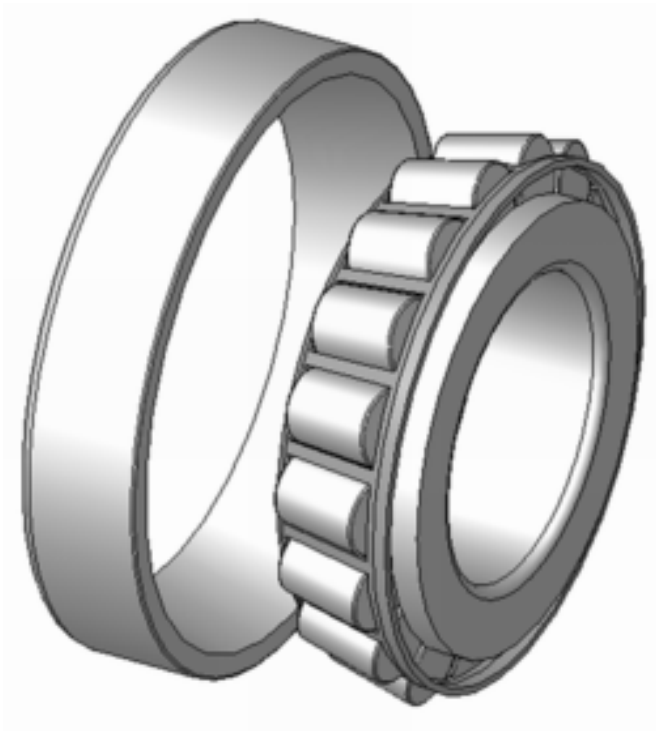


Image courtesy of Silberwolf on Wikimedia Commons.

Installing Bearings

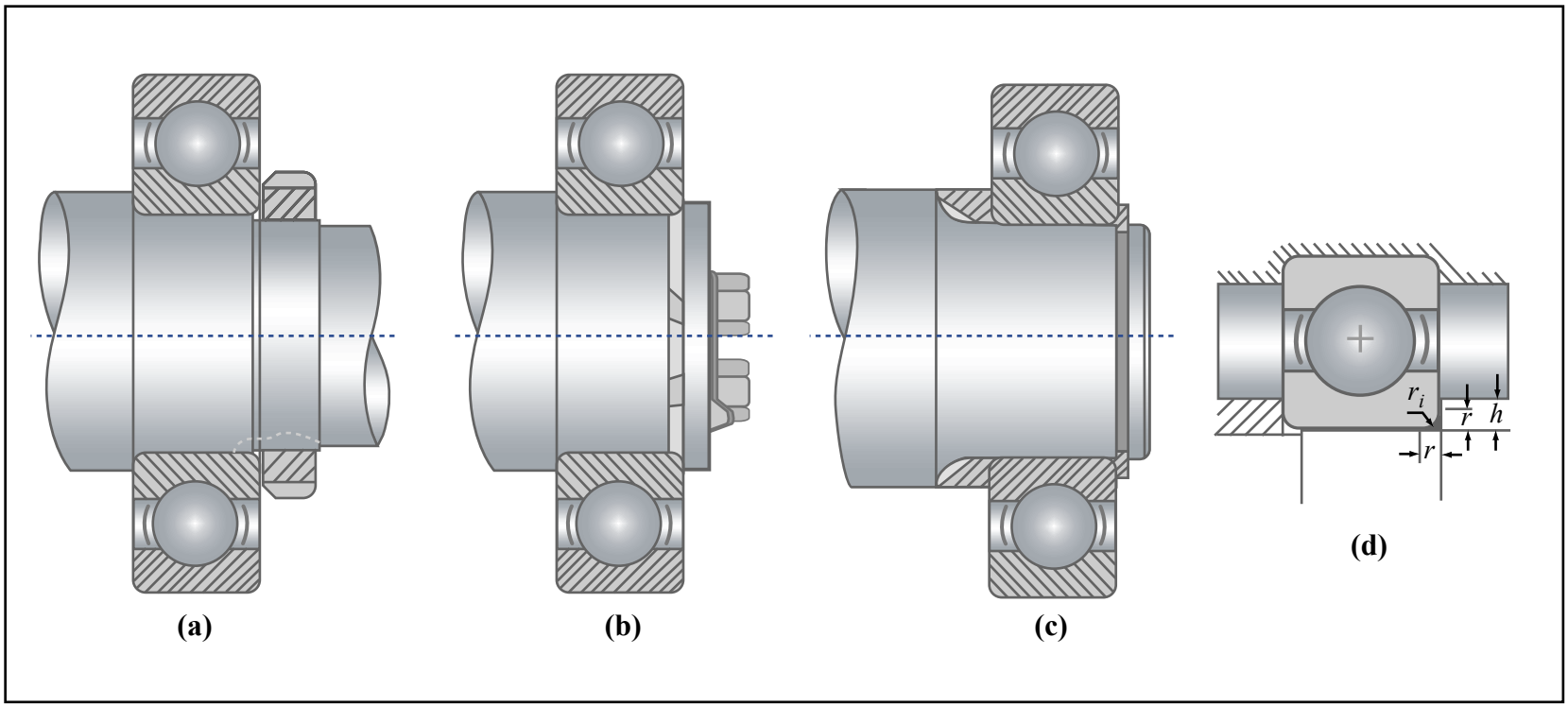


Figure by MIT OpenCourseWare.

Bearing Life

- L_{10} or Rating Life
  - The number of revolutions that 90% of a group of bearings will complete or exceed before the first evidence of fatigue develops.
- Average Life ~ 5 x L_{10}

Load Ratings

- Static Load Rating
  - The maximum load at which the most heavily loaded element experiences elastic rather than plastic deformation
- Dynamic Load Rating
  - The load a bearing can carry for 1 million inner-race revolutions with a 90% chance of survival

Load Rating

- Depends on
  - Size of rolling element
  - Number of rolling elements
  - Number of rows
  - Conformity between rolling elements and races
  - Contact angel under load
  - Material properties
  - Lubricant properties
  - Operating Temperature
  - Operating speed

Calculating Bearing Life

$$L_h = \frac{10^6 \, (C/P)^{m_k}}{60 \, N_b}$$

L_h = Life (hours)

C = dynamic load rating

P = equivalent dynamic load

N_b = rotational speed (rpm)

m_k = load-life exponent

(3 for ball bearings, 10/3 for roller bearings)

Next Steps

- Today
  - Lab hours 6:30-9:30
  - Exam review also available in the P-lab
- Thursday 16 April
  - Exam #2