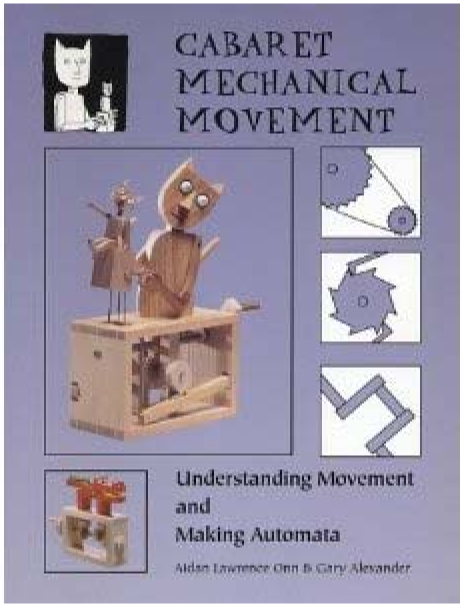
Mechanisms and Algorithms

Simple Machines I: Levers, Shafts and Cranks



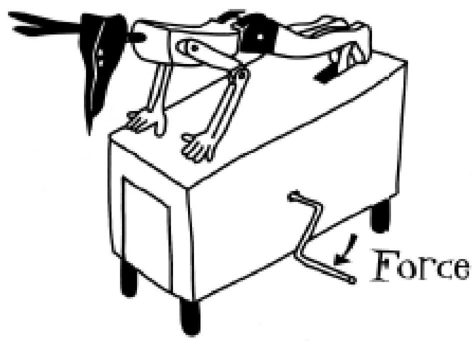
Cabaret Mechanical Movement
By Aidan Lawrence Onn and Gary Alexander

- Excellent reference book
- Lectures reference figures from this book
- Good concept book but no kinematic synthesis
- Wood and paper, but not Lego

Some Principles

- History of Automata circa 500 BC
- Movements of today's machines (e.g. industrial robots) still use same mechanisms

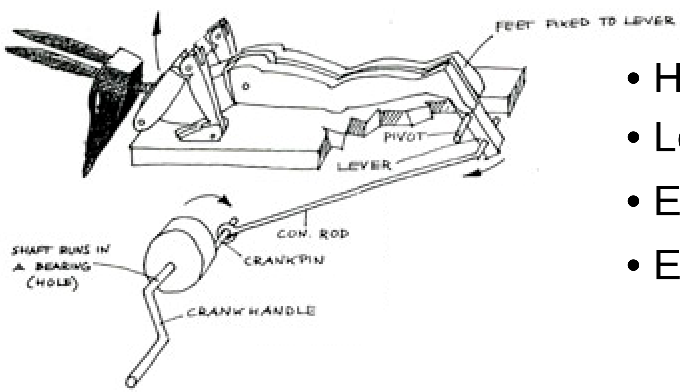
Observations: Appearances can be deceptive. Motion is not always obvious



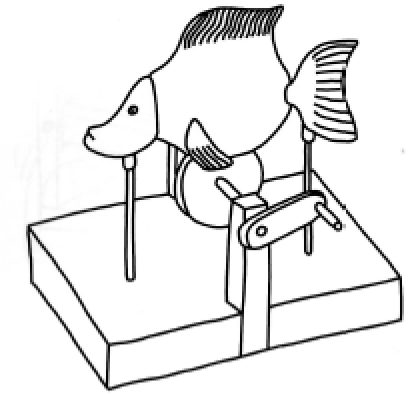
Anubis by Paul Spooner and Matt Smith

Explain how this works

http://www.youtube.com/watch?v=YFqkKn9PgNg



- Hands are fixed to the floor
- Lever: Feet (load), Pivot (fulcrum), Effort (Connecting Rod)
- Effort generated by Crank and Connecting Rod
- Effort acts on feet thus appears Anubis is doing push-ups

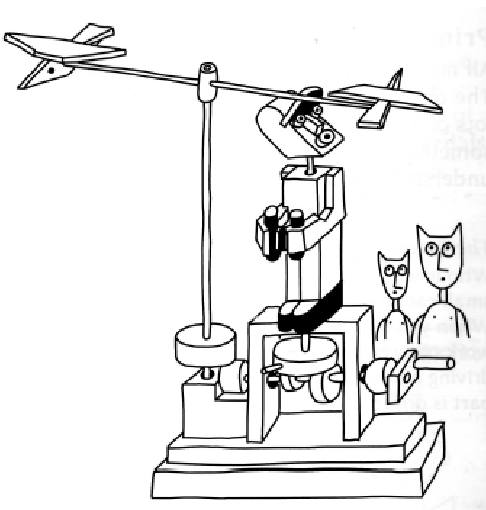


- Body moves vertically on shafts
- Body rests on cam
- Rotating crank, rotates cam
- Appears that fish undulating

http://www.youtube.com/watch?v=ClQyF_4bTy0

Wriggling Fish by Jan Zalud

Explain how this works



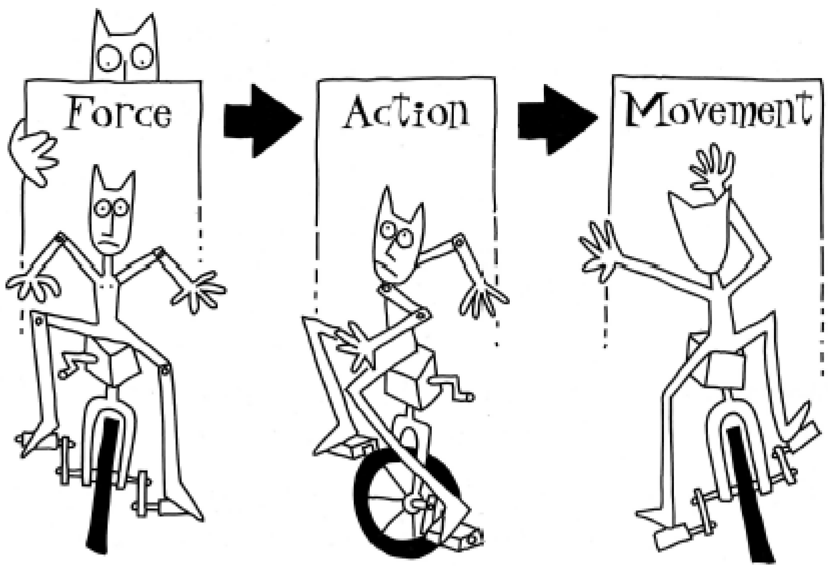
Birdwatcher by Peter Markey

- Turning handle causes man’s head to turn side-to-side
- Birds just rotate

If you want to make things move, spend time studying how other things move

Machines:

- A machine is something that modifies force
- Input is when force comes from an outside source
- The mechanical action of the machine produces output



Q1: What is the input?

A1: Legs pushing on pedals

Q2: What is the output?

A2: Wheel rotation

Mechanics: The study of the motions and forces that occur between input and output

Mechanics:

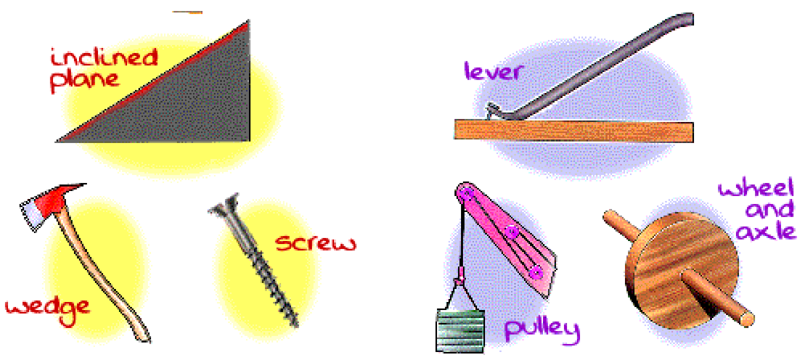
- Origins trace back to ancient Egypt
- **Archimedes:** first recorded scientific foundations for mechanics circa 3rd BC
- Archimedes: formulas for equilibrium of simple levers and centers of gravity

- **Galileo:** circa 1564 used mathematics to solve physical problems
- Galileo advanced Archimedes' work and developed the science of Dynamics

- **Newton:** circa 1642 developed the 3 laws of motion
- Law 1: motion does not require force; force only needed to accelerate motion
- Law 2: the greater the force, the greater the acceleration
- Law 3: action and reaction; if object pushed, it will push equally in opposite direction

All mechanical systems are made from combining 5 basic ones:

- Inclined Plane (or slope)
- Wedge
- Screw
- Lever
- Wheel



But…

Wedge is 2 inclined planes joined together

Screw is inclined plane wrapped around shaft

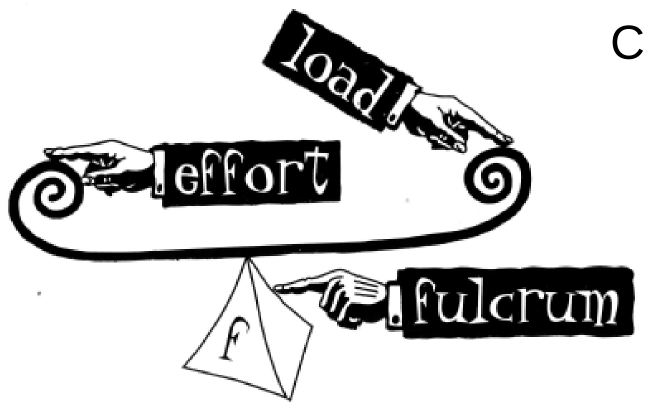
Wheel is a lever that rotates 360 degrees

Thus: Only lever and inclined plane are really the only 2 basic mechanisms

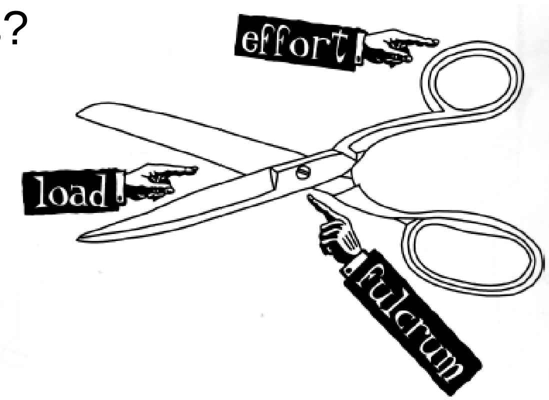
Levers

All machines (almost) always employ at least one lever

Lever of the First Order: Fulcrum is always between the load and the effort



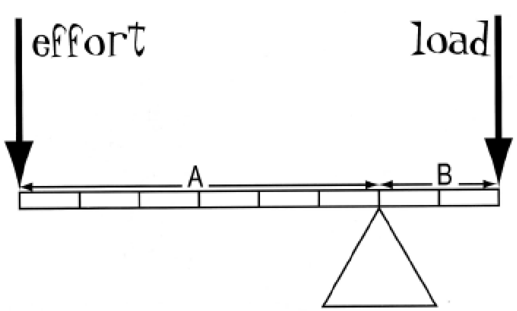
Can you think of examples?



Mechanical Advantage

- Mechanical advantage is ratio of load versus effort
- Leverage is ratio distances of the effort and load to fulcrum

Example

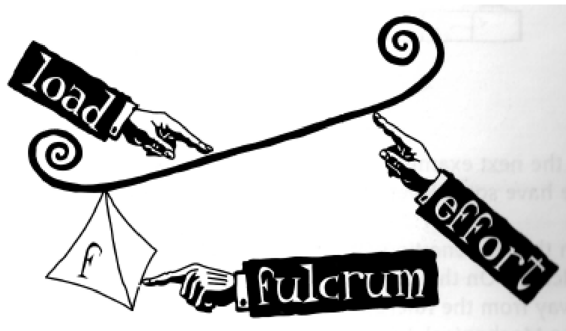


Leverage is ratio of A and B = 6:2 = 3:1

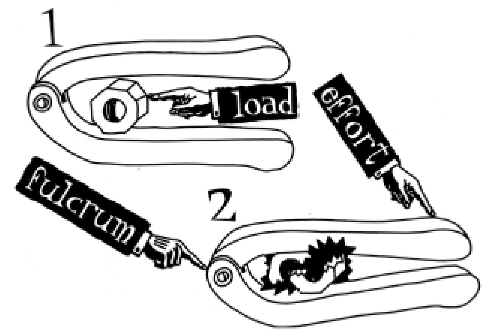
$$\text{Mechanical Advantage} = \frac{\text{Load}}{\text{Effort}}$$

Thus, effort of 1 could move a load of 3

Lever of the Second Order: Load lies between fulcrum and the effort



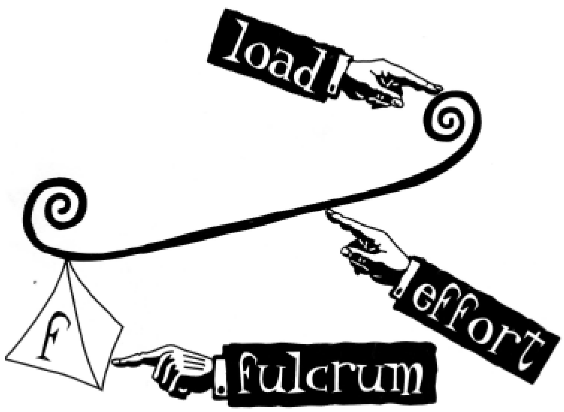
Can you think of examples?

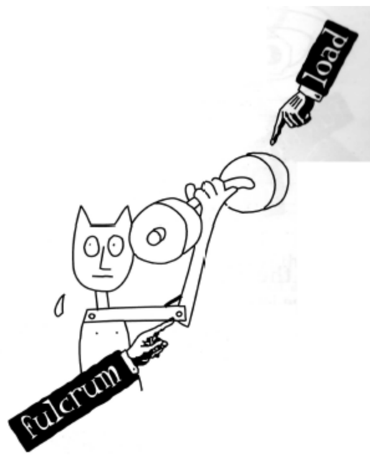


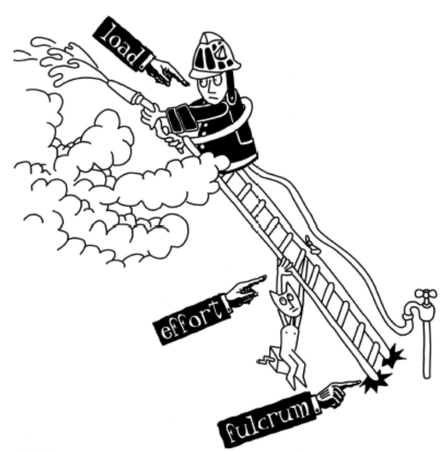
- Also known as a force multiplier (having very good mechanical advantage)
- Effort must move greater distance than the load

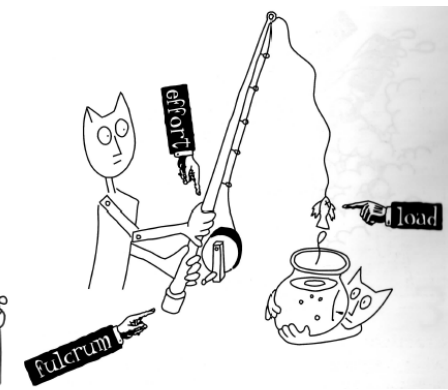
Lever of the Third Order: Effort applied between fulcrum and load

Can you think of examples?









Human Arm: Fulcrum (elbow), Effort (bicep muscle attached to forearm, just below elbow), Load (held in hand)

Ladder: Fulcrum (ground), Effort (person supporting ladder). Higher firefighter ascends, the greater the effort needed

Fishing Rod: Fulcrum (left hand grasps bottom), Effort (right hand move rod up and down), Load (tackle, bait, fish)

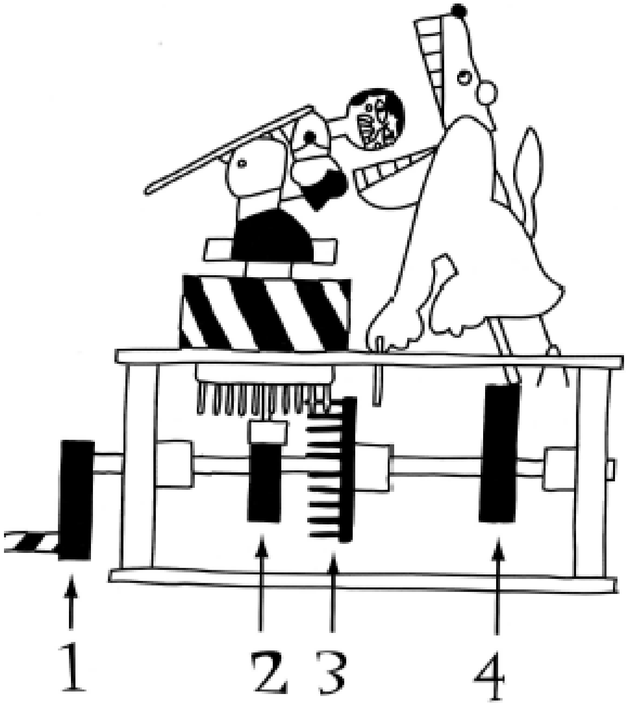
- Also known as a force reducer (efforts always greater than load)
- Load moves faster than the effort (can call this a movement amplifier)

Shafts (and Bearings)

Often, all mechanisms attach to the shaft (or axle). If not shaft not smooth, machine not smooth

The Lion Tamer by Ron Fuller

http://www.youtube.com/watch?v=zic2c080f_Y



1. The handle (or crank)
2. Eccentric cam (tamer stoops up and down)
3. Pin wheel (rotates tamer)
4. Snail cam (opens lion's mouth then snaps down)

For sequence to remain constant, mechanisms are fixed to shaft so that lion's mouth is always open when the tamer's head is in lion's mouth

Shafts:

- Shafts can be anything: from stiff piece of wire or wooden dowel, to accurately engineered rod
- Part with hole that supports shaft is called the <u>bearing</u>
- Shaft must be strong enough to support mechanisms they carry
- Shaft must fit the bearings; not too tight (friction) or not too loose (wobble)

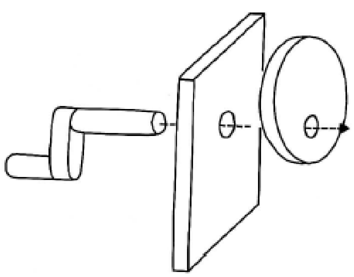
Bearings:

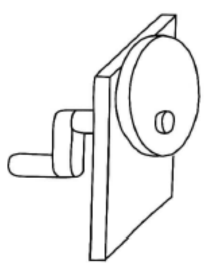
- Bearing keeps the rotating shaft stable and running smoothly
- Must be chosen together with shaft

Ball Bearings:

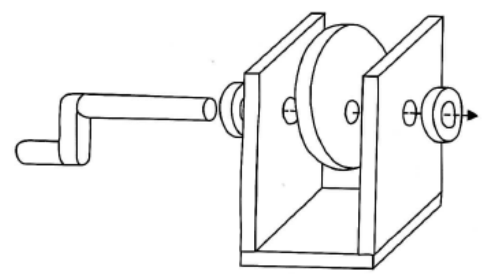
- Outer race is fixed while inner race rotates with shaft
- Balls roll with small contact area, hence friction is low
- Polished steel bearings help reduce friction too

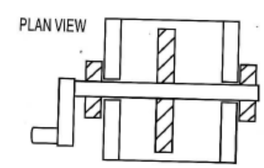
Simple Example





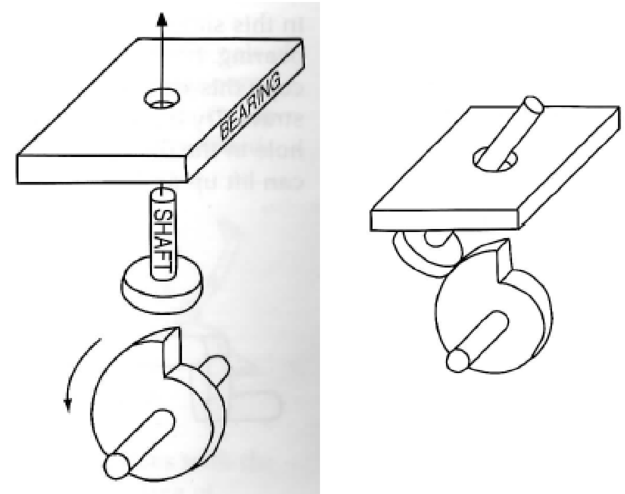
- Shaft passes through single bearing
- Shaft is attached to handle and a disc
- Off-center hole in disc will yield wobble



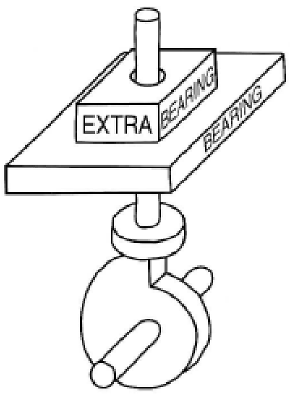


- Add second bearing for better support
- Add collars to prevent side-to-side movement

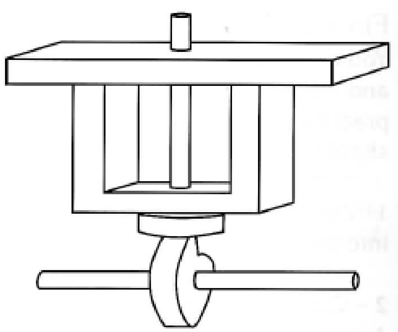
Snail Cam:



- Shafts don’t only rotate in bearings
- Snail cam pushes shaft upwards
- Shaft also needs support of a bearing
- If bearing (hole) is too big, shaft moves off-center (jamming)
- If bearing too far from cam, then also jamming

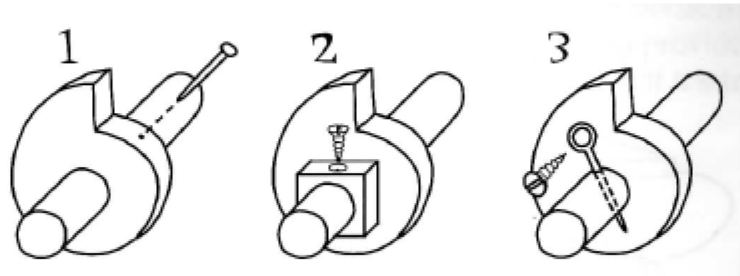


- Add thickness to bearing
- Results in more predictable up-and-down movement of cam-follower
- Hole diameter: just big enough to allow free up-and-down movement



- Add U-shaped bracket
- Positions bearing as close as possible to end of shaft where cam pushes

Fixing:



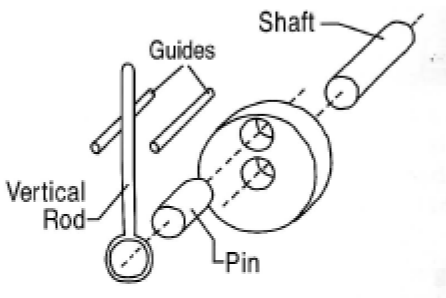
1. Pin the cam: pin pushed through pre-drilled hole into the cam and the shaft

2. Cam with hub: Hub is part of the cam or glued to it. Screw passed through hub and into the shaft. This keeps the fixing away from the radial surface of the cam

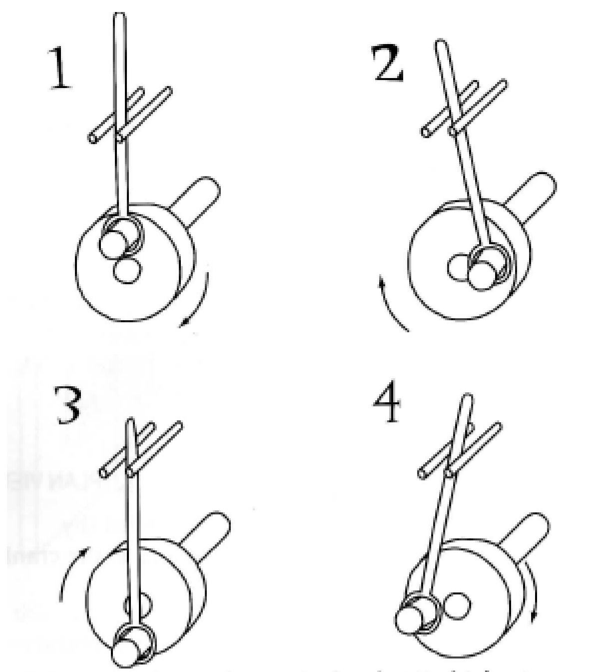
3. Screwed cross pin: Similar to 2 but easier to make. A wire or split-pin passes through the shaft only. A screw in the cam holds it in place

Cranks

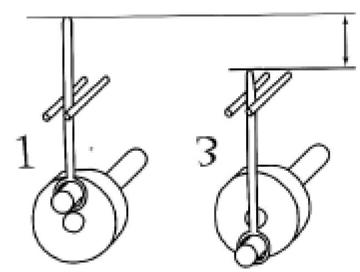
A lever attached to a rotating shaft – cranks convert rotation to reciprocation



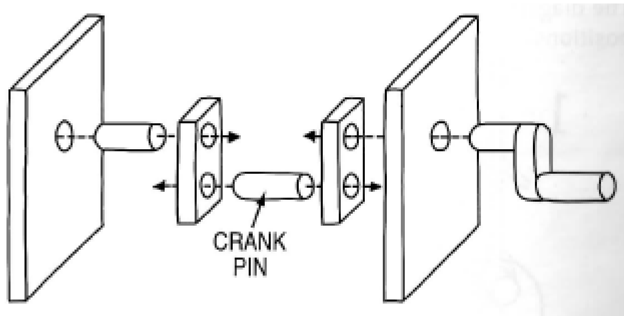
- Crank: circular disk with a pin
- Pin: connected to a vertical rod (loose enough to allow crank to rotate)
- Rod: constrained by guides
- When shaft rotates, rod reciprocates (moves up and down)



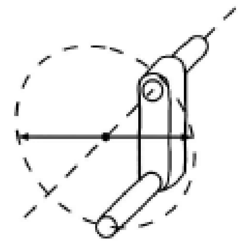
CW rotation thru 360-degrees



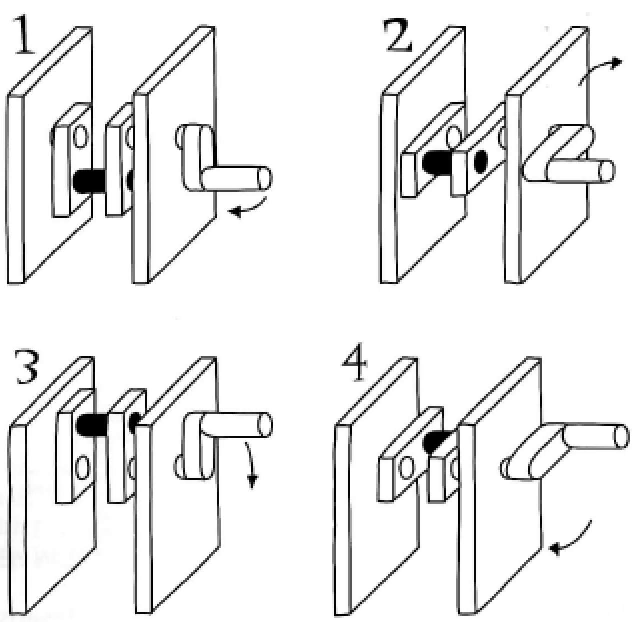
- At “1” vertical rod at highest point
- At “3” vertical rod at lowest point



• Rotating shaft needs bearings on both sides of crank

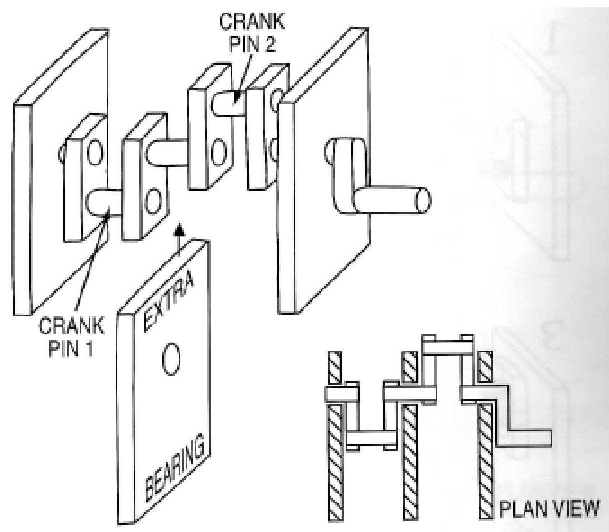


• Arrows show throw of the crank
• Throw: diameter of the path crank travels



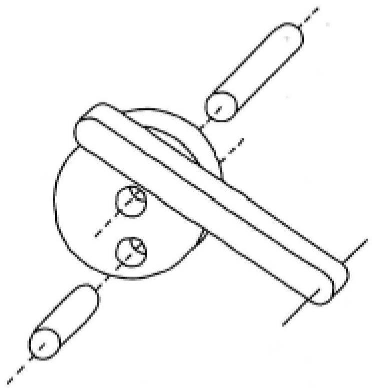
Crank rotation thru 360-degrees

Crank pin (black) simply repeats motion of the handle

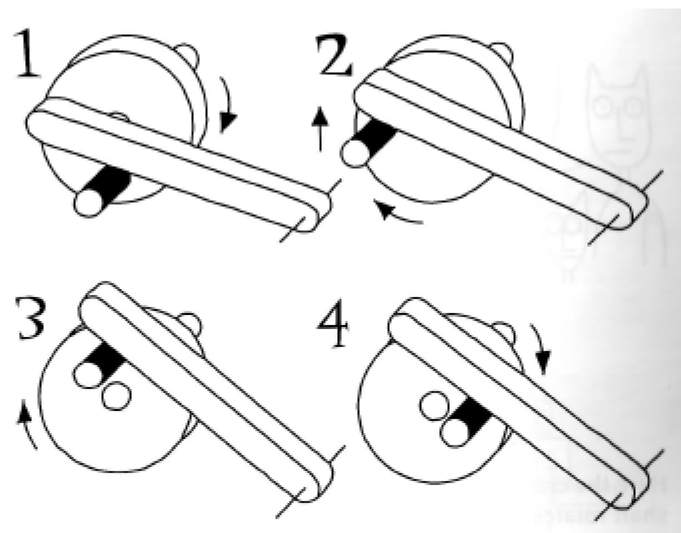


• Can add many cranks (but need more bearings)
• Offset cranks so at different positions at different times
• Above: one crank is down when other crank is up

Using Cranks to Operate Levers



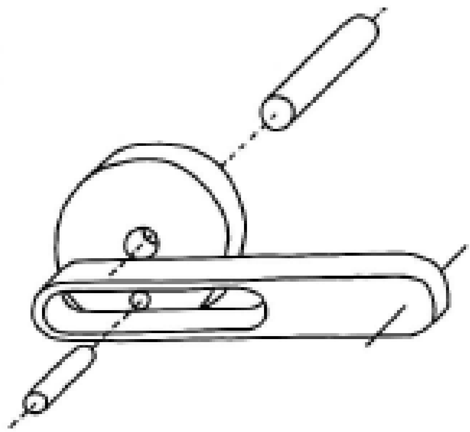
- As shaft rotates, crank will lift lever
- Lever traces a small arc
- Gravity keeps lever in contact with crank pin



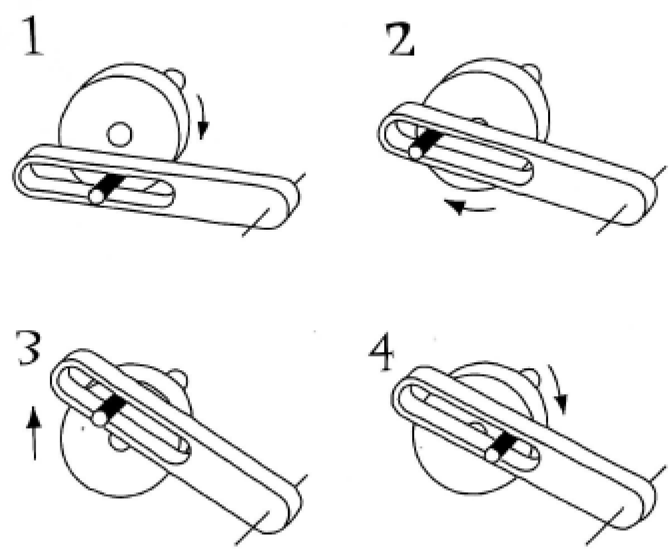
Crank rotation thru 360-degrees

- At “1”, lever is in lowest position
- At “3”, lever is in highest position
- Fast shaft rotation = lever breaks contact with crankshaft
- Lever may bounce (higher than expected) if struck hard
- Too little fall time when crankshaft at lowest position

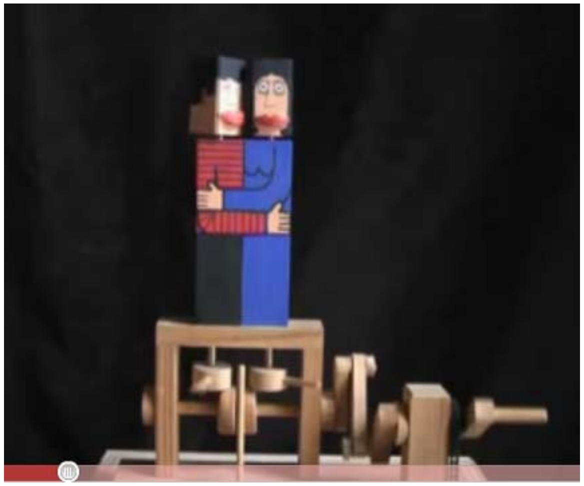
Any Possible Solutions?



- Use a slot
- Lever is driven up and down by crank
- This “positive” connection doesn’t depend on gravity
- Lever will always move through expected path

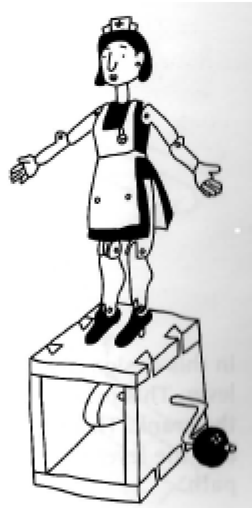


Crank rotation thru 360-degrees

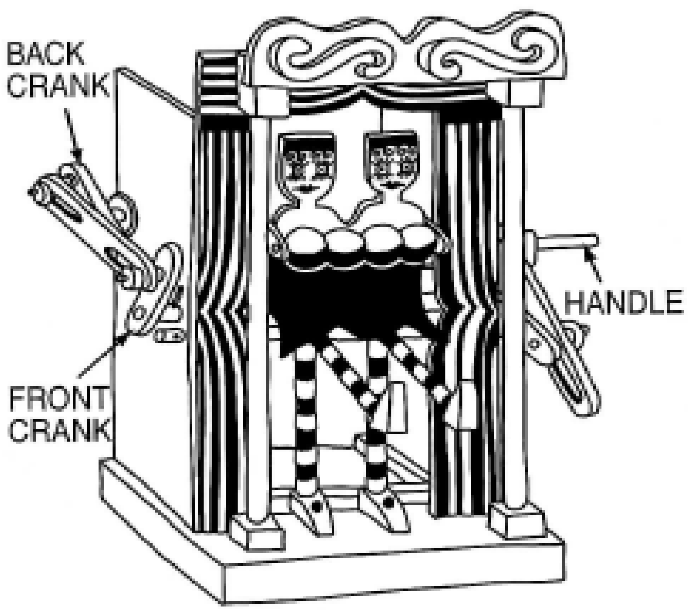


Kissing Couple

http://www.youtube.com/watch?v=3EJQcexRMig



- Jumping Nurse by Paul Spooner
- Loose joints (shoulders, elbows, etc)
- Crank and cam push her up
- Looseness provides joint "movement"



Dancing Girls by Peter Markey

- Handle rotates crank at back
- Crank at back connected to crank at the front
- Connecting piece has 2 slots to allow cranks to rotate

What motion does the front crank follow?

Next Week: Simple Machines II: Cams, Springs and Linkages