Mechanical Engineering Design II

Fourth Lecture

Examples of Design (Initial) Specifications

Part I

Ex.1: Design a power unit for a lorry:

Design specification for a power unit:

This specification is for the design of a power unit which may be used as a primary power unit in a lorry and for other purposes of similar power size. The power unit is to use normal road fuels and to have a rotating shaft output.

Introduction:

This specification is for the design of a power unit of approximately 250 hp. The power unit is intended to be marketed as a basic power source for a variety of uses, the main use is as a lorry power unit. The design is to be in the form of a gas turbine.

The power unit is to be designed for quantity production.

Markets:

The possible markets for the power unit are as follows:-

- **Lorries**
- **Small aircraft**
- **Helicopters**
- **Hovercraft & Marine uses**
- **Small electrical generators**
- **Aircraft servicing trucks**
- **Pump units & compressor units**
- **Cranes**

Related Specifications:

It is suggested that gearboxes should be used as speed reducers to change the turbine shaft speed to the output shaft speed which is quoted later in this specification.

Performance:

Consideration is to be made for uprating to 300 hp for short duration runs.

Weight:

The weight of the unit excluding the gearbox is to be less than 100 lb.

Instrumentation:

Modern instrumentation is to be incorporated to measure the jet-pipe temperature and the other relevant temperatures. Electrical pules tachometers are to be used to measure speeds.

Failsafe Devices:

Failsafe devices are to be supplied with the unit so that malfunctioning causes the power unit to shut down. Correction of the fault should then enable immediate restart.

Starter:

A conventional vehicle engine starter is to be used for starting purposes.

Operation:

The power unit should be capable of being used for long periods without maintenance.

Fuel:

The unit must be able to be run using conventional vehicle fuels, aircraft fuels and natural gas.

Multiple Unites:

Consideration is to be given to the possibility of using a standard, quantity production power unit on a special gearbox to give power units up to 1000hp limit.

Maintenance & Spares:

The unit is to be designed so that the assembly of critical high speed parts is carried out on the manufacturers premises. Assemblies requiring less skilled fitting work are to be supplied as spares. The spares are to be designed so that the value/weight ratio is high so as to make air freight a reasonable proposition for spares transportation.

Noise Level:

The noise level is to be equal to or lower than that from other gas turbines of comparable size.

Transportation:

Facilities are to be provided for easy transportation of the unit.

Price:

The selling price is to be less than ($) per horsepower output (continuous rating), including the gearbox.

Life:

The overhaul life of the unit shall be 500 hrs or greater.

Overall Size:

The unit must fit inside a rectangular box 15in x 20in x 40in.

Measure of Value for Some Items:

Priority shall be given to various parts of this specification by utilizing the measures of value given below:

Performance	20	Noise Level	10
Failsafe Devices	15	Overall Size	10
Price	15	Diversity of Market	5
Life	12	Instrumentation	5
Maintenance & Spares	8		

Mechanical Engineering Design II

Fifth Lecture

Examples of Design (Initial) Specifications

Part II

Ex.2: Design of Household Carpet Cleaner:

Environment:

Since the cleaner will be housed and used indoors weather protection is not required but the finish should be non-corrosive. Although it is expected that the carpet area being cleaned should not emit fumes or noise that will cause a nuisance to other occupants of the building.

Normal vacuum cleaning will have been carried out prior to the rinsing process and it may be assumed that the carpet is satisfactorily fixed to the floor.

Supply Services:

240 V, 13 A, 50 Hz electrical power outlets will normally be available.

Hot or cold water may well be available from taps in the vicinity of the cleaning operations but provision will need to be made for instances when this is not the case.

Performance:

- **The cleaner, when set up and operated by one person, should be capable of cleaning a carpet area of 140 m^2 in 60 minutes.**
- **The degree of soil removal achieved must be substantially better than that obtained by shampooing.**
- **The cleaning operation should include soil and fluid extraction to the extent that in normal room temperature and humidity the carpet may be reusable within two hours of completion of cleaning.**
- **The width of the cleaning path should be of the order of 0.5 m.**
- **Areas of carpet under fixtures such as radiators should be accessible to the cleaner.**
- **A special feature of this machine will be powered driving wheels/roller to reduce operator fatigue. Power will be available for both forward and reverse motions.**
- **Provision is to be made to enable carpets with different types and length of pile to be cleaned affectively.**

Control:

- **Variable speed control of the powered wheels/roller will be provided for both directions of motion.**
- **Independent control of rinsing fluid application rate shall be possible.**
- **In the event of the use of a chemical agent to cope effectively with badly soiled carpets a setting must be provided to control the amount of agent mixed with the rinsing fluid.**
- **Provision shall be made for heating and temperature control of the rinsing fluid to ensure it is applied at the desired temperature.**
- **Although each control should be considered ergonomically to ensure easy operation it should be remembered that this equipment is intended for professional cleaners.**

enable immediate restart.

Construction:

- The cleaner should be of robust construction to suit both its usage and handling.
- Any component part which is likely to require removal or replacement during the normal working life of the machine should be easily accessible.

Maintenance and Reliability:

Reliability must be regarded as an important feature of the design. It is expected that servicing will be carried out twice a year by Columbus Dixon Service Engineers.

Size and Weight:

Although no specific limit is imposed on either size or weight of the cleaner it should be as compact and light as is reasonably possible . Since the mobility is to be a special feature of the machine.

Appearance and Finish:

The equipment is to be styled in such a way as to make it attractive to the potential customer. Adequate protection from corrosion shall be given and external surfaces shall be finished in company colors where appropriate.

Safety:

The associated standards referred to earlier must be complied with in order to ensure safe operation of the equipment. Any moving parts that could provide a hazard shall be adequately covered.

Life:

In keeping with company policy the useful life of this product shall be a minimum of ten years, subject to reasonable use.

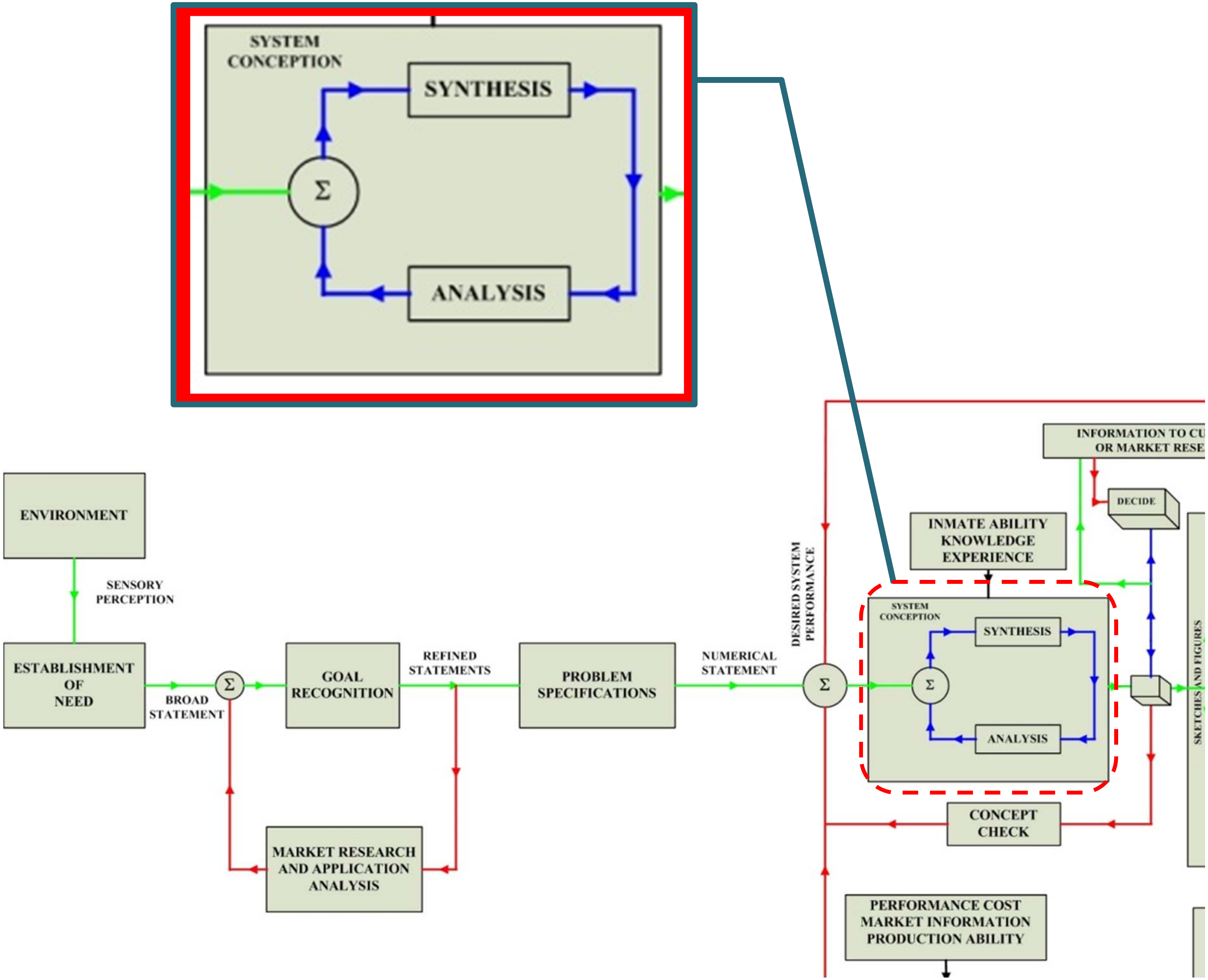
Price:

It is intended to market this product in either September 2005 or September 2006 , dependent on the development work necessary, at a selling price not exceeding ($) at present day values.

Mechanical Engineering Design II

Sixth, Seventh & Eighth Lectures

System Conception



SYSTEM CONCEPTION
SYNTHESIS
ANALYSIS
Σ
ENVIRONMENT
SENSORY PERCEPTION
ESTABLISHMENT OF NEED
BROAD STATEMENT
GOAL RECOGNITION
REFINED STATEMENTS
PROBLEM SPECIFICATIONS
NUMERICAL STATEMENT
MARKET RESEARCH AND APPLICATION ANALYSIS
DESIRED SYSTEM PERFORMANCE
INMATE ABILITY KNOWLEDGE EXPERIENCE
DECIDE
CONCEPT CHECK
PERFORMANCE COST MARKET INFORMATION PRODUCTION ABILITY
SKETCHES AND FIGURES

Synthesis and Analysis:

The processes of synthesis and analysis appear repeatedly in the System Engineering Flow Chart. For this reason Synthesis will be considered in much greater detail. Analysis is the subject of study in most undergraduate courses and will, therefore, not require such a detailed study here.

Synthesis

The process of synthesis in design is the bringing together of information which, when taken in combination, satisfies an initial requirement. The process of checking that the outcome satisfies the initial requirements is the analysis process. It has been mentioned previously that systematic methods can assist in the processes of design, the use of methods in Synthesis is by no means an exception. However, at this point in our knowledge of the design process. We, as lecturers, consider that it is best to know of a number of methods to improve synthesis, the application of any one or more of these methods in any particular circumstance being left to the discretion of the designer. Systematic methods of synthesis are termed Heuristics.

Creativity:

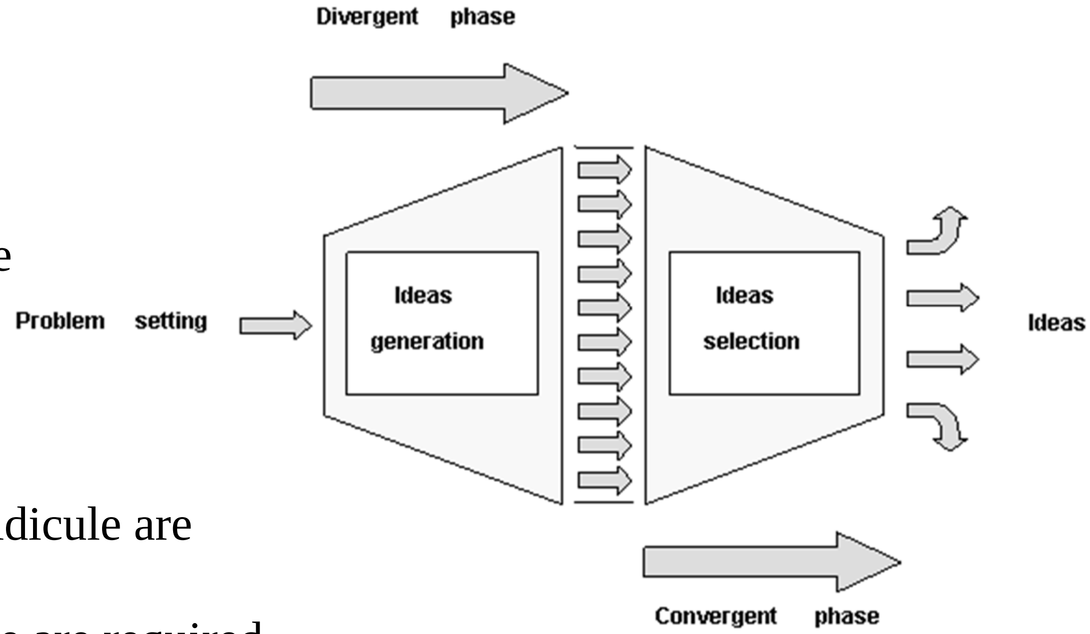
- **Creativity, synthesis and applied imagination are all terms used to denote the production of alternative solutions to problems.**
- **However, for design purposes, we must add the additional constraint that the alternative solutions must eventually lead to a useful conclusion which satisfies initial requirements.**
- **The starting point in the creative process should always be to verify the facts which initiate the creative process. Thus the goal towards which we are heading becomes clearly defined, this reduces time wastage.**
- **An aid to this verification process is to attempt to rewrite the problem in different words, carefully analyzing and verifying each point in turn. Features which need clarification or additional information should be noted on one side, but since we are eager to produce something, let us temporarily ignore these sideline points if this possible. These sideline points can be attended to and included in the synthesis at suitable times.**

- **Now, if we stop the shaking after the production of some short chains we can take these chains from the box and use various patterns of combination to join them together. We could, say, lay them onto a table to form letters, then these letters could be combined to form words, and so on. Note that we would be using rules from subjects other than those which could be devised for the ‘art’ of paperclip joining.**
- **In design synthesis we can use rules from mathematics, art, business management, language; in fact anything that will help.**

Heuristics

Brainstorming

The brainstorming technique was created by Alex Osborn in 1938.

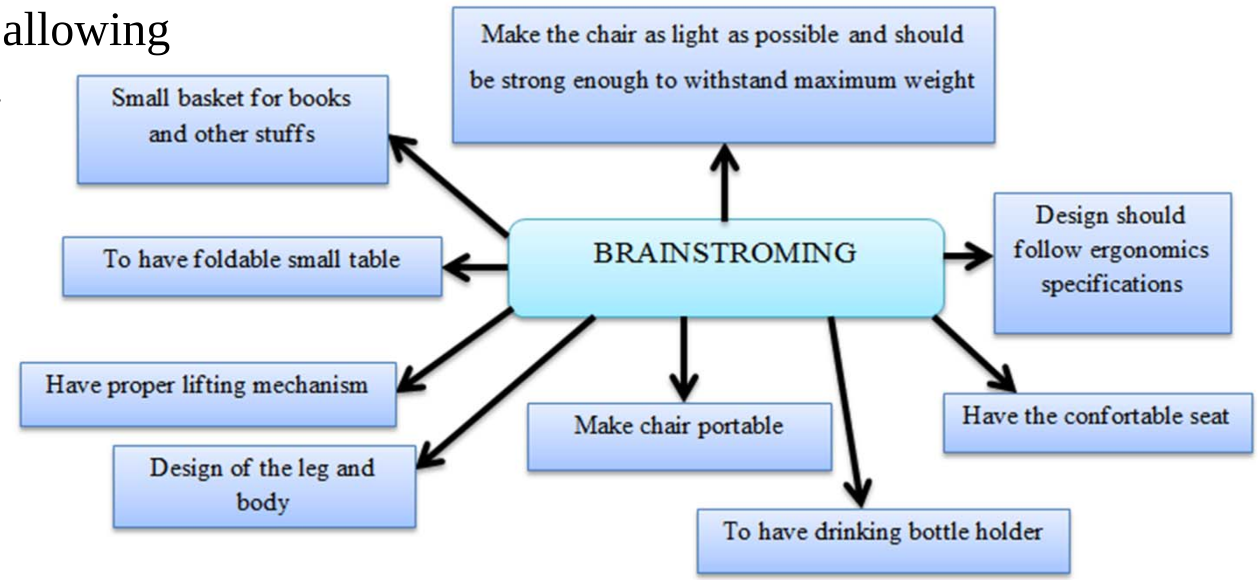


Rules of Brainstorming:

1-Criticism, judgment and ridicule are eliminated completely.

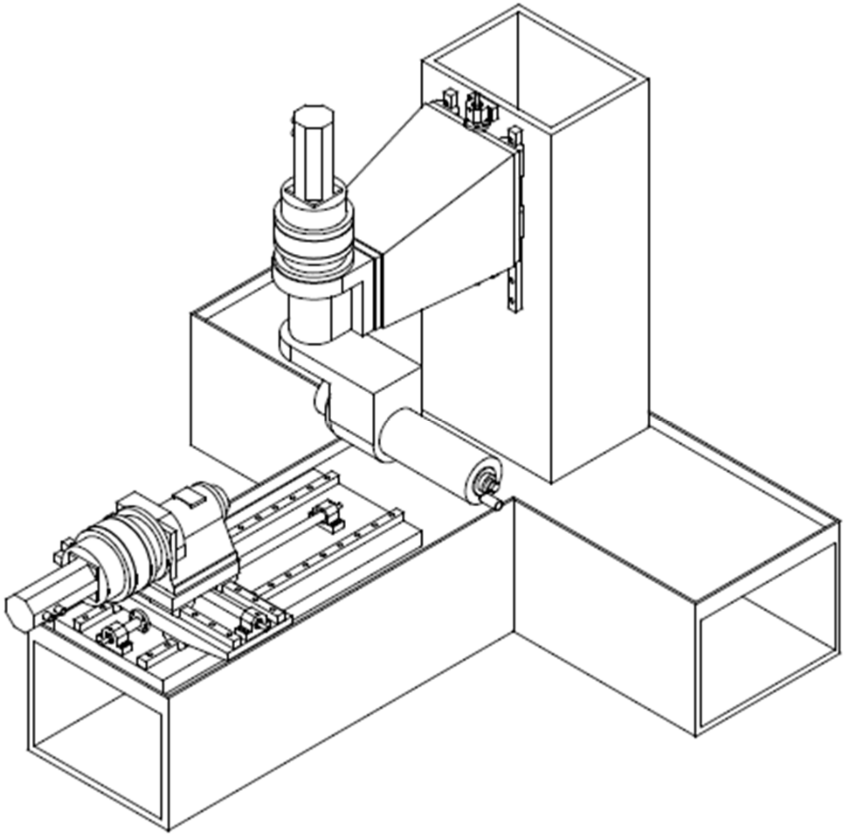
2- Copious ideas, of any type are required.

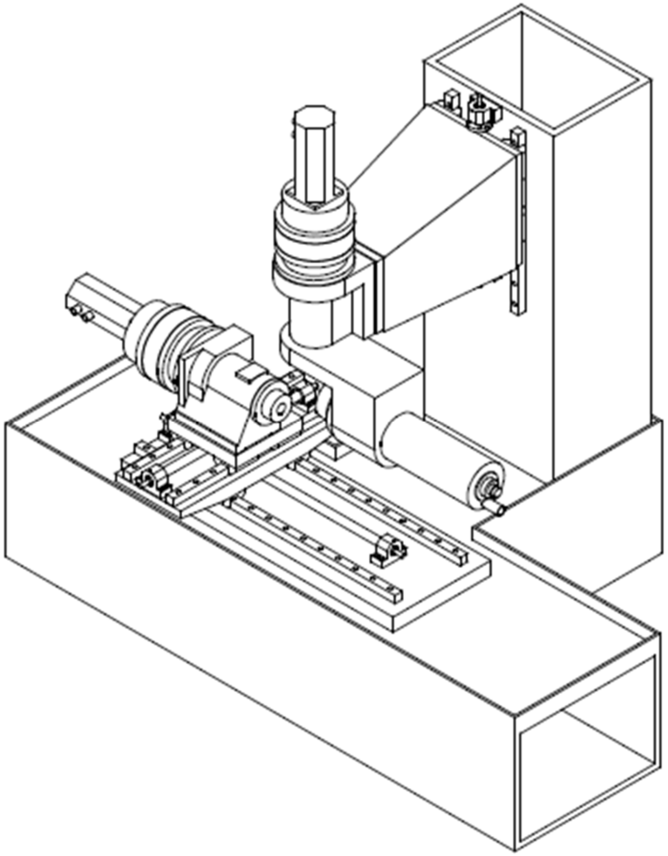
3- Think wild, don't allow criticism in your own mind before allowing the ideas to erupt.



Inversion

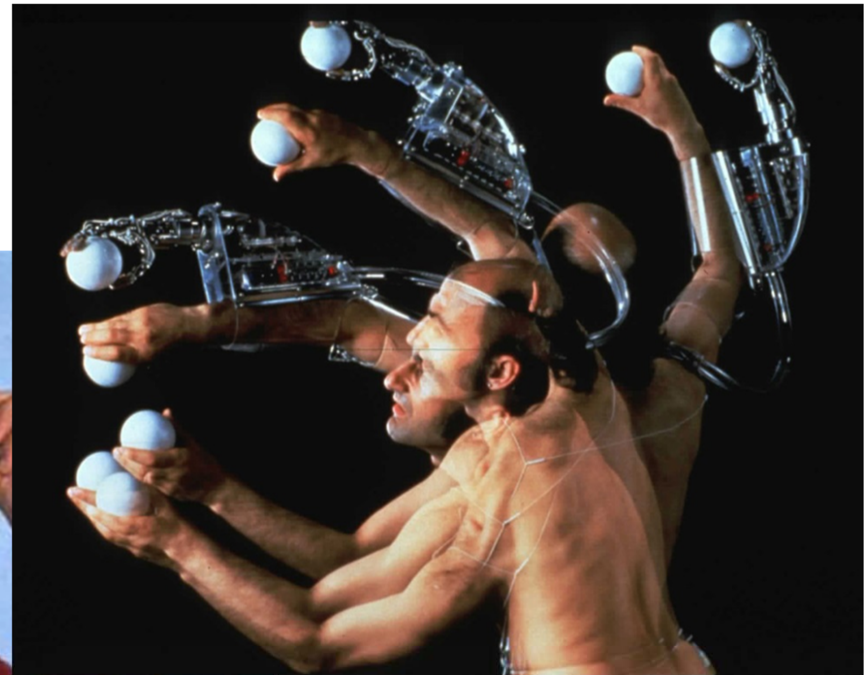
Turn things inside-out, upside down, stop moving parts, start stationary parts, …

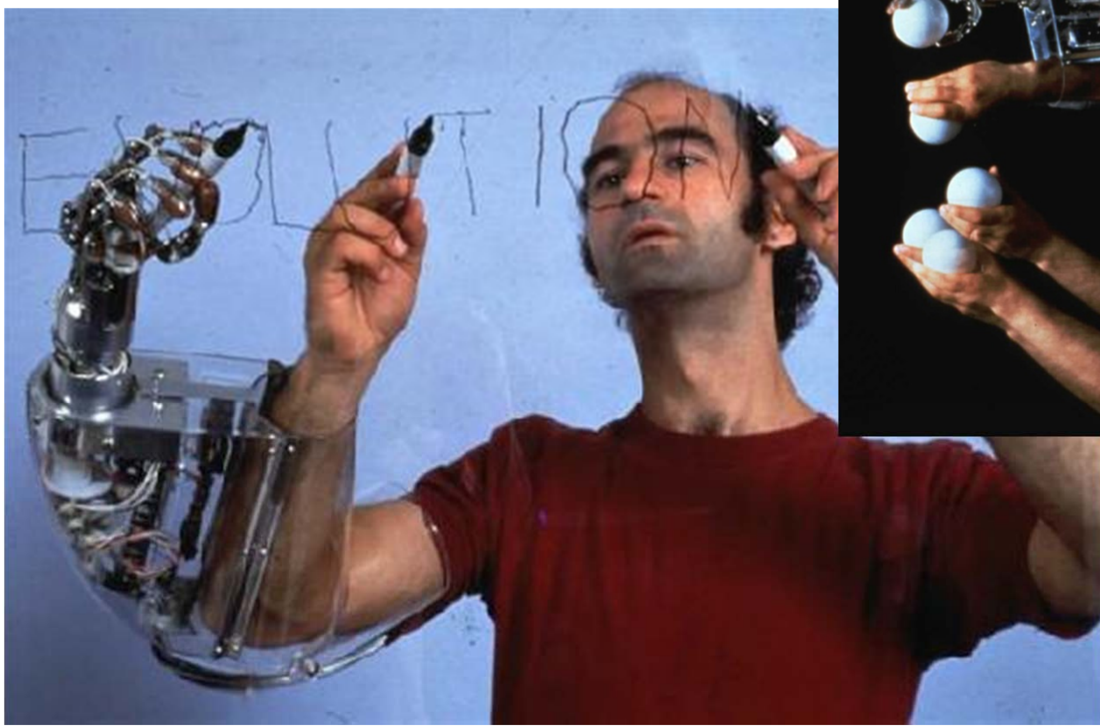




Empathy

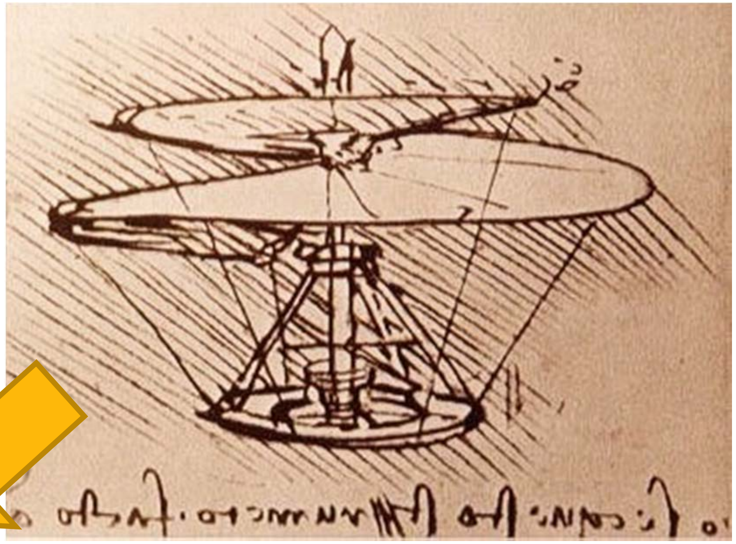
- Putting one's self in another's place.
- Identifying physically and personally with the part, product, or process that is to be created:
    - Body/mind must actually perform the function(s).
    - State how it feels and what we would need or do if we were to do the task.





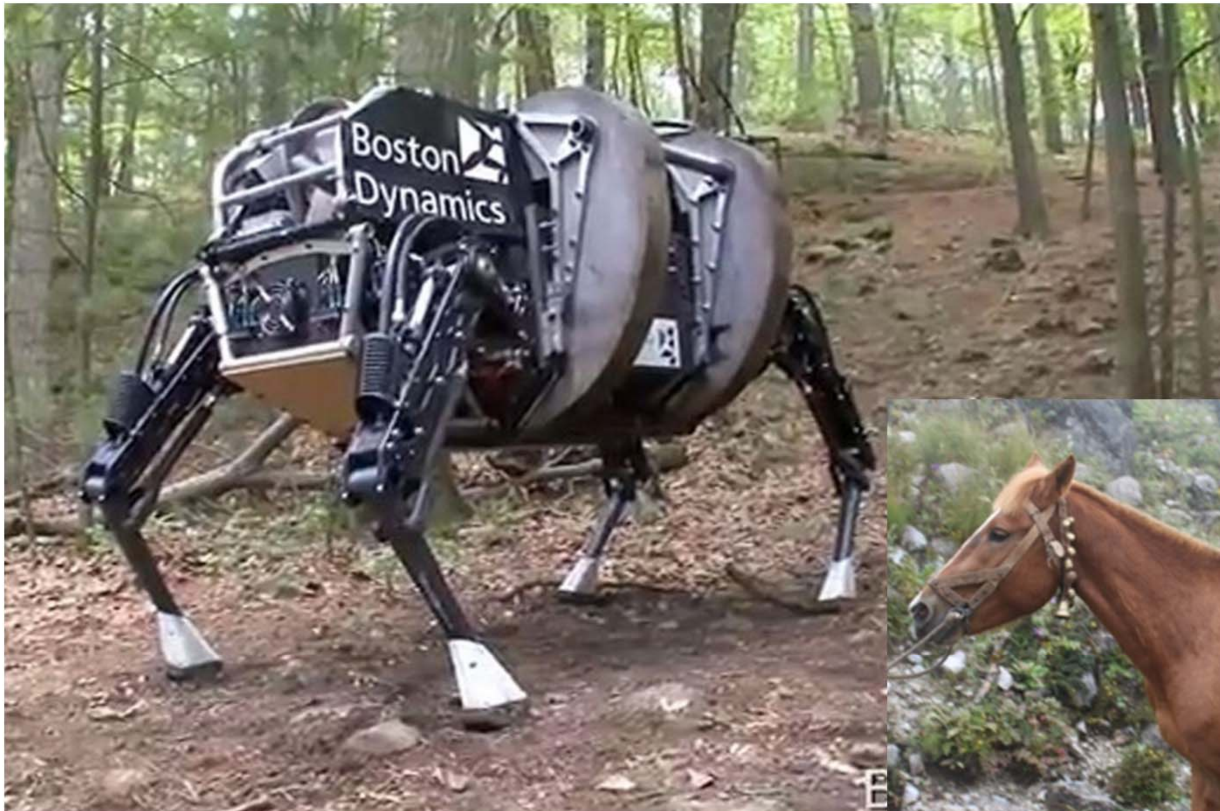
Fantasy

- Imagining or wishing that something is possible
- Sometimes impossible, but more importantly – sometimes possible and sometimes the ideas can be modified to be possible



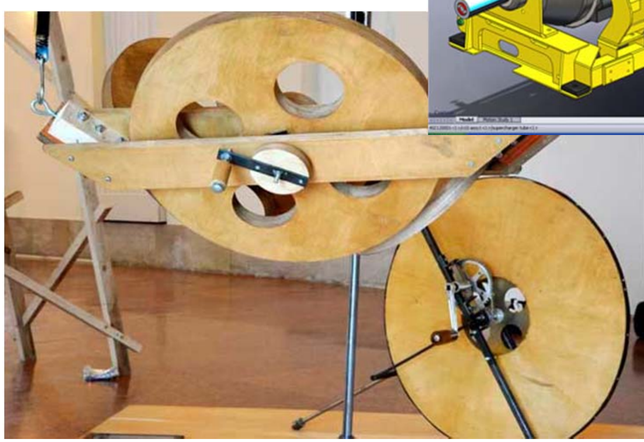
Analogy

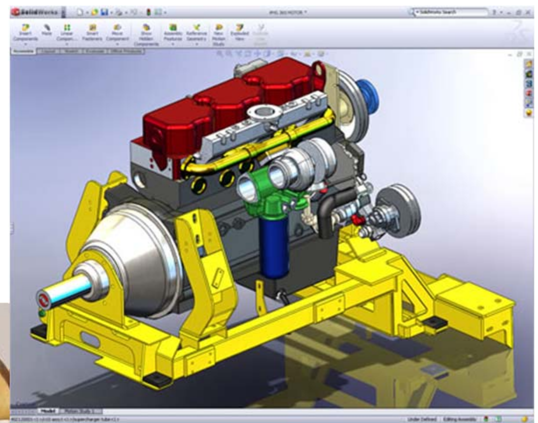
- Analogy to other physical phenomena.
- Think about the problem in general enough terms so that the characteristics that it has with other disciplines/situations become apparent.
- Remember to think about the natural world.

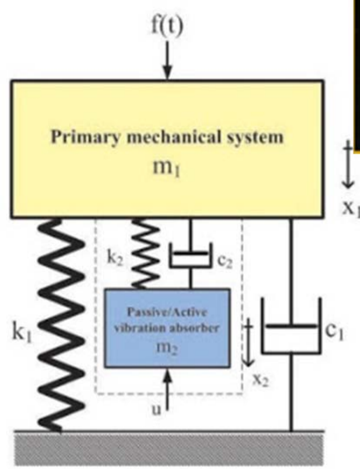


Models

- The use of model can refer to material models, which is the interpretation of the layman. The material model can be iconic model, that is model with only a change in scale.
- Other material models can have changes in material.
- Analogue models are of the type where one property is used to represent a different kind of property.
- Symbolic models cover the mathematical models.
- Digital models are a special type of model for use on digital computer.
- Graphic models such as drawings, sketches, etc.

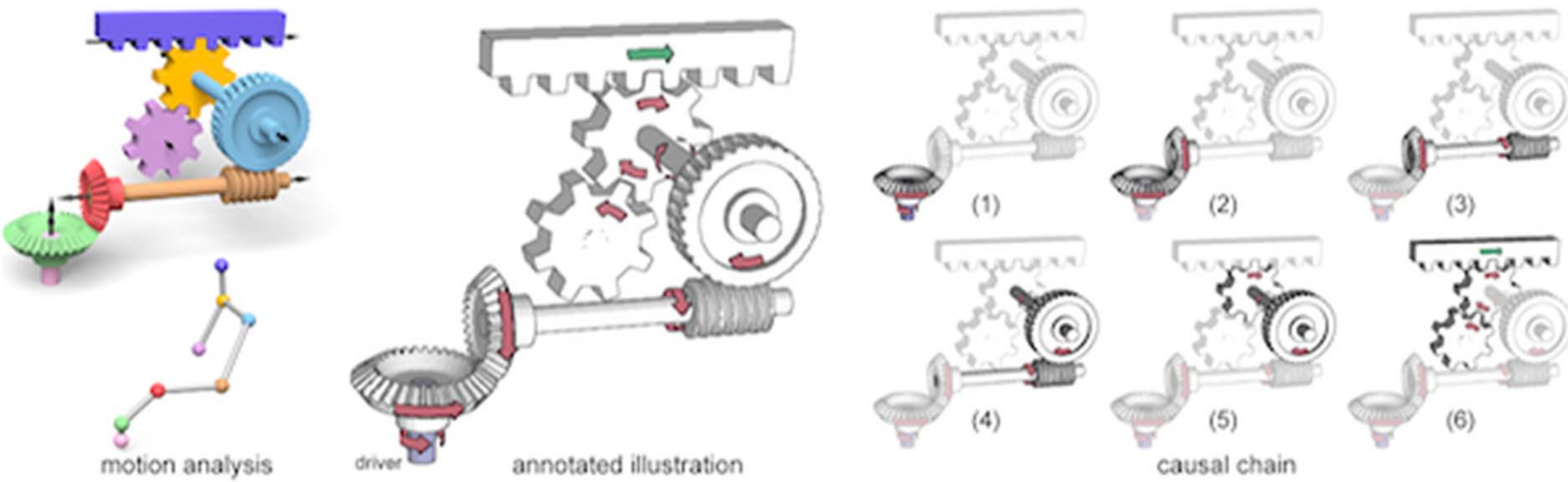






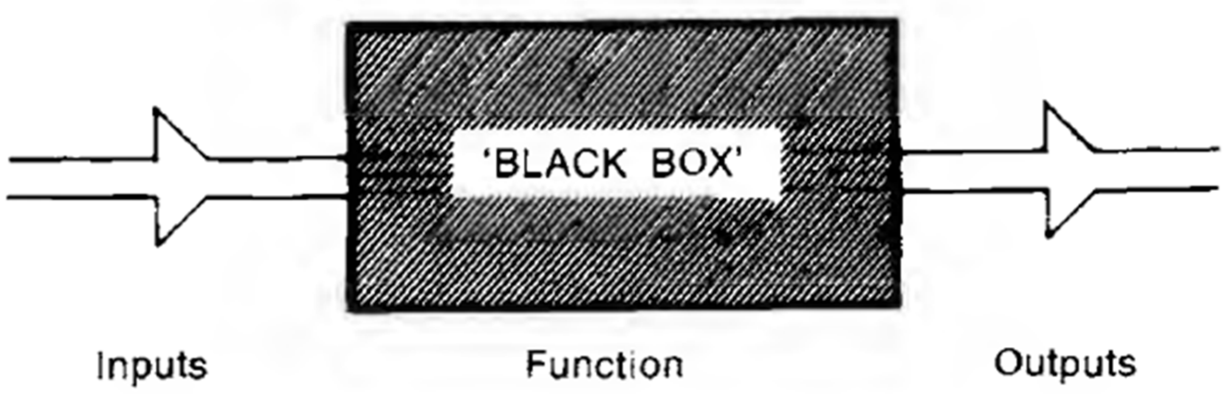
Visualization

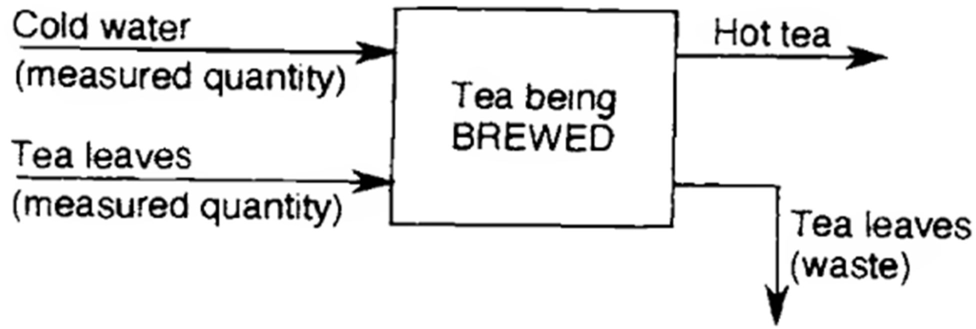
This is the use of certain types of model to enable those carrying out the synthesis process to be able to "see in their minds" a number of facts simultaneously.



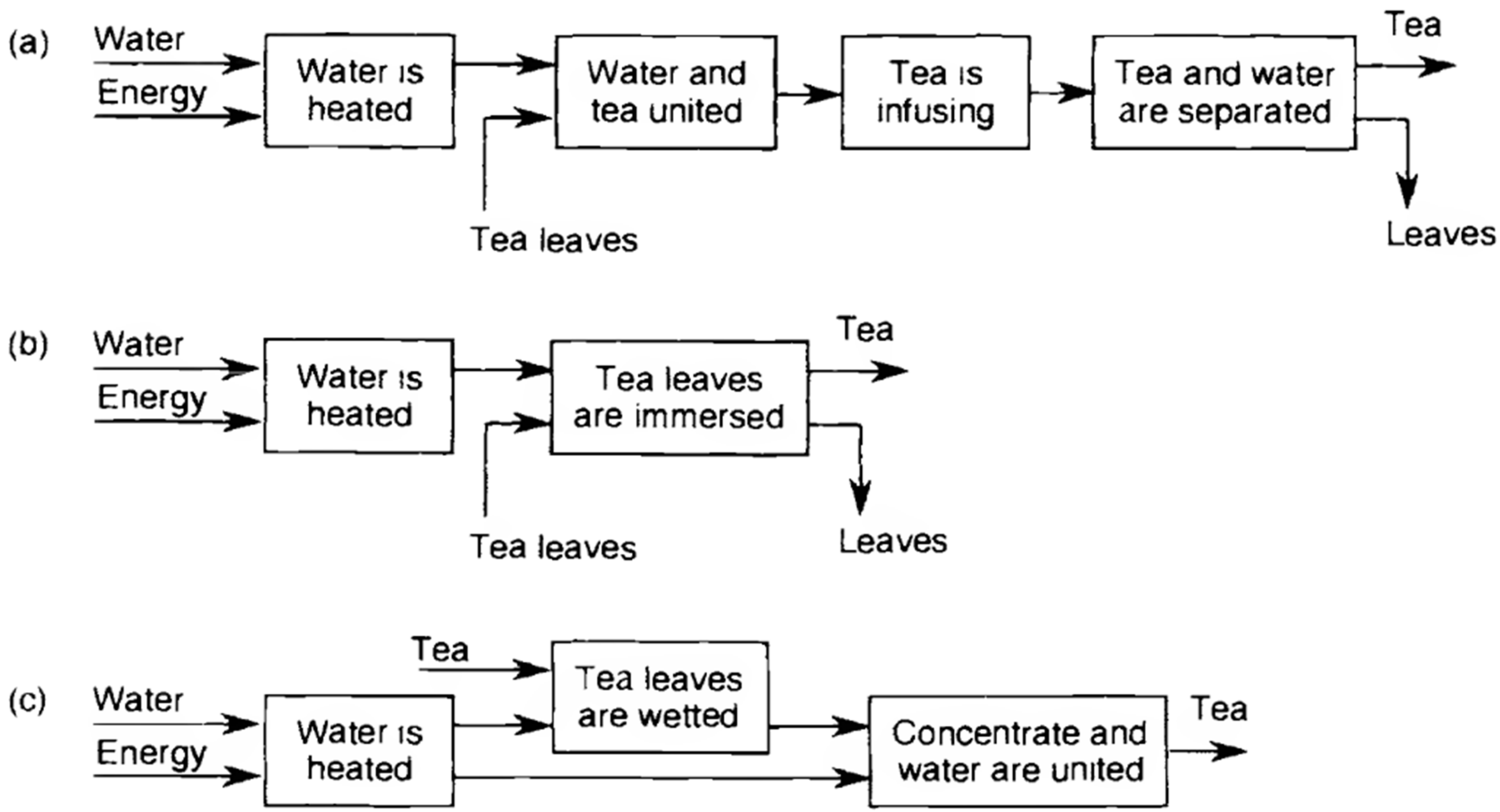
Black box concept

- This consist of a system of great complexity (in a relative manner) whose internals are impossible to characterize completely. Alternatively, there may be no desire to characterize the internals completely at a certain point in the design process.
- The main features about the black-box can be learned from observing the inputs and outputs. The output can then be expressed in a number of cases as some function of the input, i.e. the transfer function of the black box is equal to the ratio of the output to the input.
- In general there are three kinds of problem relating to the black-box. If any two of the features: input, output and transfer function are known then the third feature can be found.





Three alternative process models for tea brewing



Morphological Analysis

- **This can be described in general terms as:- The analysis or those features that may be required in the system, and how alternatives of these features way be combined.**
- **This is a well-established creative process originated in one form by Zwicky. The process is to initially describe the problem in the broadest possible manner so that the type of solution is in no way defined.**
- **Next, the various groups of features are listed so that all the alternatives of each feature appear together, combinations of these alternatives of various features which can be combined in a large number of ways to trigger off the actual creative process which results in a solution.**
- **The method can be extended by using a number of cube boxes in which one axis is common to all the boxes, the other two axis being different on all boxes and totaling up to give the required number of features.**
- **An alternative method is to put the features as columns of alternatives with liberal spacing between columns.**
- **The next stage is to select combinations of alternatives from the massive array of possibilities, either by labelling compartments of the cubes, or by joining alternatives of the columns of features.**
- **These ideas are then evaluated by subjecting each idea to a previously prepared “specification” or comparison “check-list”.**

A general morphological analysis table

Subsystem	Means			
1	Method 1 of fulfilling subsystem 1	Method 2 of fulfilling subsystem 1	Method 3 of fulfilling subsystem 1	Method *n* of fulfilling subsystem 1
2	Method 1 of fulfilling subsystem 2	Method 2 of fulfilling subsystem 2	Method 3 of fulfilling subsystem 2	Method *n* of fulfilling subsystem 2
3	Method 1 of fulfilling subsystem 3	Method 2 of fulfilling subsystem 3	Method 3 of fulfilling subsystem 3	Method *n* of fulfilling subsystem 3
4	Method 1 of fulfilling subsystem 4	Method 2 of fulfilling subsystem 4	Method 3 of fulfilling subsystem 4	Method *n* of fulfilling subsystem 4
5	Method 1 of fulfilling subsystem 5	Method 2 of fulfilling subsystem 5	Method 3 of fulfilling subsystem 5	Method *n* of fulfilling subsystem 5

Morphological chart for a pallet moving device with choices identified

Feature	Means				
Support	Track	**Wheels**	Air cushion	Slides	Pedipulators
Propulsion	**Driven wheels**	Air thrust	Moving cable	Linear induction	
Power	Electric	Diesel	**Petrol**	Bottled gas	Steam
Transmission	Belts	Chains	**Gears and shafts**	Hydraulics	Flexible cable
Steering	**Turning wheels**	Air thrust	Rails	Magnetism	
Stopping	**Brakes**	Reverse thrust	Ratchet	Magnetism	Anchor
Lifting	Hydraulic ram	Rack and pinion	Screw	Chain or rope hoist	**Linkage**
Operator	Standing	Walking	Seated at front	**Seated at rear**	Remote control

Design Trees

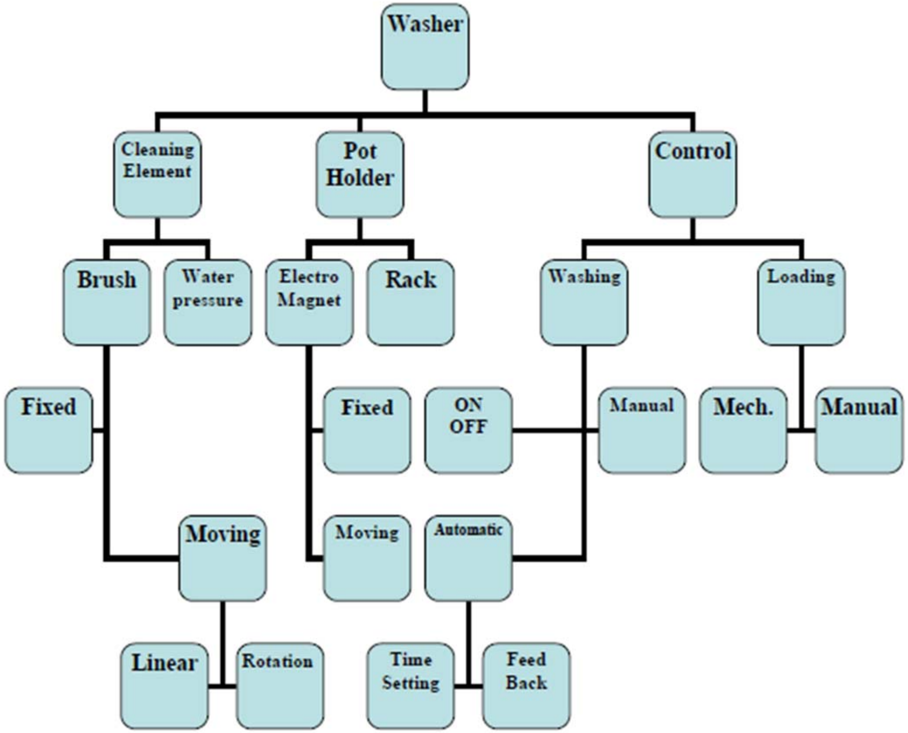
1. This is a generalized model of the design process in the form of a tree.
2. Any design can be regarded as the outcome of a sequence of problems and solutions.

The rules of results from path trees are:

1. When numbers of alternative solutions to a single problem are presented, any one may be accepted and the rest ignored.
2. All the problems dependent on the choice of a particular alternative solution must, however, be solved.
3. A particular branch of the tree must be followed until a solution is reached.

Example:

This is a Design of a cleaning device for pots and pans.



Useful Mechanisms:

Snap-action mechanisms

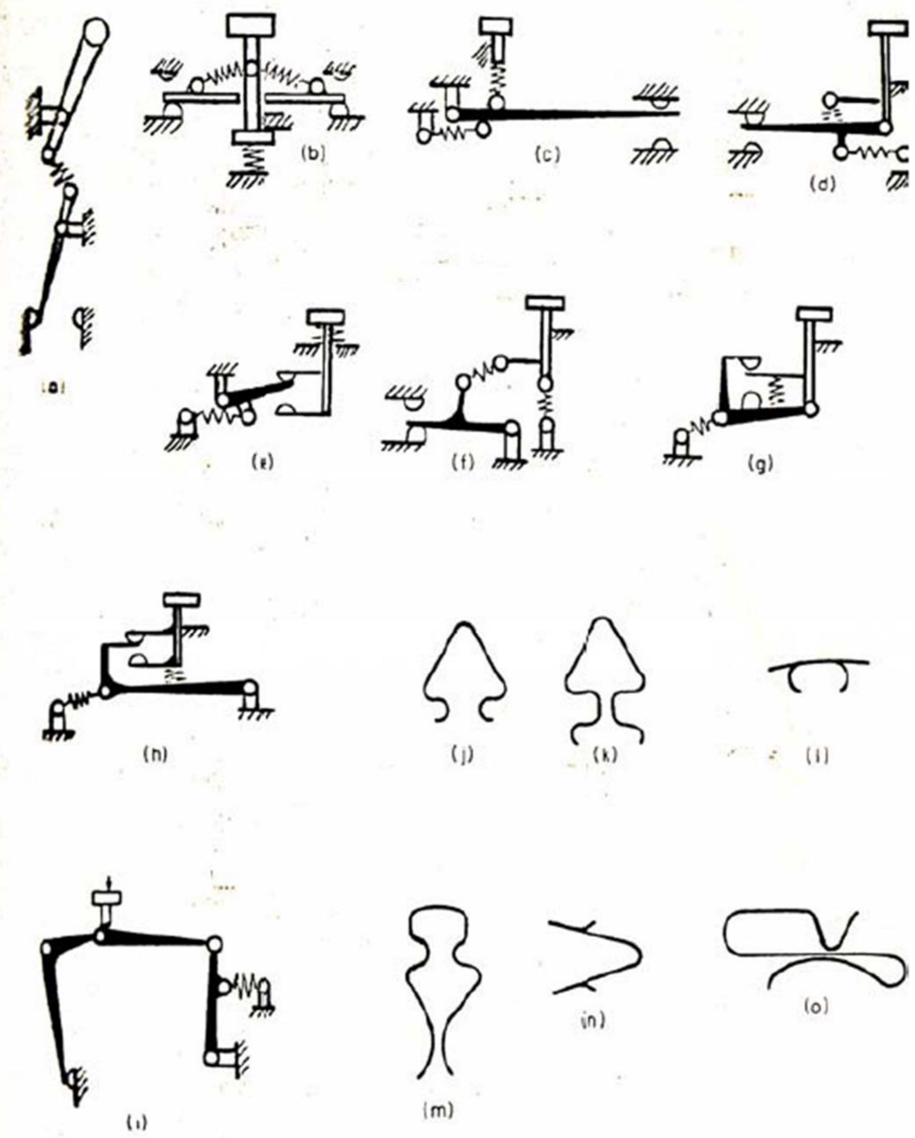


FIG. 39-1 Snap-action mechanisms. These mechanisms are bistable elements in machi... They are used in switches to quickly make and break electric circuits and for fastening ite... (a) Snap-action toggle switch; (b) to (h) seven variations of snap-action switches; (i) cir... breaker; (j) to (o), spring clips.

Robots mechanisms

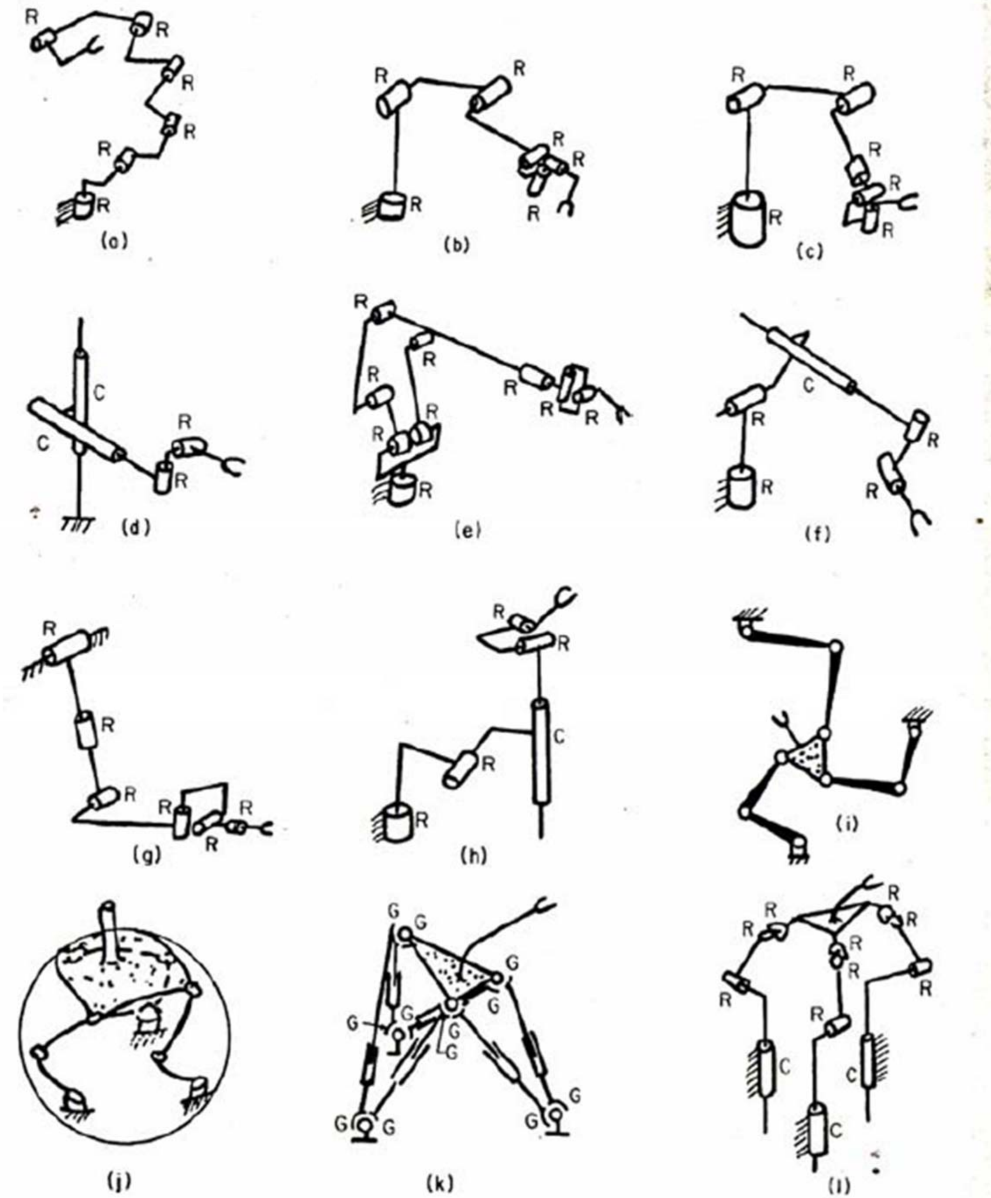


FIG. 39-28 Robots. These are multidegree-of-freedom devices used for positioning or assembly of items. They usually have some degree of machine intelligence and work under computer control. (*a*) A general 6R robot; (*b*) to (*h*) some forms of existing robots; (*i*) parallel actuation of a planar 3-degrees-of-freedom robot; (*j*) Stewart platform which uses the 3-degrees-of-freedom principle; (*k*) Florida shoulder with parallel actuation; (*l*) general robot with parallel actuation.

Clamping mechanisms

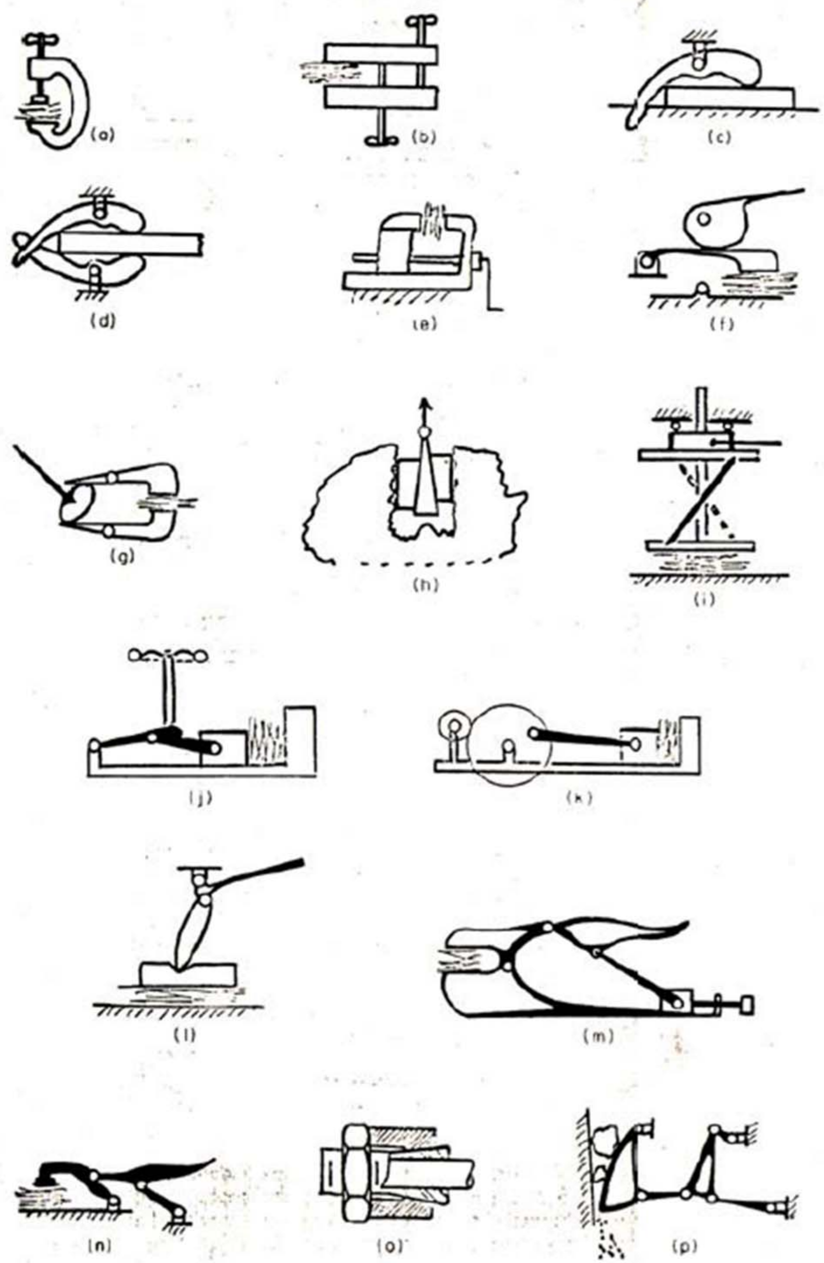


FIG. 39-5 Clamping mechanisms. These devices are used to hold items for machining operations or to exert great forces for embossing or printing. (*a*) C clamp; (*b*) screw clamp; (*c*) cam clamp; (*d*) double cam clamp; (*e*) vise; (*f*) cam-operated clamp; (*g*) double cam-actuated clamp; (*h*) double wedge; (*e*) to (*l*) toggle press; (*m*) vise grips; (*n*) toggle clamp; (*o*) collet; (*p*) rock

Fine adjustments mechanisms

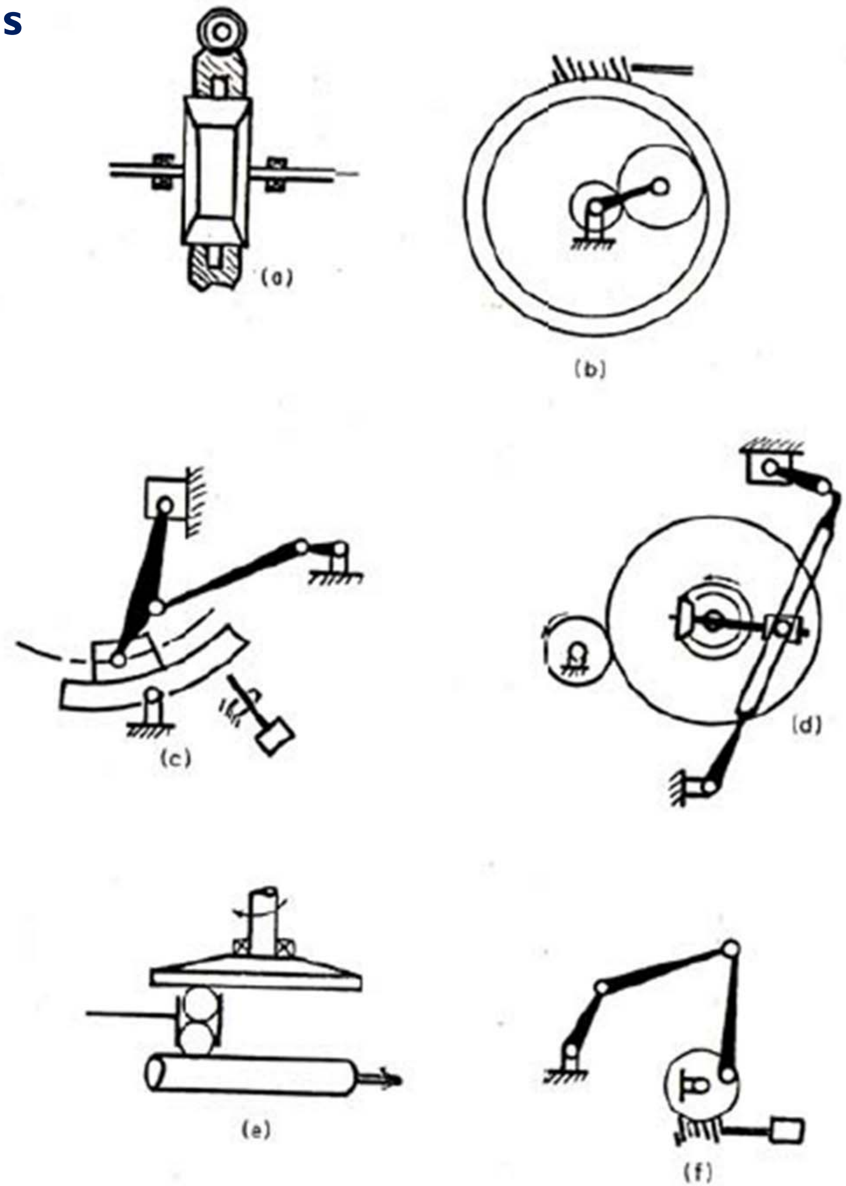


FIG. 39-4 **Fine adjustments II.** Fine adjustments for moving mechanisms are adjusting devices which control the motion of linkages such as stroke, etc., while the mechanism is in motion. (*a*), (*b*) Differential gear adjustment; (*c*) adjustable-stroke engine; (*d*) adjustable stroke of shaper mechanism; (*e*) ball and disk speed changer; (*f*) adjusting fixed center of linkage for changing motion properties.

Escarpments mechanisms

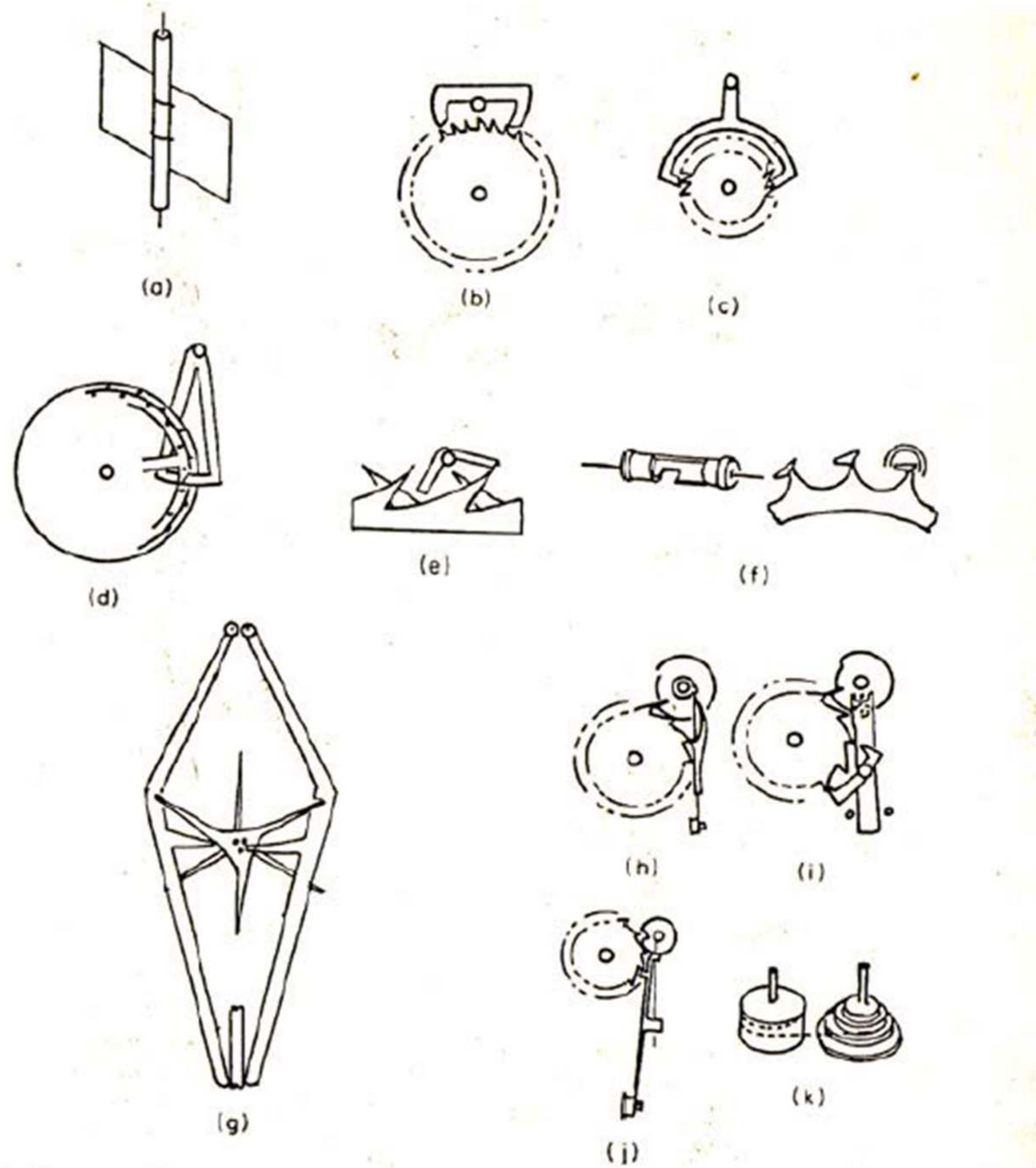


FIG. 39-7 Escapements. These devices slowly release the potential energy stored in a spring to control devices such as clocks. (*a*) Paddle wheel; (*b*) recoil escapement; (*c*) dead-beat escapement; (*d*) stud escapement; (*e*) early anchor escapement; (*f*) cylinder escapement; (*g*) double three-legged escapement for tower clocks; (*h*) to (*j*) chronometer escapements; (*k*) fuse used to give uniform torque at escapement as the spring unwinds.

Locating mechanisms

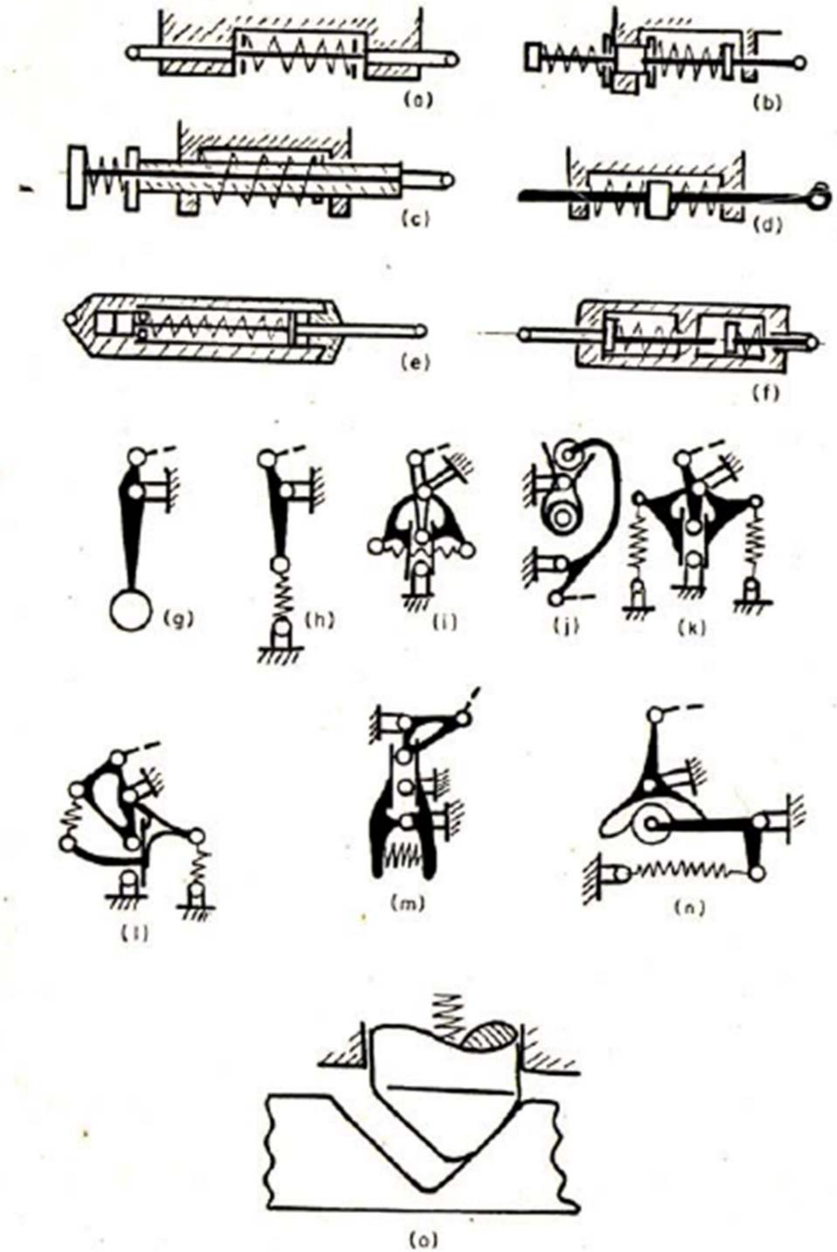


FIG. 39-6 Locating mechanisms. These are devices which properly position a linkage member when the load is removed. (*a*) to (*f*) Self-centering linear devices; (*g*) to (*n*) self-centering angular devices; (*o*) detent.

Oscillating mechanisms I

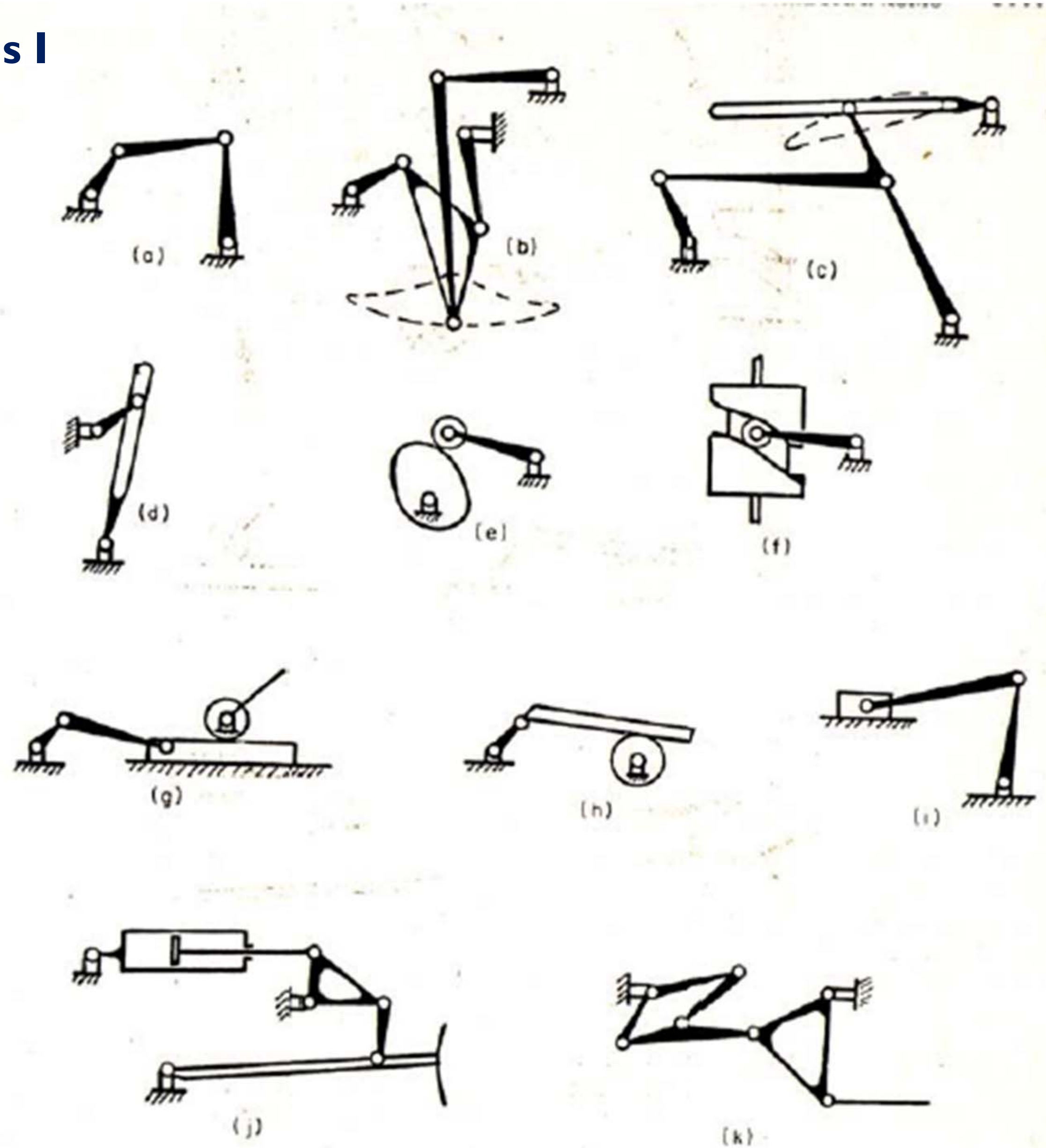


FIG. 39-9 Oscillating mechanisms I. These mechanisms cause an output to repeatedly swing through a preset angle. (*a*) Four-bar linkage; (*b*) six-bar linkage; (*c*) six-bar linkage with pin in slot; (*d*) inverted slide-crank quick-return linkages; (*e*) radial cam and follower; (*f*) cylindrical cam; (*g*) geared slider crank; (*h*) geared inverted slider crank; (*i*) slider-driven crank; (*j*) bulldozer lift mechanism; (*k*) oscillator of the Corliss valve gear.

Oscillating mechanisms II

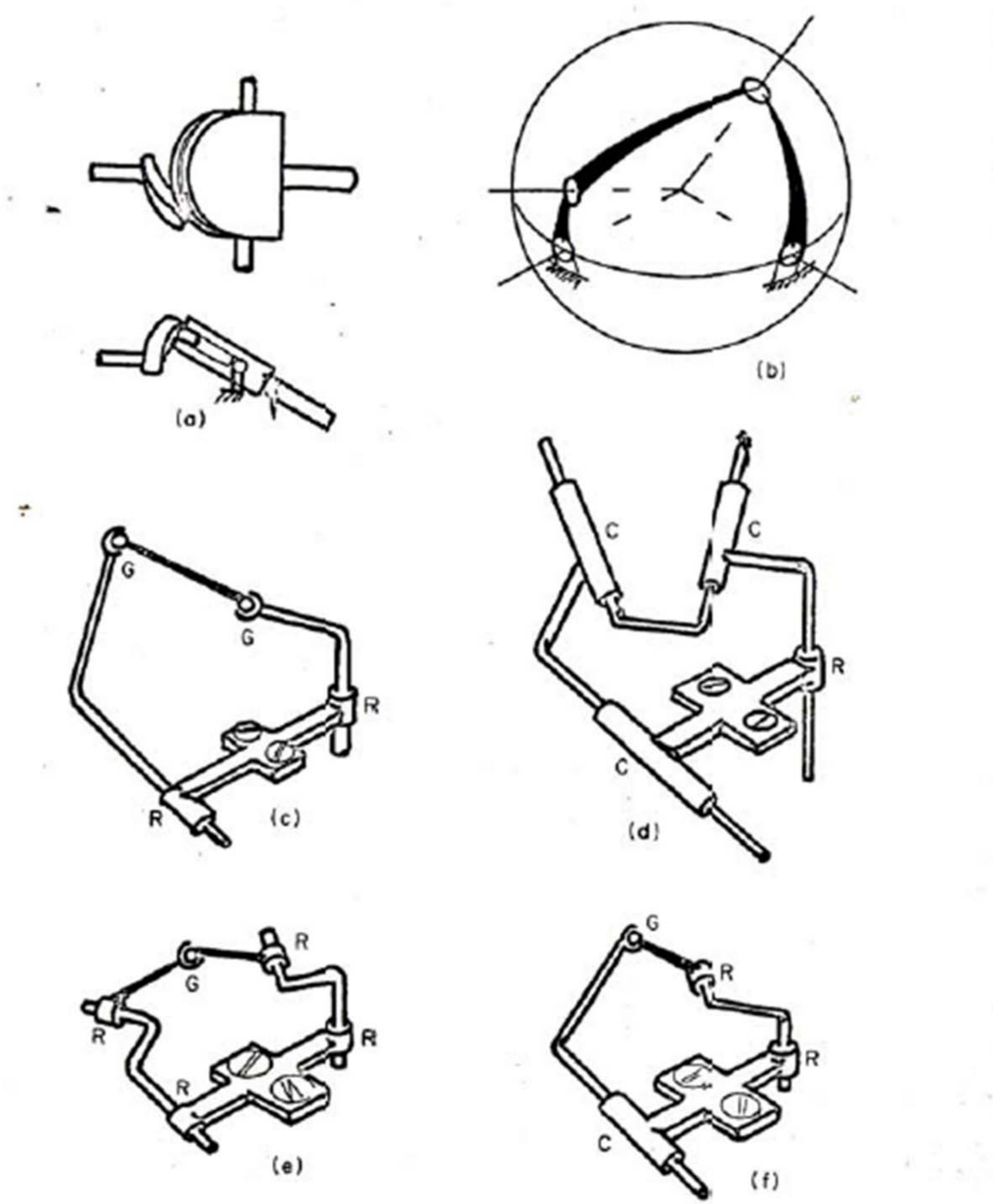


FIG. 39-10 **Oscillating mechanisms II.** These all use spatial linkages. (*a*) Spatial pin and yoke; (*b*) spherical four-bar linkage; (*c*) spatial RGGR linkage; (*d*) spatial RCCC; (*e*) spatial RRGRR; (*f*) spatial RRGC.

Indexing mechanisms

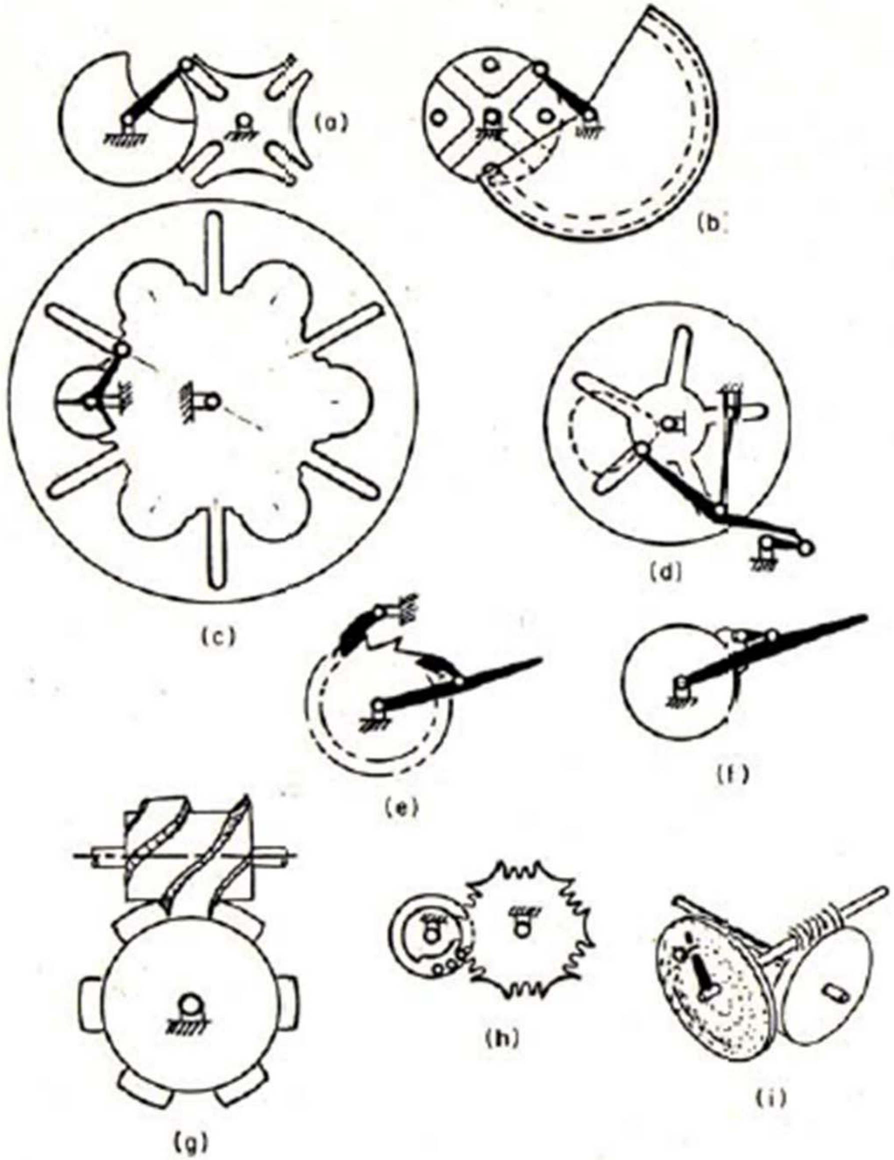


FIG. 39-8 Indexing mechanisms. These mechanical devices advance a body to a specific position, hold it there for a period, and then advance it again. (*a*) to (*c*) Geneva stops; (*d*) four-bar links used to reduce jerk; (*e*) ratchet mechanism; (*f*) friction ratchet; (*g*) cylindrical cam-stop mechanism; (*h*) pin gearing used in indexing; (*i*) dividing head.

Ratchets and latches mechanisms

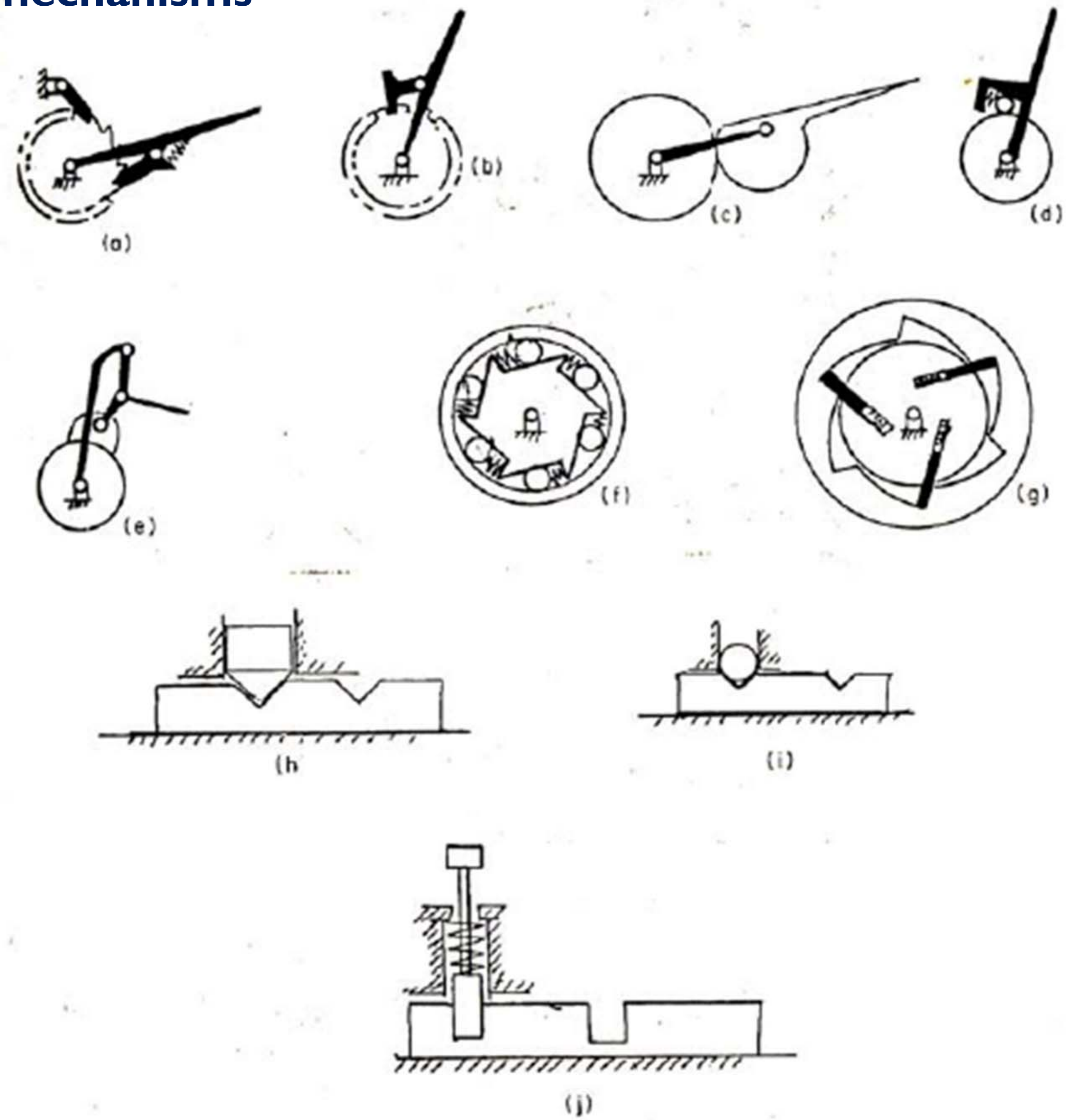


FIG. 39-11 Ratchets and latches. These are mechanisms that advance or hold a machine member. (*a*) Ratchet and pawl; (*b*) reversible ratchet; (*c*) cam-lock ratchet; (*d*) ball-lock ratchet; (*e*) toggle ratchet; (*f*) overrunning clutch; (*g*) high-torque ratchet; (*h*), (*i*) detents; (*j*) locking bolts.

Reciprocating mechanisms I

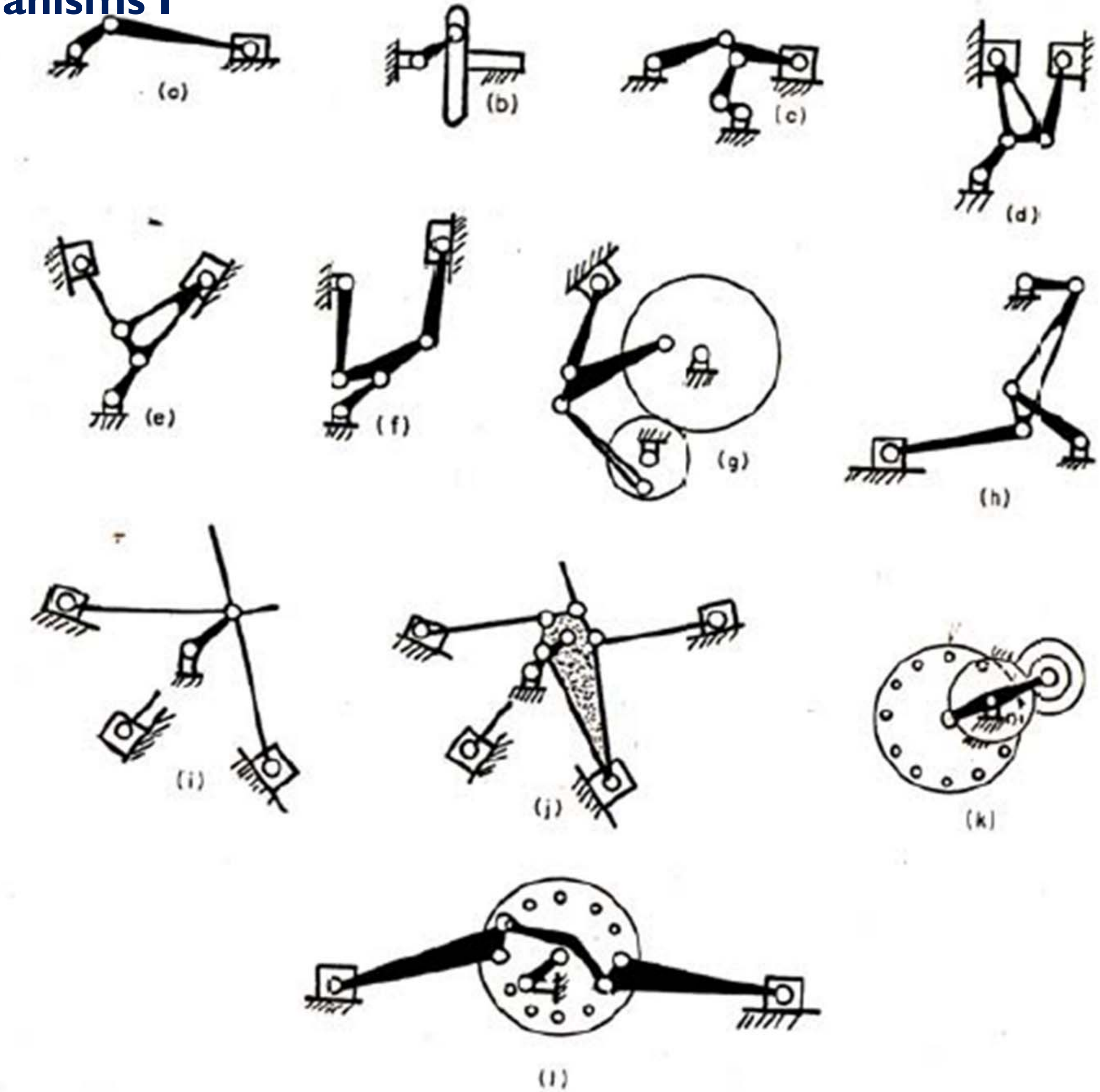


FIG. 39-12 Reciprocating mechanisms I. These mechanical devices cause a member to translate on a straight line. (*a*) Slider crank; (*b*) Scotch yoke; (*c*) toggle mechanism; (*d*) Zoller engine; (*e*) V Engine; (*f*) double-stroke engine; (*g*) geared engine; (*h*) Atkinson gas engine; (*i*) ideal radial engine; (*j*) practical radial engine; (*k*) geared Nordberg radial engine; (*l*) linked Nordberg radial engine.

Reciprocating mechanisms II

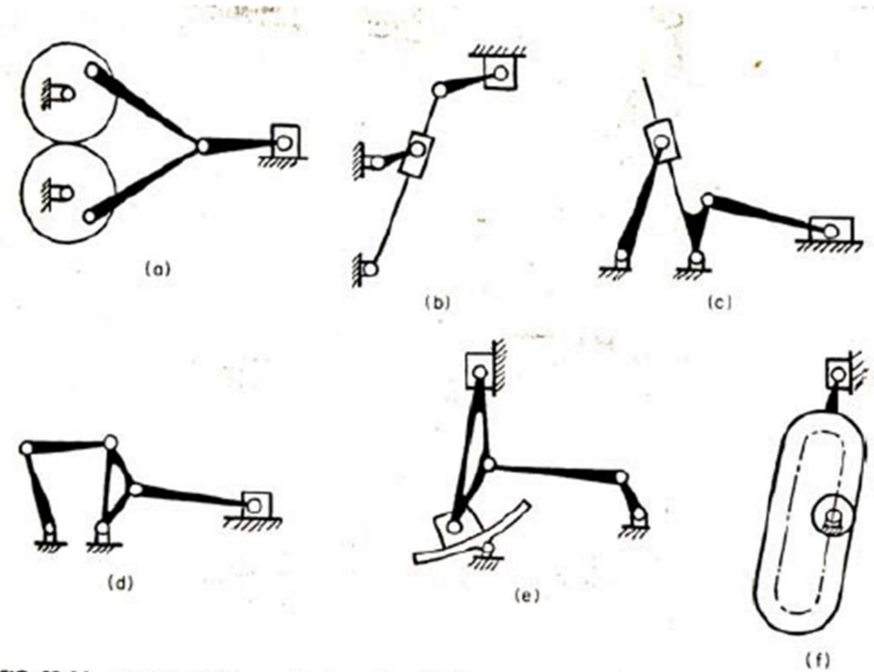


FIG. 39-13 Reciprocating mechanisms II. (*a*) Geared cranks; (*b*) shaper mechanism; (*c*) slider on Whitworth quick-return mechanisms; (*d*) slider on drag-link mechanism; (*e*) variable-stroke engine; (*f*) gear-driven slider.

Reversing mechanisms

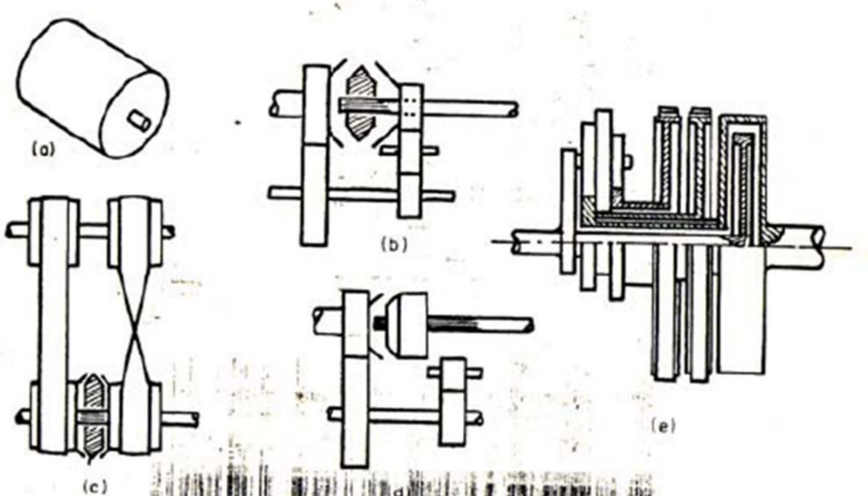


FIG. 39-14 Reversing mechanism. These mechanical devices change the direction of rotation of the output. (*a*) Reversible prime movers; (*b*) reversing gears; (*c*) reversing belts; (*d*) trasmission; (*e*) epicyclic gears as in Model T Ford.

Coupling and connectors -parallel shafts mechanisms

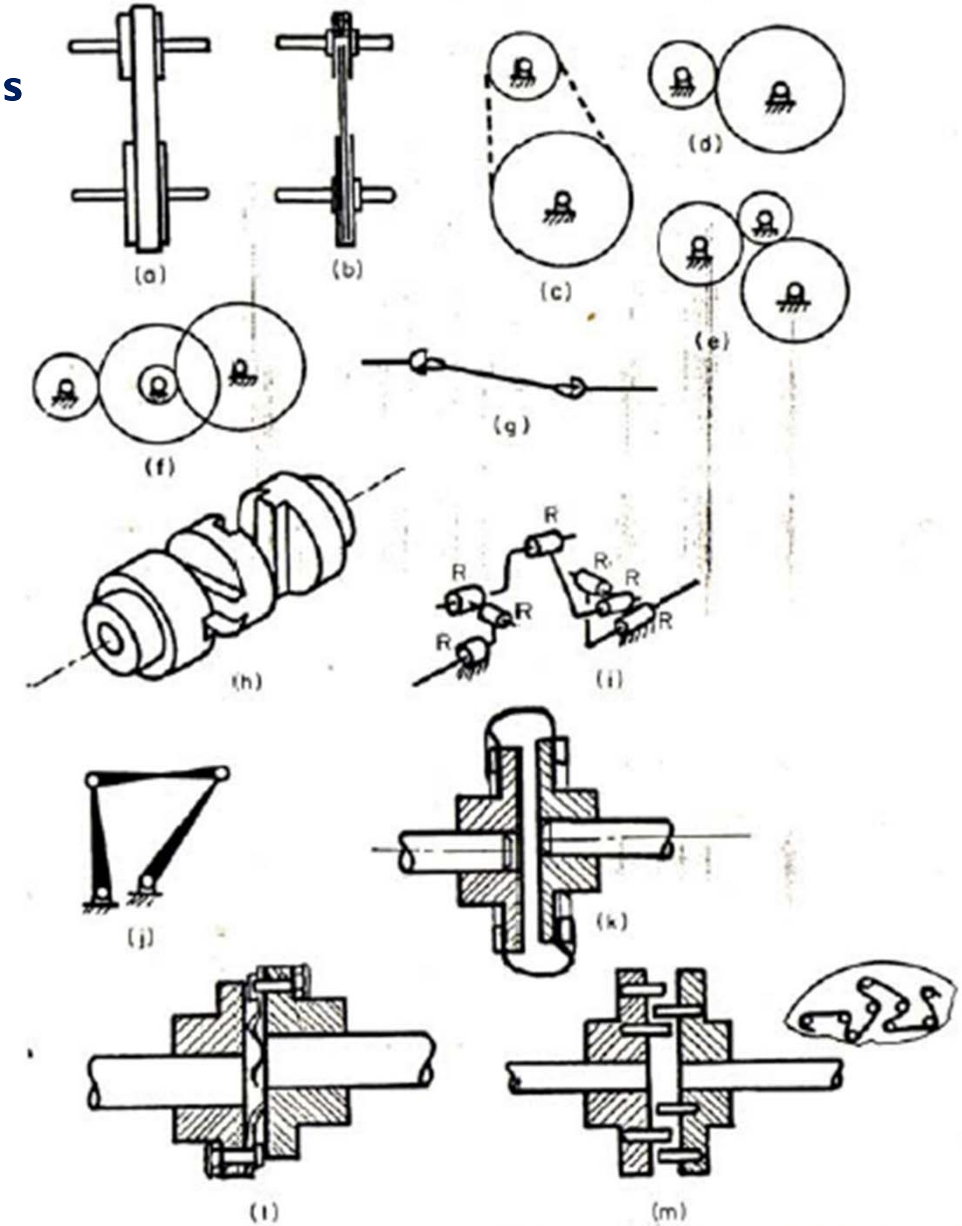


FIG. 39-16 Couplings and connectors—parallel shafts. (*a*) Flat belt; (*b*) V belt; (*c*) chain; (*d*) to (*f*) gears; (*g*) Hooke joints; (*h*) Oldham coupling; (*i*) Hunt's constant-velocity coupling; (*j*) drag link; (*k*) to (*m*) flexible coupling.

Coupling and connectors -axial mechanisms

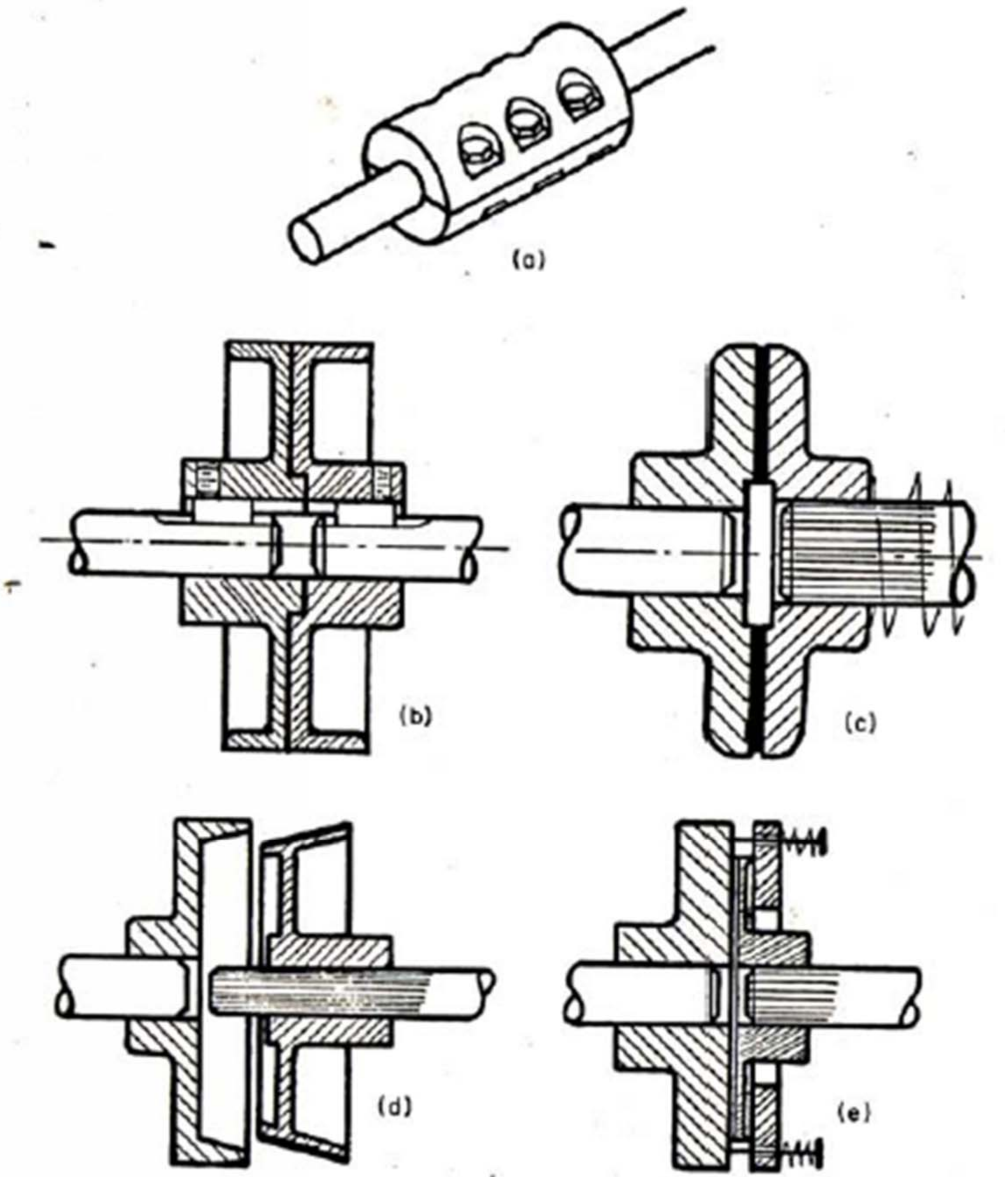


FIG. 39-15 Couplings and connectors—axial. These are used to connect coaxial shafts. (*a*) Rigid coupling; (*b*) flanged coupling; (*c*) disk clutch; (*d*) cone clutch; (*e*) plate clutch.

Coupling and connectors -skew shafts mechanisms

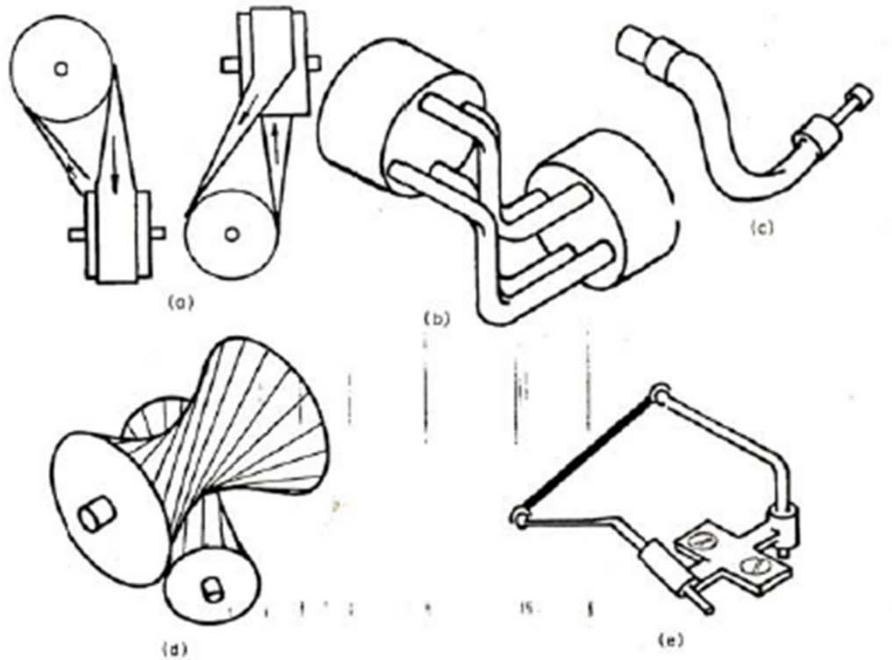


FIG. 39-18 Couplings and connectors—skew shafts. (*a*) Flat belts; (*b*) spatial RCCR; (*c*) flexible shaft; (*d*) hypoid gears; (*e*) spatial RGGR.

Slider connectors mechanisms

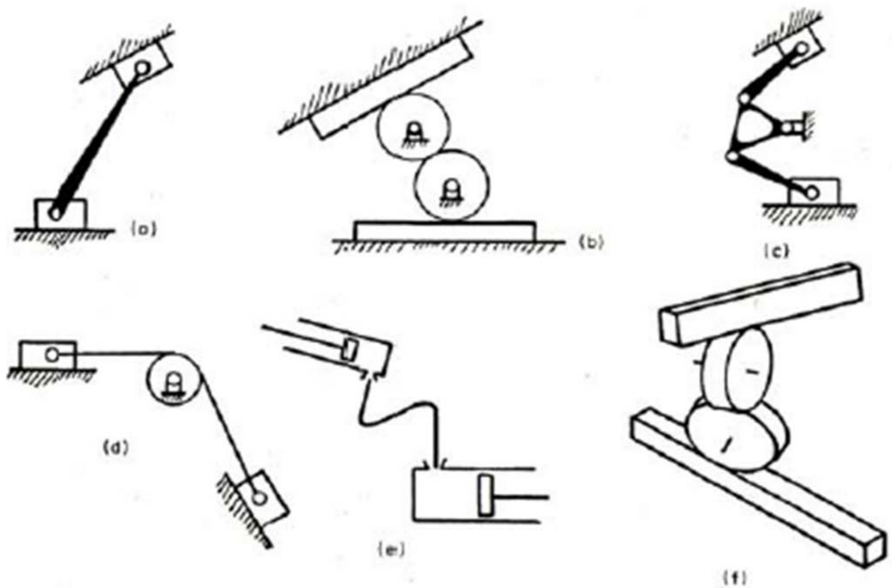


FIG. 39-19 Slider connectors. These devices connect two or more reciprocating devices. (*a*) Elliptic trammel; (*b*) gears; (*c*) slider-crank-slider; (*d*) cable; (*e*) hydraulic; (*f*) helical gearing.

Coupling and connectors -interacting shafts mechanisms

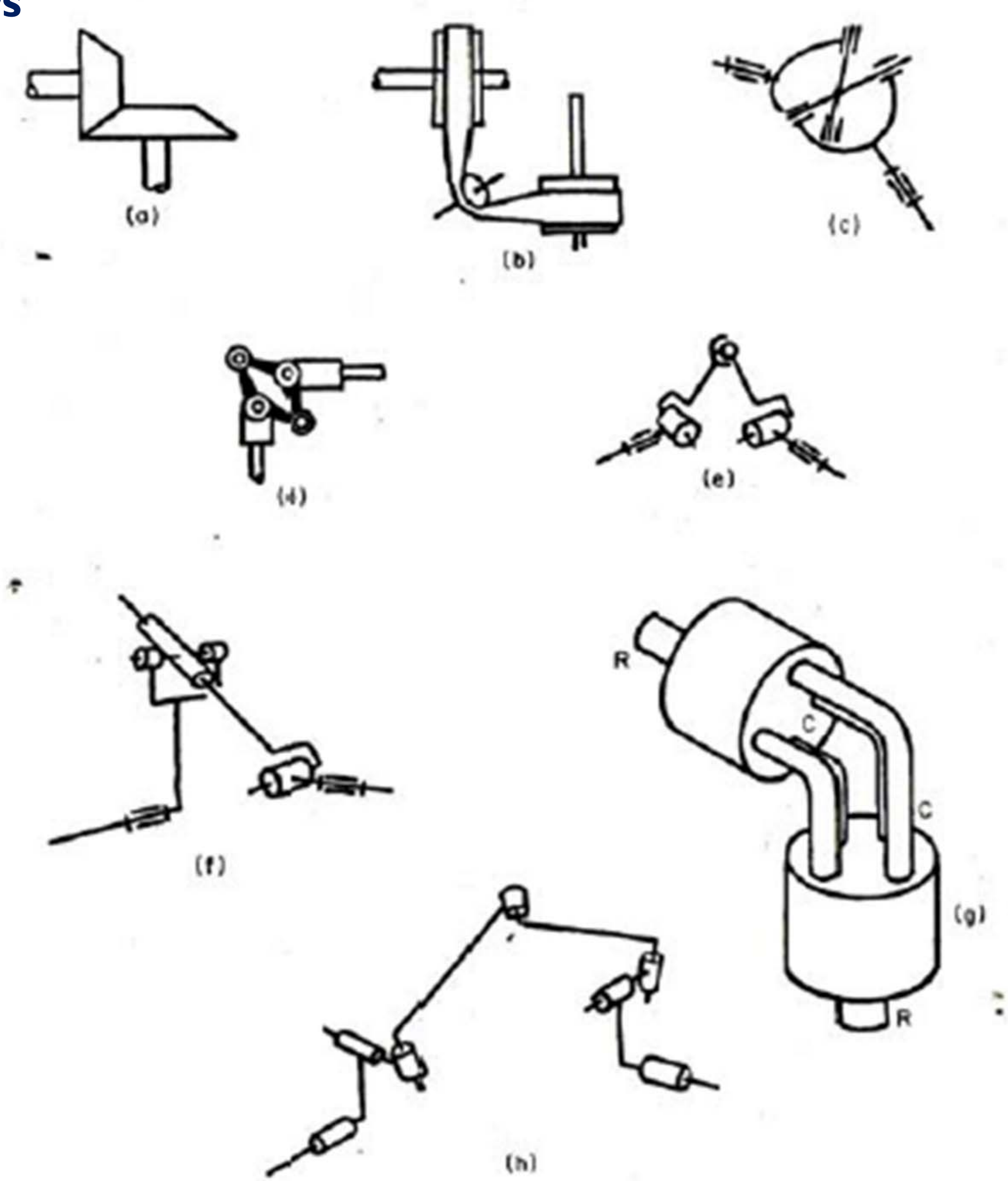


FIG. 39-17 Couplings and connectors—intersecting shafts. (*a*) Bevel gears; (*b*) flat belts with idlers; (*c*) Hooke joint; (*d*) Hooke's coupling; (*e*) Clemens coupling; (*f*) Rouleaux coupling; (*g*) spatial RCCR; (*h*) Hunt's constant-velocity coupling.

Transportation mechanisms

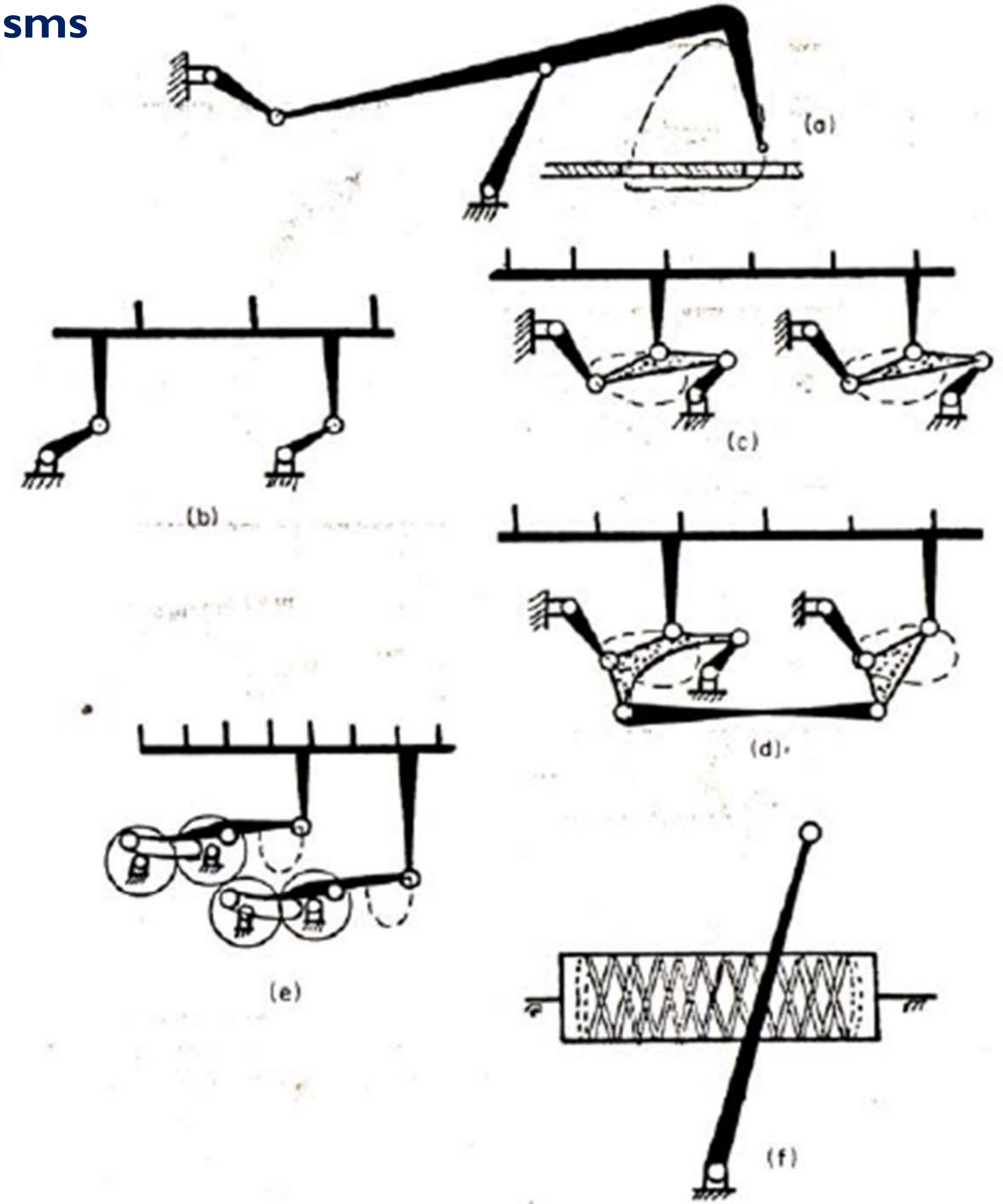


FIG. 39-21 Transportation devices. These mechanisms move one or more objects a discrete distance in stepped motion. (*a*) Four-bar film advance; (*b*) circular-motion transport; (*c*), (*d*) coupler-curve transport; (*e*) geared linkage transport; (*f*) fishing-reel feed.

Loading and unloading mechanisms I

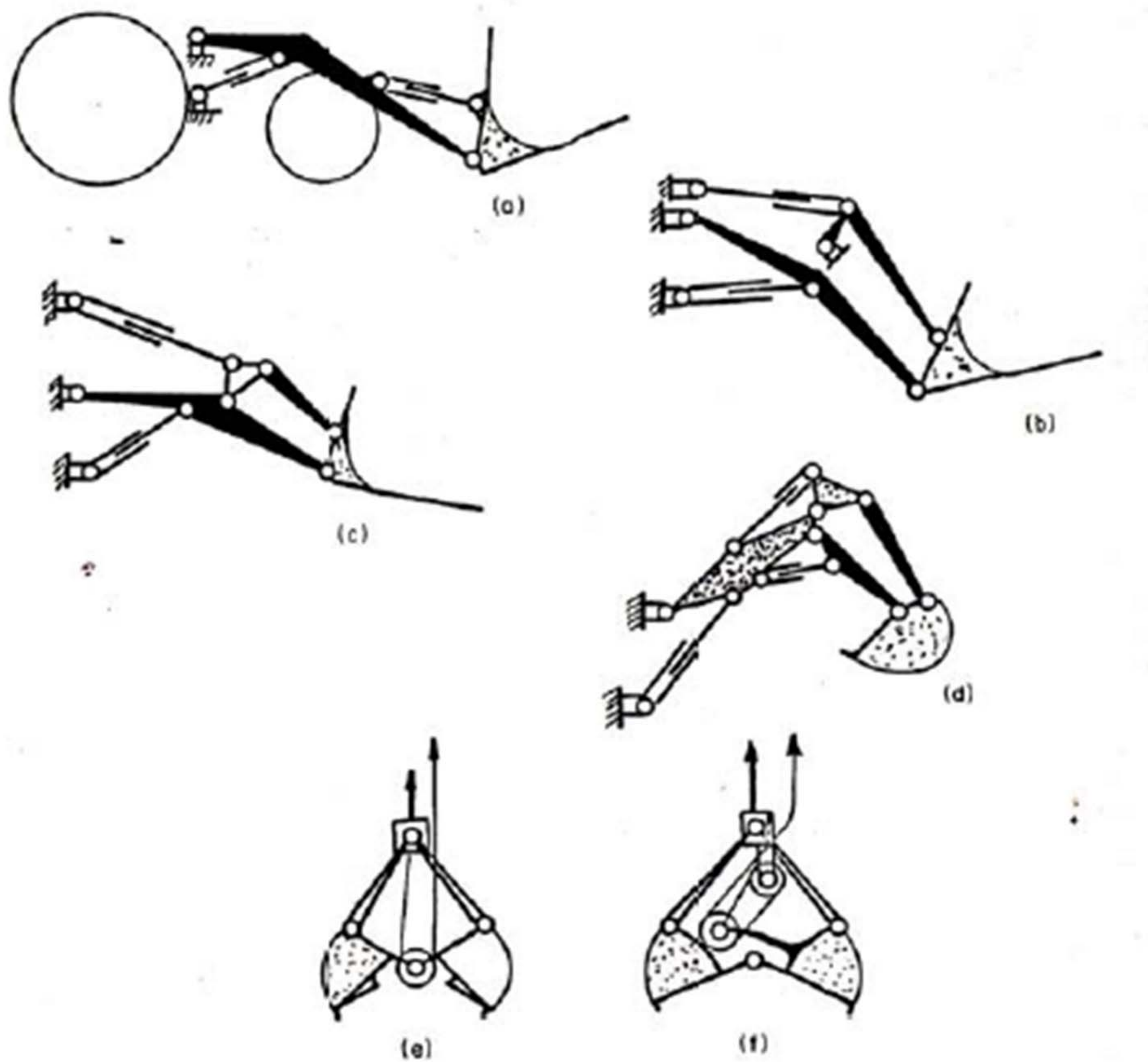


FIG. 39-22 Loading and unloading mechanisms I. These mechanisms pick up material and transport it to another location. (*a*) to (*c*) Front-end loaders; (*d*) back hoe; (*e*), (*f*) clamshell loaders.

Loading and unloading mechanisms II

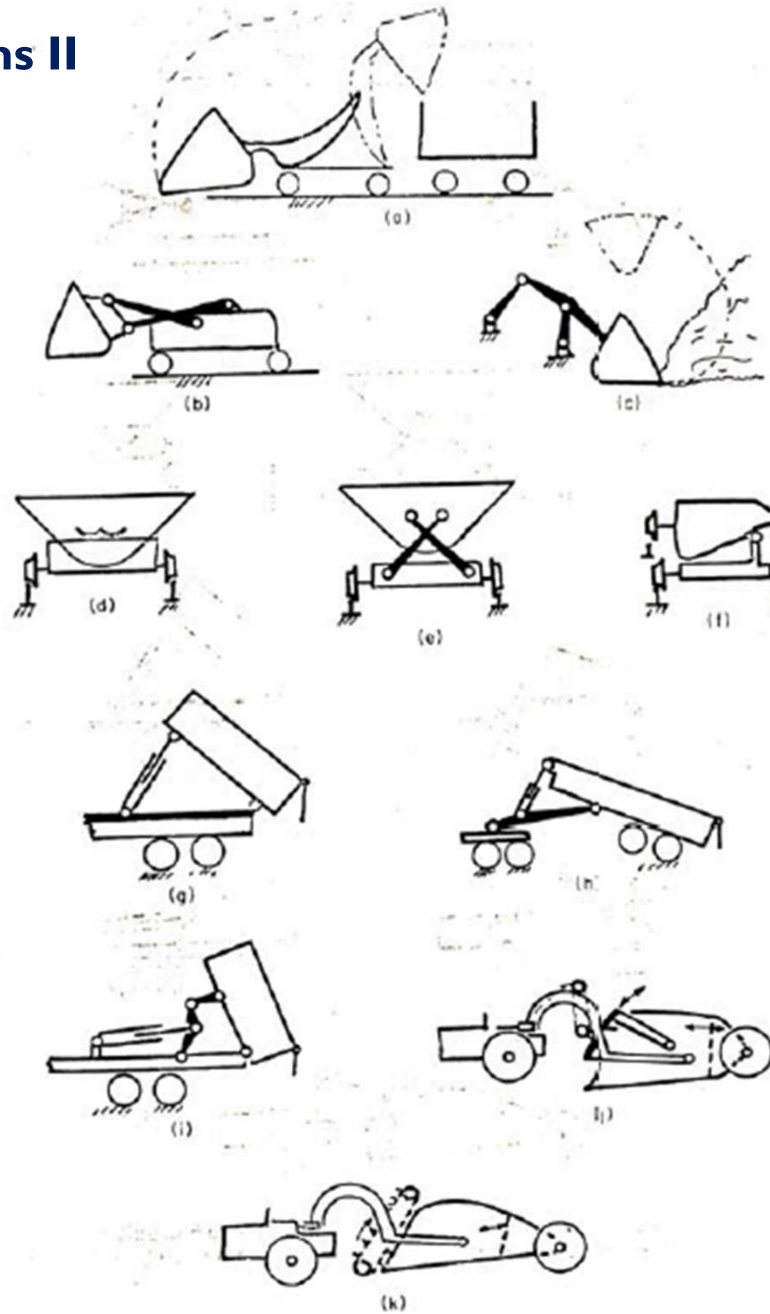


FIG. 39-23 Loading and unloading mechanisms II. (*a*), (*b*) Mucking machines; (*c*) scooping mechanism; (*d*) to (*f*) dumping mine cars; (*g*) to (*i*) dump trucks; (*j*) motor scraper; (*k*) elevat-