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MACHINE ELEMENTS IN MOTION

CHAPTER 2

A THESAURUS OF MECHANISMS

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GLOSSARY OF SYMBOLS

R	Revolute pair or pin joint
P	Prismatic pair or sliding joint
C	Cylinder pair for joints that allow rotation and sliding along the cylinder axis
G	Spheric pair (globe) for ball joints
S_L	Screw pair with lead L
F	Planar pair (flat) for a joint that maintains two planes in contact

SUMMARY[†]

This chapter is intended to be used as an idea generator. Following the adage that a picture is worth 1000 words, this chapter was assembled with millions of “words” in figures and virtually none using the alphabet. I have taken the liberty of varying dimensions to better show the principle of operation. You should not scale the figures, but follow the regular synthesis procedure to determine the proper dimensions for the application in mind.

In this chapter a new notation is used for the kinematic representation of joints or pairs in a linkage.

[†] Readers will note a difference in the style and character of the figures in this chapter. When this manuscript was received, the illustrations, all conceived and executed by Professor Torfason, were seen to be original and unique. We asked for and received from the publishers special permission to reproduce them exactly as they were drawn—Eds.

COLLATERAL READING

L. J. Kamm, *Designing Cost-Efficient Mechanisms*, McGraw-Hill, New York, 1990.

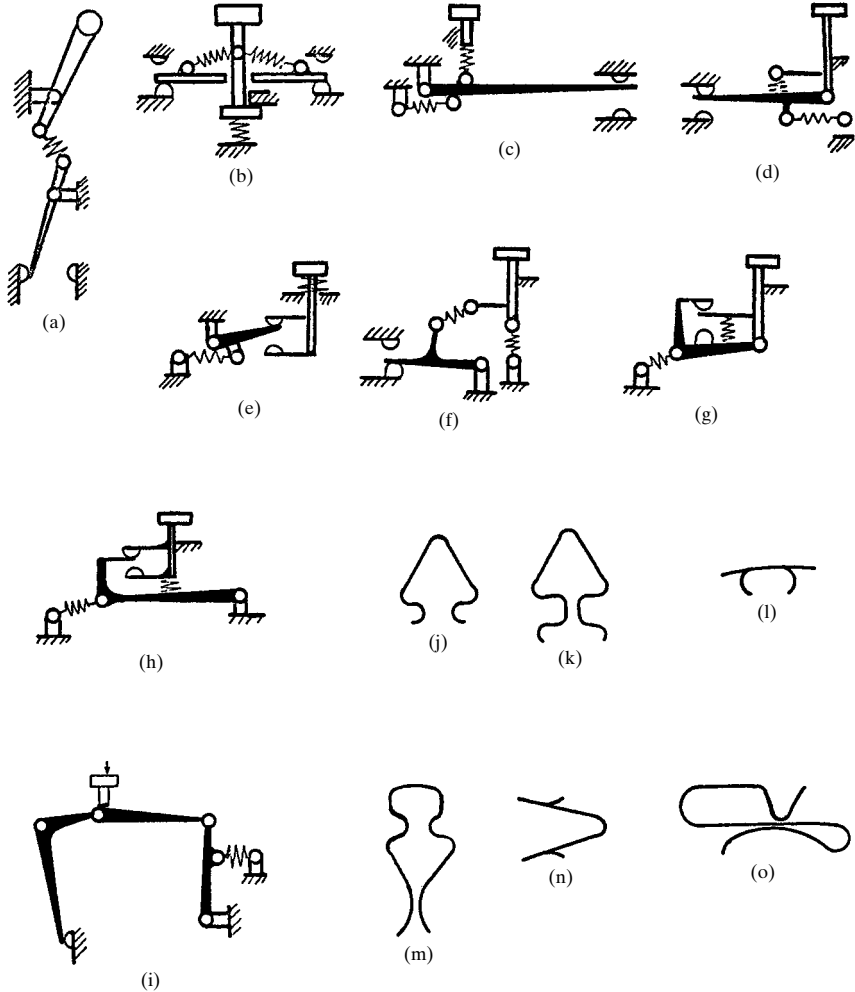


FIGURE 2.1 Snap-action mechanisms. These mechanisms are bistable elements in machines. They are used in switches to quickly make and break electric circuits and for fastening items. (a) Snap-action toggle switch; (b) to (h) seven variations of snap-action switches; (i) circuit breaker; (j) to (o), spring clips.

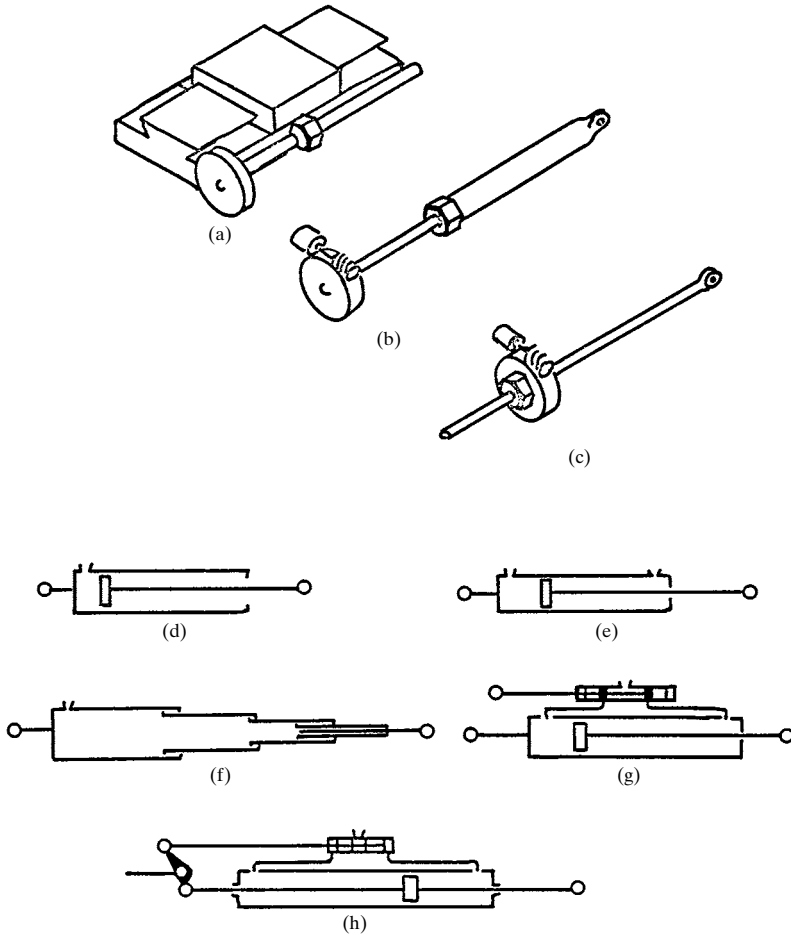


FIGURE 2.2 Linear actuators. These are devices that cause a straight-line displacement between two machine elements. (a) Lead screw; (b) worm gear with stationary nut; (c) worm gear with stationary screw; (d) single-acting hydraulic cylinder; (e) double-acting hydraulic cylinder; (f) telescoping hydraulic cylinder; (g) hydraulic cylinder with positional feedback; (h) hydraulic cylinder with floating link feedback.

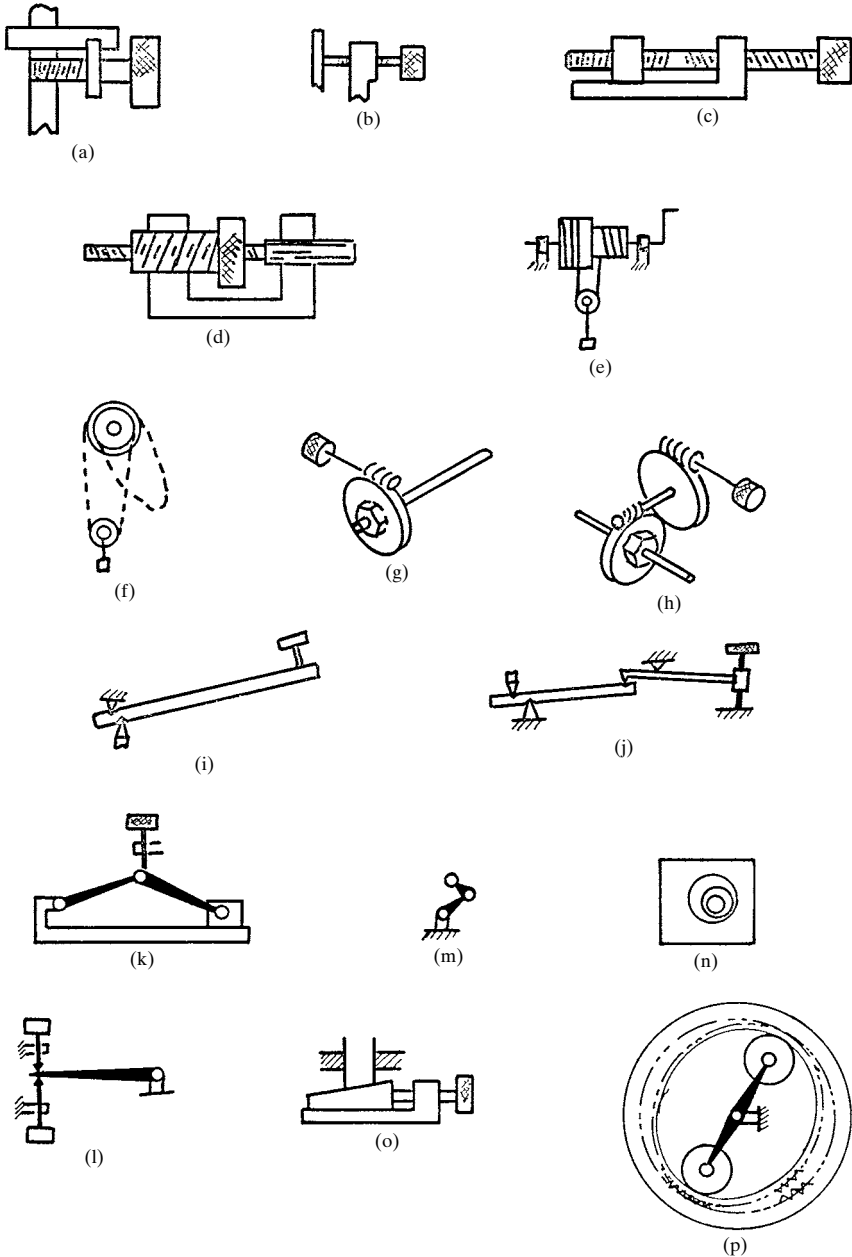


FIGURE 2.3 Fine adjustments I. Fine adjustments for stationary mechanisms are mechanisms that make a small change in the position of a mechanical member. (a), (b) Screw adjustments; (c), (d) differential screws; (e) Chinese windlass; (f) differential hoist; (g) worm gear and screw; (h) worm gears in series; (i) lever; (j) levers in series; (k) toggle mechanism; (l) screws to adjust angular position; (m), (n) eccentric cranks; (o) wedges; (p) harmonic drive.

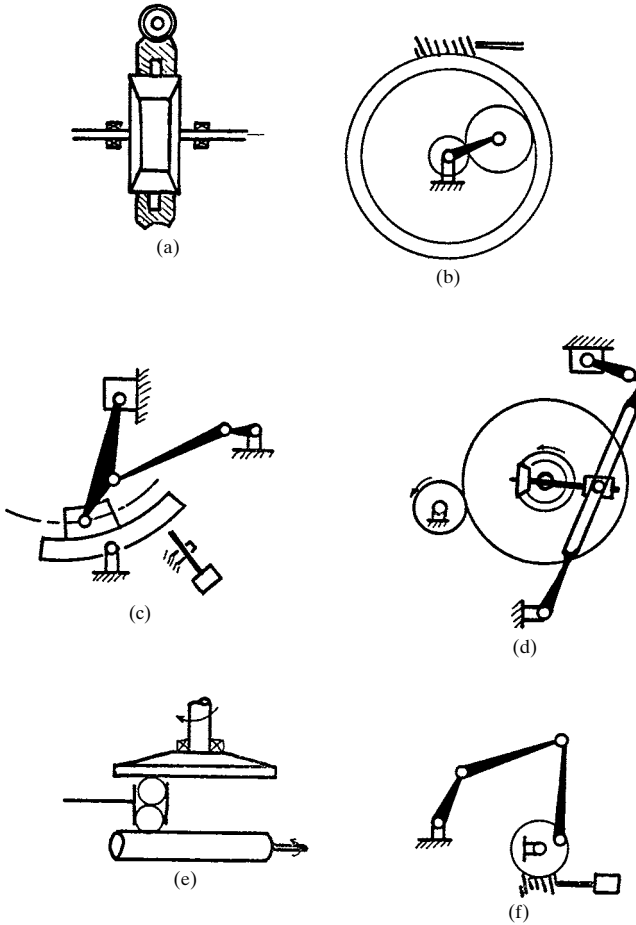


FIGURE 2.4 Fine adjustments II. Fine adjustments for moving mechanisms are adjusting devices which control the motion of linkages such as stroke, etc., while the mechanism is in motion. (a), (b) Differential gear adjustment; (c) adjustable-stroke engine; (d) adjustable stroke of shaper mechanism; (e) ball and disk speed changer; (f) adjusting fixed center of linkage for changing motion properties.

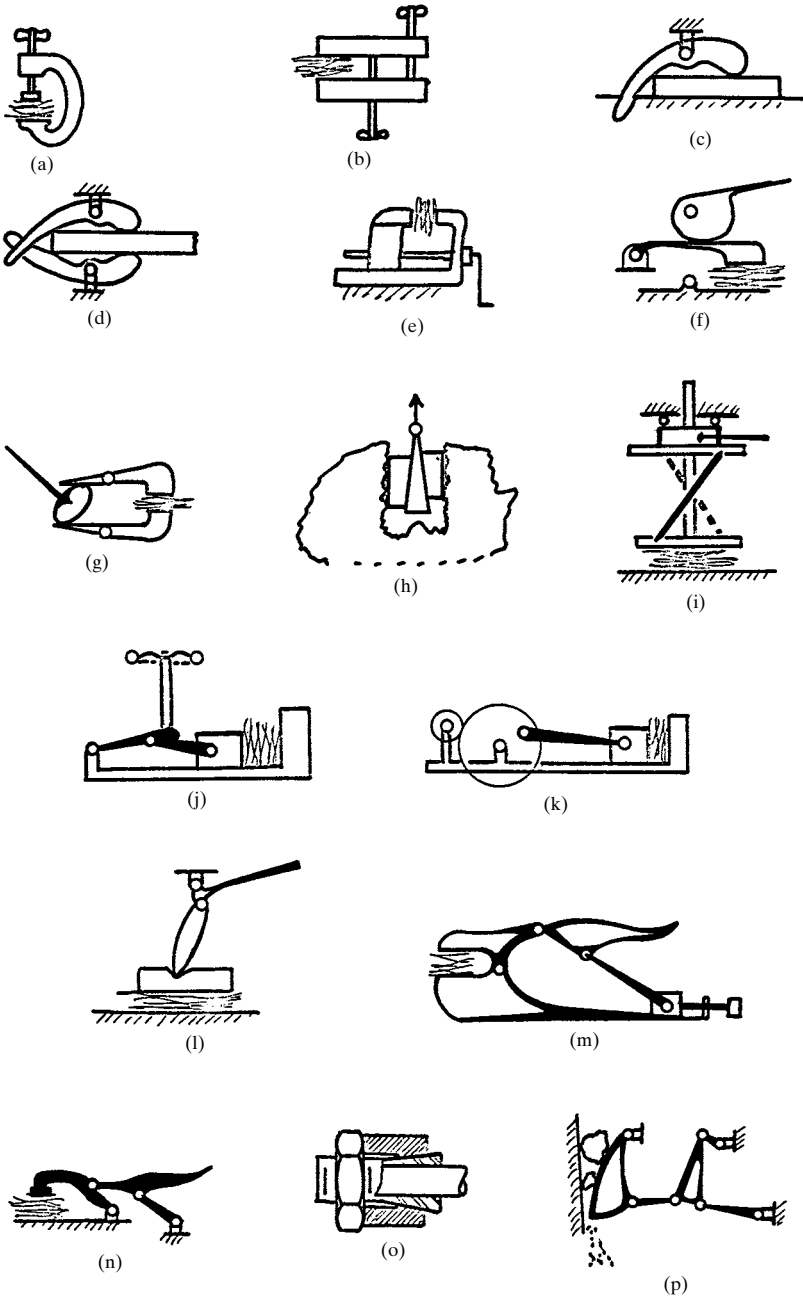


FIGURE 2.5 Clamping mechanisms. These devices are used to hold items for machining operations or to exert great forces for embossing or printing. (a) C clamp; (b) screw clamp; (c) cam clamp; (d) double cam clamp; (e) vise; (f) cam-operated clamp; (g) double cam-actuated clamp; (h) double wedge; (i) to (l) toggle press; (m) vise grips; (n) toggle clamp; (o) collet; (p) rock crusher.

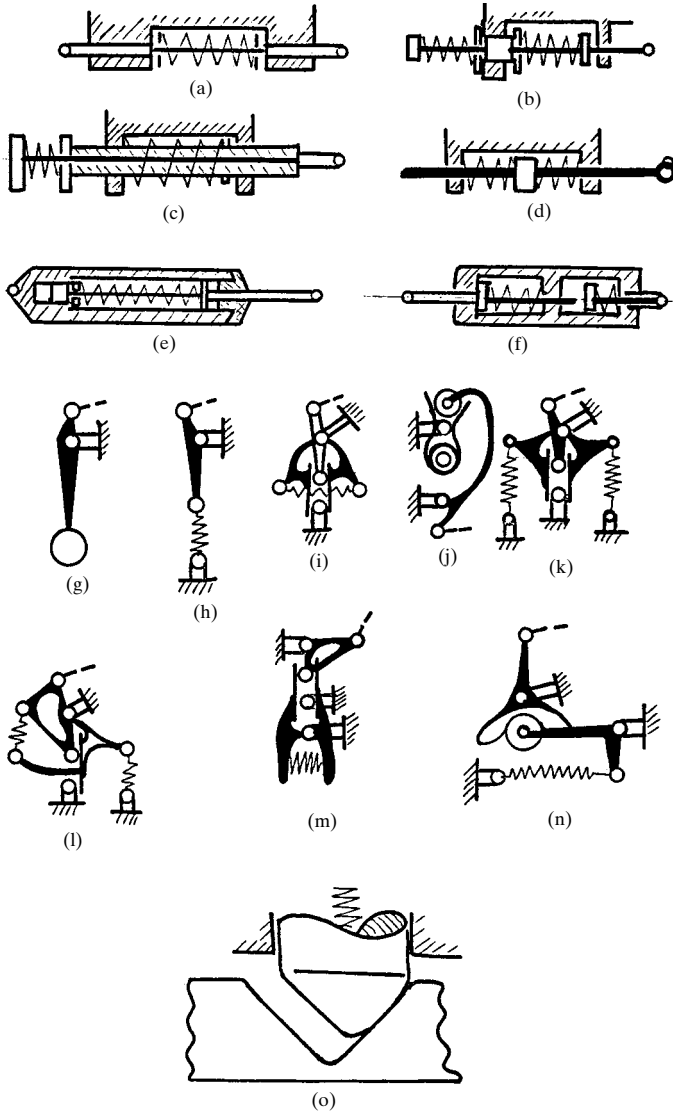


FIGURE 2.6 Locating mechanisms. These are devices which properly position a linkage member when the load is removed. (a) to (f) Self-centering linear devices; (g) to (n) self-centering angular devices; (o) detent.

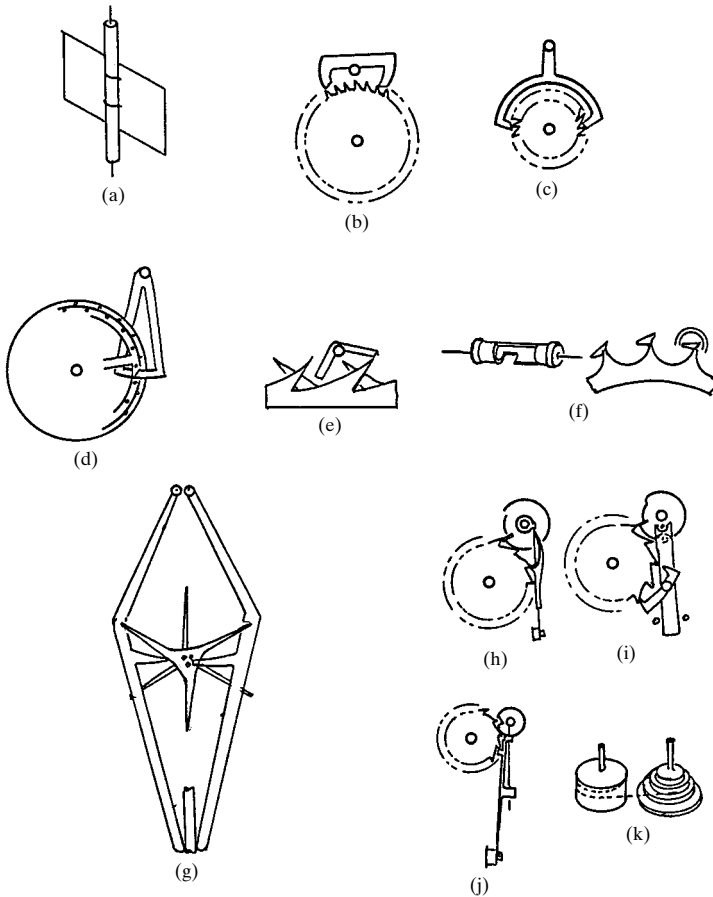


FIGURE 2.7 Escapements. These devices slowly release the potential energy stored in a spring to control devices such as clocks. (a) Paddle wheel; (b) recoil escapement; (c) dead-beat escapement; (d) stud escapement; (e) early anchor escapement; (f) cylinder escapement; (g) double three-legged escapement for tower clocks; (h) to (j) chronometer escapements; (k) fuse used to give uniform torque as the spring unwinds.

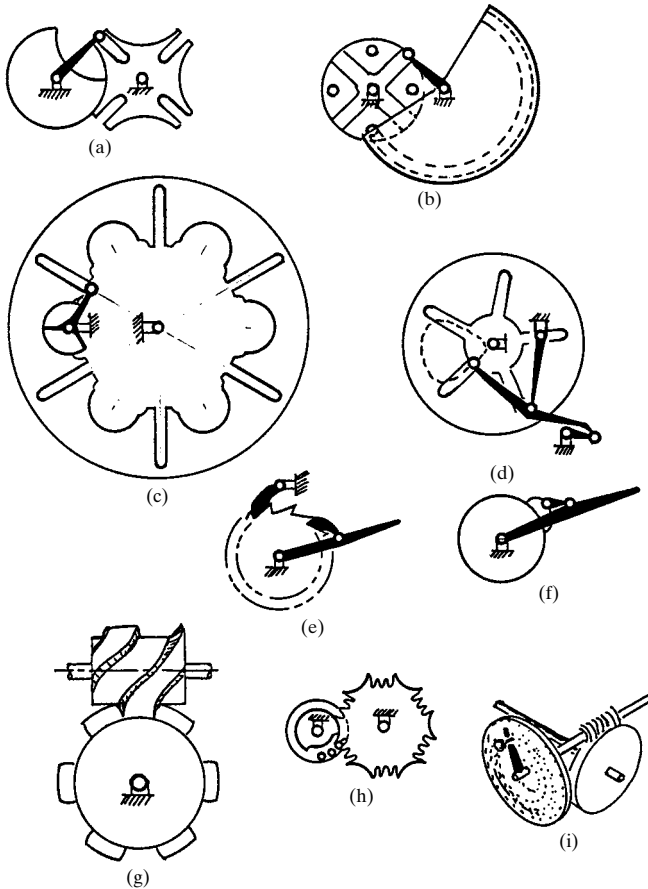


FIGURE 2.8 Indexing mechanisms. These mechanical devices advance a body to a specific position, hold it there for a period, and then advance it again. (a) to (c) Geneva stops; (d) four-bar links used to reduce jerk; (e) ratchet mechanism; (f) friction ratchet; (g) cylindrical cam-stop mechanism; (h) pin gearing used in indexing; (i) dividing head.

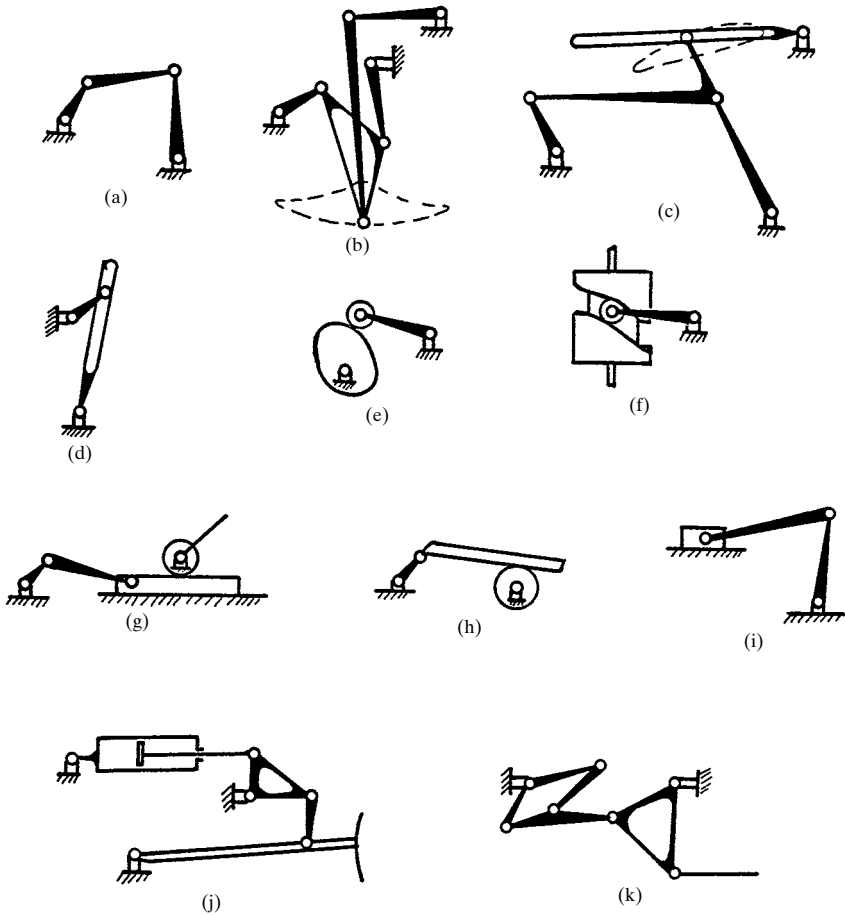


FIGURE 2.9 Oscillating mechanisms I. These mechanisms cause an output to repeatedly swing through a preset angle. (a) Four-bar linkage; (b) six-bar linkage; (c) six-bar linkage with pin in slot; (d) inverted slide-crank quick-return linkages; (e) radial cam and follower; (f) cylindrical cam; (g) geared slider crank; (h) geared inverted slider crank; (i) slider-driven crank; (j) bulldozer lift mechanism; (k) oscillator of the Corliss valve gear.

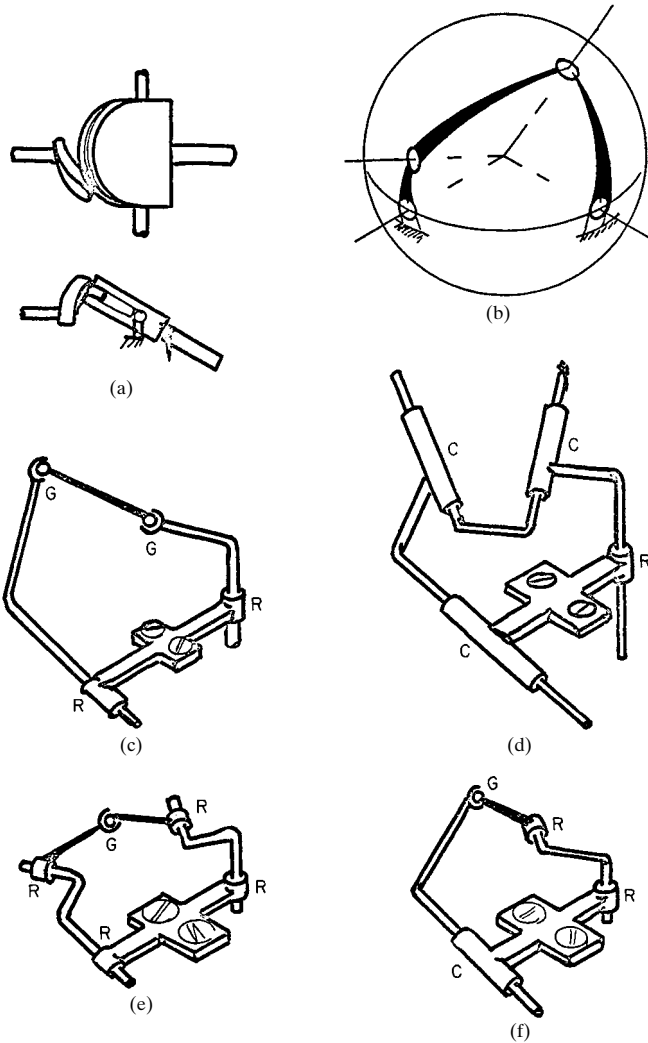


FIGURE 2.10 Oscillating mechanisms II. These all use spatial linkages. (a) Spatial pin and yoke; (b) spherical four-bar linkage; (c) spatial RGGR linkage; (d) spatial RCCC; (e) spatial RRGR; (f) spatial RRGC.

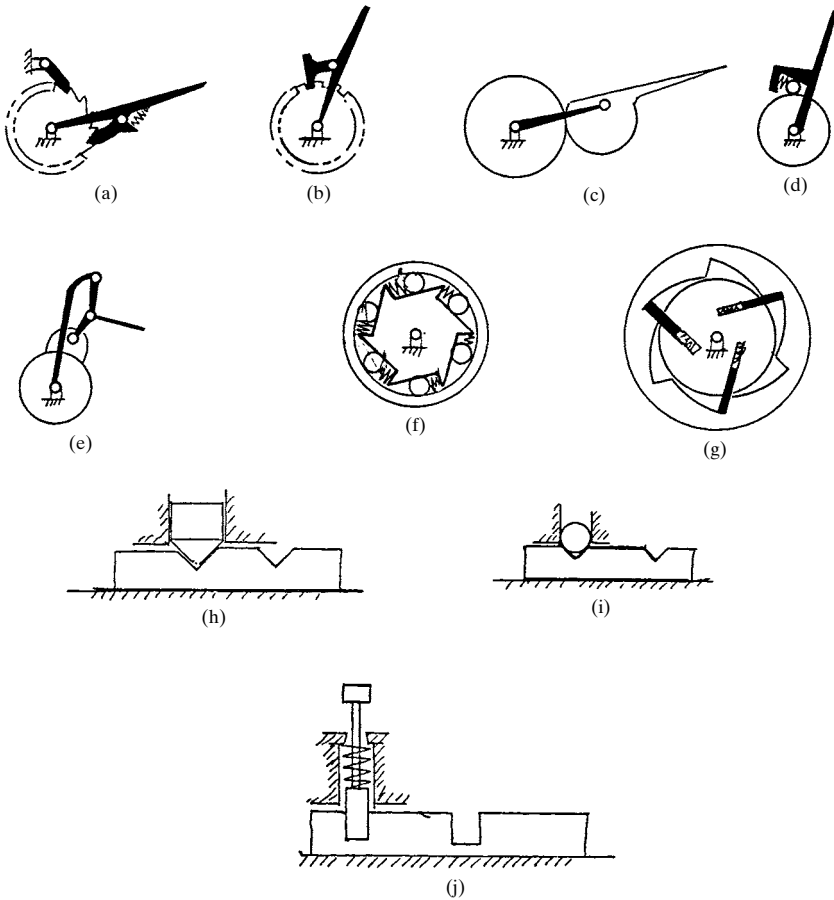


FIGURE 2.11 Ratchets and latches. These are mechanisms that advance or hold a machine member. (a) Ratchet and pawl; (b) reversible ratchet; (c) cam-lock ratchet; (d) ball-lock ratchet; (e) toggle ratchet; (f) overrunning clutch; (g) high-torque ratchet; (h), (i) detents; (j) locking bolts.

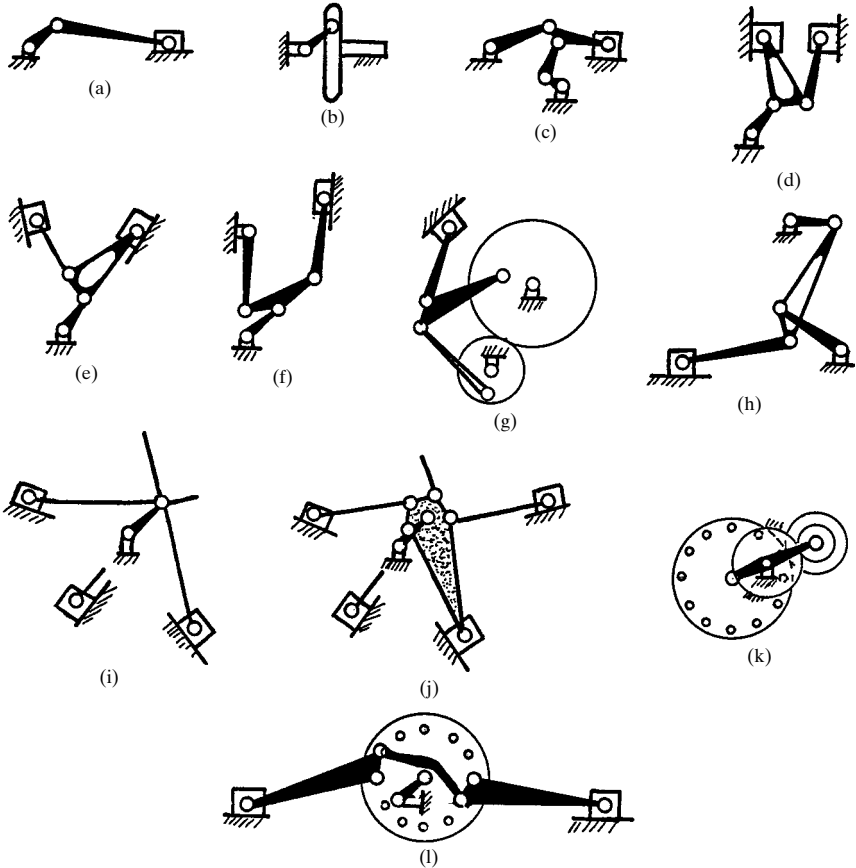


FIGURE 2.12 Reciprocating mechanisms I. These mechanical devices cause a member to translate on a straight line. (a) Slider crank; (b) Scotch yoke; (c) toggle mechanism; (d) Zoller engine; (e) V engine; (f) double-stroke engine; (g) geared engine; (h) Atkinson gas engine; (i) ideal radial engine; (j) practical radial engine; (k) geared Nordberg radial engine; (l) linked Nordberg radial engine.

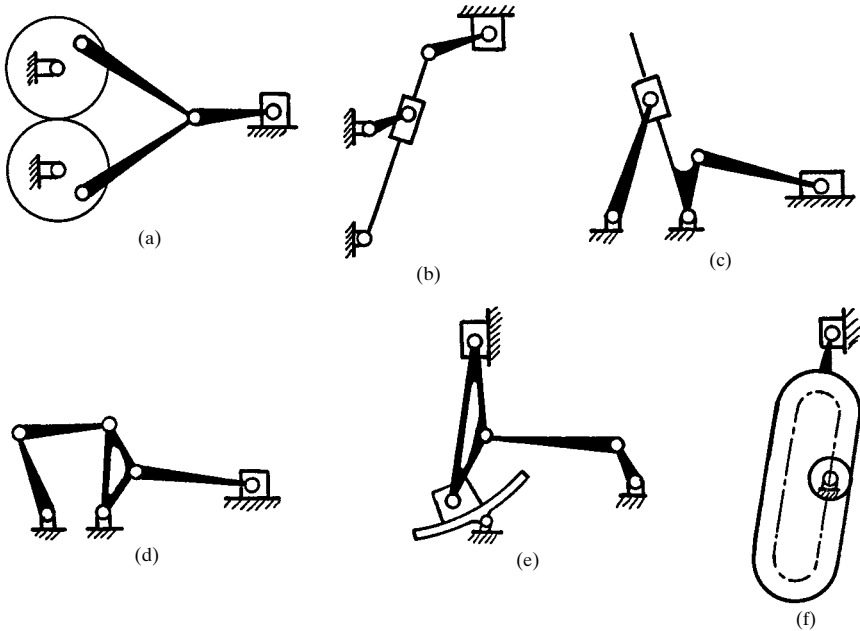


FIGURE 2.13 Reciprocating mechanisms II. (a) Geared cranks; (b) shaper mechanism; (c) slider on Whitworth quick-return mechanisms; (d) slider on drag-link mechanism; (e) variable-stroke engine; (f) gear-driven slider.

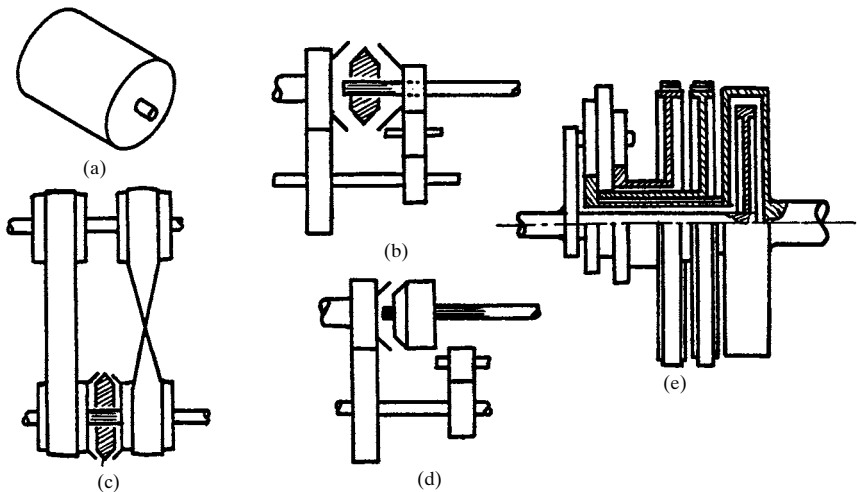


FIGURE 2.14 Reversing mechanism. These mechanical devices change the direction of rotation of the output. (a) Reversible prime movers; (b) reversing gears; (c) reversing belts; (d) transmission; (e) epicyclic gears as in Model T Ford.

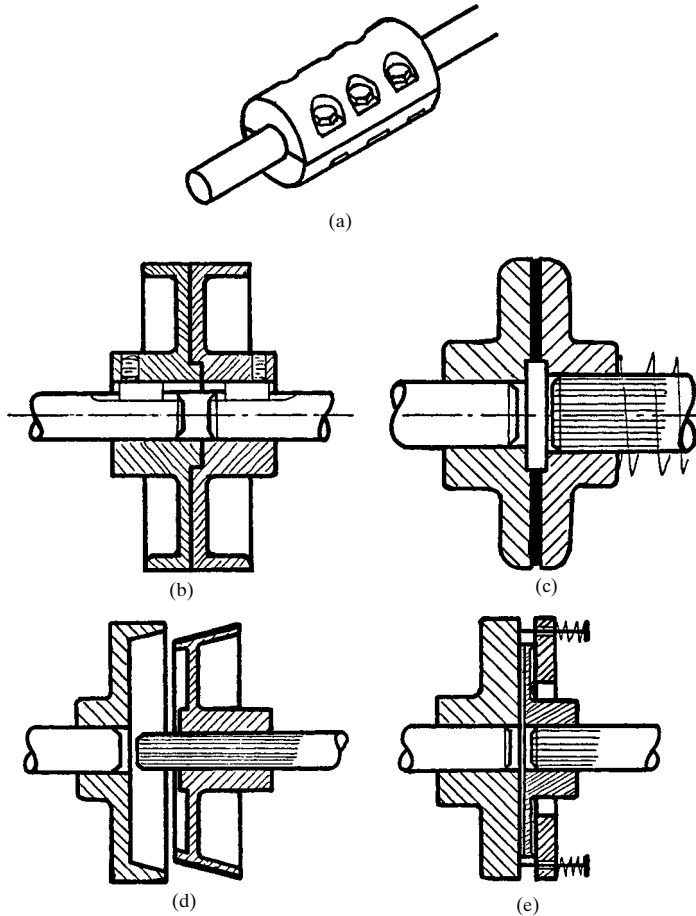


FIGURE 2.15 Couplings and connectors—axial. These are used to connect co-axial shafts. (a) Rigid coupling; (b) flanged coupling; (c) disk clutch; (d) cone clutch; (e) plate clutch.

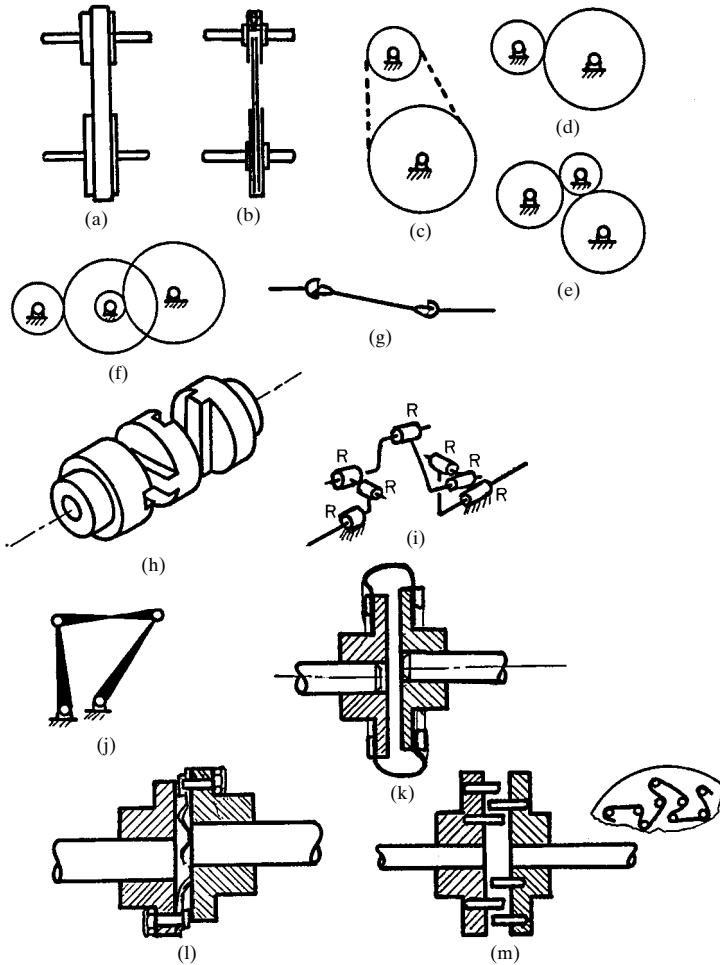


FIGURE 2.16 Couplings and connectors—parallel shafts. (a) Flat belt; (b) V belt; (c) chain; (d) to (f) gears; (g) Hooke joints; (h) Oldham coupling; (i) Hunt's constant-velocity coupling; (j) drag link; (k) to (m) flexible coupling.

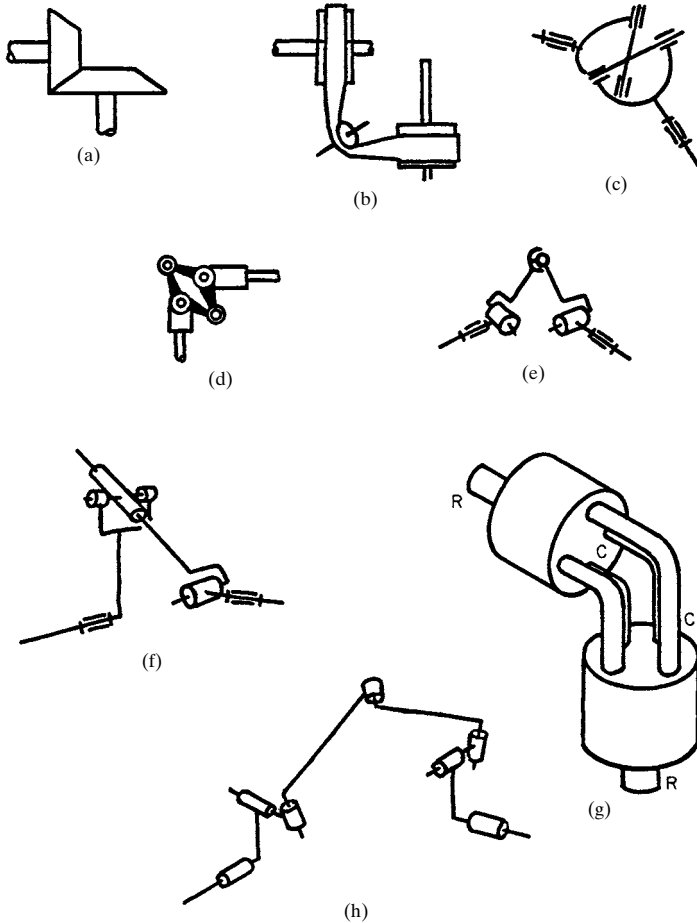


FIGURE 2.17 Couplings and connectors—intersecting shafts. (a) Bevel gears; (b) flat belts with idlers; (c) Hooke joint; (d) Hooke's coupling; (e) Clemens coupling; (f) Rouleaux coupling; (g) spatial RCCR; (h) Hunt's constant-velocity coupling.

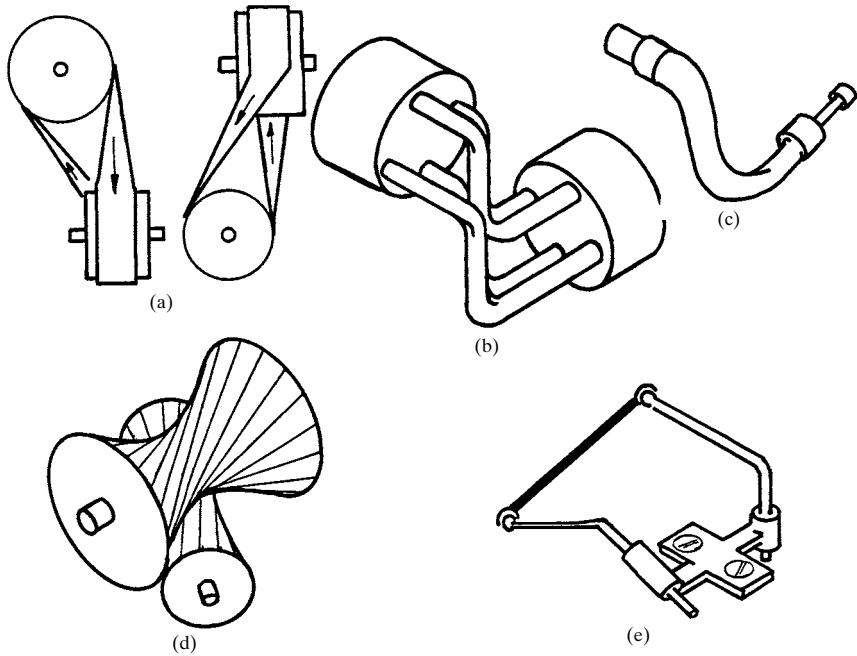


FIGURE 2.18 Couplings and connectors—skew shafts. (a) Flat belts; (b) spatial RCCR; (c) flexible shaft; (d) hypoid gears; (e) spatial RGGR.

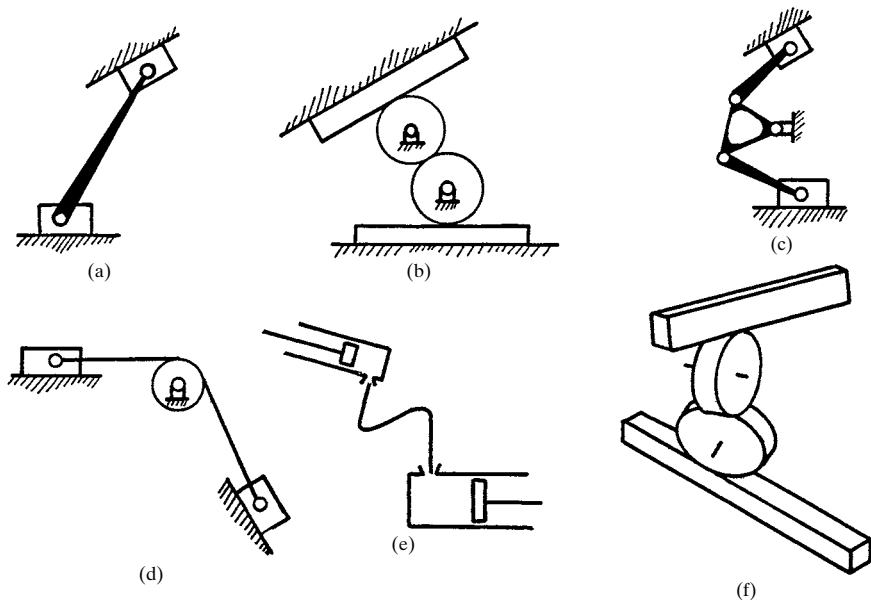


FIGURE 2.19 Slider connectors. These devices connect two or more reciprocating devices. (a) Elliptic trammel; (b) gears; (c) slider-crank-slider; (d) cable; (e) hydraulic; (f) helical gearing.

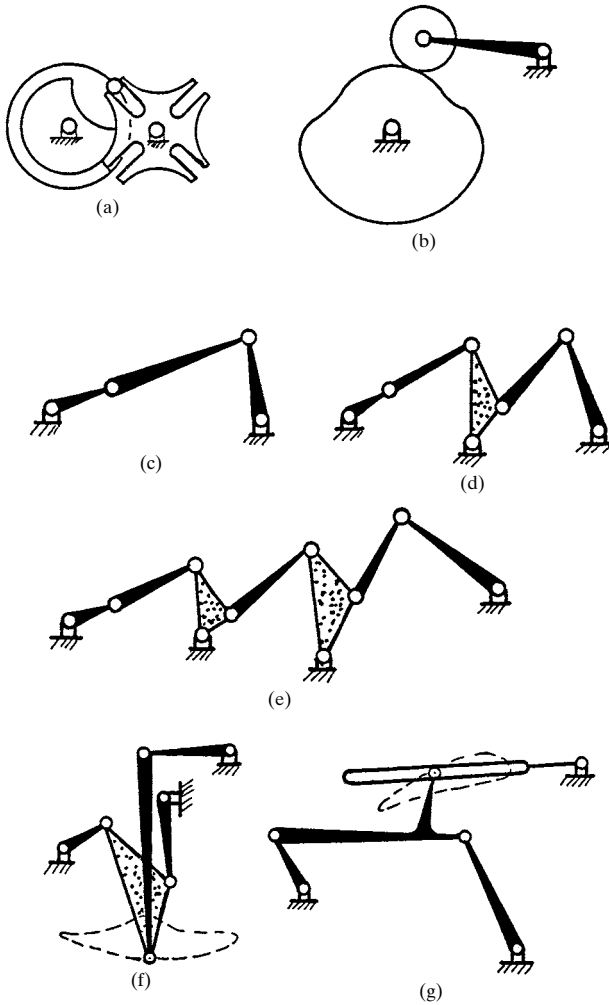


FIGURE 2.20 Stops, pauses, and hesitations. These machine elements cause an output to stop and dwell, to stop and return, to stop and advance, etc. The derivatives of the motion at the stop determine which category the motion fits. (a) Geneva stops (this includes all motions in Fig. 2.8); (b) cams; (c) linkage at extreme limits; (d), (e) combination of linkages at a limit; (f), (g) outputs derived from coupler curves.

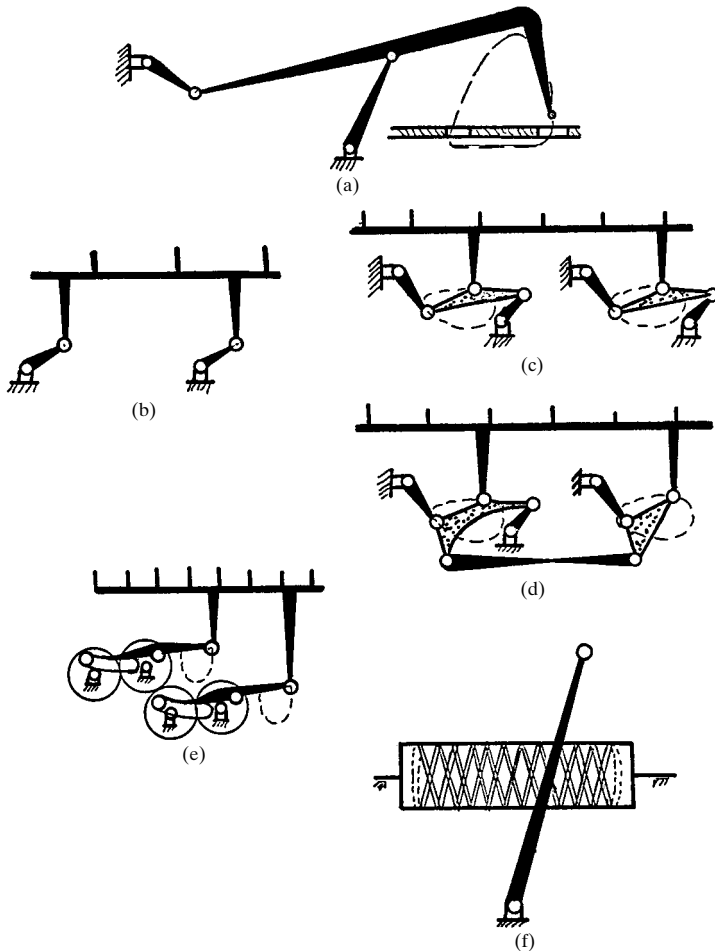


FIGURE 2.21 Transportation devices. These mechanisms move one or more objects a discrete distance in stepped motion. (a) Four-bar film advance; (b) circular-motion transport; (c), (d) coupler-curve transport; (e) geared linkage transport; (f) fishing-reel feed.

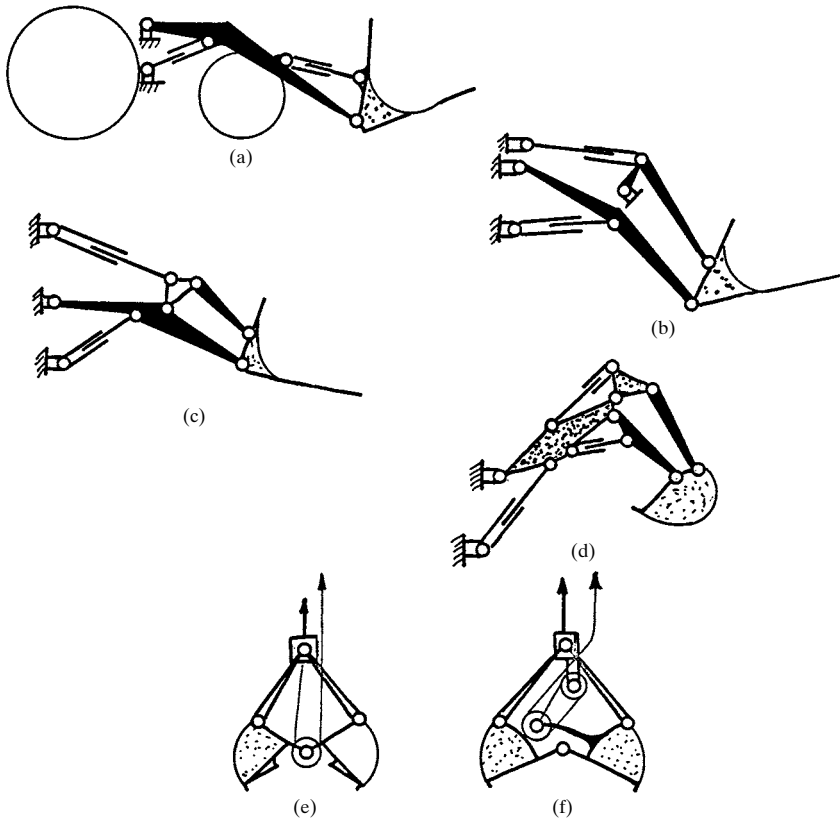


FIGURE 2.22 Loading and unloading mechanisms I. These mechanisms pick up material and transport it to another location. (a) to (c) Front-end loaders; (d) backhoe; (e), (f) clamshell loaders.

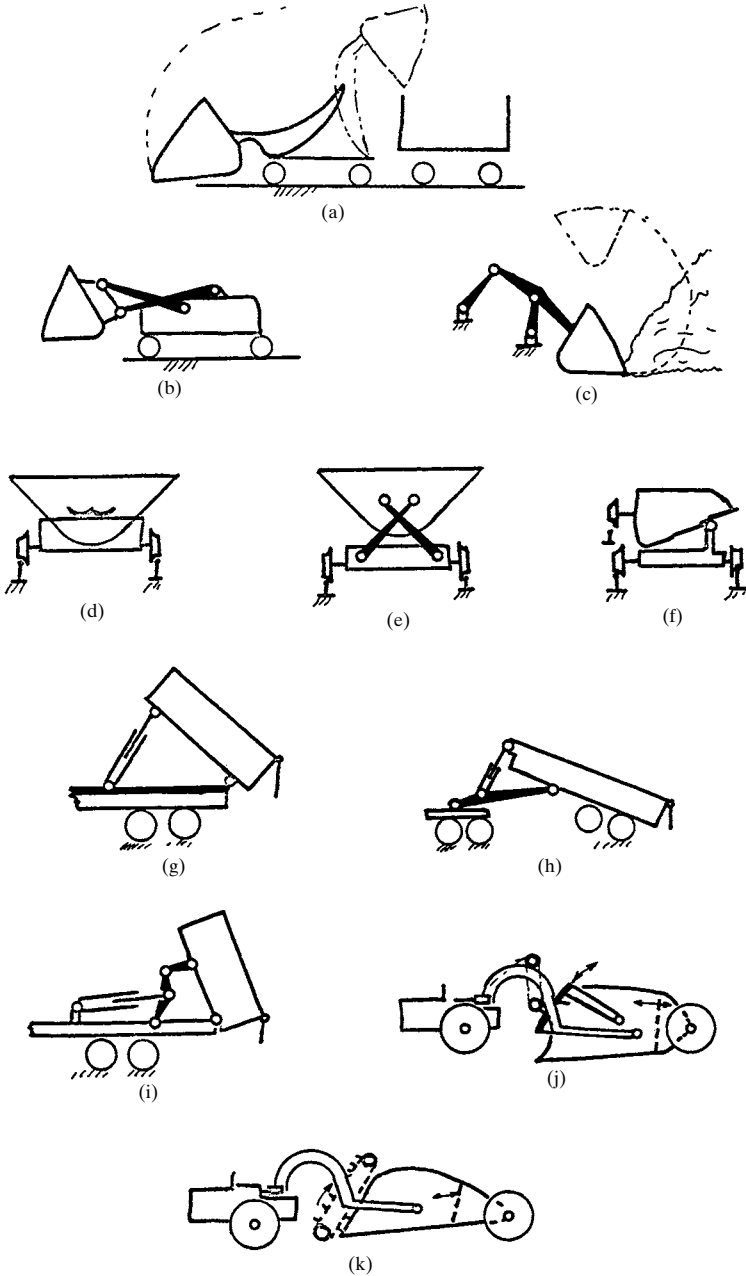


FIGURE 2.23 Loading and unloading mechanisms II. (a), (b) Mucking machines; (c) scooping mechanism; (d) to (f) dumping mine cars; (g) to (i) dump trucks; (j) motor scraper; (k) elevating scraper.

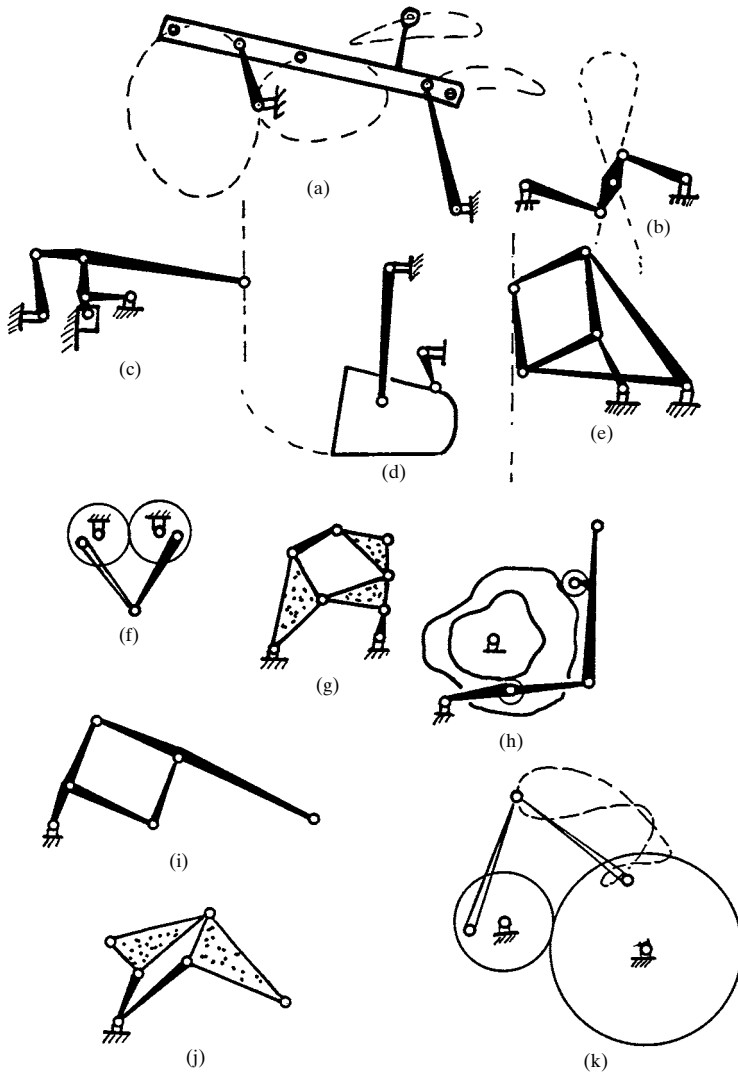


FIGURE 2.24 Path generators. These linkages approximately generate a required curve. (a) Four-bar coupler curve; (b) Watt straight-line linkage; (c) Crosby steam-engine indicator approximates straight line; (d) scooping mechanism; (e) Peaucellier exact straight-line linkage; (f) geared straight-line generators; (g) six-bar coupler curve; (h) double-cam line generator; (i) pantograph; (j) Sylvester skew pantograph; (k) geared linkage curve generator.

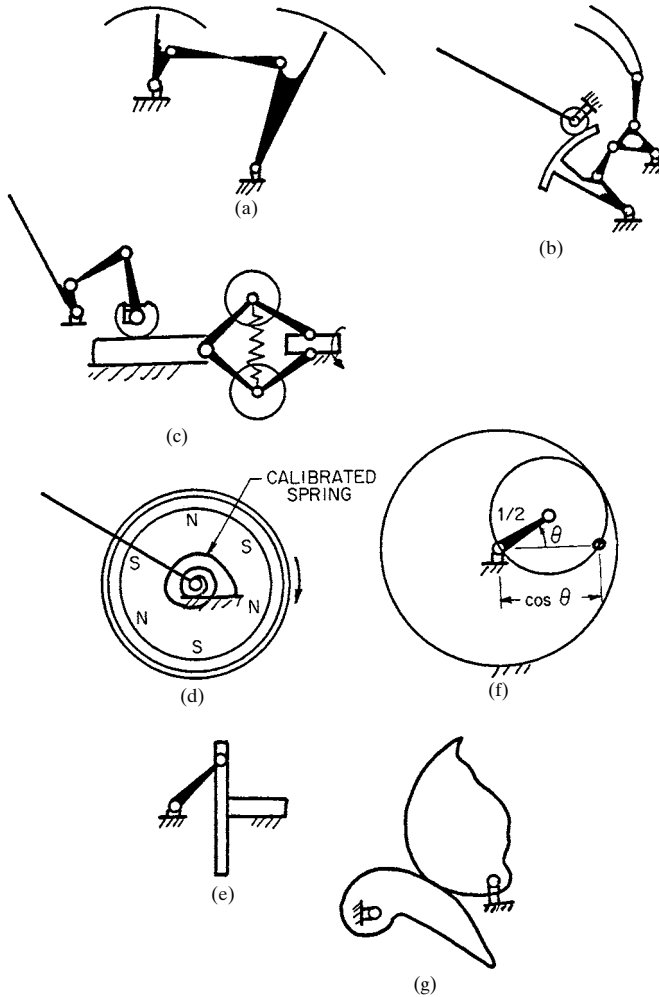


FIGURE 2.25 Function generators. These are mechanical devices in which the output moves as some function of the input $y = f(x)$. (a) Four-bar linkage function generator; (b) function generator in pressure gauge; (c), (d) function generator in a speedometer; (e) Scotch yoke sine-cosine generator; (f) epicyclic sine-cosine generator; (g) noncircular gears.

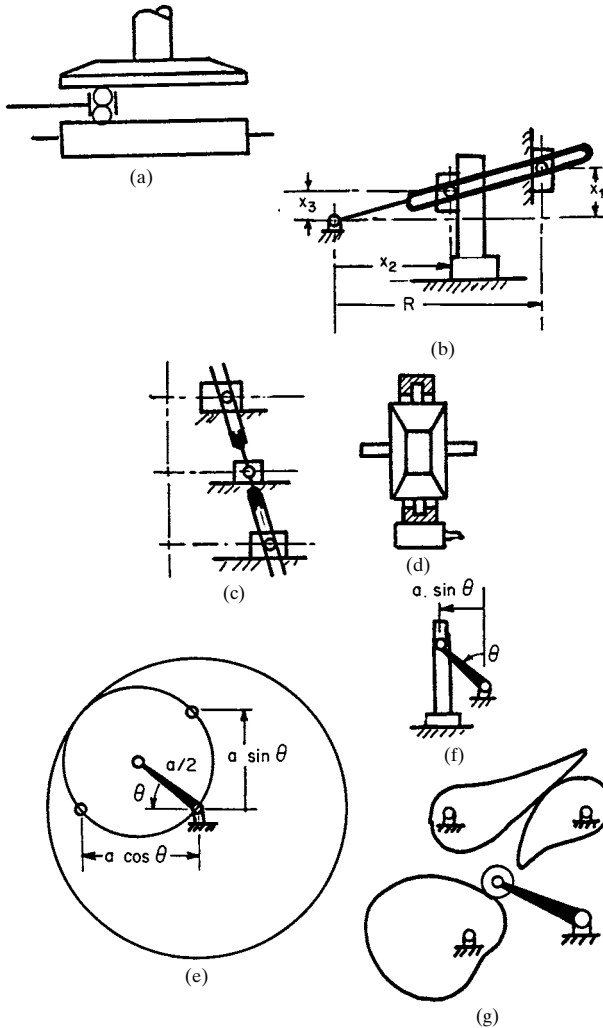


FIGURE 2.26 Computing mechanisms. These devices are used on mechanical computers for performing mathematical operations. (a) Ball disk integrator; (b) multiplier; (c), (d) adders; (e) epicyclic sine generators; (f) Scotch yoke sine generator; (g) noncircular gears; (h) special-function cams.

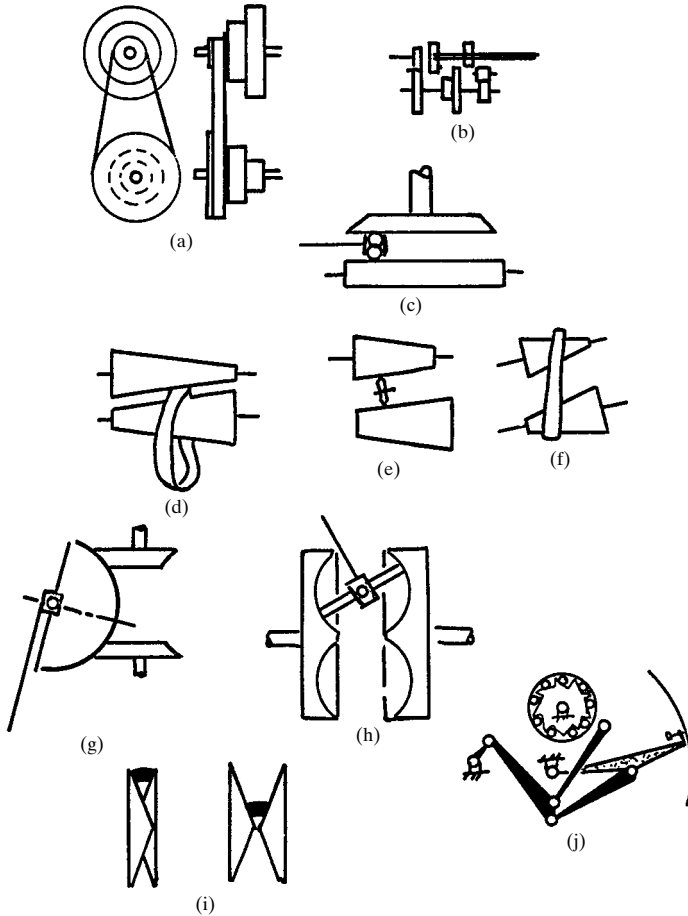


FIGURE 2.27 Speed-changing mechanisms. These devices change the speed of an output shaft while the input shaft has constant speed. (a) Stepped pulleys and flat belt; (b) geared transmission; (c) ball and disk speed changer; (d) to (f) cone drives; (g) sphere drive; (h) toroidal drive; (i) variable-pitch V belt; (j) zero maximum drive.

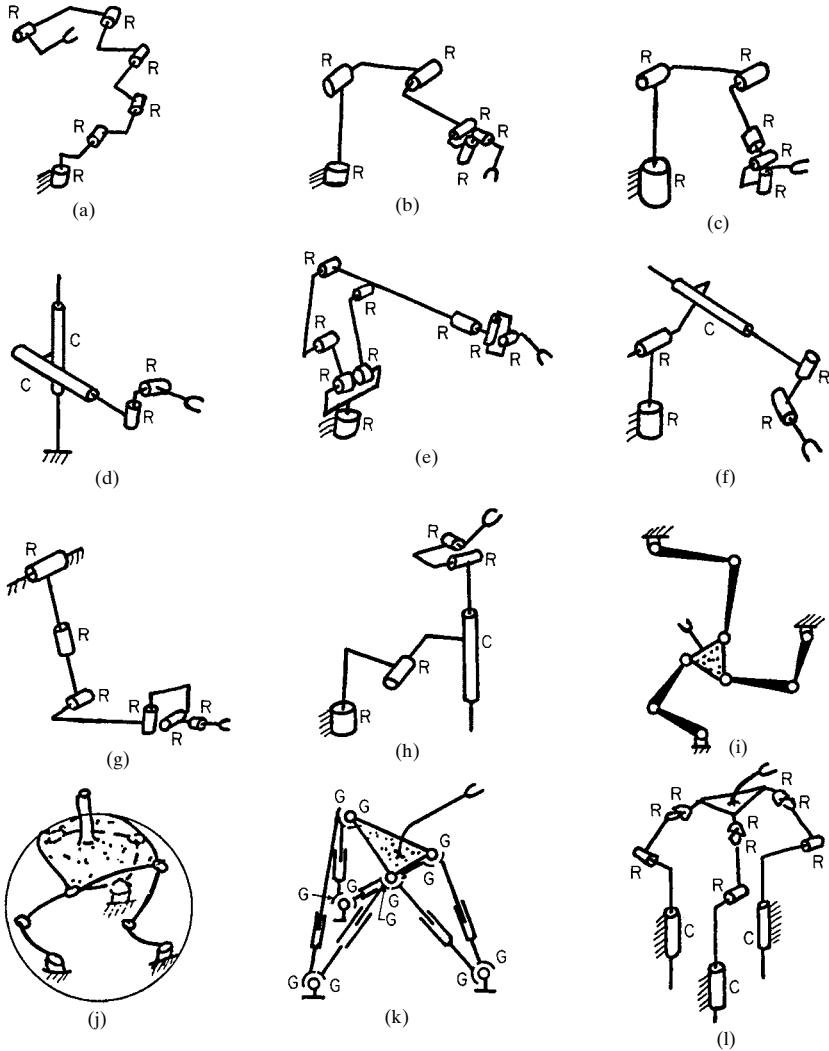


FIGURE 2.28 Robots. These are multidegree-of-freedom devices used for positioning or assembly of items. They usually have some degree of machine intelligence and work under computer control. (a) A general 6R robot; (b) to (h) some forms of existing robots; (i) parallel actuation of a planar 3-degrees-of-freedom robot; (j) Stewart platform which uses the 3-degrees-of-freedom principle; (k) Florida shoulder with parallel actuation; (l) general robot with parallel actuation.

