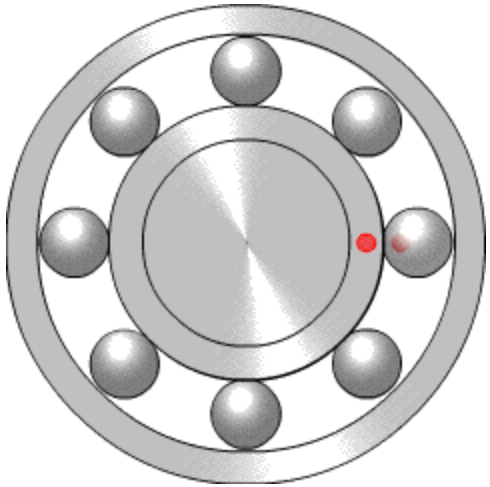
Bearing

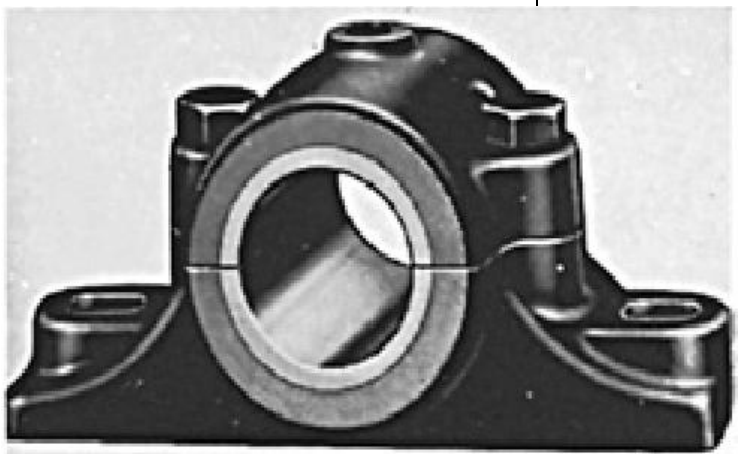


FUNCTION OF A BEARING

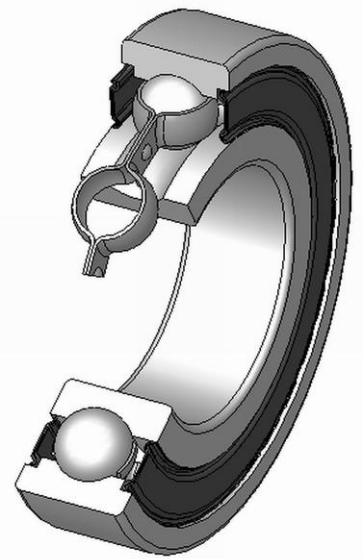
- The main function of a rotating shaft is to transmit power from one end of the line to the other.
  - It needs a good support to ensure stability and frictionless rotation. The support for the shaft is known as **“bearing”**.
- The shaft has a “**running fit**” in a bearing. All bearing are provided some lubrication arrangement to reduced friction between shaft and bearing.

Bearings are classified under two main categories:

- **Plain or slider bearing** : -
  - In which the rotating shaft has a sliding contact with the bearing which is held stationary . Due to large contact area friction between mating parts is high requiring greater lubrication.

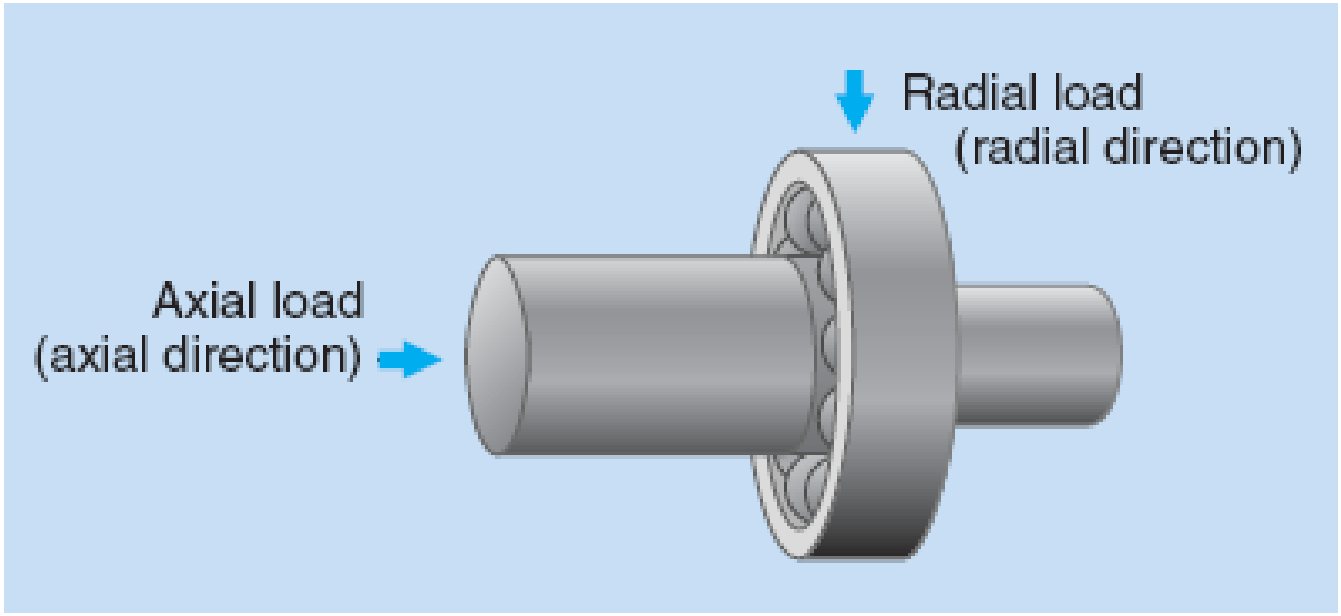


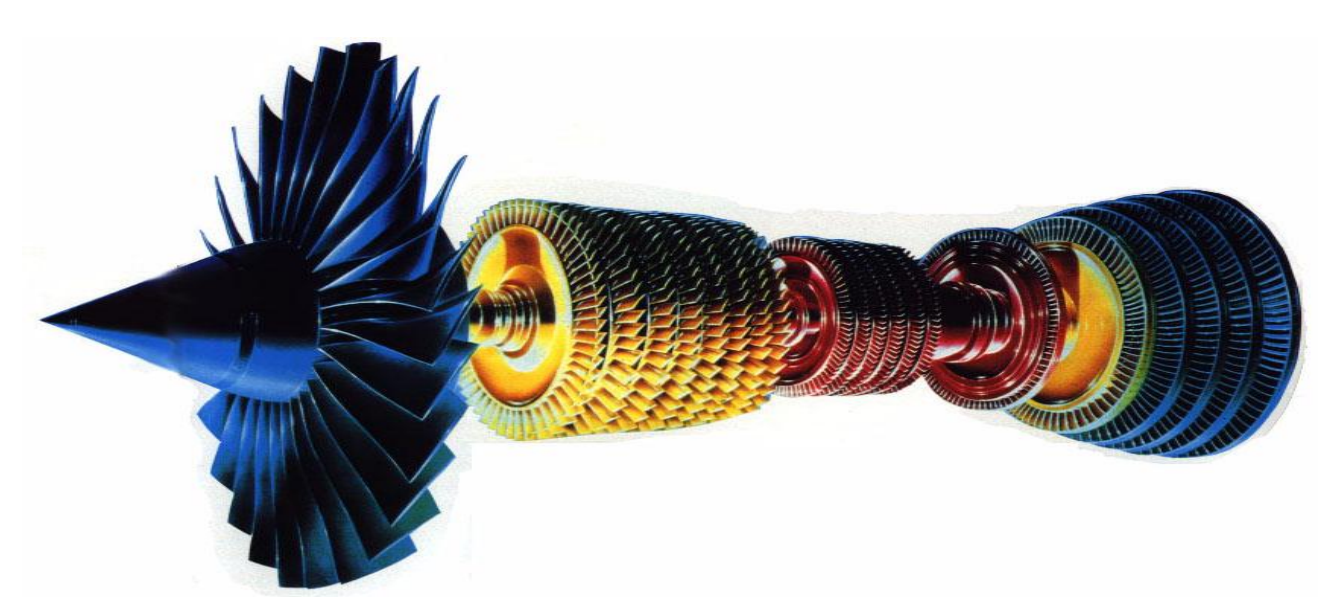
- **Rolling or anti-friction bearing** : -
  - Due to less contact area rolling friction is much lesser than the sliding friction , hence these bearings are also known as **antifriction bearing**.



Rolling or anti-friction bearing

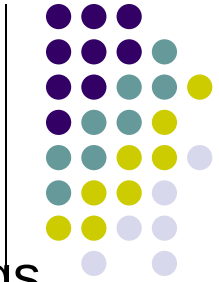
Load Direction and Name





Ball and roller bearings

due to low rolling friction these bearings are aptly called "antifriction" bearing.

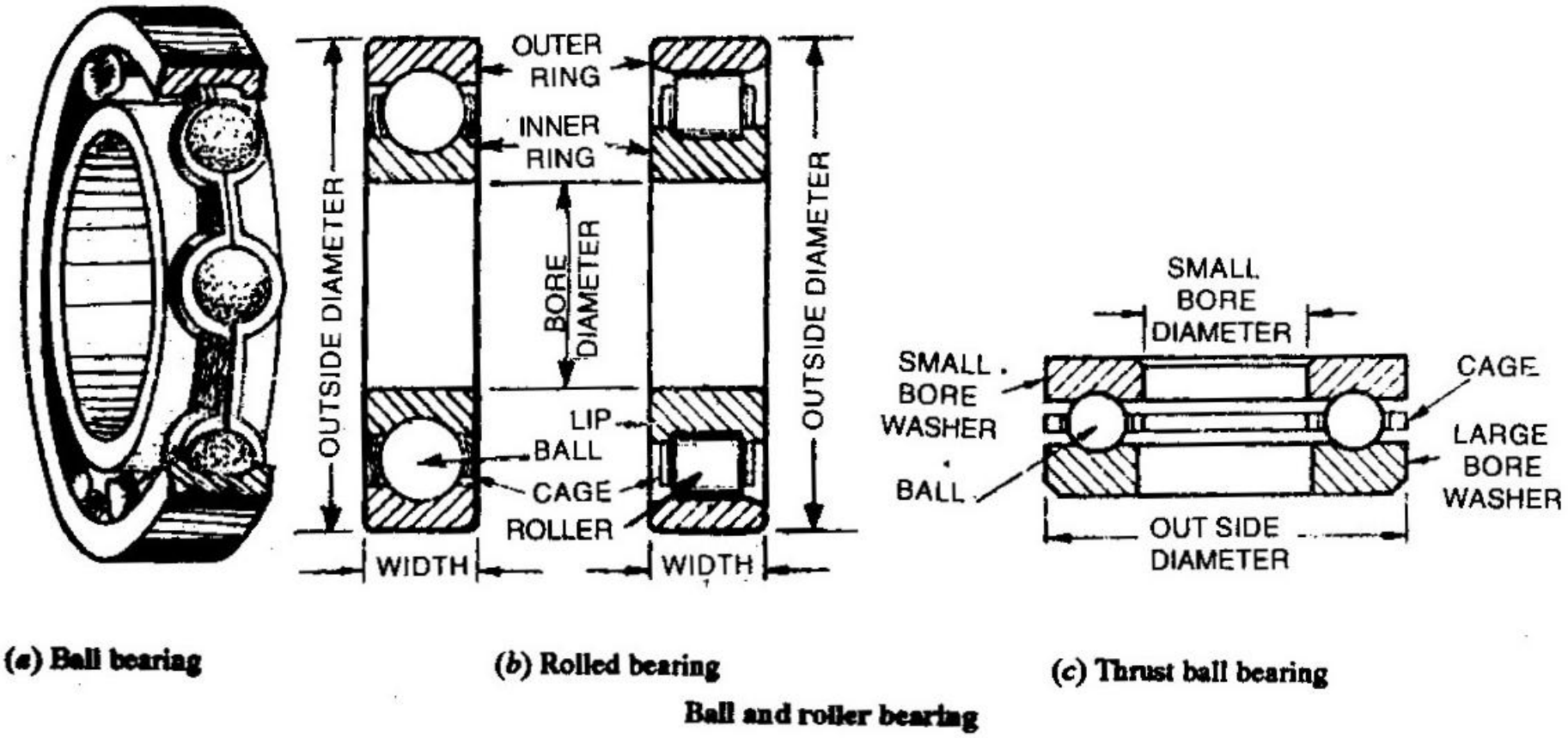


- Frictional resistance considerably less than in plain bearings
- Rotating – non-rotating pairs separated by balls or rollers
- Ball or rollers has rolling contact and sliding friction is eliminated and replaced by much lower rolling friction.
- In plain bearing the starting resistance is much larger than the running resistance due to absence of oil film.
- In ball and rolling bearings the initial resistance to motion is only slightly more than their resistance to continuous running.
- Hence ball and rolling bearing are more suitable to drives subject to frequent starting and stopping as they save power.
- Owing to the low starting torque, a low power motor can be used for a line shaft running in ball bearing.

Types of rolling bearing

- Single row deep-groove ball bearing:
  - Incorporating a deep hardened raceway which makes them suitable for radial and axial loads in either direction, provided the radial loads are greater than the axial loads.
- Single row roller bearing:
  - Roller bearing have a greater load-carrying capacity than ball bearing of equivalent size as they make line contact rather than point contact with their rings.
    - Not suitable for axial loading, cheaper to manufacture, used for heavy and sudden loading, high speed and continuous service.

Ball and Roller bearing

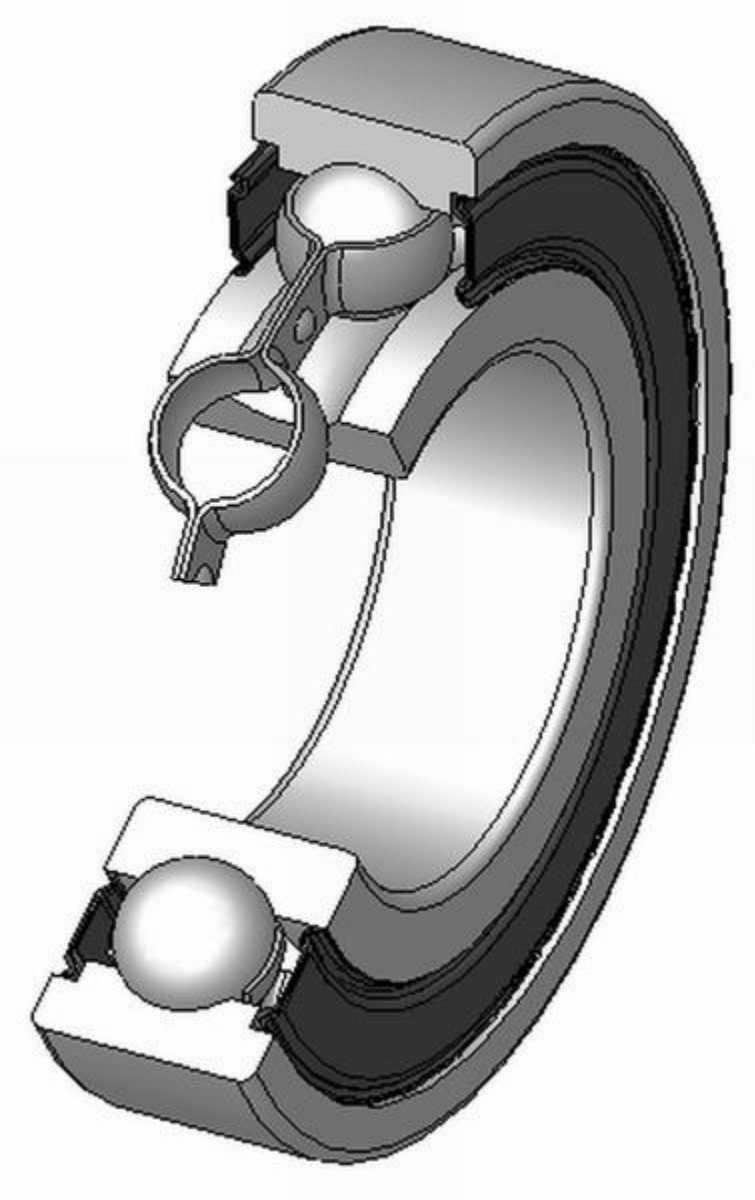


(a) Ball bearing (b) Rolled bearing (c) Thrust ball bearing

Ball and roller bearing

Races and balls are high carbon chrome steel (to provide resistance to wear) machined and ground to fine limits of 0.0025 mm, highly polished and hardened.

The cages are made of low-carbon steel, bronzes or brasses, though for high temperature application case-hardened and stainless steels are used.

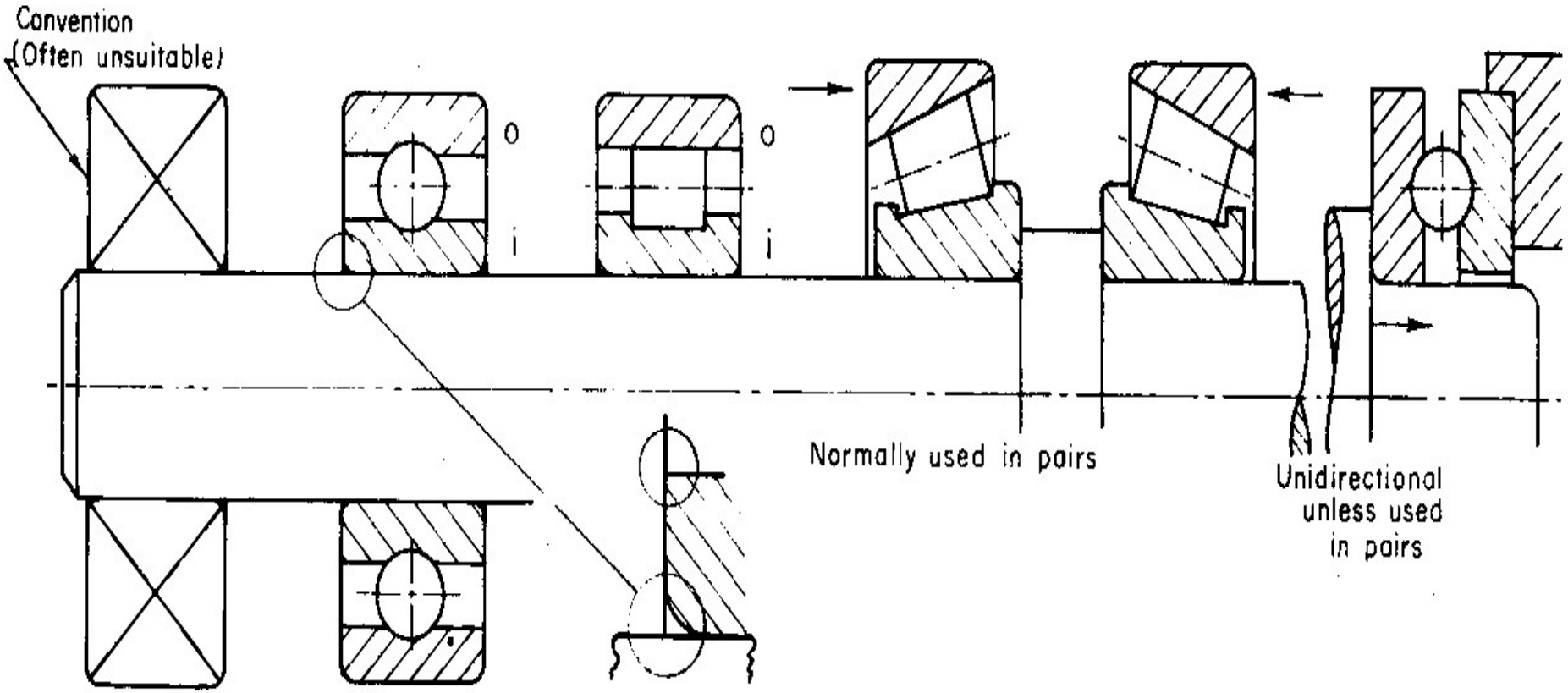


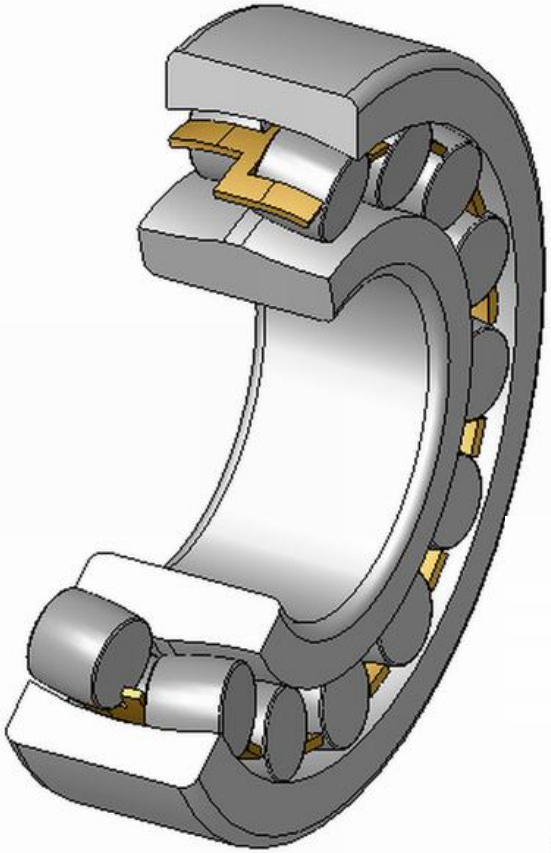
The ball and roller bearing consists of following parts:

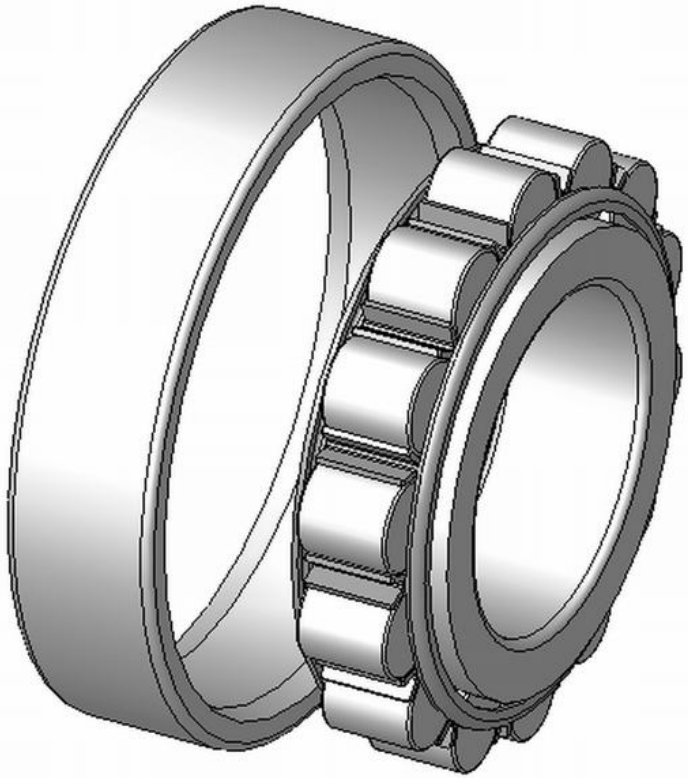
- Inner ring or race which fits on the shaft.
- Outer ring or race which fits inside the housing.
- Ball and roller arranged between the surfaces of two races. These provide rolling action between the races.
  - the radius of the track for balls is slightly greater 5 to 10 % than that of the ball themselves.
  - Note that the rotating surfaces rotate in opposite directions.
- Cage which separates the balls or rollers from one another.

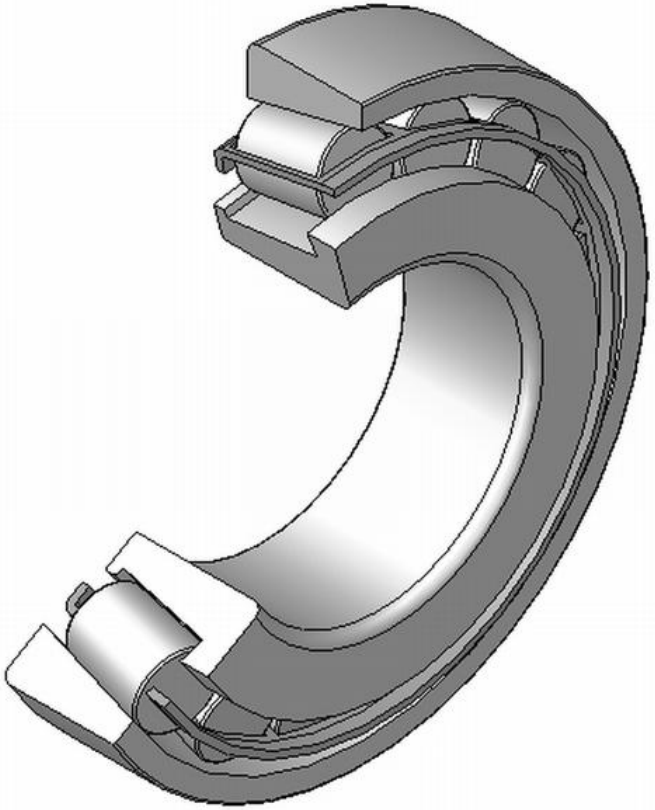
The disadvantage of the ball and roller bearings are high cost, they cannot be used in half, and greater noise.

Types of bearing

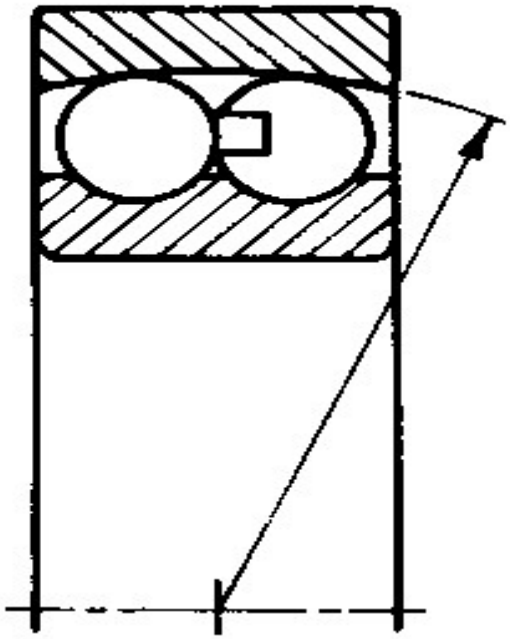




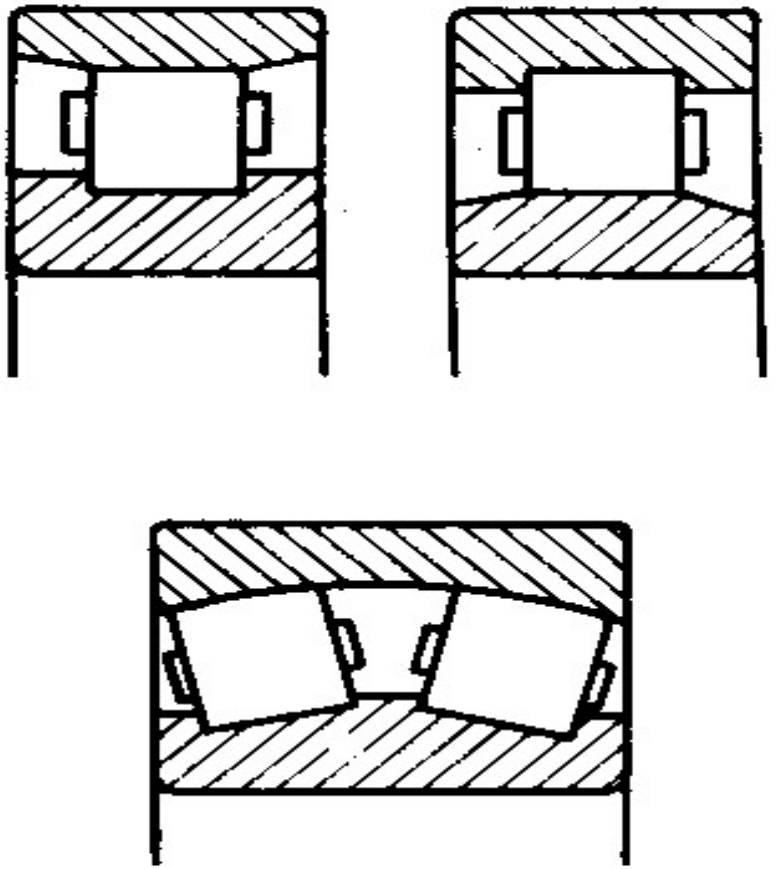




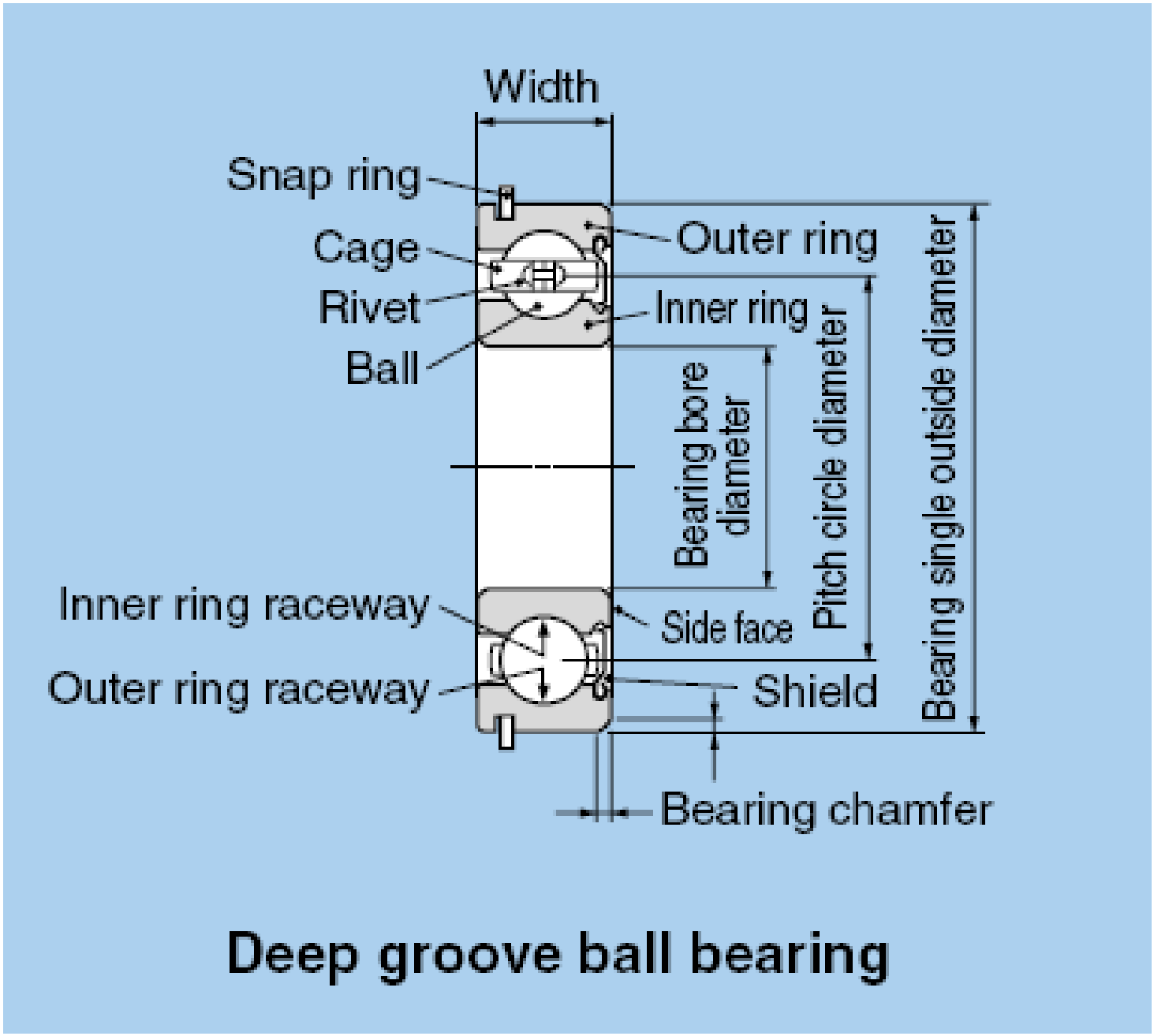
Types of ball bearings



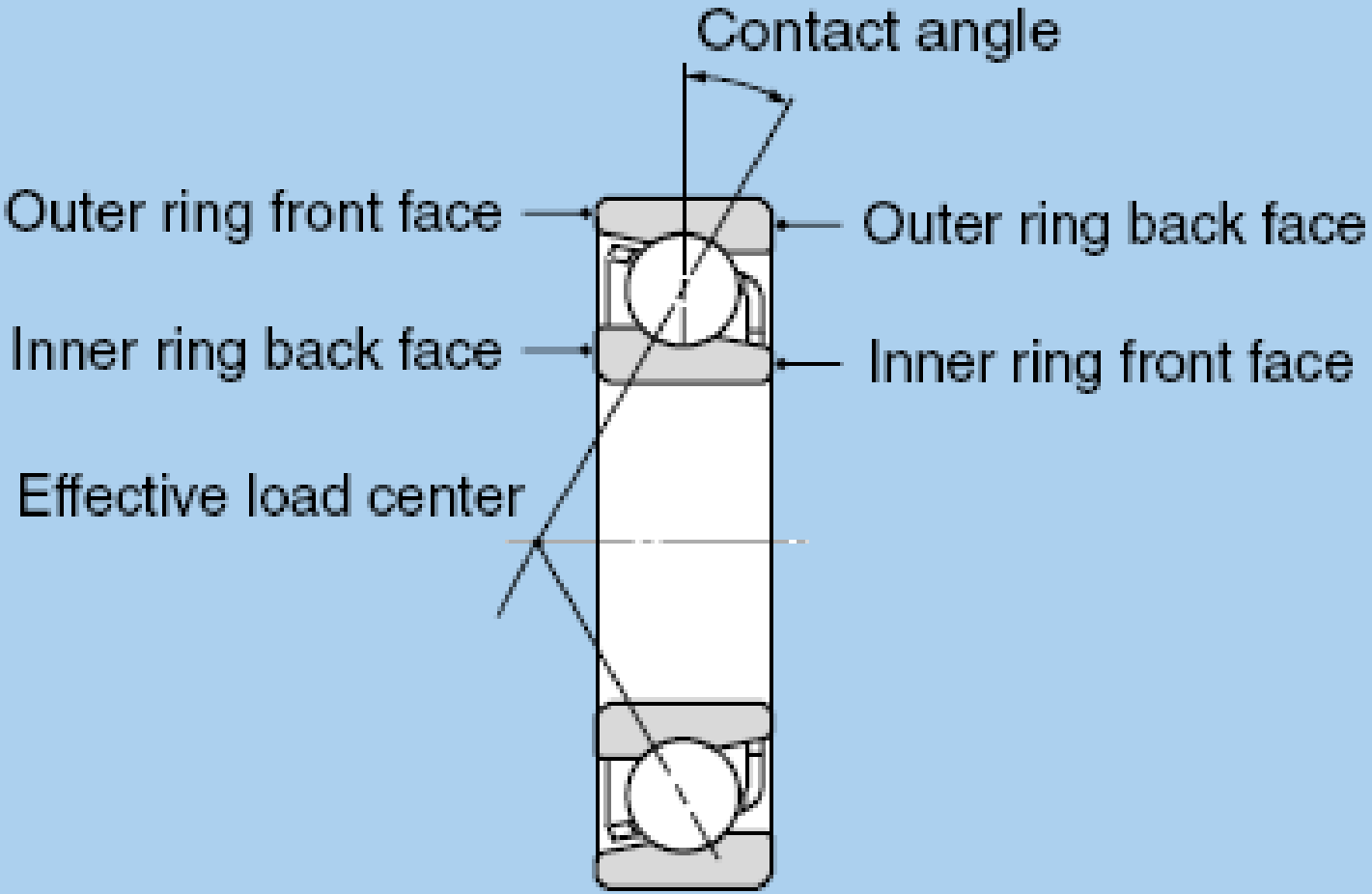
(*a*) Double-row self-algning ball beaing



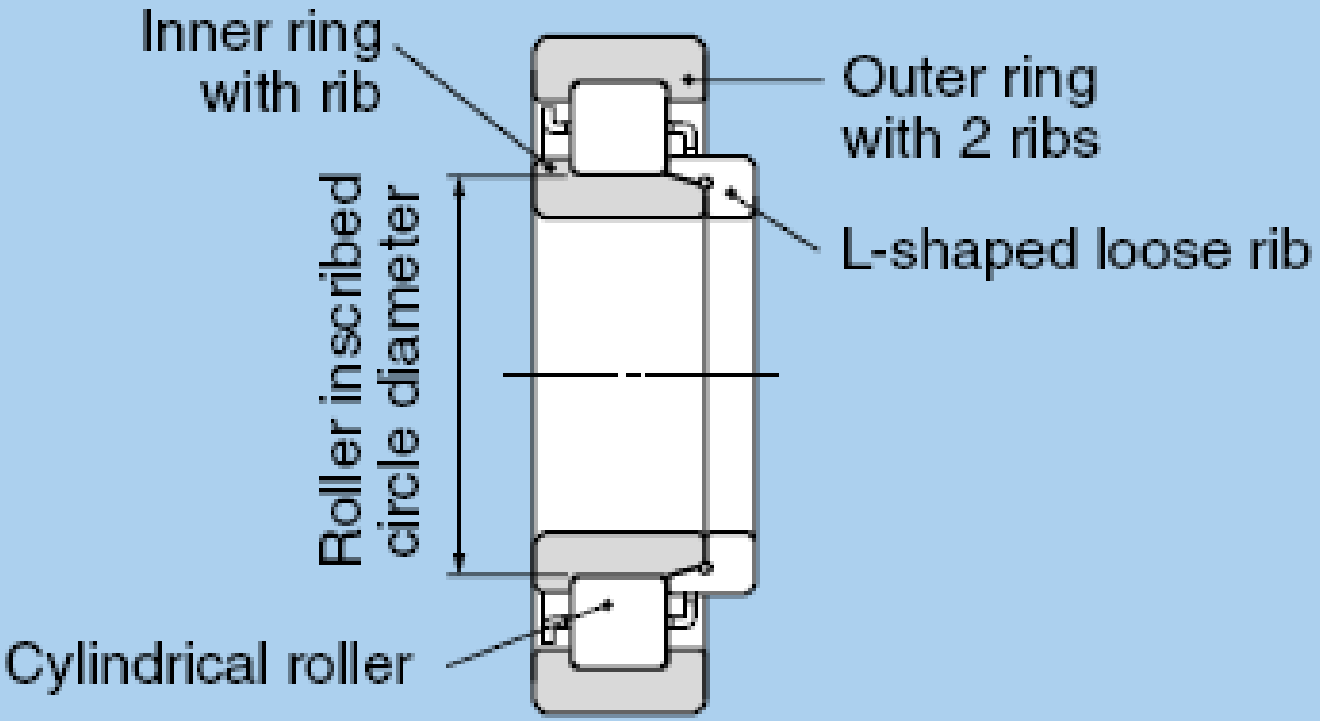
(*b*) Single and double-row roller bearing



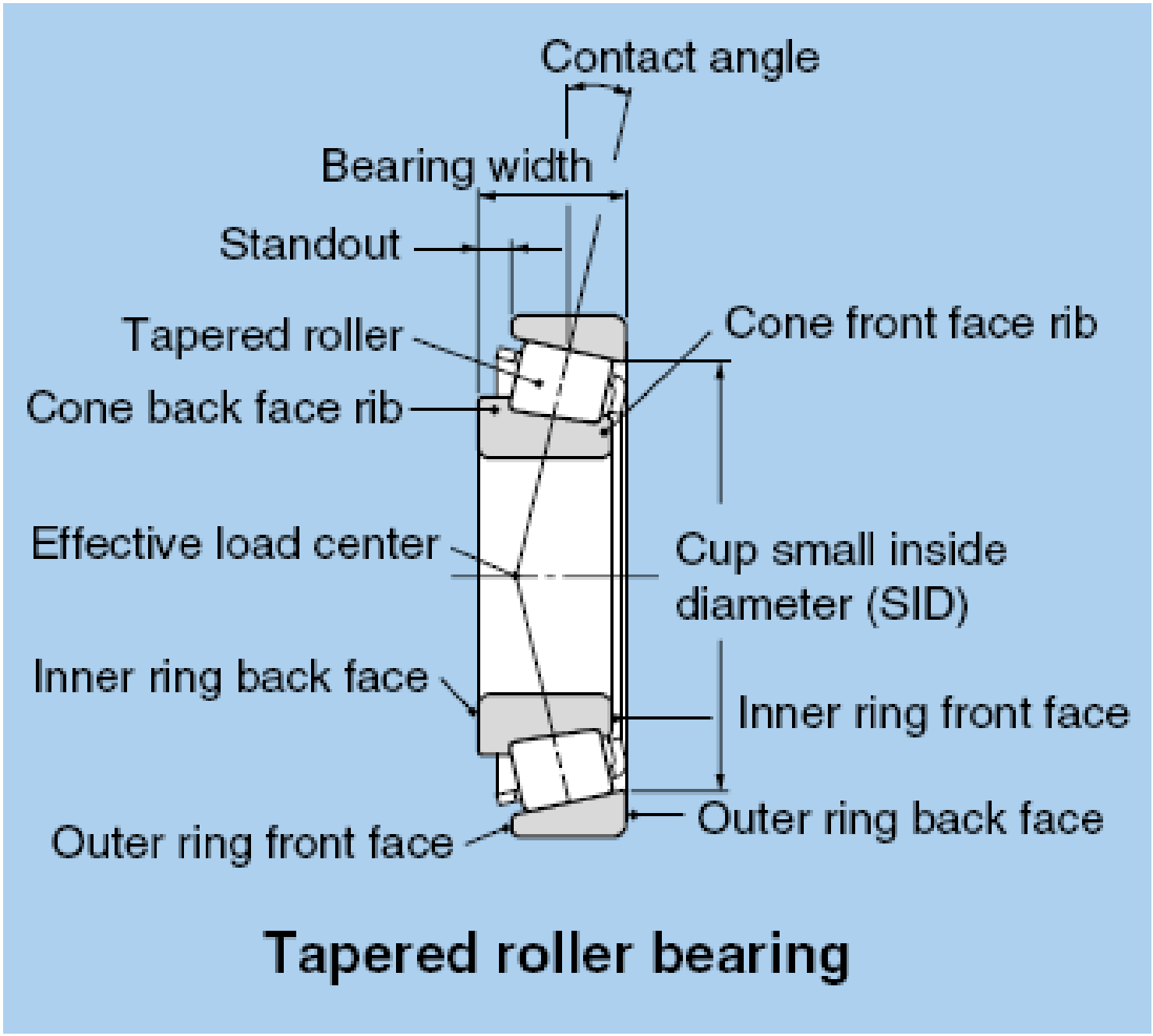
Deep groove ball bearing



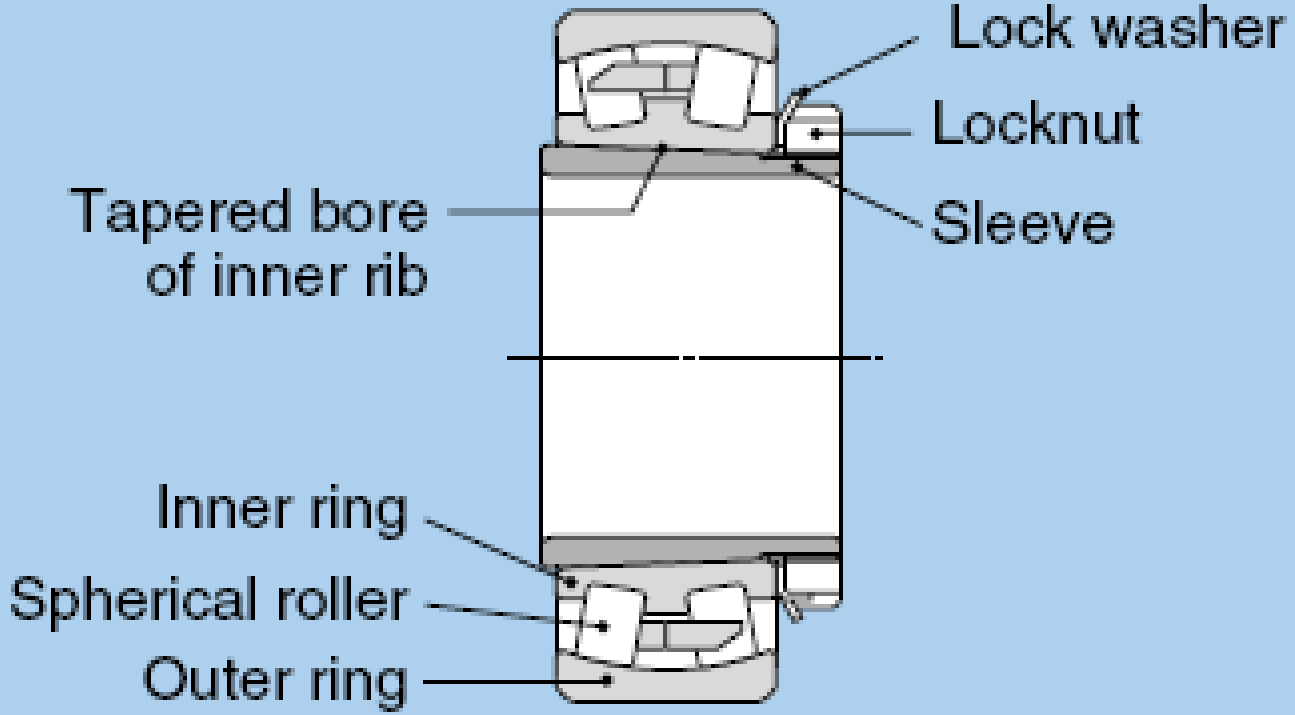
Angular contact ball bearing



Cylindrical roller bearing

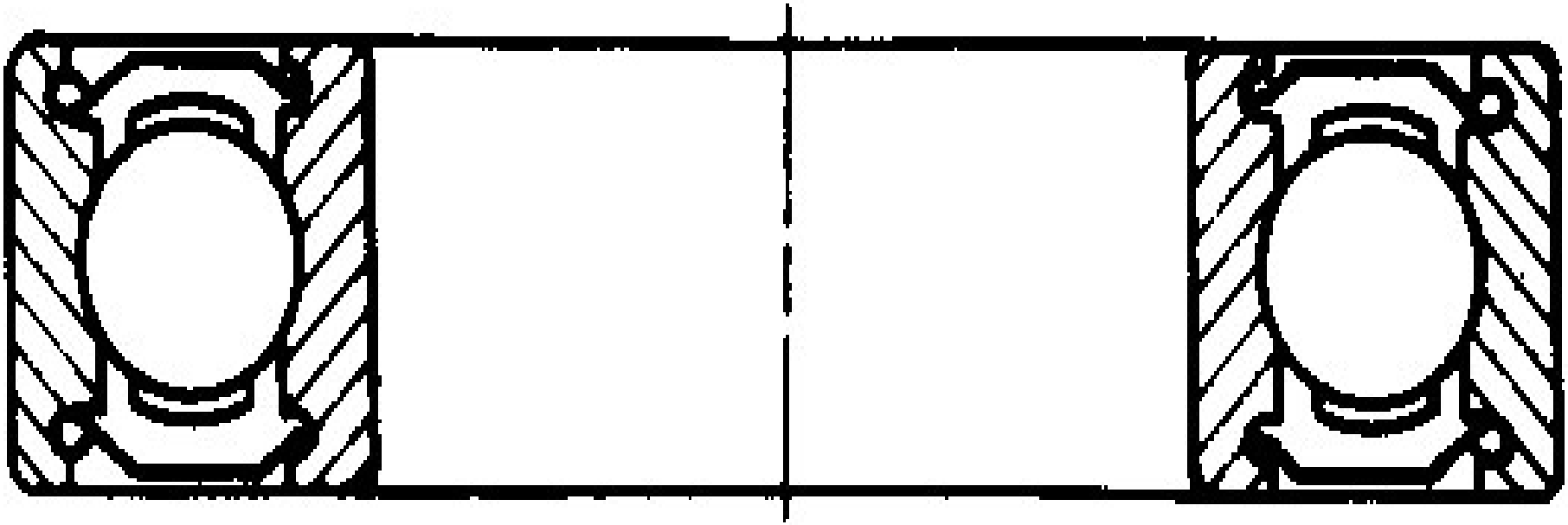


Tapered roller bearing



Self-aligning roller bearing

Prelubricated sealed ball bearing



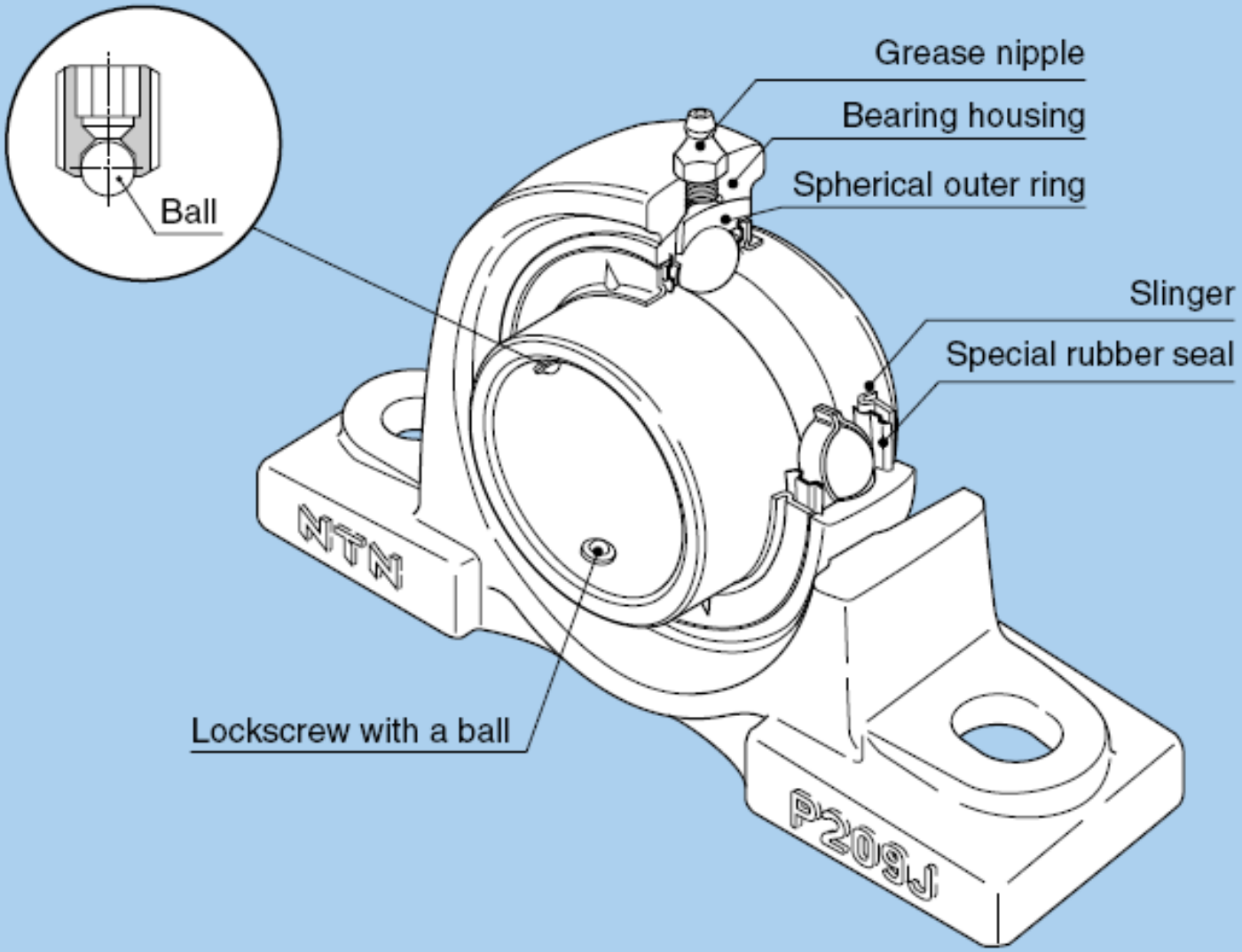


Fig. 2.7 Oiling Type Bearing Unit

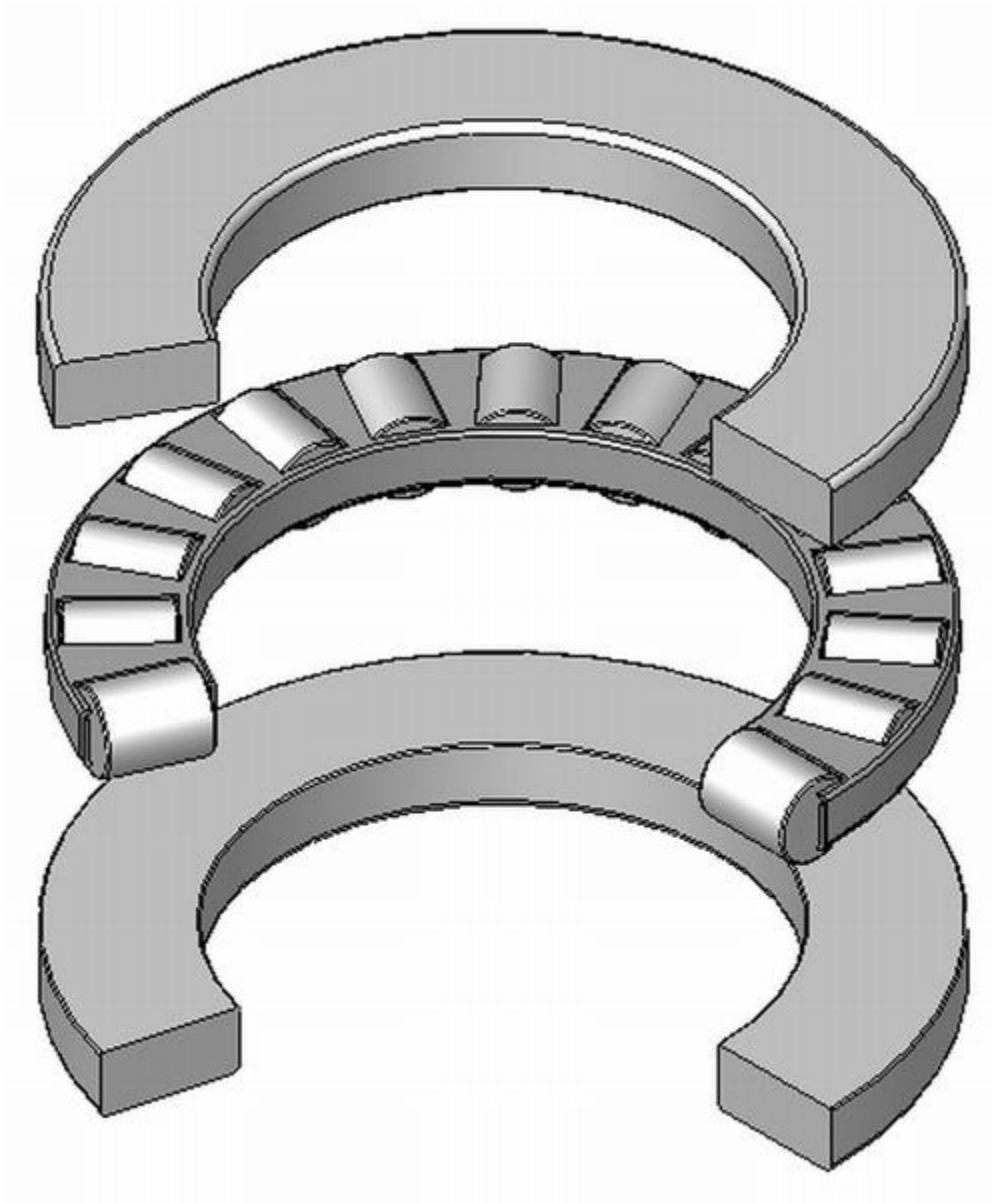
Table 3.1 Types and Performance of Rolling Bearings

Characteristics \ Bearings types	Deep groove ball bearings	Angular contact ball bearings	Cylindrical roller bearings	Needle roller bearings	Tapered roller bearings	Self-aligning roller bearings	Thrust ball bearings
Load carrying capacity (Radial load / Axial load)							
High speed rotation ❶	☆☆☆☆	☆☆☆☆	☆☆☆☆	☆☆☆	☆☆☆	☆☆	☆
Low noise/vibration ❶	☆☆☆☆	☆☆☆	☆	☆			☆
Low friction torque ❶	☆☆☆☆	☆☆☆	☆				
High rigidity ❶			☆☆	☆☆	☆☆	☆☆☆	
Allowable misalignment for inner/outer rings ❶	☆					☆☆☆	★
Non-separable or separable ❷			○	○	○		○

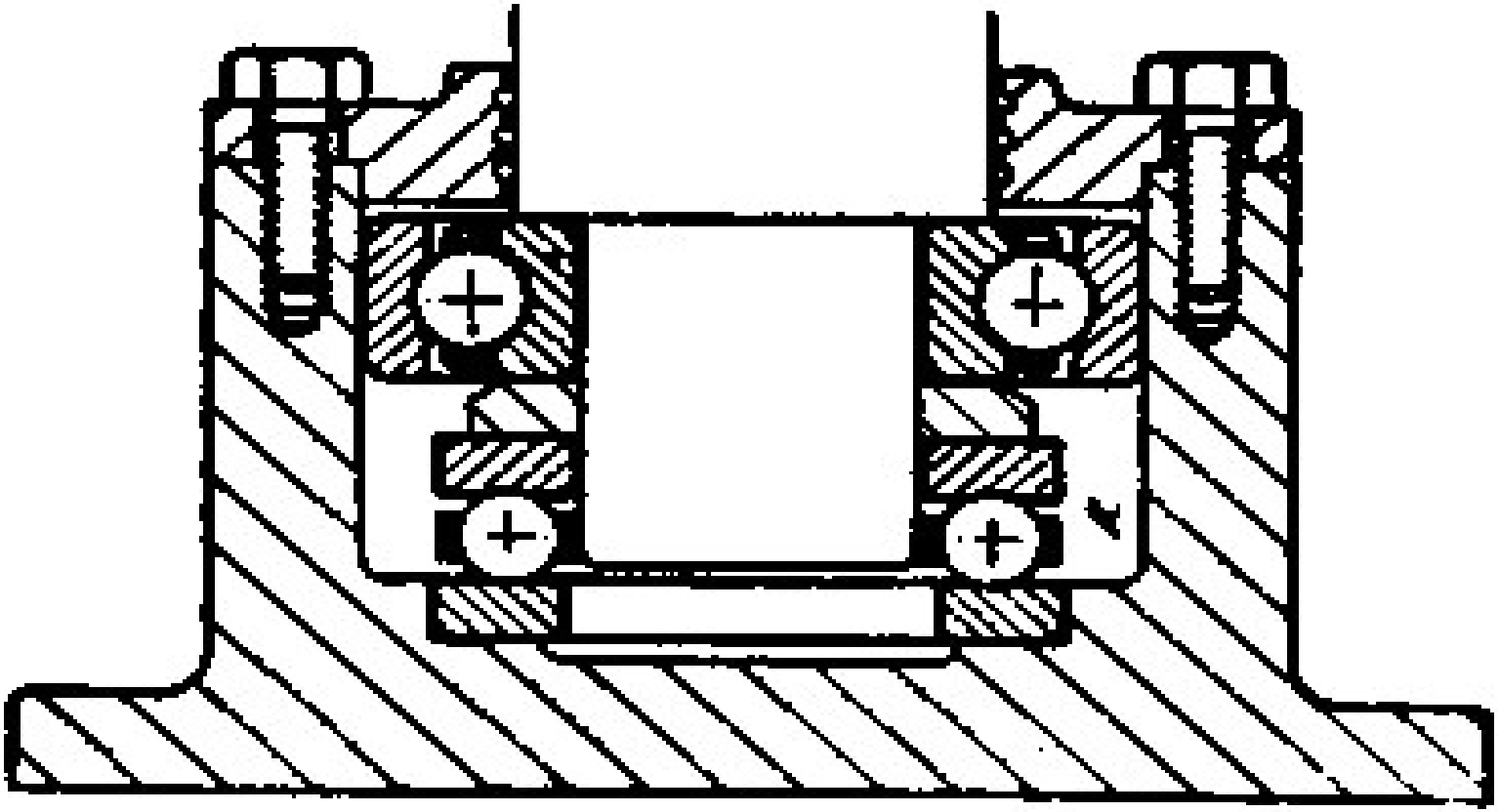
❶ ☆The number of stars indicates the degree to which that bearing type displays that particular characteristic.
★Not applicable to that bearing type.

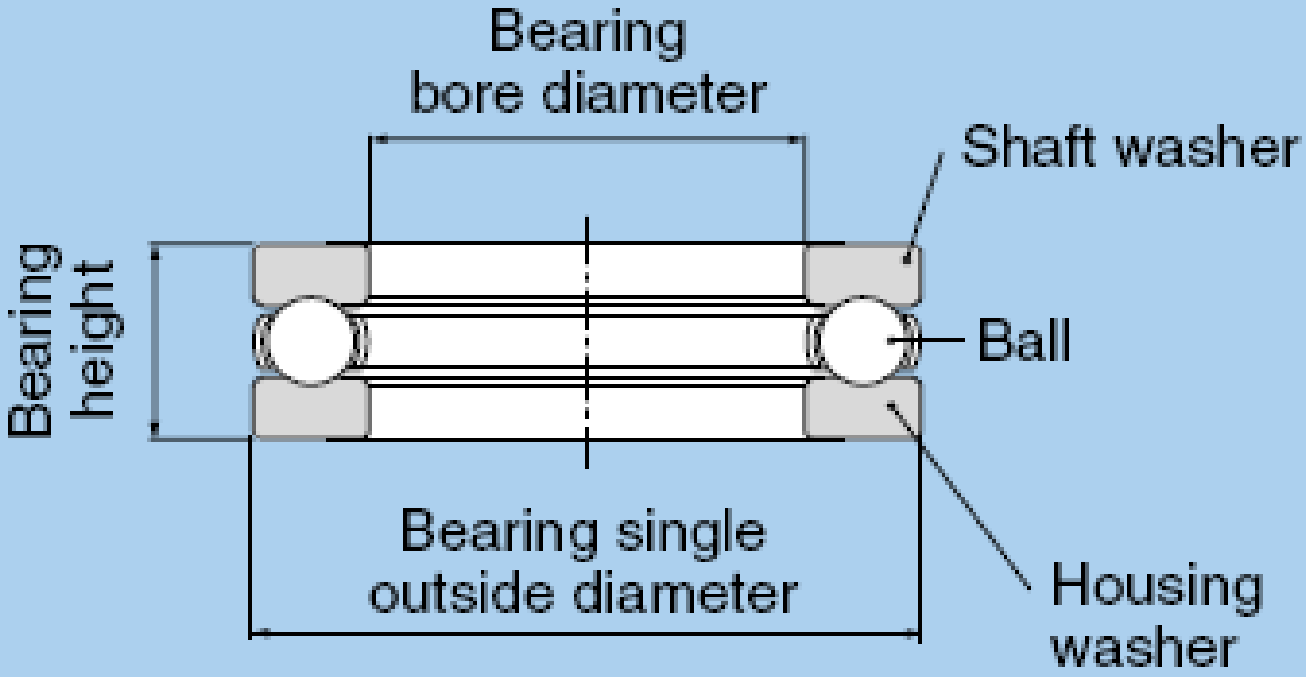
❷ ○Indicates both inner ring and outer ring are detachable.

❸ Some cylindrical roller bearings with rib can bear an axial load.



Thrust ball bearings



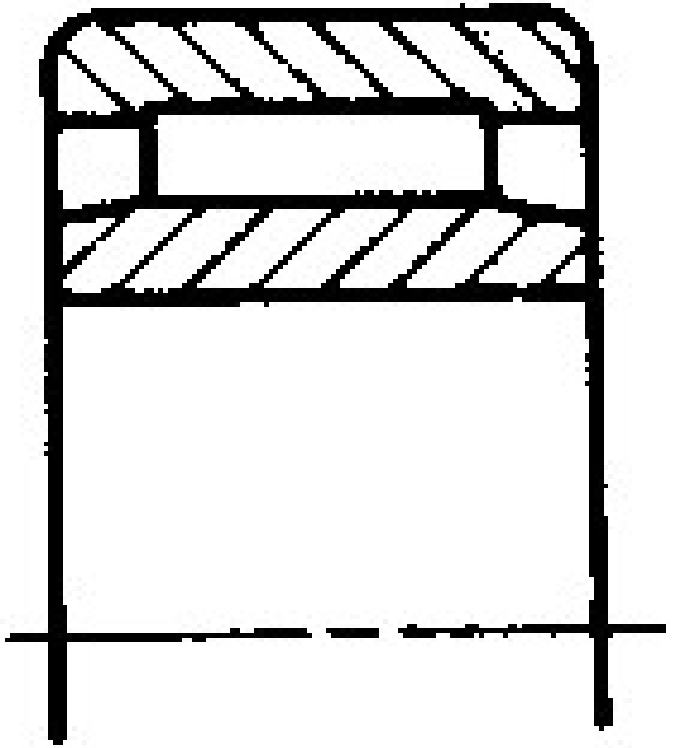


Thrust ball bearing

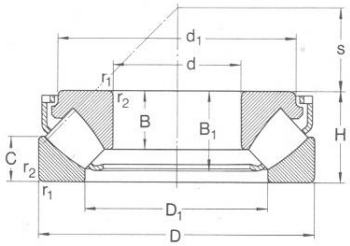
APPLICATIONS OF ROLLER BEARINGS

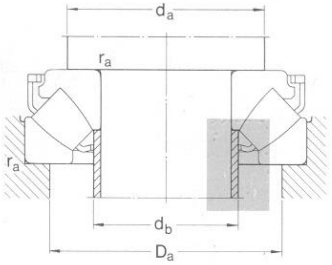
- Tapered roller bearing (TRB):
  - TRB can take both radial and axial loads and used for gear boxes for heavy trucks, bevel-gear transmission, lathe spindles, etc.
- Thrust ball bearing:
  - It can take only thrust loads.
  - Thrust ball bearing are used for heavy axial loads and low speeds.
- Needle roller bearing:
  - It use small diameter of rollers. They are used for radial load at slow speed and oscillating motion.
    - They have the advantage of light weight and occupy small space.
    - They are used in aircraft industry, live tail stock centers, bench-drill spindles, etc.

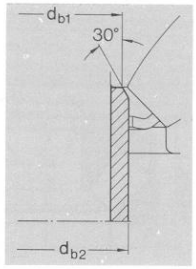
Needle ball bearing



Selection of bearing through catalogue





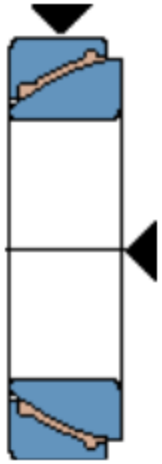


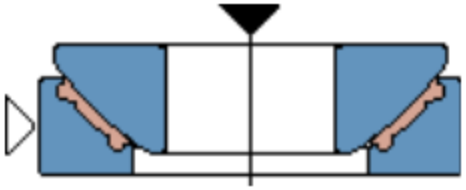
Principal dimensions			Basic load ratings dynamic	static	Minimum load factor	Limiting speed Lubrication oil	Mass	Designation
d	D	H	C	C_0	A			
mm			N		–	r/min	kg	–
60	130	42	345 000	465 000	88	2 600	2,60	**29412 E**
65	140	45	397 000	550 000	125	2 400	3,20	**29413 E**
70	150	48	449 000	630 000	160	2 200	3,90	**29414 E**
75	160	51	518 000	720 000	210	2 200	4,70	**29415 E**
80	170	54	575 000	815 000	270	2 000	5,60	**29416 E**
85	150	39	334 000	510 000	110	2 200	2,75	**29317 E**
	180	58	633 000	900 000	330	1 900	6,75	**29417 E**
90	155	39	345 000	530 000	120	2 200	2,85	**29318 E**
	190	60	702 000	1 000 000	410	1 800	7,75	**29418 E**
100	170	42	408 000	620 000	160	2 000	3,65	**29320 E**
	210	67	863 000	1 250 000	640	1 600	10,5	**29420 E**
110	190	48	535 000	850 000	300	1 800	5,30	**29322 E**
	230	73	1 010 000	1 500 000	920	1 400	13,5	**29422 E**
120	210	54	656 000	1 040 000	440	1 600	7,35	**29324 E**
	250	78	1 170 000	1 760 000	1 200	1 300	17,5	**29424 E**
130	225	58	753 000	1 220 000	610	1 500	9,00	**29326 E**
	270	85	1 380 000	2 080 000	1 700	1 200	22,0	**29426 E**
140	240	60	845 000	1 400 000	800	1 400	10,5	**29328 E**
	280	85	1 400 000	2 160 000	1 900	1 200	23,0	**29428 E**
150	250	60	863 000	1 400 000	800	1 400	11,0	**29330 E**
	300	90	1 610 000	2 550 000	2 600	1 100	28,0	**29430 E**
160	270	67	1 010 000	1 700 000	1 200	1 200	14,5	**29332 E**
	320	95	1 790 000	2 800 000	3 200	1 000	33,5	**29432 E**
170	280	67	1 050 000	1 700 000	1 200	1 200	15,0	**29334 E**
	340	103	2 020 000	3 250 000	4 300	950	44,5	**29434 E**
180	300	73	1 240 000	2 080 000	1 700	1 100	19,5	**29336 E**
	360	109	2 250 000	3 650 000	5 400	900	52,5	**29436 E**

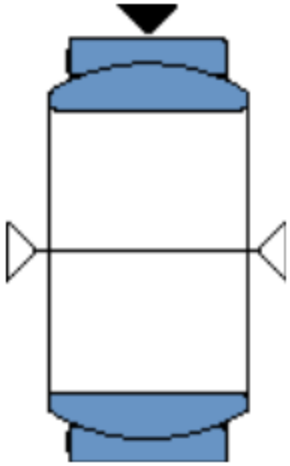
Dimensions								Abutment and fillet dimensions				
d	d_1	D_1	B	B_1	C	$r_{1,2}$ min	s	d_a min	d_{b1} max	d_{b2} max	D_a max	r_a max
mm								mm				
60	112,2	85,5	27	36,7	21	1,5	38	90	67	67	107	1,5
65	120,6	91,5	29,5	39,8	22	2	42	100	72	72	115	2
70	129,7	99	31	41	23,8	2	44	105	77,5	77,5	124	2
75	138,3	105,5	33,5	45,7	24,5	2	47	115	82,5	82,5	132	2
80	147,2	112,5	35	48,1	26,5	2,1	50	120	88	88	141	2
85	134,8	109,5	24,5	33,8	20	1,5	50	115	90	90	129	1,5
	155,8	121	37	51,1	28	2,1	54	130	94	94	150	2
90	138,6	115	24,5	34,5	19,5	1,5	53	118	95	95	135	1,5
	164,6	127,5	39	54	28,5	2,1	56	135	99	99	158	2
100	152,3	127,5	26,2	36,3	20,5	1,5	58	132	107	107	148	1,5
	182,2	141,5	43	57,3	32	3	62	150	110	110	175	2,5
110	171,1	140	30,3	41,7	24,8	2	64	145	117	117	165	2
	199,4	155,3	47	64,7	34,7	3	69	165	120,5	129	192	2,5
120	188,1	154,5	34	48,2	27	2,1	70	160	128	128	182	2
	216,8	171	50,5	70,3	36,5	4	74	180	132	142	210	3
130	203,4	165,5	36,7	50,6	30,1	2,1	76	170	138	143	195	2
	234,4	184,5	54	76	40,9	4	81	195	142,5	153	227	3
140	216,1	177	38,5	54	30	2,1	82	185	148	154	208	2
	245,4	194,5	54	75,6	41	4	86	205	153	162	237	3
150	223,9	190	38	54,9	28	2,1	87	195	158	163	220	2
	262,9	207,5	58	80,8	43,4	4	92	220	163	175	253	3
160	243,5	203	42	60	33	3	92	210	169	176	236	2,5
	279,3	223,5	60,5	84,3	45,5	5	99	230	175	189	271	4
170	251,2	215	42,2	61,1	30,5	3	96	220	178	188	247	2,5
	297,7	236	65,5	91,2	50	5	104	245	185	199	288	4
180	270	227	46	66,2	35,5	3	103	235	189	195	263	2,5
	315,9	250	69,5	96,4	53	5	110	260	196	210	305	4

SKF

SKF







Bearing Arrangement

- **Shafts are generally supported by two bearings in the radial and axial directions.**

- **The side that fixes relative movement of the shaft and housing in the axial direction is called the “fixed side bearing," and the side that allows movement is called the "floating side bearing."**

- **The floating side bearing is needed to absorb mounting error and avoid stress caused by expansion and contraction of the shaft due to temperature change.**

In the case of bearings with detachable inner and outer rings such as cylindrical and needle roller bearings, relative movement is accomplished by the raceway surface.

Bearings with non-detachable inner and outer rings, such as deep groove ball bearings and self-aligning roller bearings, are designed so that the fitting surface moves in the axial direction.

If bearing clearance is short, the bearings can be used without differentiating between the fixed and floating sides. In this case, the method of having the bearings face each other, such as with angular contact ball bearings and tapered roller bearings, is frequently used.

Positions of bearing

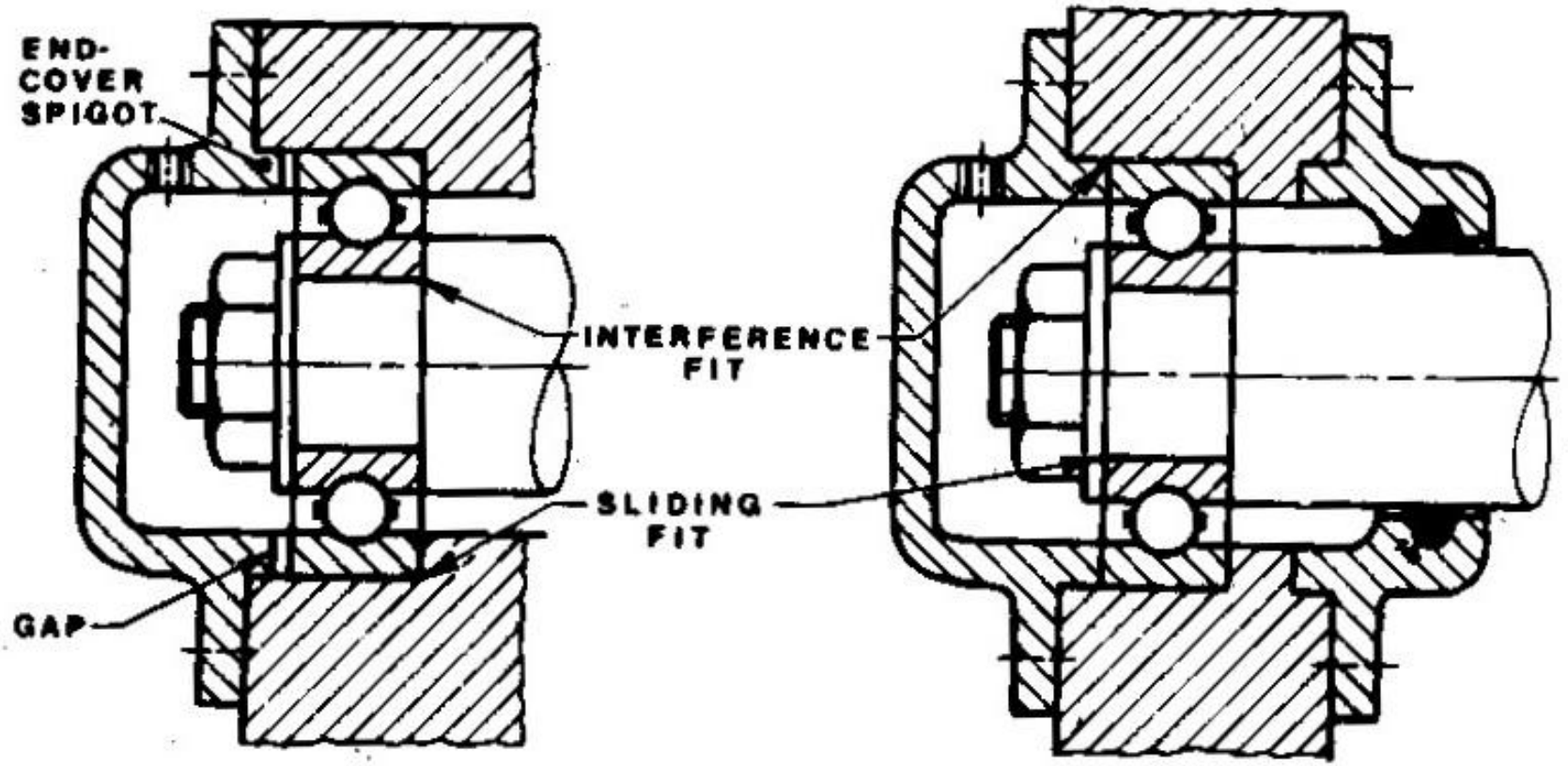


Table 2: Housing fits

Operating conditions	Tolerance Sliding contact surface combination steel-on-steel	 maintenance-free
Radial bearings		
Light loads, axial displacement required	H7	H7
Heavy loads	M7 (N7)	K7
Light alloy housings	N7	M7
Angular contact bearings		
Loads of all kinds, interference fit	M7 (N7)	M7
Loads of all kinds, can generally be displaced axially	J7	J7
Thrust bearings		
Purely axial loads	H11	H11
Combined loads	J7	J7

The tolerances given in brackets may be chosen for very heavily loaded bearings.
If chosen, it is necessary to check that the residual operating clearance is sufficient for correct performance of the bearing or whether a bearing with larger clearance must be used.

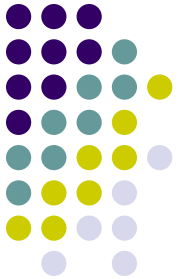
Table 1: Shaft fits

Operating conditions	Tolerance Sliding contact surface combination steel-on-steel	 maintenance-free
Radial bearings		
Loads of all kinds, interference fit	m6 (n6)	k6
Loads of all kinds, clearance or transition fit	h6	h6 or g6
Angular contact bearings		
Loads of all kinds, interference fit	m6 (n6)	m6
Thrust bearings		
Loads of all kinds, interference fit	m6 (n6)	m6

The tolerances given in brackets may be chosen for very heavily loaded bearings. If chosen, it is necessary to check that the residual operating clearance is sufficient for correct performance of the bearing or whether a bearing with larger clearance must be used

Bearing fits:

- Extreme fits, whether loose or tight, are not recommended. The effect of press fits on contact angle or radial play must be considered. As a rule of thumb, mounted radial play (and hence contact angle) will be reduced by approximately 75% of the press fit. This is important where precise control on deflection rates is required or where low-radial-play bearings are used.
- Size tolerance of the shaft and housing should be equal to those of the bearing bore and OD. Roundness and taper should be held to one-half of size tolerance. Surface finish should be held as close as possible.
- Extreme fits will depend upon tolerances on the bearings, shaft, and housing. Upon request, the bearing manufacturer will code the bearing bores and OD into increments within the size tolerance. These increments are normally 0.0001 in., but can be supplied as low as 0.00005 in.
- When operating at a temperature considerably different from room temperature, material expansion differences must be considered.



- Adhesives offer several advantages in producing proper fits:
- End play can be removed by applying a light external thrust load during curing time.
- Extreme fits can be eliminated, since the adhesive will fill up any reasonable clearance.
- Rotational accuracy can be improved by driving the shaft at slow speed during cure time.
- Disadvantages to using adhesives include:
- Certain adhesives are attacked by lubricants or solvents.
- To ensure a good bond, bearing surface, shaft, and housing must be thoroughly clean of oil and dirt.
- Adhesives may get into the bearing and cause damage.
- To ensure a good bond without rotational inaccuracies, clearance should be held reasonably close. The tolerances on the shaft and housing should be of the same magnitude as standard-fits practice. Actual clearance depends upon the specific adhesive.
- Under vibration, some adhesives may break loose.

Table 3.2 (1) Sample Bearing Arrangement (fixed and floating sides differentiated)

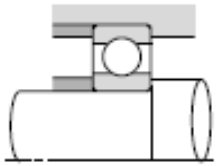
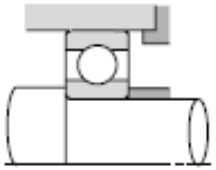
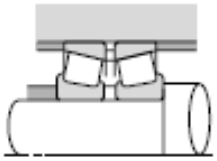
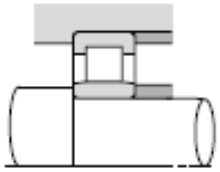
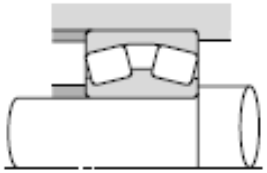
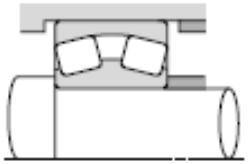
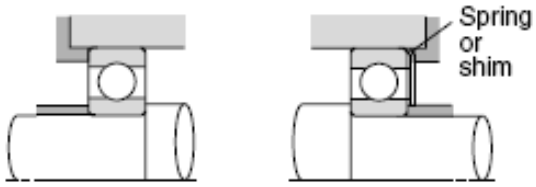
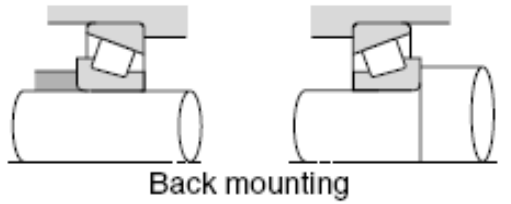
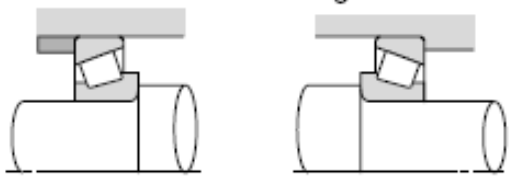
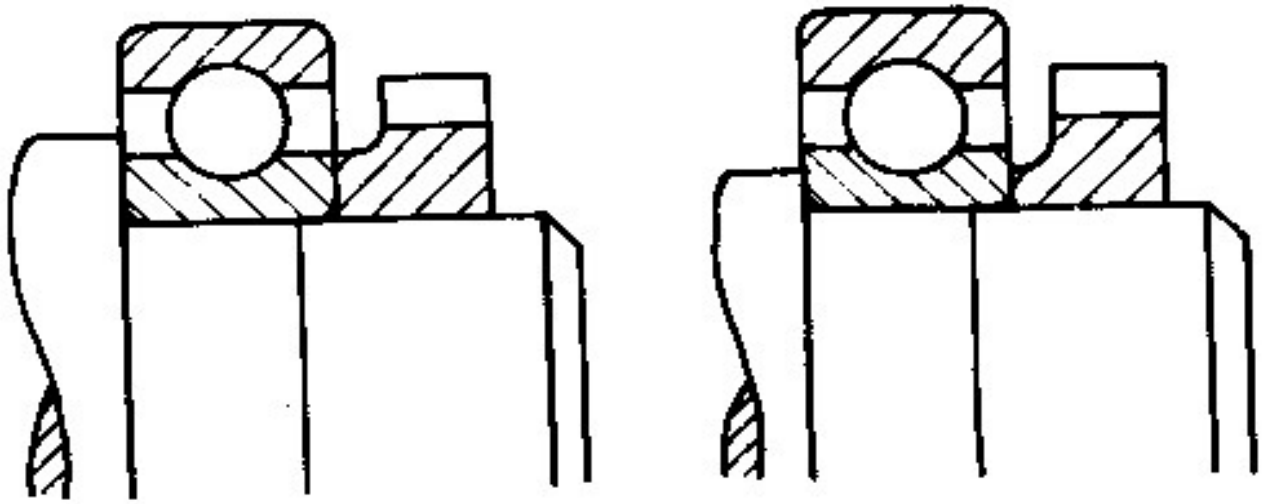
Arrangement		Abstract	Application example (reference)
Fixed side	Floating side		
		1. Typical arrangement for small machinery. 2. Capable of bearing a certain degree of axial load, as well as radial loads.	Small pumps Automobile transmissions
		1. Capable of bearing heavy loads. 2. You can enhance rigidity of shaft system by using back-to-back duplex bearing and applying preload. 3. Required improvement of shaft/housing precision and less mounting error.	General industrial machinery Reduction gears
		1. Frequently used in general industrial machinery for heavy loads and shock loads. 2. Able to tolerate a certain degree of mounting error and shaft flexure. 3. Capable of bearing radial loads and a certain degree of axial load in both directions.	General industrial machinery Reduction gears

Table 3.2 (2) Sample Bearing Arrangement (fixed and floating sides not differentiated)

Arrangement	Abstract	Application example (reference)
	1. Typical usage method for small machinery. 2. Preload sometimes provided by spring or adjusted shim on outer ring side.	Small electrical machinery Small Reduction gears
 Back mounting  Front mounting	1. Able to withstand heavy loads and shock loads, and has a wide range of use. 2. Rigidity can be enhanced by applying preload, but be careful not to apply too much preload. 3. Back mounting is suitable when moment load is produced, and front mounting when there is mounting error. 4. Front mounting facilitates mounting when the inner ring is tight-fitted.	Reduction gears Front and rear axles of automobiles

Assembly of ball bearing

Correct assembly



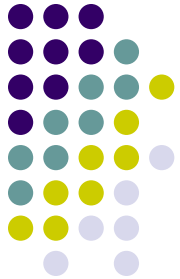
WRONG

CORRECT

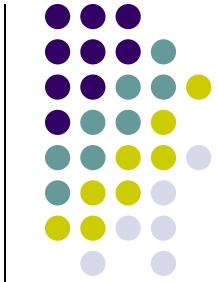
Bearing Mounting

- For instrument bearings, certain special considerations should be emphasized:
- Heavy press fits should be avoided.
- Accuracy of mounting surfaces should be equal to accuracy of mating bearing surface.
- Misalignment for low torque and running accuracy should not exceed 1/4°. Loading across the bearing during assembly should be avoided.

Axial positioning:



- Accurate axial positioning of the shaft relative to the housing requires shoulders, snap rings, or bearing flanges.
- *Shaft and housing shoulders:* Diameter of a shaft or housing shoulder must be sufficient to ensure solid seating and support for applied thrust loads, yet small enough to avoid interference with other parts of the bearing. Most manufacturers provide recommended shoulder dimensions for each bearing size. Fit accuracy between shoulder and mounting diameter should be as good as bearing accuracy.
- The corner between the shoulder and mounting diameter should be undercut because undercutting provides a more accurate machining of the shoulder surface. However, a radius is permissible if proper clearance is allowed.



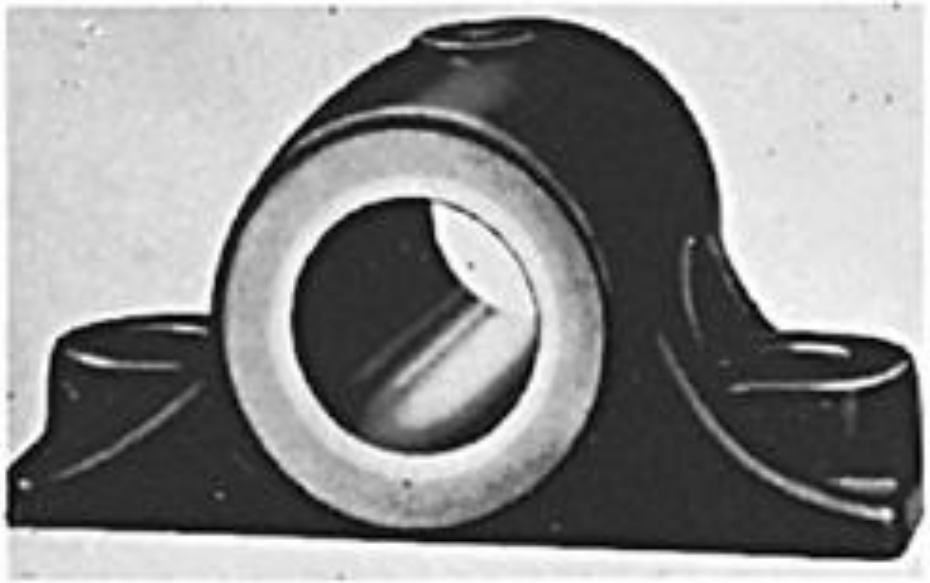
- *Retaining rings:* Certain cautions must be observed with this method:
- Recommendations as to the groove dimensions should be followed.
- Locating grooves machined into the shaft or housing must be controlled for squareness of groove face to bearing mounting diameter. Recommended value is 0.0002-in. TIR max.
- Parallelism of the faces of the ring should be held to 0.0002-in. TIR max.
- Lug dimensions should be checked to ensure there is no interference with the bearing. (Extended inner-ring bearings may offer an advantagehere.)
- Avoid a snap ring that locates directly on the shaft or housing diameter (no groove) if heavy thrust loads are involved.
- *Flanges:* Squareness of face-to-bore of the housing is critical and should be maintained to within 0.0003-in. TIR. Corners may be broken or left sharp because the flange is undercut and flush seating is ensured.

Axial adjustment:

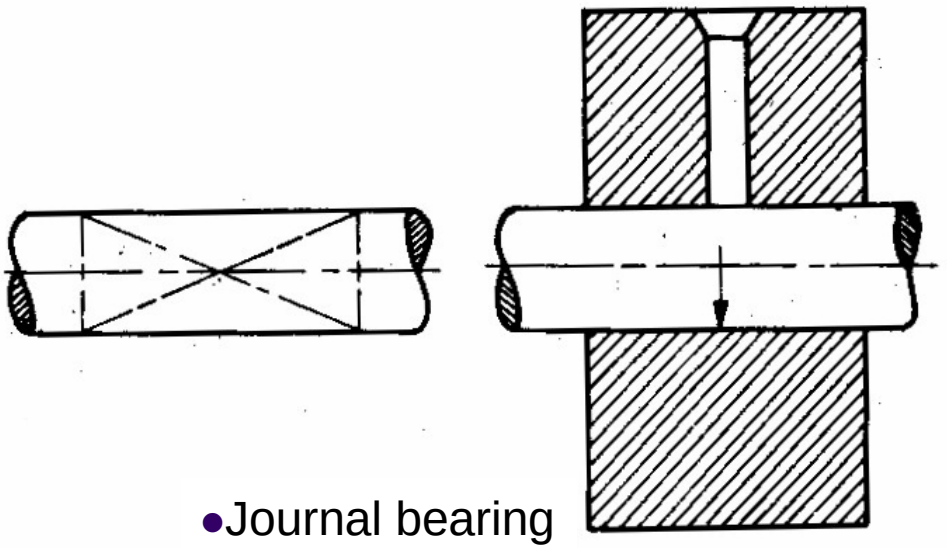
- Removal of excess bearing end play, when required, may involve preloading of the bearings. However, the most common requirement is to establish an allowable range of end play under a given reversing thrust load.
- *Shims:* Best material is stainless steel. Brass shims can also be used; however, they wear more easily and produce abrasive particles that could contaminate the bearing. Shims, particularly brass or other soft materials, should be used only against the nonrotating ring.
- *Spring washers:* Belleville and wave washers are the two most common types used. The washer should exert a very light load on the bearings. If extreme rigidity under external load is required, preloaded bearings should be used.

- The use of a spring washer usually involves a loose fit between the bearing ring and its mounting surface. Therefore, the washer should apply its force against the nonrotating ring.
- *Threads:* Generally, threads are not recommended to remove end play. They are too easily overtightened and can cause brinelling in the bearings.
- If threads must be used, the bearings should be locked against a solid shoulder or spacer. It is important to achieve a solid locking force without overloading the bearing rings. A Class 2 fit is normally recommended because it provides for slight misalignment of the nut, enabling the nut face to be flush with the bearing. The nut-face squareness to the thread pitch circle should be held to 0.0005-in. max wherever possible.

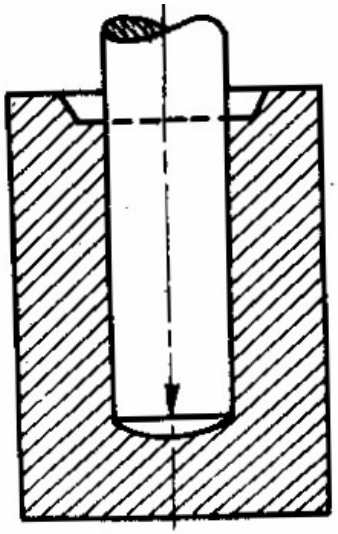
SLIDING CONTACT BEARING



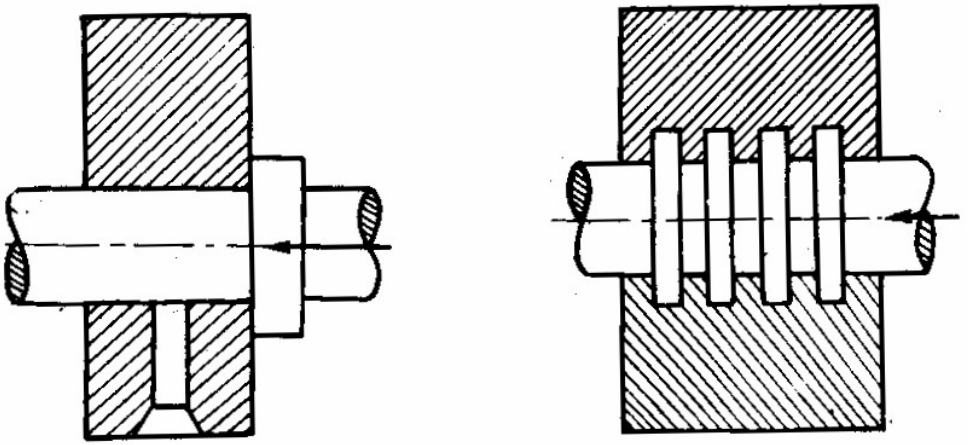
Classification of the sliding contact bearing



- Journal bearing



- Footstep bearing



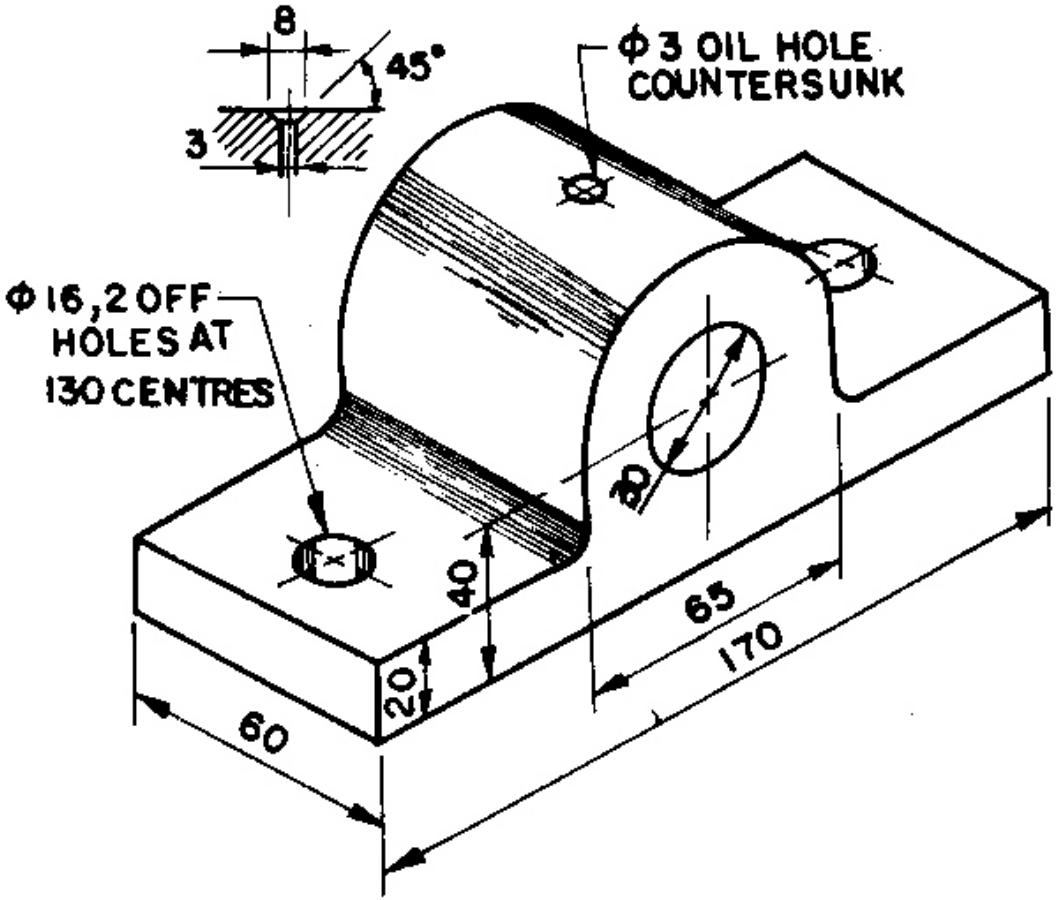
- Collar thrust bearing

- **Journal bearing** – in this the bearing pressure is exerted at right angles to the axis of the axis of the shaft. The portion of the shaft lying within the bearing in known as journal. Shaft are generally made of mild steel.
- **Foot step or pivot bearing** – in this bearing the bearing pressure is exerted parallel to the shaft whose axis is vertical. Note that in this case the end of the shaft rests within the bearing.
- **Thrust bearing** – in this bearing supporting pressure is parallel to the axis of the shaft having end thrust. Thrust bearing are used in bevel mountings, propeller drives, turbines, etc. note here the shaft ,unlike foot-strep bearing passes through and beyond the bearing.
  - Thrust bearings also known as "**collar bearing**".

Journal bearing

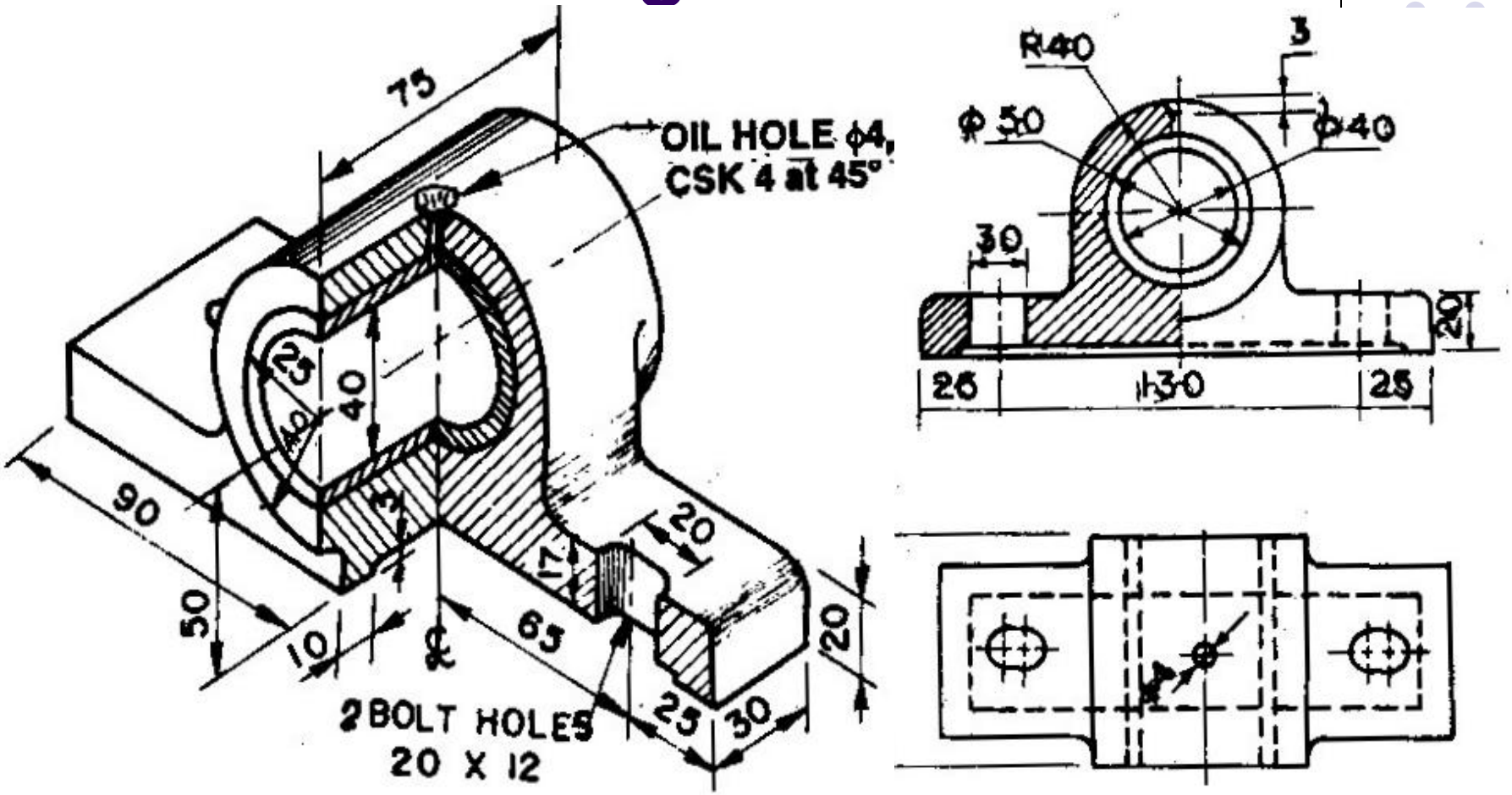
- Simple journal or solid bearing
  - It is simply a block of cast iron with a hole for the shaft providing running fit. An oil hole is drilled at the top for lubrication.
  - The main disadvantage of this type of bearing are
    - There is no provision for wear and adjustment on account of wear.
    - The shaft must be passed into the bearing axially, i.e. endwise.
    - Limited load on shaft and speed of shaft is low.

Solid bearing



- Bush bearing
  - In this the bush of soft material like brass or gun metal is provided and the body or main block is made of cast iron. Bush is hollow cylindrical piece which is fitted in a housing to accommodate the mating part. When the bush gets worn out it can be easily replaced.

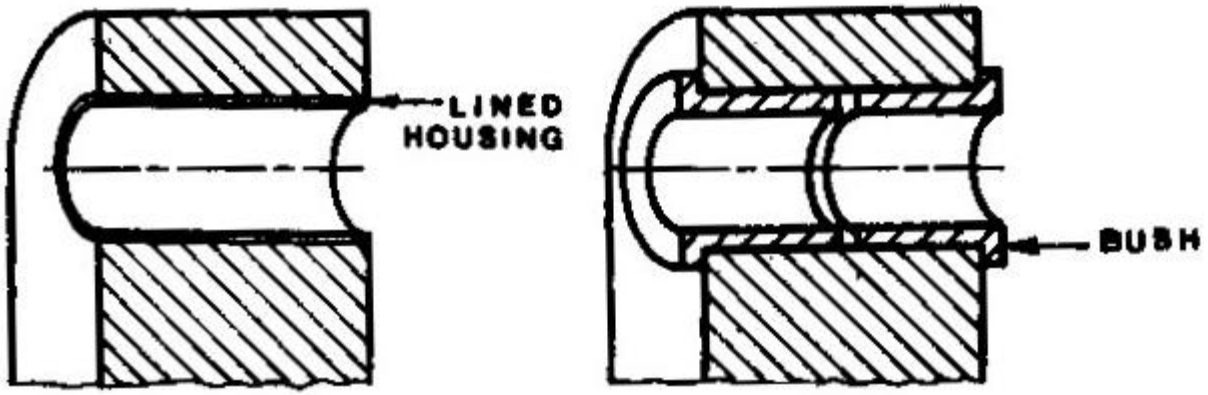
Bushed bearing



Note that the insertion of the shaft in this bearing is endwise.

- The outside of the bush is a driving fit (interference fit) in the hole of the casting where as the inside is a running fit for the shaft.
- The bearing material used may be white metal (Babbit – Tin/Cu/Lead/antimony) , copper alloy (brass, gunmetal) or aluminum alloy.
- Solid bushes are entirely made of bearing material and find the general application. In lined bush as the bearing material is applied as a lining to a backing material .
- Applications: turbines, large diesel engines etc

Bush and Direct-lined housing



(*a*) Direct-lined housing (*b*) Bush

- Direct lined housings
- In this type of the housing is lined directly by means of metallurgical bonding.
- Low-melting point white metal is used as a lining on the cast iron housing

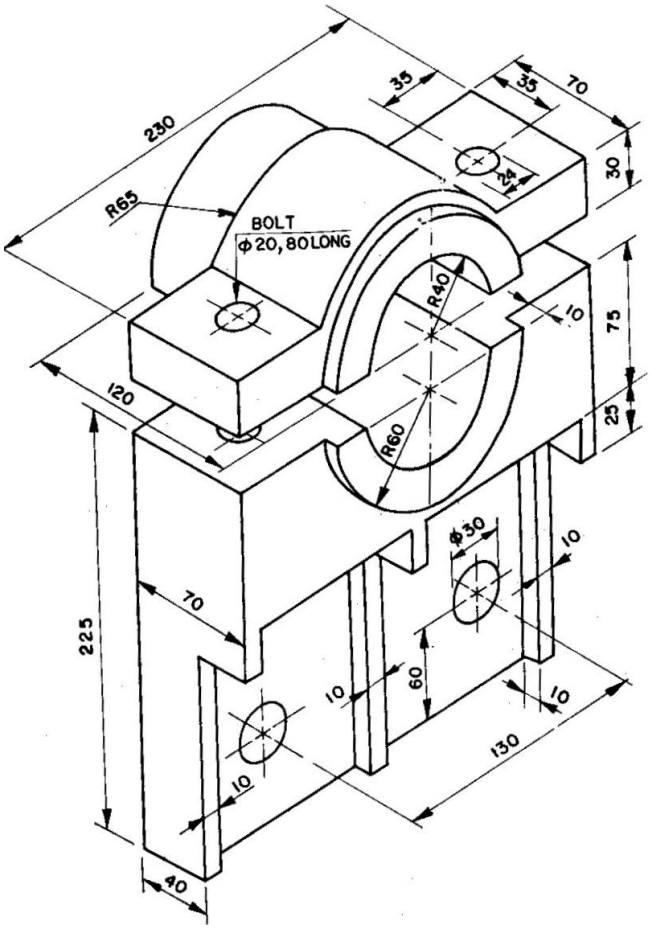
Plummer block or Pedestal bearing

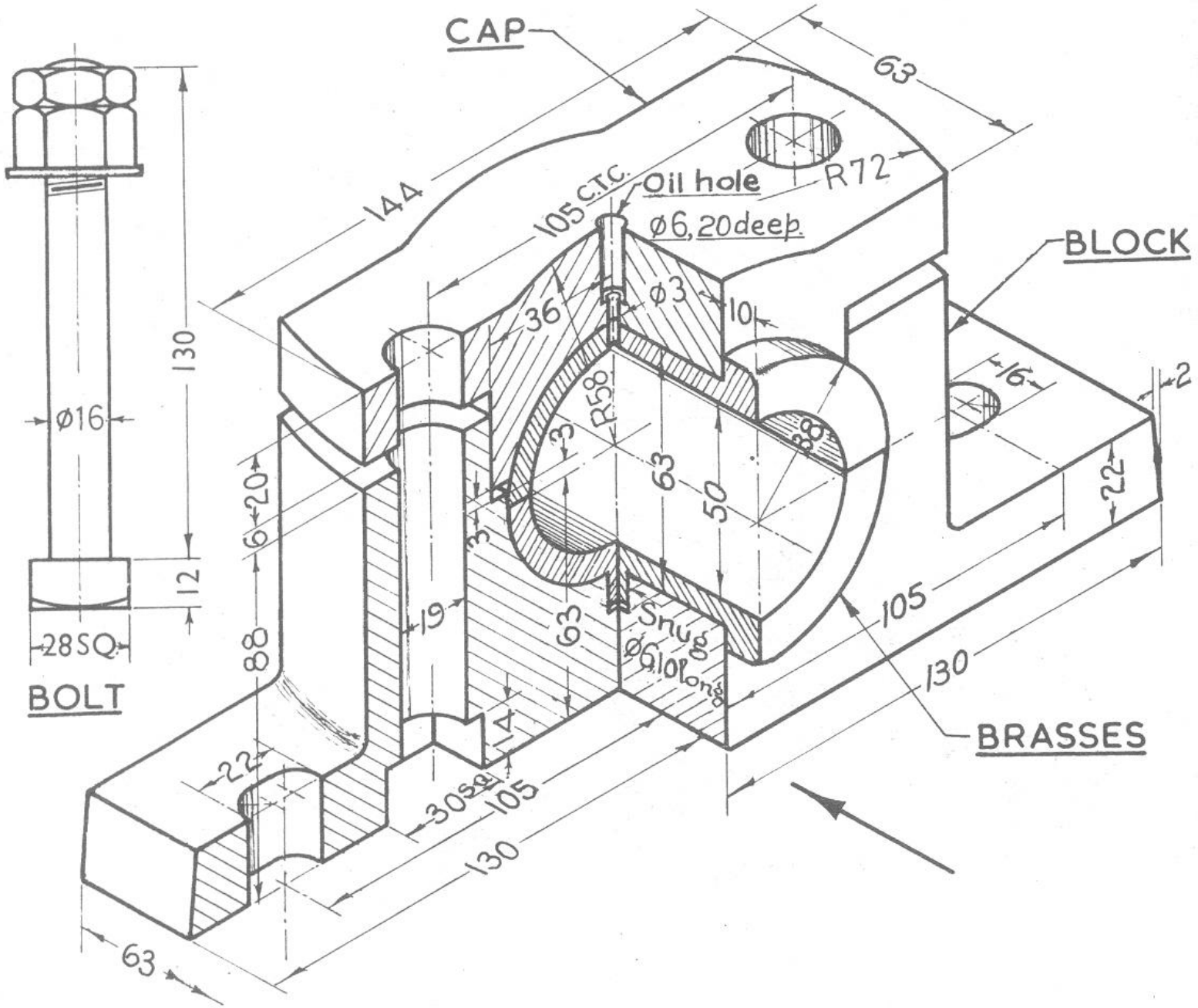
- It is a split type of bearing. This type of bearing is used for higher speeds, heavy loads and large sizes.
- The component of the bearing:
  - **Cast iron pedestal or block with a sole**
  - **Brass or gun-metal or phosphorus-bronze “Brasses”, bushes or steps made in two halves.**
  - **Cast iron cap.**
  - **Two mild steel bolts and nuts.**

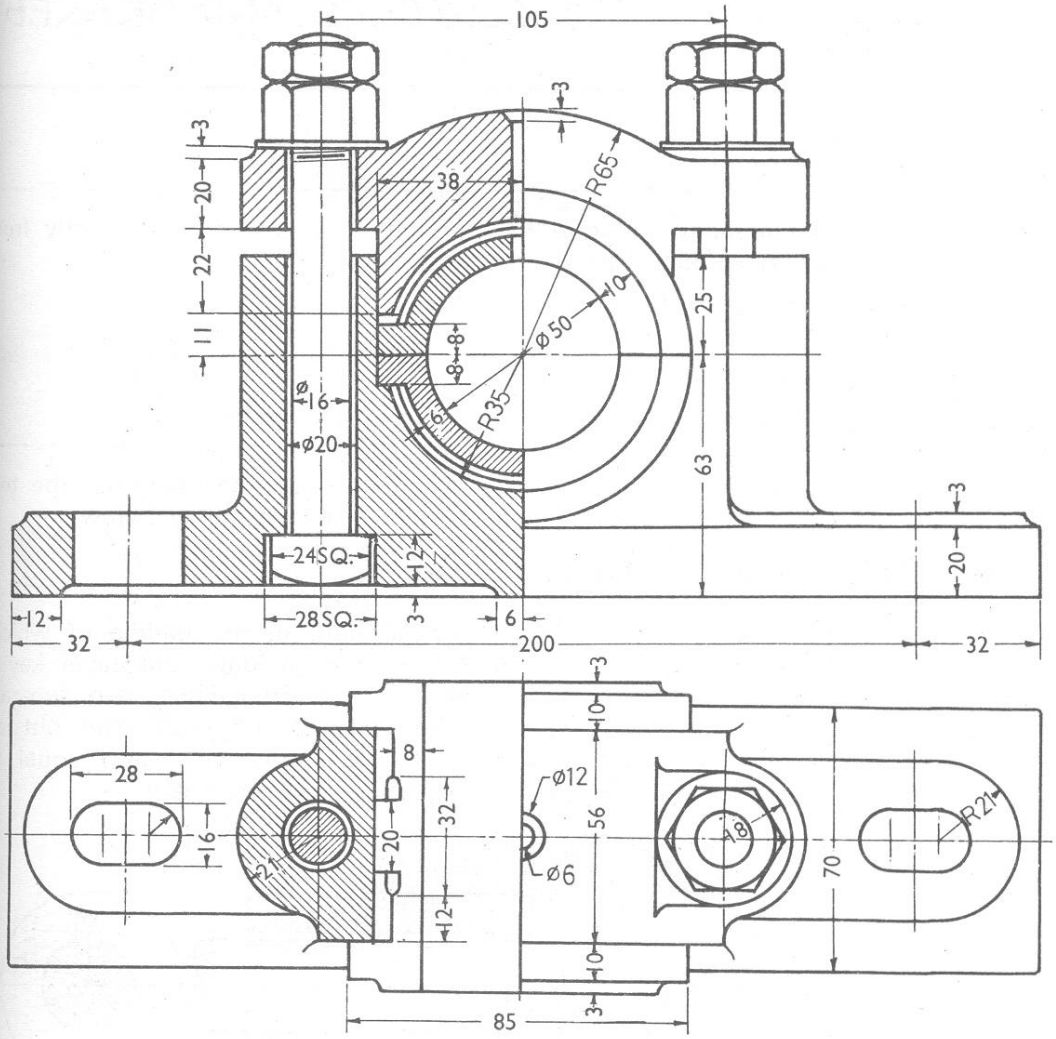
Care is taken that the brasses do not move axially nor are allowed to rotate. For preventing this rotation , usually a snug at the bottom fitting inside a recess at the bottom of the pedestal is provided.

This bearing facilitates the placements and removal of the of the shaft from the bearing. Unlike the solid bearing which are to be inserted end-wise and hence are kept near the ends of the shaft, these can be placed anywhere. This bearing ensures a perfect adjustment for wear in the brasses by screwing the cap.

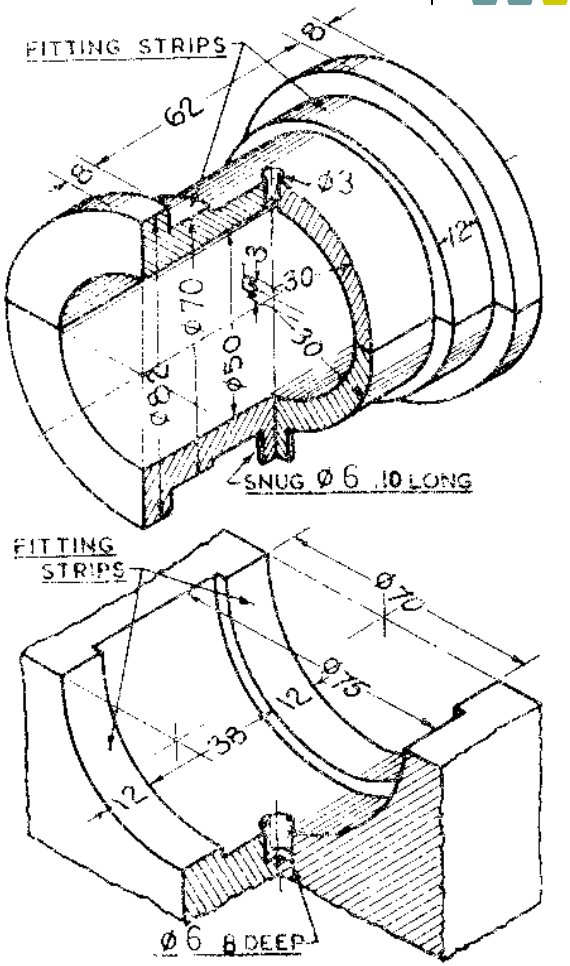
Journal bearing



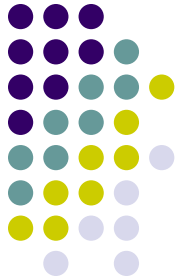

CAP
63
144
105 C.T.C.
Oil hole
Ø6, 20 deep
R72
BLOCK
Ø3
36
10
16
2
R58
3
63
50
88
22
6
20
3
19
63
Snug
Ø10 long
105
130
BRASSES
14
22
30 sq
105
130
63
130
Ø16
28 SQ
12
BOLT



Plummer block
FIG. 13-15

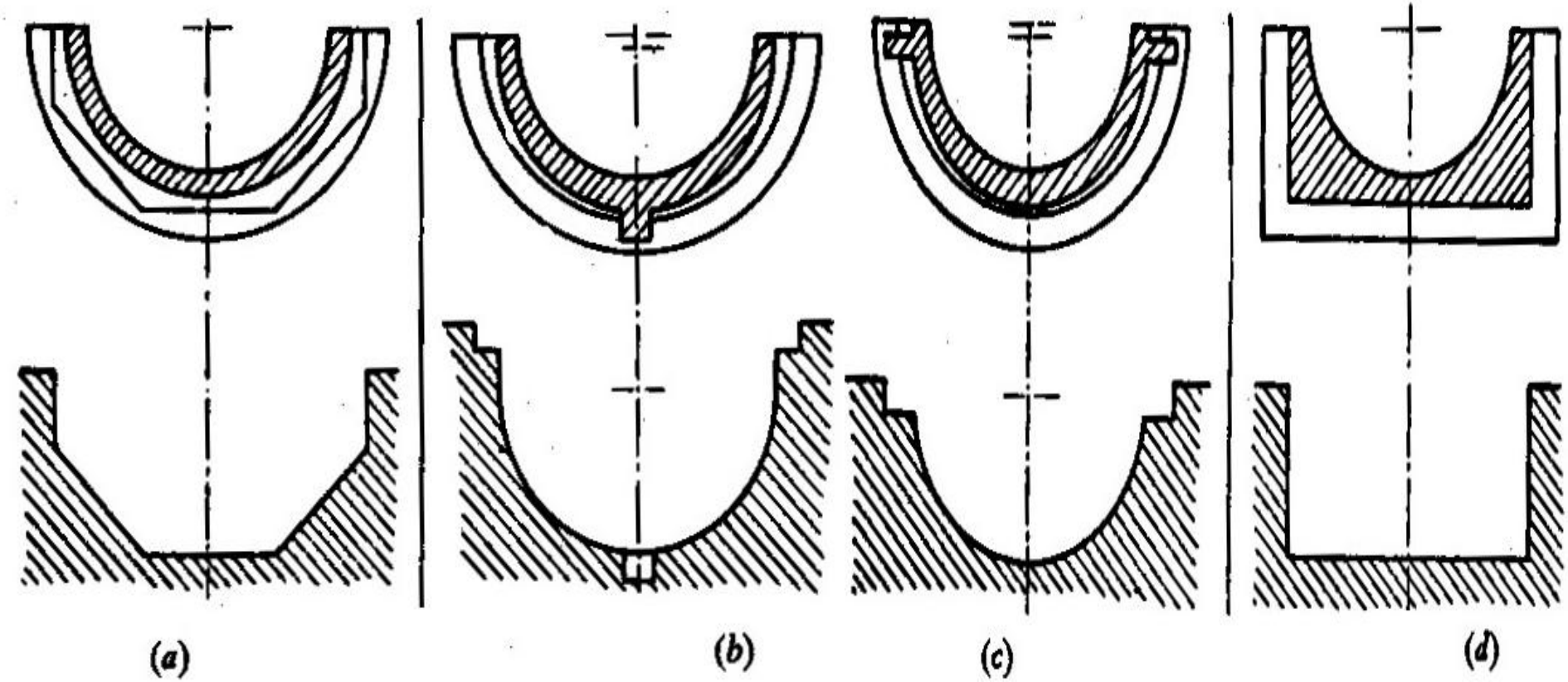


Prevention of rotation of brasses

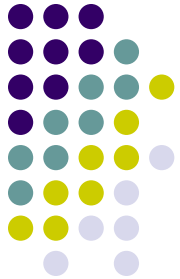


- The steps are made octagonal on the outside and they are made to fit inside a corresponding hole.
- A snug is cast on the lower brass top which fits a corresponding hole in the casting. The oil hole is drilled through the sung.
- Snug are provided at the side, and the corresponding recesses left in the casting
- The steps on the lower brass are made rectangular on the outside and they are made to fit inside a corresponding hole.

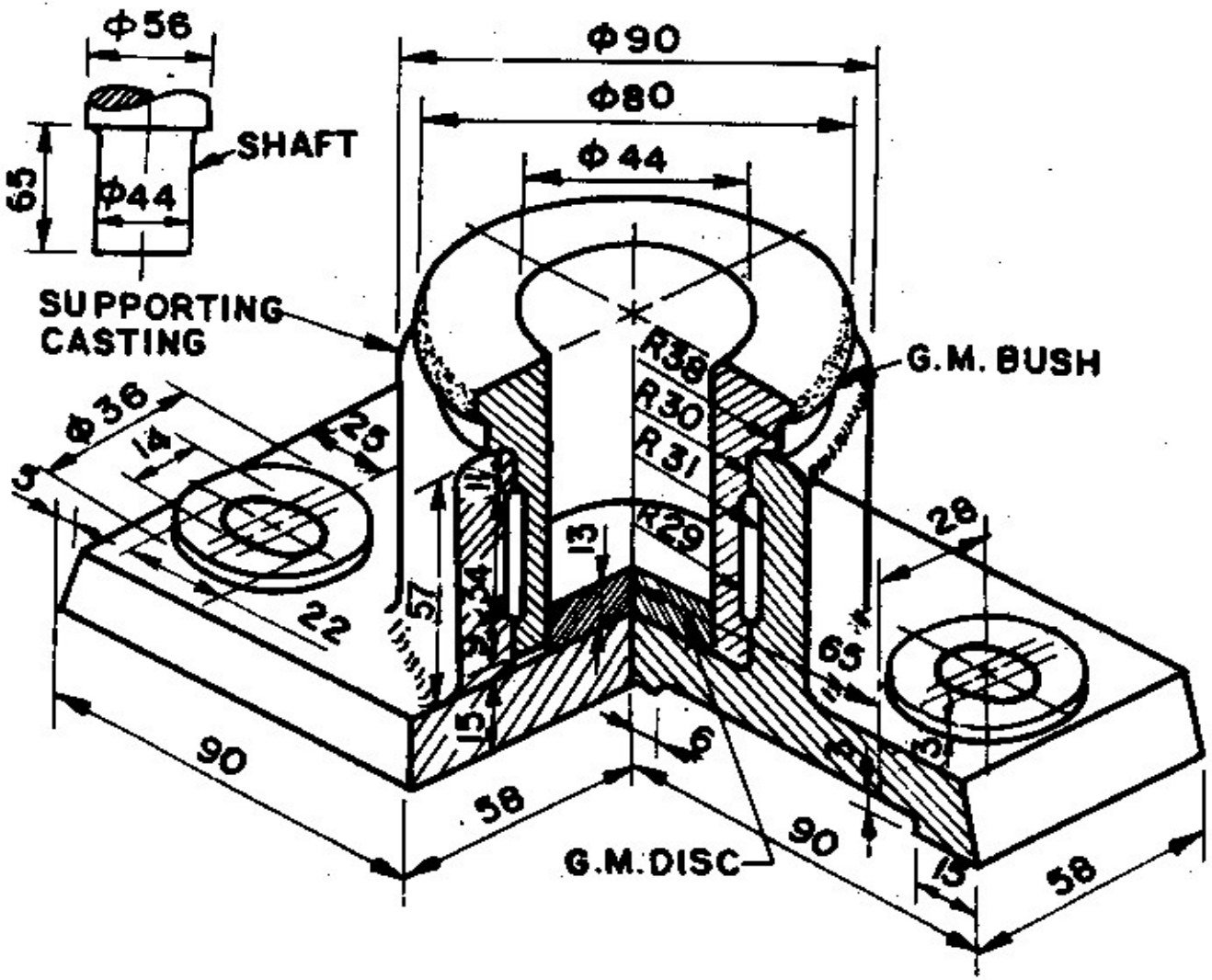
Prevention of rotation of brasses



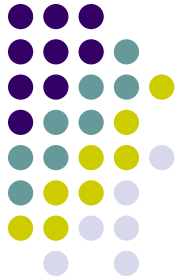
Footstep or pivot bearing



- suitable for supporting a vertical shaft with axial loads.
- In a footstep bearing a gun metal bush having a collar on top is placed inside the C.I. sole. The end of the shaft rests on a gun metal disc placed at the bottom in the bush. The disc is prevented from rotation with the help of a pin or sung fitted in the sole. The disc act as a thrust bearing whereas the bush fitted in the casting supports the shaft in position. The bush can take radial loads, if any, on the shaft.
- The disadvantage of footstep bearing is that it cannot be efficiently lubricated and there is unequal wear on the bottom disc.


Φ56
Φ90
Φ80
Φ44
SHAFT
65
Φ44
SUPPORTING CASTING
G.M. BUSH
R38
R30
R31
R29
Φ36
14
25
3
22
13
28
65
90
58
6
G.M.DISC
90
58

Advantages and disadvantages of the plain bearing



- **Plain bearing are cheap to produce and have noiseless operation. They can be easily machined, occupy small radial space and have vibration damping properties. Also they can cope with tapped foreign matter.**
- **Disadvantages are they require large supply of lubricating oil, they are suitable only for relative low temperature and speed; and starting resistance is much greater than running resistance due to slow build up of lubricant film around the bearing surface.**