Chapter 5

Metrology and Inspection Computer Integrated Manufacturing

CHAPTER HIGHLIGHTS

- *Combinational Logic Design*
- *Arithmetic Circuit*
- *Half Adder*
- *Full Adder*
- *Half Subtractor*
- *Full Subtractor*
- *n-bit Comparator*
- *Parity Bit Generator and Parity Bit Checker*
- *Code Converter*
- *Decoder*
- *Designing High Order Decoders from Lower Order Decoder*
- *Combinational Logic Implementation*
- *Encoders*
- *Multiplexer*
- *Demultiplexer*

Limits, Fits and Tolerances

An article manufactured consists of assembly of a number of components. Thus a component manufactured should be matching with some other mating component. This is important for the proper functioning and prolonged life of the product.

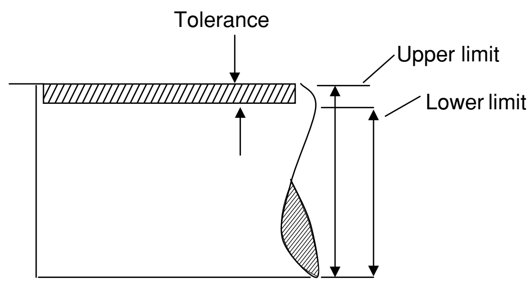
In the production of a component, it is not possible to make any part precisely to a given dimension, due to variability of elements of production processes. If attempts are made to achieve the perfect size, the cost of production will increase tremendously. But for practical purposes, perfect fitting of the mating components are not necessary. Slight dimensional variations are acceptable for the proper functioning.

The allowable variation in the basic size required in production is called tolerance.

Larger and smaller dimensions allowable are called limits– the high limit and low limit.

Thus difference between high and low limits is the tolerance. It is the margin allowed for variation in workmanship.

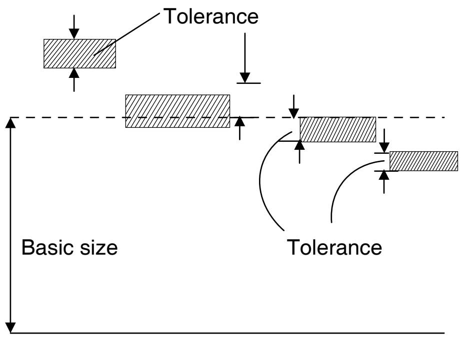
Tolerance can also be defined as the amount by which the job is allowed to go away from accuracy and perfectness without causing any functionable trouble, when assembled with its mating part and put into actual service.



Systems of Writing Tolerances

1. Unilateral system
2. Bilateral system

In unilateral system dimension of a part is allowed to vary only on one side of the basic size i.e., tolerance zone is either above or below the basic size line.



Unilateral tolerance

With a 25 mm of basic size examples of unilateral tolerance are

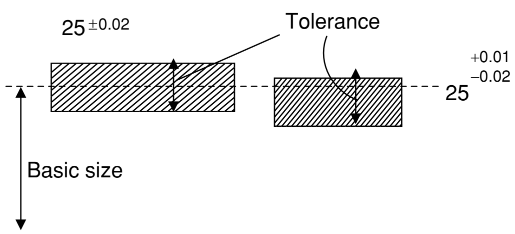
$$25^{+0.02}_{+0.01}, \quad 25^{+0.01}_{-0.00}, \quad etc$$
$$25^{+0.00}_{-0.02}, \quad 25^{-0.02}_{-0.03}$$

The first case means upper limit is 25.02 mm and lower limit is 25.01 mm

$\therefore$ Tolerance = 25.02 – 25.01
= 0.01 mm

In the fourth case,
Upper limit = 24.98
Lower limit = 24.97
Tolerance = 24.98 – 24.97
= 0.01 mm

In bilateral system, the dimension of the part is allowed to vary on both sides of the basic size.

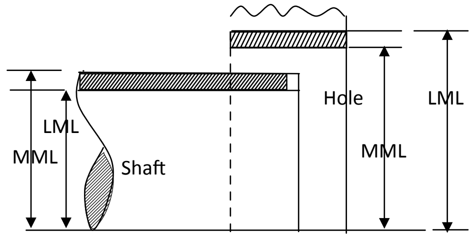


$25^{\pm 0.02}$ $25^{+0.01}_{-0.02}$ etc are examples of bilateral tolerance.

In the first case,
Upper limit = 25.02 mm
Lower limit = 24.98 mm
Tolerance = 25.02 – 24.98
= 0.04 mm

Maximum or Minimum Metal Limits

If the tolerance for the shaft is given as $25^{\pm 0.02}$ the shaft is said to have maximum metal limit (MML) of 25.02 mm. Since at this limit, the shaft has maximum possible amount of metal 24.98 mm will be minimum or least metal limit (LML) as shaft at this limit will have the least possible amount of metal



Terminology for Limits and Fits

Shaft: It is the external dimension of a component (need not be a circular shaft)

Hole: It is the internal dimension of a component (need not be a circular hole)

Basic or Nominal Size

It is the standard size of a part with reference to which limits of dimensions are determined. Basic size is same for hole and shaft. In design calculations basic size is used.

Actual sizes is the measured size of a manufactured part.

Zero line: It is the horizontal line representing the basic size.

Deviation is the algebraic difference between the size (maximum, minimum, actual etc) with the basic size. Deviations are shown with respect to the zero line or datum line.

Upper deviation is a positive quantity when maximum limit of size is greater than the basic size. It is negative when maximum limit of size is less than the basic size. For hole it denoted by ES and for shaft it is es

Lower deviation is a positive quantity when the lower limit of size is greater than the basic size and negative when it is less than the basic size. It is denoted by EI and ei for hole and shaft respectively.

Tolerance is represented by IT which stands for international tolerance grade.

Relationship of Tolerance and Deviations

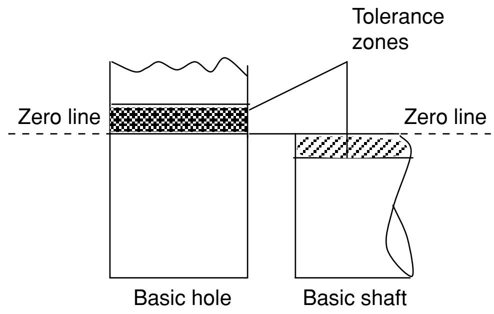
For shaft, IT = es – ei
(upper deviation – lower deviation)
For hole, IT = ES – EI

Fundamental Deviation

It is the deviation (either upper or lower) nearest to the basic line. It fixes the position of the tolerance zone in relation to the zero line.

Basic shaft is the shaft whose upper deviation is zero. Basic size and maximum size is same in this case. It is denoted by '*h*'.

Basic hole is the hole whose lower deviation is zero. Its low limit is same as the basic size. It is denoted by letter '*h*'.



Tolerance grade is an indication of degree of accuracy and is represented by letters IT followed by a number. For example, IT0, IT01, IT1 etc

Standard Tolerance Unit

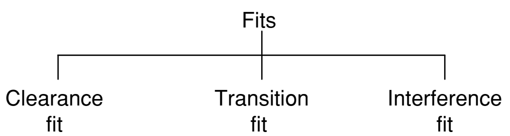
It serves as a basis for determining standard tolerance (IT). It is denoted by '*i*' and expressed in microns.

Fits

When two parts are to be assembled, the relation resulting from the difference between their sizes before assembly is called a fit. It is the degree of tightness or looseness between two mating parts.

Types of Fits

Depending on the basis of positive, zero or negative clearance values between mating parts fits are classified as under



(a) Slide fit	(a) Push fit	(a) Force fit
(b) easy slide fit	(b) Wringing fit	(b) Tight fit
(c) Running fit	(c) Shrink fit	

Clearance Fit

Clearance is the difference between sizes of hole and shaft. Minimum clearance is the difference between minimum size of hole and maximum size of shaft.

Maximum clearance is the difference between maximum size of hole and minimum size of the shaft.

In clearance fits, the largest permissible shaft diameter is smaller than the diameter of the smallest hole. So the shaft can rotate or slide in the hole with different degrees of freedom.

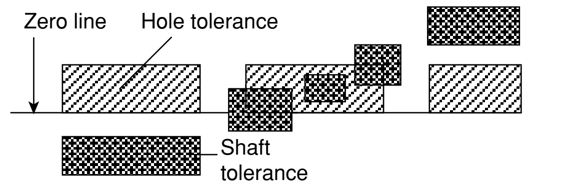
Interference Fit

Interference is the arithmetical difference between sizes of hole and shaft, when shaft is of bigger size.

In Interference fit, the minimum permissible diameter of the shaft is larger than the maximum allowable diameter of the hole. After fitting the members are permanently attached.

Transition Fit

Transition fit is in between clearance fit and interference fit. Depending upon the actual sizes of the parts clearance or interference may occur.



(a) Clearance fit (b) Transition fit (c) Interference fit

Hole Basis System for Three Types of Fits

Figure above gives hole basis system where the fundamental deviation of hole is zero (For shaft basis system fundamental deviation of shaft is zero)

Hole basis system is generally used because it is easier to vary the size of the shaft and to measure it than to vary the hole size, provided the work is not very large.

Shaft basis system is useful when a number of accessories such as bearings, collars etc are to be fitted on same shaft.

Allowance

Allowance is the intentional difference between the lower limit of hole and higher limit of the shaft.

It is the variation given for the purpose of providing different classes of fit. It is the difference between maximum material size limits of mating parts.

The allowance may be positive or negative. Positive allowance is the minimum clearance and negative allowance is the maximum interference intended between the mating parts.

Allowance vs Tolerance

Allowance is the prescribed difference between the dimensions of two mating parts (hole and shaft). Tolerance is the permissible variation in dimension of a part (either hole or a shaft)

Standard Limit Systems

The aim of a standard limit system is

1. To select basic functional clearances and interferences for a given application or type of fit
2. to establish tolerances which will provide a reasonable and economical balance fits, consistency and cost

British standard, international standard (ISO) and Indian standards are some of the standard limit systems

Indian Standard System of Limits and Fits (IS-919 and 2709)

Indian standards are in line with ISO recommendations. The standards cover holes and shafts from the smallest size to 3150 mm. For any size over this range there is a wide choice of fits available and for each of the fits there is a series of tolerance grades from very fine to wide tolerances.

Standard tolerance and fundamental deviations are used in the limit system.

18 grades of fundamental tolerances are used. These are designated as IT01, IT0, IT1 to IT16

Fundamental deviations are indicated by 25 letters A to Z_C for holes and letters a to z_C for shafts. (For holes: A, B, C, D, E, F, G, H, J_S, J, K, M, N, P, R, S, T, U, V, X, Y, Z, Z_A, Z_B, Z_C. For shafts corresponding small letters are used)

For A to H holes lower deviation is above zero line and for J to Z_C it is below the zero line.

For shafts a to h upper deviation is below the zero line and for j to z_c it is above the zero line.

Standard tolerances are expressed in terms of standard tolerance unit, *i*. It is given by

$$i = 0.45\sqrt[3]{D} + 0.001D \text{ microns}$$

Where *D* is the geometric mean upper and lower values of a diameter step in which the diameter lies. IS–919 specifies the following diameter steps.

1–3, 3–6, 6–10, 10–14, 14–18, 18–24, 24–30, 30–40, 40–50, etc upto 180–200 mm.

Values of tolerances for tolerance grades IT5 to IT16 are obtained from the following table.

Grade	IT5	IT6	IT7	IT8	IT9
Value	7i	10i	16i	25i	40i

IT 10	64*i*
IT 11	100*i*
IT 12	160*i*
IT 13	250*i*
IT 14	400*i*
IT 15	640*i*
IT 16	1000*i*

Other tolerances–

For IT01 : 0.3 + 0.08 *D*

For IT0 : 0.5 + 0.12 *D*

For IT1 : 0.8 + 0.02 *D*

For IT2 to IT4 values are approximated between IT1 and IT5

Designation of Holes, Shafts and Fits

A shaft or a hole is completely described if the basic size followed by the appropriate letter and the tolerance grade is given.

For example,

50 H6 means 50 mm H hole with tolerance grade IT6

50 f7 means 50 mm f shaft with tolerance grade IT7

Tolerance and Fundamental Deviation for Larger Sizes

The finer tolerance grades IT01 to IT5 are not provided for sizes above 500 mm.

For size above 500 mm and up to 3150 mm

IS : 2101 specify various grades

$I\,(\text{in } \mu) = 0.004D + 2.1$

Tolerance Analysis in Manufacturing and Assembly

Tolerance can be defined as the amount of variation permissible from accuracy and perfectness of the dimension of a component without causing any functional trouble. Human failure and machine limitations prevent the achievement of ideal dimensions of the part during fabrication.

By providing tolerance the cost of production can be reduced; without sacrificing the functional requirement. The difference between upper limit and lower limit of a dimension is called the tolerance zone. It is the margin for variation in workmanship. Selection of tolerance is based on the following.

1. Functional requirement : With the permitted tolerance, assembly should be possible and the equipment should be able to perform the required function.
2. Standardisation: Standardisation of the parts are required for interchangeability which is essential for mass production.
3. Manufacturing needs

When the functional requirement is not so rigid tolerance choice may be influenced and determined by factors like methods of tooling, equipment available etc.

Need for Tolerance

1. Different materials have different properties. Variation in properties cause errors during machining.
2. Production machines may have inherent inaccuracies and have limitation to produce parts with perfect dimensions.
3. Machine operators have limitation to make perfect settings. There are chances of errors in setting up machines, adjusting tools and work piece on the machine etc.

Aiming at ideal conditions of dimensions will result in exhorbitant costs. If the components are made with large tolerances without affecting the functional requirement, cost of production can be reduced. So the tolerance selected should be just enough to the required job and not better.

So it can be said that tolerance is a compromise between accuracy required for proper functioning and ability for economic production of this accuracy.

Solved Examples

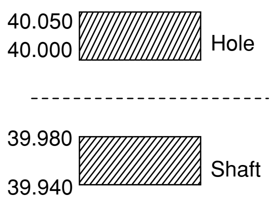
Example 1: What is meant by 20 H 7 f8 in Indian standard limit system?

Solution: It means a 20 mm basic size H-hole with tolerance grade IT7 is fitted with a f-shaft of tolerance grade IT8.

Example 2: A hole is specified as $40_{0.000}^{0.050}$ mm. The mating shaft has a clearance fit with minimum clearance 0.02 mm. The tolerance on the shaft is 0.04 mm. Maximum clearance between hole and shaft is

Solution: Low limit of hole: 40.000 mm

High limit of hole: 40.050 mm



High limit of shaft $= 40.000 - 0.02$

$= 39.980$ mm

Low limit of shaft $= 39.980 - 0.04$

$= 39.940$ mm

Maximum clearance $= 40.050 - 39.940$

$= 0.110$ mm

Types of Assemblies

In assembly of components the mating parts can be made to fit in three ways. These are

1. By trial and error
2. Interchangeable assembly
3. Selective assembly

Assembly by Trial and Error

When the assemblies required are only small in number and they are similar, these can be produced by trial and error by same craftsman. In this method one part is made to its nominal size as accurately as possible and the mating part is made to suit it by trial and error.

Interchangeable Assembly

In mass production the quantities required are very large and it is not economical to produce it by trial and error by same person. In mass production the components are produced by different craftsmen or operators in different batches in different machines. In this case the parts are produced within specified tolerance limits so that a component selected at random will assemble correctly with any other mating component, selected at random. By this method manufacturing cost is considerably reduced.

Selective Assembly

When high degree of accuracy is required in mass production, interchangeable assembly also become not economical. In this case selective assembly method can be used. In selective assembly parts are produced with wider tolerances so that the cost is reduced. The components produced are classified into groups according to their sizes by automatic gauging. Assemblies can be made only with matched sets of parts such that the clearances are within limits

An example for selective assembly is the assembly of pistons with cylinder bores.

If the basic size is 50 mm for bore and 49.88 mm for piston and required clearance is 0.12 mm, these can be produced with a wide tolerance of 0.04 mm.

Then dimension of bore $= 50^{\pm 0.02}$

Dimension of piston $= 49.88^{\pm 0.02}$

In interchangeable assembly the clearance can go upto $50.02 - 49.86 = 1.16$ mm which is not acceptable.

But the components are grouped in match sets as follows the required clearance of 0.12 mm can be achieved.

Cylinder bore	49.98	50.00	50.02
Piston	49.86	49.88	49.90

Gauges

In mass production where a large number of similar components are produced, inspection by measuring each component will be time consuming and not economical. Therefore the conformance of each part is checked with the tolerance specification using tools called gauges.

Gauges are inspection tools of rigid design without a scale, which serve to check the dimensions of manufactured parts. They check only whether the inspected parts are made within the specified limits. Plain gauges are used for checking plain (unthreaded) holes and shafts.

Classification—

1. According to type
   (a) standard gauges
   (b) limit gauges
2. According to purpose
   (a) Workshop
   (b) Inspection
   (c) reference or master gauges

3. According to form of tested surface
   (a) plug gauge
   (b) snap and ring gauges
4. According to their design
   (a) Single limit and double limit
   (b) Single ended and double ended
   (c) Fixed and adjustable gauges

Standard gauge is an exact of copy of their mating part. For example a shaft and a bush. The shaft can be inspected with a gauge which is an exact copy of the bush.

Limit gauges are used to check whether the parts are within the specified limits.

Limit plug gauges are used for checking holes. The GO plug gauge has the size of low limit of the hole while NO GO plug gauge has the size of high limit of the hole. If the inspected hole is within their tolerance limits the GO gauge will enter the hole while the NO GO gauge cannot enter the hole.

Plug gauges can be plain or screwed.

Plain plug gauges are generally double ended type for sizes up to 63 mm and single ended for sizes above 63 mm size.

Ring gauges are used to check shafts.

Plain ring gauges are made of suitable wear resisting steel and gauging surfaces are hardened. GO and NO GO type ring gauges are available.

Snap and gap gauges are also used to check shafts. The jaws of the gauge is made use of for checking. Double ended type plate snap gauges are used for sizes in the range of 2 to 100 mm and single ended progressive type in the range of 100 to 250 mm. In adjustable type gap gauges, the gauging anvils are adjustable end wise in the horse shoe frame.

These gauges are set by means of slip gauges to any particular limit required.

Combined limit gauges are used for gauging of cylindrical holes. In these a single gauge is used to check both upper and lower limits.

Contour gauges are employed for checking the dimensional accuracy and shapes of irregular work. Radius gauge is an example.

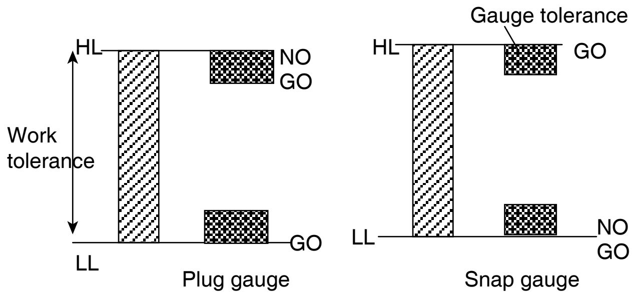
Taper plug gauge is used for checking tapered holes and **taper ring gauge** is used for checking shafts. These check the diameter at the bigger end and the change in diameter per unit length.

Slip gauges or gauge blocks are used as standards of measurement. It is the universally accepted end standard of length. These are rectangular blocks of high grade steel with exceptionally close tolerances. Faces are round and lapped. These are available in standard sets. The blocks are placed one over other by the phenomenon of wringing to get a specified length. Slip gauges are also made from Tungsten carbide which is extremely hard and wear resistant. They are carefully finished by high grade lapping to a high degree of finish flatness and accuracy.

Gauge Maker's Tolerance or Gauge Tolerance

Gauges cannot be manufactured to the exact sizes. If closer limits are held, the gauge become expensive. Therefore some allowance is given in the manufacturing of gauges This is known as gauge tolerance.

Limit gauges are usually provided with a tolerance of 10% of the work tolerance. For inspection gauges it is 5% of work tolerance.



Wear Allowance

The measuring surfaces of GO gauges which constantly rub against the surface of parts in inspection are consequently subjected to wear and lose their initial size, while the size of snap GO gauges are increased. Therefore a wear allowance is added in a direction opposite to the wear. Wear allowance is taken as 10% of the gauge tolerance. Wear allowance is applied to a normal GO gauge diameter before gauge tolerance is applied. As per British standards when the work tolerance is more than 0.09 mm, wear allowance is provided.

Inspection gauges are used by inspectors for final inspection of the manufactured parts. These have slightly larger tolerance than work shop gauges. This is to ensure that work which passes the work shop gauges will be accepted by inspection gauges. The tolerance on inspection gauges fall outside the work tolerance.

Taylor's Principle for The Design of Limit Gauge

1. GO gauges should inspect all the features of a component at a time and should be able to control the maximum metal limit, or in other words the maximum metal limit of as many related dimensions as possible should be incorporated in the GO gauge.
2. NOT GO gauge should check only one element at a time for the minimum metal limit.

Example 3: What are the upper and lower limits of the shaft represented by 60*f*8. Diameter 60 mm lies in diameter step of 50 –80 mm. Fundamental deviation of *f* shaft is –5.5 $D^{0.41}$ µm.

Solution: Geometric mean diameter $= \sqrt{50 \times 80}$

$= 63.246$ mm

Fundamental tolerance unit

$$i = 0.45\sqrt[3]{D} + 0.001D$$

$$= 0.45\sqrt[3]{63.246} + 0.001 \times 63.246$$

$$= 1.859\ \mu\text{m}$$

$$= 0.00186\ \text{mm}$$

$$\text{IT8} = 25i$$

$$= 25 \times 0.00185$$

$$= 0.04646\ \text{mm}$$

Fundamental deviation of f shaft

$$= -5.5\ D^{0.41}$$

$$= -5.\ 5\ [63.246]^{0.41}\ \mu\text{m}$$

$$= -0.03012\ \text{mm}$$

Upper limit of shaft = 60 – 0.03012

= 59.97 mm

Lower limit of shaft = 59.97 – 0.0465

= 59.924 mm.

Example 4: Find the values of allowance and tolerances for hole and shaft assembly for the following mating parts

Hole: $25^{-0.03}_{-0.05}$ shaft: $60^{+0.25}_{+0.00}$

Solution:

(a) Hole

Tolerance = 25.04 – 25.00

= 0.04 mm

(b) Shaft

Tolerance = HL – LL

HL = 25.00 – 0.03

= 24.97

LL = 25.00 – 0.05

= 24.95

Tolerance = 24.97 – 24.95

= 0.02 mm

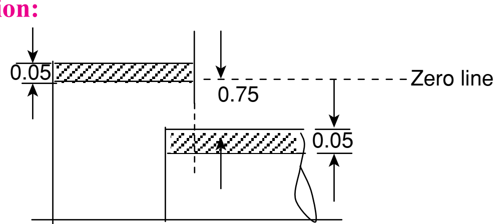
(c) Allowance = LL of hole – HL of shaft

= 25.00 – 24.97

= 0.03 mm.

Example 5: A 60 mm diameter shaft is made to rotate in the bush. Tolerance for both bush and shaft are 0.050 mm. Determine dimension shaft and bush to give a minimum clearance 0.075 mm with hole basis system

Solution:



HL of hole = LL + tolerance = 60 + 0.050 = 60.050 mm

HL of shaft = LL of hole – Allowance

= 60.00 – 0.075 = 59.925

LL of shaft = 59.925 – 0.050 = 59.875

Example 6: For the following hole and shaft assembly find shaft tolerance, hole tolerance and state the type of fit.

Hole: $60^{+0.05}_{+0.002}$ shaft: $60^{+0.05}_{+0.005}$

Solution: HL of hole: 60.025 mm

LL of hole: 60.00

Hole tolerance : 60.025 – 60.000 = 0.025 mm

HL of shaft : 60.05

LL of shaft : 60.005

Shaft tolerance = 60.05 – 60.005 = 0.045 mm

Allowance = LL of hole – HL of shaft

= 60.00 – 60.05

= –0.05 mm (interference)

HL of hole – LL of shaft = 60.025 – 60.005

= 0.025 mm (clearance)

∴ The type of fit is transition fit

Example 7: In a limit system, the following limits are specified to give a clearance fit between shaft and hole

Shaft: $40^{-0.006}_{-0.020}$ mm

Hole: $40^{+0.30}_{-0.000}$ mm

Determine–

(A) basic size
(B) shaft and hole tolerances
(C) Minimum clearance
(D) Maximum clearance

Solution:

(a) Basic size : 40 mm

(b) Shaft tolerance:

(40 – 0.006) – (40 – 0.02)

= (–0.006) – (–0.020) = 0.014 mm

Hole tolerance: (+0.030) – (0.00)

= 0.030 mm

(c) Minimum clearance = LL of hole – HL of shaft

= 50 – (50 – 0.006)

= 0.006 mm

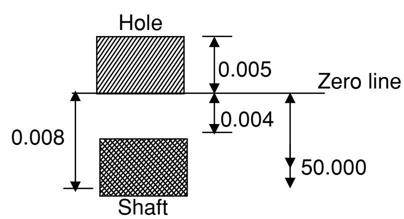
(d) Maximum clearance

HL of hole – LL of shaft

= (50 + 0.030) – (50 – 0.020)

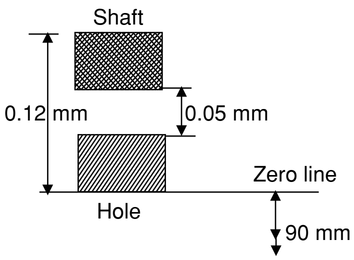
= 0.050 mm

In an assembly of two parts with 50 mm nominal diameter, the lower deviation of the hole is zero and the higher is 5 microns. For the shaft lower and higher deviations are –8 and –4 microns respectively. Determine the allowance and type of fit of the assembly.



HL of hole = 50 + 0.005
= 50.005
LL of hole = 50.000
HL of shaft = 50.000 – 0.004 = 49.996 mm
LL of shaft: 50.000 – 0.008 = 49.992 mm
Allowance = LL of hole – HL of shaft
= 50.000 – 49.996
= 0.004 mm
(Clearance fit)

Example 8: Between two mating parts of 90 mm basic size the actual interference fit is to be from 0.05 mm to 0.12 mm. For shaft and hole tolerance is same. Determine the shaft size and hole size in hole basis unilateral system.



Solution:
LL of hole = 90.00 mm
HL of shaft = 90.000 + 0.12
= 90.12 mm
Tolerance of shaft = Tolerance of hole

$$= \frac{(0.12 - 0.05)}{2}$$

= 0.035 mm
∴ HL of hole = 90 + 0.035 = 90.035 mm
LL of shaft = 90.035 + 0.05 = 90.085 mm

∴ Size of shaft $= 90^{+0.12}_{+0.085}$

Size of hole = $= 90^{+0.035}_{+0.000}$

Example 9: Design the general GO and NO GO gauge for hole of the assembly 20 H7 f 8 fit. The following data can be used

(a) $i = 0.001\,D + 0.45\sqrt[3]{D}$ microns
(b) Upper deviation of f shaft
$= -5.5D^{0.41}$
(c) Diameter step for 20 mm
= 18 –30
(d) IT7 = 16i
(e) IT8 = 25i
(f) Wear allowance = 10% of gauge tolerance

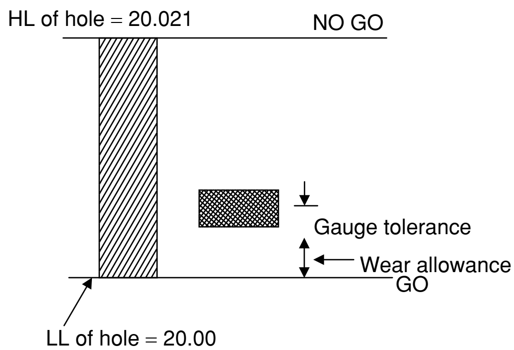
Solution:

$D = \sqrt{18 \times 30} = 23.24$ mm
$i = 0.001 \times 23.24 + 0.45\sqrt[3]{23.24}$
= 1.3074 microns

IT7 = 16 × i = 20.918 microns
= 0.021 mm
IT8 = 25 × i = 32.69 microns
= 0.033 mm
Upper deviation of shaft
= –5.5 × (23.24)0.41
= –20 microns
= –0.020 mm
Fundamental or lower deviation of hole = 0

∴ Limits for 20 H7 $= 20^{+0.021}_{+0.000}$

Limits for shaft f8
HL for shaft = 20 – 0.020
LL for shaft = 20 – 0.02 – 0.033 = 20 – 0.053



∴ Shaft limits are $20^{-0.020}_{-0.053}$

Tolerance for plug gauge for gauging the hole = 10% of work tolerance = 0.021 × 0.1 = 0.0021 mm
Wear allowance = 10% of gauge tolerance
= 0.1 × 0.0021
= 0.0002 mm
Upper limit of GO plug gauge = 20 + 0.0002 + 0.0021
= 20.0023 mm
Low limit of GO gauge = 20 + 0.0002 = 20.0002

Limits of GO gauge $= 20^{+0.0023}_{+0.0002}$

Linear and Angular Measurements

For linear measurements various standards followed are

1. Line standard
2. End standard
3. Wavelength standard

When length is measured between two engraved lines it is called line standard.

When length is expressed as the distance between two flat parallel faces, it is called end standard. In wavelength standard, wavelength of mono chromatic light is used as unit of length.

Imperial standard yard (England) and international standard meter (France) are line standards.

Metre in wavelength standard is defined as 1650763.73 wavelengths of orange radiation in vacuum of krypton 86 isotope.

Any system of measurement must be related to a known standard for maintaining uniformity of measurement throughout the world.

Standards can be classified as international standard, national standard, national reference standard working standard, Laboratory reference standard, Laboratory working standard and shop floor standard.

Linear Measurements

Linear measurement means measurement of lengths diameters, heights, thicknesses etc. It can be external or internal.

For linear measurements the instruments used are, non-precision instruments, precision instruments, comparators, measuring machines etc.

Non-precision instruments are steel rule, calipers, dividers, telescopic gauges, depth gauges etc

Precision instruments are micrometers, vernier calipers, height gauges, slip gauges etc.

Linear measuring instruments can also be classified as

1. Direct measuring instruments
2. Indirect measuring instruments

Direct measuring instruments can be graduated or non graduated.

Rules, vernier calipers, micrometers, dial indications etc are examples of graduated instruments.

Callipers, trammels, straight edges, wire gauges, screw pitch gauges, radius gauges, thickness gauges, slip gauges etc are examples of non-graduated instruments.

Callipers

Callipers are used when direct linear measurement is not possible. Callipers consist of two legs, hinged at top. The leg ends are used for measurement. For example measurement of diameter of a rod. Value of the measurement is obtained with the help of a rule. The hinge joint can be firm joint or spring loaded.

Outside Calliper, inside calliper, Transfer calliper and hermophrodite calliper are examples of callipers.

Hermophrodite calliper is also called odd leg calliper. This is a scribing tool having one leg bent and the other leg equipped with a scriber. This is used for scribing distances from the edge of a work piece. The curved leg has a notch at its end.

Surface Plate

Surface plate is a flat plate on which measurement of parts are carried out. They are used in workshops and metrological laboratories. Surface plate form a datum surface for testing flatness of surfaces.

V-block

V-blocks are used in workshops as a support for round shaped work pieces. The work pieces are placed on this *V*-shaped groove on top of the block. The angle of the groove is generally 90°. *V*-block is used for checking roundness of rods, marking centres accurately etc.

Straight Edge

Straight edges are used for checking straightness and flatness of work pieces with the help of spirit levels. Types of straight edges are

1. Tool maker's straight edge
2. Wide edged straight
3. Angle straight edge
4. Box straight edge

Spirit Level

Spirit levels are used for measuring small angles or inclinations, to determine position of a surface relative to horizontal position and for establishing horizontal datum.

In spirit level a sealed glass tube is mounted on a base. A scale is engraved on top of the glass tube. The tube contains ether or alcohol with a bubble. For measuring flatness or angle the position of the bubble is made use of

Frame Level

Frame level is used for checking vertical surfaces. In frame levels base and side edge is exactly at 90°. A glass tube with ether and bubble is fixed on the base. Side edge of the level is kept in contact with the vertical edge. Position of the bubble in the glass tube is noted for checking the verticality.

Vernier Instruments

Vernier instruments consists of a main scale and vernier scale. The vernier scale can be moved on the main scale. The difference between value of vernier scale division and a main scale division forms the basis for precision measurements. Vernier callipers and vernier height gauges are examples of vernier instruments. Least count of a vernier instrument is the difference in value of a vernier scale division and a main scale division. For example if the value of one main scale division is 0.5 mm and 24 main scale divisions coincide with 25 vernier scale divisions,

$$\begin{aligned}\text{Least count } &= \left[1-\frac{24}{25}\right]\times 0.5\\ &= \frac{1}{25}\times 0.5\\ &= \frac{1}{50}\text{ mm}\\ &= 0.02\text{ mm.}\end{aligned}$$

Main scale reading + coinciding division on the vernier scale × least count gives the measurement value.

Micrometers (Screw Gauges)

Micrometers are used when more accuracy in measurement is required. Least count of micrometers is in the order of 0.01 mm where as that of a vernier caliper is 0.02 mm. Micrometer works on the principle of a screw and nut. For one revolution of the screw in the nut the axial distance moved by it is equal to the pitch of the screw.

Micrometer consists of a U-shaped frame, spindle, barrel and thimble. By rotating the thimble on the barrel the spindle advances. The object to be measured is placed in between spindle end and an anvil at the end of the frame. Main scale is marked on the barrel. The thimble has equal divisions around its periphery, usually 50 nos. Therefore for rotation through one division of the thimble, axial distance moved is $\frac{1}{50} \times$ pitch of the screw.

If pitch of the screw corresponds to one division on the main scale and if it is 0.5 mm, the least count is $0.5 \times \frac{1}{50}$ = 0.01 mm.

Measurement value using a micrometer is obtained similar to that of a vernier calliper i.e Main scale reading + reading on the thimble × least count.

A comparator is a precision instrument used for comparing the dimension of a given component with a standard such as slip gauges. It does not measure the exact dimension, but indicates the difference from the basic dimension. Dial gauge is the simplest form of mechanical comparator. Apart from mechanical comparators, mechanical optical comparators, electrical and electronic comparators, pneumatic comparators etc are available.

Measuring machines are generally used for measurement of length over the outer faces of a length–bar or any other long member. These are generally used for measurement of considerably greater dimension.

Angular Measurements

Various instruments used for angular measurements are, bevel protractors, angle gauges, sinebars, clinometers, auto collimators etc.

Angle Gauges

Angle gauges are taper pieces of hardened and stabilized steel. The measuring pieces are lapped and polished to a high degree of accuracy and flatness. These pieces can be wrung together just like slip gauges. The pieces are 75 mm long and 16 mm wide. Angle gauges are generally available in 2 sets of 12 and 13 numbers and a square block. In the 13 piece set the following angles are available –

1°, 3°, 9°, 27°, 41°

1′, 3′, 9′, 27′

3″, 6″, 18″ , and 30″

In a 12 piece set all the above except 3″ is available.

Selecting and placing the gauge pieces one over the other different angles can be set for the measurement

Sine Bars

Sine bar is a precision instrument used along with slip gauges for the measurement of angles. Their general uses are

1. To measure angles very accurately
2. To locate a work to a given angle within very close limits

Sine bars are graded as A grade and B grade. A grade sinebars are made with an accuracy of 0.01 mm/m of length and B grade sine bars with an accuracy of 0.02 mm/m of length

Clinometers

Clinometer is a spirit level mounted as a rotary member carried in a housing. One face of the housing forms the base of the instrument. There is a circular scale on the housing. Clinometers can be used to measure the included angle between two adjacent slanted sides of a work piece.

Different types are vernier clinometers, micrometer clinometers and dial clinometers.

Comparators

A comparator is a precision instrument employed to compare the dimension of a given component with a standard, such as slip gauges. It does not measure the actual dimension but indicates how much it differs from the basic specimen. The indicated difference is usually small and suitable magnification device is provided.

Optimeters or Optical Comparators

In these comparators the fundamental optical law is made use of If a ray of light falls on a mirror and is reflected and the mirror is titled by an angle α, the reflected light moves through an angle 2α. In optimeters the mirror is titled by a measuring plunger movement and the movement of the reflected light is recorded as an image on a screen. The shadow of the object is projected on to a curved graduated scale to indicate in comparison measurement. Optical comparators which make use of the enlarged image principle are commonly known as optical projectors or optical projection comparators. Optical projector is used for checking the shape or profile of relatively small engineering components with an accurate standard or drawing. It enables a magnified image of part of a component to be projected on to a screen where it is compared with an enlarged profile drawing. The degree of magnification may range from five to hundred.

Tool Maker's Microscope

This is used for measurement of small and delicate parts. It is used for complex measurement of profile of external threads as well as tools, templates and gauges, centre to center distance of holes in a plane etc. and for accurate angular measurements.

Interferometry

The advantage and peculiar property of monochromatic light is that its wave length has precise value until the primary colours which have ill defined wavelengths and the monochromatic light such as from mercury 198 or krypton 86 are exactly reproducible.

For interference to occur, two conditions are necessary

1. Light rays are obtained by division from a single source
2. Rays before being combined at the eye must travel paths whose lengths differ by an odd number of half wavelengths.

For interference of light waves, the light should be from coherent sources. i.e., the two sources should continuously have light rays of same wavelength and equal intensity and maintain same phase differences. Further two sources should be very narrow and close to each other.

Optical Flat

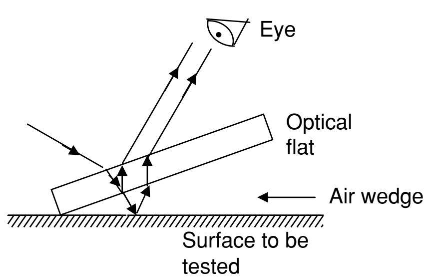
Optical flat is a circular piece of optical glass or fused quartz having its two plain faces flat and parallel and the surfaces are finished to an optical degree of flatness.

Optical flats are used to test flatness of lapped surfaces such gauge blocks, gauges, micrometer anvils etc. When an optical piece placed on a work piece surface, it will not be perfectly parallel to the surface, but will be at slight inclination to the surface, forming an air wedge between the surfaces.

When the optical flat is illuminated by monochromatic source of light interference fringes will be obtained. These are produced by the interference of light rays reflected from bottom face of optical flat and the top piece of the work piece. If they are in phase, it will result brightness. If the rays are out of phase, it will cause dark fringes. Each adjacent fringe represent a change in elevation by half wavelength.

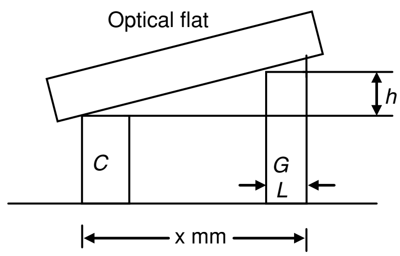
There are four possible cases, when the contact between optical flat and work surface is at one point only

1. If the surfaces are perfectly wrung together no air gap exist and no fringe pattern will be observed.
2. If angle is increased, fringes are brought closer together
3. If angle is decreased, fringes spacing increases.
4. When angle is made too large, then fringes will be closely spaced, as to be undistinguishable and no observable pattern will be visible.



Method of Checking Height of a Component with the Help of Optical Flat

By using an optical flat the height of a given component can be checked against a known standard.



The component C and the standard gauge block G are placed on a reference surface at a known distance x. The optical surface is placed over them as shown. The optical flat will be inclined at a small angle producing an air wedge. If N number of dark fringes are observed over the width L mm of the block G,

The difference in height

$$\boxed{h = \frac{\lambda}{2} \cdot \frac{xN}{L}}$$

Where λ = wavelength

If $x = 50$ mm

$L = 25$ mm

$N = 5$

$$\frac{\lambda}{2} = 0.000333909 \text{ mm}$$

$h = 0.00333909$ mm

Interferometers are optical instruments used for measuring flatness and determining the length of slip gauges. These are based on interference principle and employs wavelengths of light as measuring units. Disadvantages of a optical flat are overcome in this by providing refined arrangement

Screw Thread Measurement

Measurement of effective diameter.

Effective diameter is the most important of all thread elements. It plays a big role in perfect fitting of the mating threads.

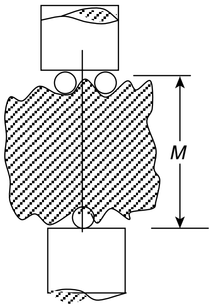
Effective diameter or pitch diameter is the diameter of an imaginary co-axial cylinder which intersects the flanks of the threads, such that the width of the threads (metal) and widths of the spaces between the threads are equal, each being-half the pitch.

Effective diameter can be measured by the following methods.

1. Thread micrometer method
2. One wire, two wire or three wire methods

Three Wire Method

In this method, three wires of equal and precise diameter are placed in the groves of the threads, two on one side and one on the other side and the outer distance M is measured.



Effective diameter = E

$$E = M - Q$$

Where M = Micrometer reading across the top of wires.

Q = a constant depending up on wire diameter and flank angle.

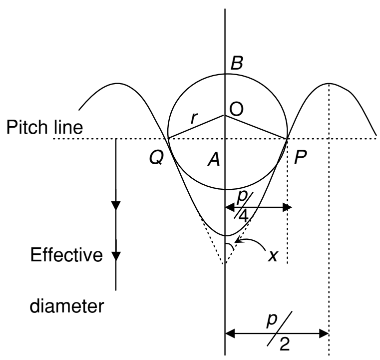
$= W(1 + \operatorname{cosec}\theta) - \dfrac{P}{2}\cot\theta$

Where W = wire diameter

P = pitch

Best Wire Size

Best size of wire is the size of wire of such diameter that it makes contact with the flanks of the thread on the pitch line. Depending up on the pitch the best wire size varies. Measured with any other wire size will include error in the measurement.



Line OP is perpendicular to the flank position of the thread.

Let x = half the included angle.

In triangle OAP

$$\text{Sin } POA = \frac{AP}{OP}$$

$$\text{i.e., } \sin(90 - x) = \frac{AP}{OP}$$

$$\therefore \quad OP = \frac{AP}{\sin(90 - x)} = \frac{AP}{\cos x} = AP\sec x$$

But $OP = r$, the radius of wire

∴ Best wire diameter

$$db = 2AP\sec x = 2\frac{p}{4}\sec x$$

$$\text{i.e., } \boxed{db = \frac{p}{2}\sec x}$$

Surface Finish Measurement

The irregularity on the surface which is in the form of hills and valleys varying in height and spacing are usually termed as surface roughness, surface finish, surface texture or surface quality. If the respective or random deviations from the nominal surface which forms pattern on the surface. Surface texture, includes roughness, waviness, lays and flaws.

Surface irregularities of small wavelength are called primary texture or roughness. These are caused by direct action of the cutting elements.

The surface irregularities of considerable wavelength of a periodic character are called secondary texture or waviness.

Lay is the predominant direction or pattern of the surface texture.

Flaws are surface irregularities or imperfections which occur at infrequent and at random intervals. Cracks, scratches, inclusions and similar defects are included in this.

Evaluation of Surface Finish

Surface finish is evaluated by the following methods.

1. Peak to valley height method
2. The average roughness
3. Form factor or bearing curves

Peak to Valley Height Method (R_t Measurement)

It is the maximum peak to valley height within the assessment length. The draw back of the method is that it may give same R_t value for two largely different texture.

Average Roughness

1. CLA method
2. RMS method
3. Ten point height method

CLA (Centre Line Average) Method

In this average values of ordinates from the mean line, regardless of the arithmetic signs of the ordinates (average deviations from the nominal surface) are measured

CLA value (R_a)

$$= \frac{h_1 + h_2 + h_3 + \cdots h_n}{n}$$

$$= \frac{A_1 + A_2 + A_3 + \cdots A_n}{L}$$

$$= \frac{\sum A}{L}$$

$= \dfrac{1}{L}\displaystyle\int_0^L |h|\,dx$ over 2 to 20 consecutive sampling lengths

RMS (Root Mean Square) Method

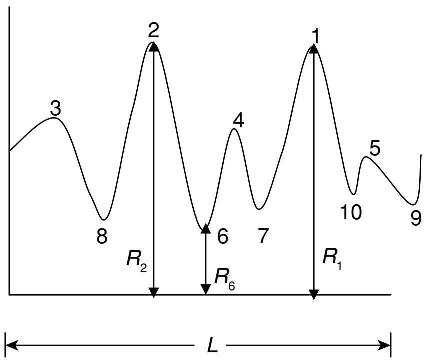
In this method also, the roughness is measured as the average deviations from the nominal surface.

$$\text{RMS value } = \sqrt{\frac{h_1^2 + h_2^2 + \cdots h_n^2}{n}}$$

$$= \sqrt{\frac{1}{L}\int_0^L h^2 dx}$$

Ten Point Height Method (R_z)

Ten point height of irregularities is defined as the average difference between the five highest peaks and five deepest valleys within the sampling length measured from a line, parallel to the mean line and not crossing the profile.



$$R_z = [(R_1 + R_2 + R_3 + R_4 + R_5) - (R_6 + R_7 + R_8 + R_9 + R_{10})] \times \frac{1}{5}$$

This method is relatively simple, but does not account for the frequency of the irregularities and profile shape. It is used when cost is to be controlled and for checking rough machining.

Computer Integrated Manufacturing System (CIMS)

CIMS is a production system consisting of a group of Numerical controlled (NC) machines connected together by an automated material handling system and operating under computer control. Many of the individual CAD/CAM technologies are incorporated in CIM. Other concepts incorporated in CIM are Computer Numerical control (CNC), Direct Numerical Control (DNC), Computer Aided Process planning (CAPP), Computer integrated production management and Industrial robots.

CIMS depend upon the production requirements. Each system vary according to the requirements.

Computer integrated manufacturing (CIM) is a recent technology. It comprises of a combination of software and hardware for product design, production planning, production control, production equipment and production process.

In a CIM system a group of NC machines are connected together by an automated material handling system and operating under computer control.

A computer integrated manufacturing system incorporate many of the individual CAD/CAM technologies and concepts such as

Computer numerical control or CNC

Direct Numerical control or DNC

Computer aided process planning CAPP

Computer integrated production management industrial roots.

Numerical Control

Numerical control (NC) refers to the operations of machine tools from numerical data. Data for operations may be stored on paper tape, magnetic tape, magnetic discs etc. As numerical information is used, it is called numerical control. Machine tools and other machines are operated by a series of loaded instructions. If the machine tool works with a built in computer controlling, the system is known computer numerical control (CNC)

The basic components of a NC system are

1. A program. i.e., a set of instructions
2. A machine control unit (MCU)
3. The machine tool

The MCU is further divided into two elements: The data processing unit (DPU) and control loops unit (CLU). Data process unit processes the coded data read from storage devices and passes information such as position of each axis, required direction of motion, speed, feed etc and auxiliary function control signals to CLU.

A typical program may contain an instruction like x + 100, y + 50, s + 90

This instruction is interpreted as to move a distance 100 mm in the x positive direction, 50 mm in the y + direction and rotate the spindle at 90 rpm clockwise.

The information pieces are decoded by the DPU and sent to CLU. The CLU operates the drive mechanisms as per the instructions, then receive feed back signals regarding the actual positions velocity etc. When one instruction is executed another is read.

Advantages of NC Systems

1. High machine utilization
2. Need for special tooling is mostly eliminated
3. High quality products can be manufactured
4. Consistency in quality
5. Quality is not dependent on operator skill
6. Cost of production is less
7. Minimum scrap
8. In process inventory is less
9. Higher productivity
10. Reduced set up time

Disadvantages of NC System

1. Initial investment is very high for the specialized equipment
2. Redundancy of labour
3. Down time is highly expensive
4. Special skill is required for programming and operating the equipment

CNC Retrofitting

Retrofitting means adding accessories to a given object to improve its performance. High initial investment of the CNC machines make it not affordable to small scale industries which are back bone of our economy. It is possible to modernize the existing conventional machines to CNC machines by adding accessories and making slight design modification. This is known as CNC retrofitting. Even though the retrofitted machines are not as good as CNC machines, their performance is far better than the original machines. So when there is a budgetary constraint retrofitting can be resorted to.

Direct Numerical Control (DNC)

DNC is a manufacturing system in which a number of machines are inter connected using a computer through direct connection in real time. In the case of NC or CNC systems one computer is used to control one machine tool. But in the case of DNC system one computer can be used to control more than 100 machines. One computer is designed to provide instructions to each machine tool on demand. The components of a DNC system are

1. Central computer
2. Bulk memory which stores the CNC programs
3. Tele communication lines
4. Machine tolls

In DNC, the computer calls the program instruction from bulk storage and sends to machines as the need arises. It also receives feed back from the machines.

DNC system has the main draw back that if the central computer goes down, all the machines become in operative. This draw back is overcome by using Distributed Numerical control system in place of direct numerical control. In this type even if there is a central computer, the individual NC machines are not directly controlled by this central computer. Each NC machine has its own dedicated on – board microcomputer just like a CNC system.

With the development of dedicated min- computers the benefits of DNC system can be realized in CNC system also.

More over with the availability of small computers with large memory, microprocessors and program editing capabilities CNC machines are widely used at present. Also the availability of low cost programmable logic controlled has helped in the successful implementation of CNC system.

Advantages of CNC System over Conventional NC System

1. As the computer can be easily and readily reprogrammed the system is very flexible. The machine can manufacture a part followed by other parts of different designs.
2. Editing and debugging programs, reprogramming and plotting and printing part shapes etc are simpler.
3. Manufacturing programme for a component can be easily called by computer.

This saves time and eliminates errors due to tape reading

4. Greater accuracy
5. Ease of operation
6. Trouble shooting is easier as the microprocessors have self diagnostic features.

Adaptive Control Systems (ACS)

ACS is a logical extension of CNC system in the sense that in CNC system operating conditions are specified by the user in the form of a program. But in ACS calculation and setting up of operating conditions like speed, feed, depth of cut etc are done during machining by the control system itself.

For example in drilling the torque on the drill is measured and feed and speed or both are adjusted within programmed limits . Adaptive control is still in its infancy, since the effect of various process variables on the finished part is still relatively unknown.

Basic Concepts of CAD and CAM

CAD/CAM means computer aided design and computer aided manufacturing. It is the technology concerned with the use of digital computers in design and production

Therefore CAD is the use of computer systems to assist in the creation, modification, analysis or optimization of a design.

CAM is the use of computer systems to plan, manage and control the operations of a manufacturing unit through direct or indirect computer interface with the plants production resources.

A digital computer is the essential ingredient of a CAD/CAM.

A digital computer can be used for image processing, real time process control and for solving complex problem in a few seconds.

A digital computer consists of the following three components

1. Central processing unit (CPU)
2. Memory
3. Input/output section

A modern CAD system can perform graphics and non-graphics is function. It is based on interactive computer graphics (ICG)

Computer Aided Process Planning (CAPP)

Process planning means the determination of the sequence of individual manufacturing operations required to produce a given part or product. In CAPP production planning is done with the use of computers. The operation sequence is documented on a route sheet. The advantages of CAPP are

1. Process rationalization
2. Increased productivity of process planners
3. Reduced turn around time
4. Improved legibility
5. Incorporation of other application programs.

Exercises

Practice Problems I

1. A 60 mm diameter shaft is made to rotate in a bush. Tolerances for both bush and shaft are 0.050 mm. The dimensions of the bush to give a minimum clearance of 0.075 in the shaft basis system is

(A) $60^{-0.075}_{-0.125}$ (B) $60^{+0.125}_{+0.075}$
(C) $59^{+0.125}_{+0.025}$ (D) $60^{-0.125}_{-0.075}$

2. The following is the hole and shaft dimensions of an assembly

Hole: $30^{+0.04}_{+0.00}$ mm

Shaft: $30^{+0.06}_{+0.04}$ mm

The type of fit is

(A) Transition (B) Clearance
(C) Interference (D) Running

3. In a hole and shaft assembly of 30 mm nominal size with following dimensions. Maximum and minimum (Least) metal limits of the shaft are

Hole: $30^{+0.02}_{-0.00}$ mm

Shaft: $30^{-0.040}_{-0.070}$ mm

(A) 29.960, 29.930 mm (B) 30.02, 30 mm
(C) 30.07, 30.04 mm (D) 29.950, 29.930 mm

4. A hole and mating shaft have nominal size of 50 mm. Maximum clearance is 0.15 mm and minimum clearance is 0.05 mm. Hole tolerance is 1.5 times the shaft tolerance. Limits for hole in a shaft basis system is

(A) 49.02, 49.08 mm (B) 51.04, 51.10 mm
(C) 49.05, 49.11 mm (D) 50.05, 50.11 mm

5. The interference between two mating parts of basic size 100 mm is to be from 0.05 mm to 0.12 mm. Tolerance of shaft and hole are same. The hole size in a shaft basis system is

(A) 100.035, 100.000 mm
(B) 100.020, 100.085 mm
(C) 100.00, 99.965 mm
(D) 99.915, 99.88 mm

6. A 25 mm H8 hole is to be checked using a plug gauge. The hole high limit is 25.030 mm. Taking gauge maker's tolerance as 10% of work tolerance dimensions of the GO plug gauge will be

(A) $25.000^{+0.003}_{-0.000}$ mm (B) $25.000^{+0.000}_{+0.003}$ mm
(C) $25.030^{+0.003}_{-0.000}$ mm (D) $25.030^{+0.000}_{-0.003}$ mm

7. A hole of size $30^{+0.05}_{-0.03}$ mm is to be checked by workshop GO and NO GO plug gauges. Assuming wear allowance and gauge allowance as 10% of work tolerance, size of the NO GO gauge will be

(A) $30^{+0.014}_{-0.022}$ mm (B) $30^{+0.014}_{+.0.014}$ mm
(C) $30^{-0.014}_{+.0.022}$ mm (D) $30^{-0.014}_{-.0.022}$ mm

8. Determine the size of the general type NO GO plug gauge for checking hole of a 30 H7/f8.

Given: $i = 0.453\sqrt{D} + 0.001D$ microns (D in mm)

Upper deviation of shaft = $-5.5\ D^{0.41}$

Diameter step for 30 mm = 18 – 30 mm

(A) $30^{-0.0231}_{-0.0231}$ (B) $30^{+0.0210}_{+0.0189}$
(C) $30^{+0.0231}_{+0.0210}$ (D) $30^{+0.0210}_{-0.0189}$

9. Cold drawn shafts upto accuracy ±0.01 mm are available. An interference fit is to be designed for a 50 mm basic size hole. Maximum and minimum interferences are 0.02 mm and 0.01 mm respectively. Tolerance for hole will be

(A) 0.04 mm (B) 0.06 mm
(C) 0.05 mm (D) 0.03 mm

10. For a 90 H8 *e*9 hole shaft assembly the GO gauge for shaft will be

(given:

IT8: 25*i*

T9: 40*i*

Fundamental deviation

For '*e*' type shaft

$= -11D^{0.41}$

(Assume hole basis system)

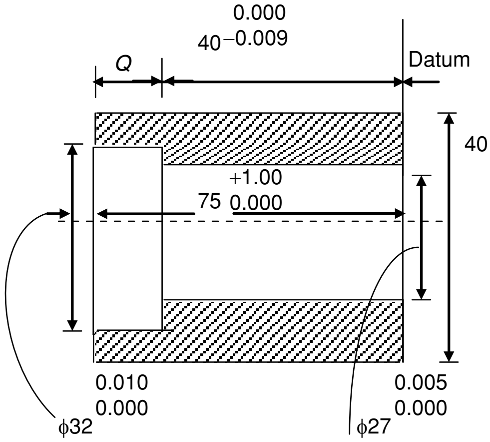
(A) $90^{0.0693}_{-0.677}$ (B) $90^{+0.0693}_{-0.0777}$
(C) $90^{+0.0693}_{+0.677}$ (D) $90^{-0.0693}_{-0.777}$

11. For the above problem the size of NO gauge for shaft will be

(A) $90^{+0.1524}_{-0.1608}$ (B) $90^{-0.1524}_{-0.1608}$

(C) $90^{+0.0693}_{-0.677}$ (D) $90^{+0.1524}_{-0.1608}$

Direction for questions 12 and 13:



Refer the figure given above
Given IT7 = 16i diameter steps for 40 mm = 30 and 50 mm.
Fundamental deviation
for *f* shaft = –5.5 $D^{0.41}$ micron

12. Size 40 *f* 7 will be

(A) $40^{+0.0245}_{+0.0494}$ (B) $40^{+0.0140}_{+0.0480}$

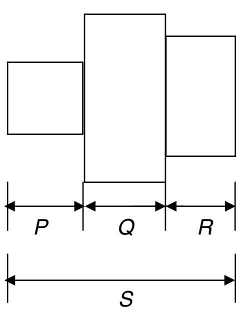
(C) $40^{-0.0245}_{-0.0494}$ (D) $40^{-0.0140}_{-0.0480}$

13. Dimension of length *Q* will be

(A) $34^{+0.009}_{-0.100}$ (B) $35^{+0.009}_{-0.100}$

(C) $34^{+0.100}_{-0.009}$ (D) $35^{0.100}_{+0.009}$ mm

14.



The part shown in figure is machined to the sizes given below:
$S = 35.00 \pm 0.08$ mm
$P = 12.00 \pm 0.02$ mm
$Q = 9.99 \pm 0.03$ mm
Dimension *R* will have specifications

(A) $13^{+0.04}_{-0.02}$ (B) $12^{+0.04}_{-0.02}$

(C) $13^{+0.04}_{-0.01}$ (D) $12^{+0.02}_{-0.04}$

15. In an interchangeable assembly shafts of size $30^{+0.040}_{-0.010}$ mm mates with holes of size $30^{+0.030}_{+0.020}$ The maximum interference in microns in the assembly is

(A) 16 microns
(B) 18 microns
(C) 22 microns
(D) 20 microns

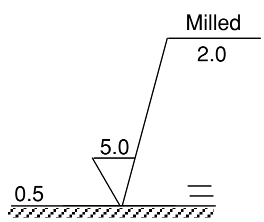
16. Two slip gauges of 10 mm width measuring 1.000 mm and 1.015 mm are kept side by side in contact with each other lengthwise. An optical flat is kept resting on them and inspected using monochromatic light of wavelength 0.0058928 mm. The total number of straight fringes that can be observed on both slip gauges will be

(A) 4 (B) 6
(C) 3 (D) 8

17. In surface roughness measurement for a sampling length of 0.8 mm, the graph is drawn to a vertical magnification of 15000 and horizontal magnification of 100 and areas above and below datum line are 160, 90, 170, 150 mm^2 respectively. CLA value for this surface is

(A) 0.6 µm (B) 0.9 µm
(C) 0.8 µm (D) 0.5 µm

18.



In a drawing the machined surface was represented as shown above. The machining allowance of the surface is

(A) 0.5 mm (B) 5.0 mm
(C) 2.0 mm (D) Not shown

19. Match the following:

P. Limits	1. Algebraic difference between the actual size and the corresponding basic size
Q. Fits	2. Permissible variation in size
R. Tolerance	3. Prescribed difference between the dimensions of mating parts to perform specific function
S. Allowance	4. The ranges of permissible variation in dimensions of a part.
	5. Degree of lightness and looseness between the mating parts

(A) P–4, Q–5, R–2, S–3 (B) P–2, Q–3, R–4, S–1
(C) P–3, Q–4, R–2, S–5 (D) P–1, Q–2, R–3, S–4

20. A sine bar was used to set up an angle with the help of slip gauges. Distance between roller centres is 100 mm. 4 slip gauges totalling a height of 54.464 mm was inserted below the top roller. The angle set up was
(A) 30° (B) 25°
(C) 33° (D) 15°

Practice Problems 2

1. Allowance and maximum clearance of a 30 H7/h8 fit will be
(A) 0.0054, 0.001 mm (B) 0,0.0054 mm
(C) 0.0054, 0.005 mm (D) 0,0.054 mm

2. It is possible to drill a 25 mm nominal size hole to an accuracy of $25^{+0.02}_{-0.02}$ mm using a standard drill. A shaft is to be machined to obtain a clearance fit in the above hole such that allowance should be 0.01 mm and maximum clearance should not be more than 0.08 mm. The tolerance on the shaft will be
(A) 0.04 mm (B) 0.05 mm
(C) 0.03 mm (D) 0.06 mm

3. A hole and shaft assembly has the following dimensions 50H8/C8. Multiplier for grade IT8 is 25. Fundamental deviation for shaft C for $D > 40$ mm is $(-95 + 0.8D)$ and diameter step for 50 mm is 50 to 80 mm. Maximum size of the shaft will be
(A) 49.8544 mm (B) 51.9072 mm
(C) 50.9623 mm (D) 48.8233 mm

4. For the shaft assembly 90 H8 e9 the minimum size of the shaft is
(Given: value of tolerance for IT8 = $25i$
IT9 = $40i$

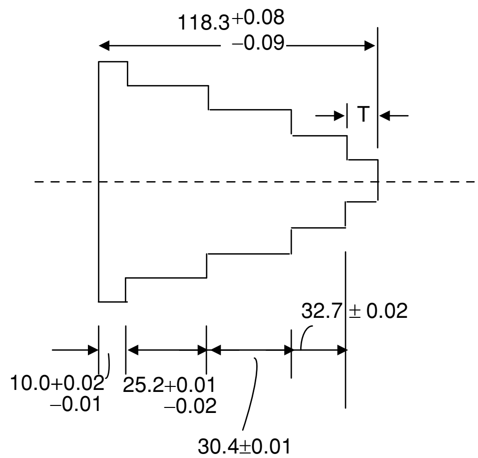
Value of fundamental deviation for 'e' type shaft = $-11D^{0.41}$
(A) 84.7476 mm (B) 86.7475 mm
(C) 92.3456 mm (D) 89.8476 mm

5. For the above problem GO plug gauge size will be
(A) $90^{+0.0005}_{-0.0057}$ (B) $90^{+0.0057}_{+0.0005}$
(C) $89^{+0.0057}_{+0.0005}$ (D) $89^{+0.0005}_{-0.0025}$

6. For the above problem NO GO plug gauge size will be
(A) $90^{+0.0576}_{-0.0524}$ (B) $90^{+0.0082}_{+0.0076}$
(C) $90^{+0.0576}_{+0.0524}$ (D) $90^{+0.0576}_{-0.0524}$

7. For a hole shaft assembly $60\dfrac{H-7}{m-6}$, the type of fit will be
(Diameter step for 60 mm = 50 to 80 mm.
Fundamental deviation for an shaft
$= +(\text{IT7} - \text{IT6})$
IT7 = $16i$
IT6 = $10i$
For i use the standard formula)
(A) Transition fit (B) Interference fit
(C) Clearance fit (D) Shrink fit

8.



In the above sketch the dimension T will be
(A) $19^{+0.02}_{-0.01}$ mm (B) $20^{+0.03}_{-0.02}$ mm
(C) $19^{+0.02}_{-0.03}$ mm (D) $20^{+0.02}_{-0.03}$ mm

9. In an interchangeable assembly shaft of size $20^{-0.040}_{-0.0100}$ mm mate with holes of size $20^{+0.020}_{-0.000}$. The minimum clearance in the assembly will be
(A) 10 microns (B) 15 microns
(C) 8 microns (D) 12 microns

10. GO and NO GO plug gauges are to be designed for a hole of $20^{+0.050}_{+0.010}$ mm. Gauge tolerance can be taken as 10% of the hole tolerance. Following ISO system of gauge design, sizes of GO and NO GO gauge will be respectively
(A) 20.134 mm, 20.164 mm
(B) 20.014 mm, 20.054 mm
(C) 21.123 mm, 21.136 mm
(D) 21.227 mm, 21.732 mm

11. An unknown specimen and a set of slip gauges are placed over flat surface at a distance x. Using cadmium light source of wave lengths 0.509 μm, and an optical flat about 4.75 fringes were observed over distance between the slip gauges and the specimen. Difference in height between them will be
(A) 1.3 μm (B) 1.1 μm
(C) 1.2 μm (D) 1.4 μm

12. A threaded nut having 2 mm pitch with a pitch diameter of 14.7 mm is to be checked for its pitch diameter using wires. Angle of threads is 60°. The diameter of wire used should be

(A) 1.155 mm (B) 2.255 mm
(C) 1.055 mm (D) 2.055 mm

13. Match the following:

Features to be inspected	Instrument
P. Pitches and angle errors of screw thread	1. Auto collimator
Q. latness error of surface	2. Optical interferometer
R. Alignment error of machine slide way	3. Deviding head and dial gauge
S. Profile of a cam	4. Spint level
	5. Sine bar
	6. Toolmaker's microscope

(A) P–2, Q–3, R–4, S–1 (B) P–3, Q–4, R–5, S–2
(C) P–4, Q–5, R–2, S–3 (D) P–5, Q–2, R–1, S–6

14. A shaft has a dimension, $\phi\ 40^{-0.008}_{-0.025}$. The respective values of fundamental deviation and tolerance are.
(A) –0.008, –0.025
(B) –0.008, –0.017
(C) –0.017, 0.008
(D) –0.017, +0.025

15. A hole is of dimension $\phi\ 90^{+0.018}_{+0.000}$ mm and the corresponding shaft is of dimension $9^{+0.012}_{+0.001}$ mm. When they are assembled they will form a
(A) Interference fit (B) Clearance fit
(C) Transition fit (D) Running fit

16. A 30 h7 shaft has the dimensional limits
(A) 30.000, 29.979
(B) 30.000, 30.021
(C) 30.000, 30.007
(D) 30.000, 29.993

17. Essential condition for an interference fit is that the lower limit of the shaft should be
(A) Lesser than upper limit of the hole
(B) Greater than the lower limit of the hole
(C) Lesser than the lower limit of the hole
(D) Greater than the upper limit of the hole

18. In measuring the surface roughness of an object, a graph was drawn to a vertical magnification of 10000 and a horizontal magnification of 100 and the areas above and below the datum lines were

Above	150	80	170	40 mm^2
Below	80	60	150	120 mm^2

The sampling length was 0.8 mm.

R_a value (CLA) of the surface is
(A) 0.08 μm (B) 1.53 μm
(C) 0.85 μm (D) 1.06 μm

Direction for questions 19 and 20: In the measurement of surface roughness, heights of 20 successive peaks and troughs were measured from a datum and these were
35, 25, 40, 20, 35
18, 42, 25, 35, 22
36, 18, 42, 22, 32
21, 37, 18, 35, 20 microns
These measurements were obtained over a length of 18 mm

19. Approximate CLA or R_a value will be
(A) 27 micron (B) 29 micron
(C) 31 micron (D) 26 micron

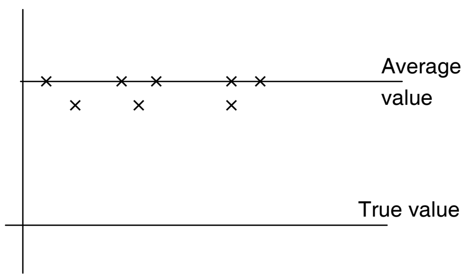
20. Approximate RMS value will be
(A) 29.32 micron (B) 32.73 micron
(C) 31.18 micron (D) 28.87 micron

21. In the measurement of surface roughness the height of 10 successive peaks and valleys over datum line over a specified sampling length were found to be

Peaks	45	42	40	35	35 mm
Valleys	30	25	25	24	18 mm

The R_z value of the surface will be
(A) 15 μm (B) 20 μm
(C) 12 μm (D) 18 μm

22. Figure given below shows the dimension obtained on a component by a certain instrument
The instrument is
(A) Precise but not accurate
(B) Accurate but not precise
(C) Neither precise nor accurate
(D) Sensitive



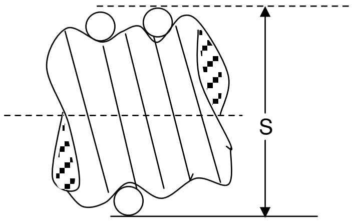
23. The reflector combined with auto collimater can be used for checking
(A) parallelism (B) Circularity
(C) Surface finish (D) Alignment

24. According to Taylor's principle, NO GO gauge checks
(A) Only important dimensions at a time
(B) All the dimensions at a time
(C) Only one feature at a time
(D) Only related dimensions at a time

25. Expressing a dimension as 42.5/42.3 mm is the case of
(A) Unilateral tolerance (B) Bilateral tolerance
(C) Limiting dimensions (D) None of the above

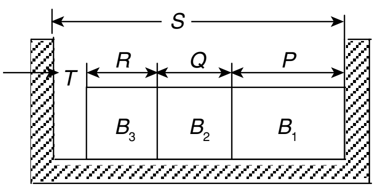
26. Most accurate instrument is
(A) Vernier caliper
(B) Screw gauge
(C) Slip gauge
(D) Optical projector

27. Figure shows 3 wire method of inspecting screw threads. The screw thread is ISO metric M 16 with pitch 2 mm and effective diameter = 14.701 mm. Diameter of roller used for measurement is 1.155 mm and corresponds to best wire diameter (i.e., touches at points of effective diameter)



Over write measurement S will be
(a) 17.6 mm (B) 18.8 mm
(C) 18.2 mm (D) 19.4 mm

28.



3 blocks B_1, B_2 and B_3 are to be inserted in a channel of width S maintaining a minimum gap of width T = 0.125 mm, as shown in figure. For $P = 18.75 \pm 0.08$, $Q = 15.00 \pm 0.12$, $R = 18.125 + 0.1$ and $S = 52.35 + x$ the tolerance x is
(A) –0.05 mm
(B) +0.05 mm
(C) –0.35 mm
(D) +0.35 mm

29. For measuring taper of a ring gauge, two balls of diameter 30 mm and 15 mm were used. During inspection the ball of 30 mm diameter was protruding by 2.5 mm above top surface of the ring. This surface was located at a height of 50 mm from the top of the 15 mm diameter ball. The taper of the angle is
(A) 25° (B) 20°
(C) 15° (D) 18°

30. A fits is specified as 25 H8/e8. The tolerance value for a basic diameter 25 mm in IT8 is 33 microns and fundamental deviation for the shaft is –40 microns. The maximum clearance of the fit in microns is
(A) 66 microns
(B) 73 microns
(C) 33 microns
(D) 106 microns

Previous Years' Questions

1. In an interchangeable assembly, shafts of size $25.000^{+0.040}_{-0.0100}$ mm mate with holes of size $25.000^{+0.020}_{-0.000}$ mm . the maximum possible clearance in the assembly will be **[2004]**
(A) 10 microns (B) 20 microns
(C) 30 microns (D) 60 microns

2. During the execution of a CNC part program block NO20 GO2 X45.0 Y25.0 R5.0 the type of tool motion will be **[2004]**
(A) circular interpolation – clockwise
(B) circular interpolation – counter clockwise
(C) linear interpolation
(D) rapid feed

3. GO and No-Go plug gages are to be designed for a hole $20.000^{+0.050}_{+0.010}$ mm. Gauge tolerances can be taken as 10% of the hole tolerance. Following ISO system of gauge design, sizes of GO and NO-GO gauge will be respectively **[2004]**
(A) 20.010 mm and 20.050 mm
(B) 20.014 mm and 20.046 mm
(C) 20.006 mm and 20.054 mm
(D) 20.014 mm and 20.054 mm

4. In a 2-D CAD package, clockwise circular arc of radius 5, specified from $P_1(15,10)$ to $P_2(10, 15)$ will have its center at **[2004]**
(A) (10, 10) (B) (15, 10)
(C) (15, 15) (D) (10, 15)

5. Match the following: **[2004]**

Feature to be Inspected	Instrument
P. Pitch and Angle errors of screw thread	1. Auto Collimator
Q. Flatness error of a Surface plate	2. Optical Interferometer
R. Alignment error of a machine slideway	3. Dividing Head and Dial gauge
S. Profile of cam	4. Spirit Level
	5. Sine bar
	6. Tool makes's microscope

(A) P-6 Q-2 R-4 S- 6 (B) P-6 Q-4 R-1 S-3
(C) P-5 Q-2 R-1 S-6 (D) P-1 Q-4 R-4 S-2

6. In order to have interference fit, it is essential that the lower limit of the shaft should be **[2005]**
(A) greater than the upper limit of the hole
(B) lesser than the upper limit of the hole
(C) greater than the lower limit of the hole
(D) lesser than the lower limit of the hole

7. The tool of an NC machining has tomove along a circular arc from (5, 5) to(10, 10) while performing an operation. The center of the arc is at (10, 5). Which one of the following NC tool path commands performs the above mentioned operation? **[2005]**
(A) N010 G02 X10 Y10 X5 Y5 R5
(B) N010 G03 X10 Y10 X5 Y5 R5
(C) N010 G01 X5 Y5 X10 Y10 R5
(D) N010 G02 X5 Y5 X10 Y10 R5

8. Which among the NC operations given below are continuous path operations? **[2005]**

Arc welding (AW)	Milling (M)
Drilling (D)	Punching in sheet metal (P)
Laser cutting of Sheet Metal(LC)	Spot welding (SW)

(A) AW, LC and M
(B) AW, D, LC and M
(C) D, LC, P and SW
(D) D, LC and SW

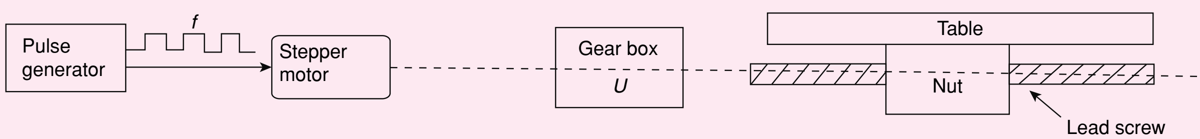
9. NC contouring is an example of **[2006]**
(A) continuous path positioning
(B) point-to-point positioning
(C) absolute positioning
(D) incremental positioning

10. A ring gauge is used to measure **[2006]**
(A) outside diameter but not roundness
(B) roundness but not outside diameter
(C) both outside diameter and roundness
(D) only external threads

11. Which type of motor is **NOT** used in axis or spindle drives of CNC machine tools? **[2007]**
(A) induction motor (B) dc servo motor
(C) stepper motor (D) linear servo motor

12. A hole is specified as $40^{0.050}_{0.00}$ mm. The mating shaft has a clearance fit with minimum clearance of 0.01 mm. The tolerance on the shaft is 0.04 mm. The maximum clearance in mm between the hole and the shaft is **[2007]**
(A) 0.04 (B) 0.05
(C) 0.10 (D) 0.11

Direction for questions 13 and 14:



In the feed drive of a Point–to–Point open CNC drive, a stepper motor rotating at 200 steps/rev drives a table through a gear box and lead screw-nut mechanism (pitch = 4 mm, number of starts = 1). The gear ratio = $=\left(\dfrac{\text{Output rotational speed}}{\text{Input rotational speed}}\right)$ is given by U $=\dfrac{1}{4}$. The stepper motor (driven by voltage pulses from a pulse generator) executes 1 step/pulse of the pulse generator. The frequency of the pulse train from the pulse generator is f = 10,000 pulses per minute.

13. The Basic Length Unit (BLU), i.e., the table movement corresponding to 1 pulse of the pulse generator, is **[2008]**
(A) 0.5 microns
(B) 5 microns
(C) 50 microns
(D) 500 microns

14. A customer insists on a modification to change the BLU of the CNC drive to 10 microns without changing the table speed. The modification can be accomplished by **[2008]**
(A) Changing U to $\dfrac{1}{2}$ and reducing f to $\dfrac{f}{2}$
(B) Changing U to $\dfrac{1}{8}$ and increasing f to $2f$
(C) Changing U to $\dfrac{1}{2}$ and keeping f unchanged
(D) Keeping U unchanged and increasing f to $2f$

15. Which of the following is the correct data structure for solid models? **[2009]**
(A) solid part → faces → edges → vertices
(B) solid part → edges → faces → vertices
(C) vertices → edges → faces → solid parts
(D) vertices → faces → edges → solid parts

16. Match the following: **[2009]**

NC Code	Definition
P M05	1. Absolute coordinate system
Q G01	2. Dwell
R G04	3. Spindle stop
S G90	4. Linear interpolation

(A) P-2, Q-3, R-4, S-1
(B) P-3, Q-4, R-1, S-2
(C) P-3, Q-4, R-2, S-1
(D) P-4, Q-3, R-2, S-1

17. What are the upper and lower limits of the shaft represented by 60 f_8?
Use the following data:
Diameter 60 lies in the diameter step of 50–80 mm
Fundamental tolerance unit, i, in mm = $0.45D^{1/3} + 0.001D$, where D is the representative size in mm;
Tolerance value for IT8 = 25i. Fundamental deviation for 'f' shaft = $-5.5D^{0.41}$ **[2009]**

(A) Lower limit = 59.924 mm, Upper Limit = 59.970 mm
(B) Lower limit = 59.954 mm, Upper Limit = 60.000 mm
(C) Lower limit = 59.970 mm, Upper Limit = 60.016 mm
(D) Lower limit = 60.000 mm, Upper Limit = 60.046 mm

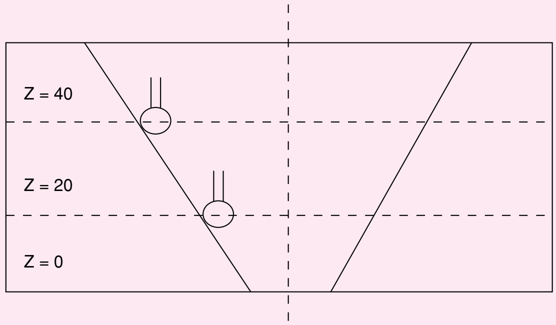
18. A shaft has a dimension, $\phi 35^{-0.009}_{-0.025}$. The respective values of fundamental deviation and tolerance are **[2010]**

(A) −0.025, ±0.008
(B) −0.025, 0.016
(C) −0.009, ±0.008
(D) −0.009, 0.016

19. In a CNC program block, N002 G02 G91 X40 Z40…, G02 AND G91 refer to **[2010]**

(A) circular interpolation in counterclockwise direction and incremental dimension
(B) circular interpolation in counterclockwise direction and absolute dimension
(C) circular interpolation in clockwise direction and incremental dimension
(D) circular interpolation in clockwise direction and absolute dimension

20. A taper hole is inspected using a CMM, with a probe of 2 mm diameter. At a height, $Z = 10$ mm from the bottom, 5 points are touched and a diameter of circle (not compensated for probe size) is obtained as 20 mm. Similarly, a 40 mm diameter is obtained at a height $Z = 40$ mm. The smaller diameter (in mm) of hole at $Z = 0$ is **[2010]**



(A) 13.334 (B) 15.334
(C) 15.442 (D) 15.542

21. A hole is of dimension $\phi 9^{+0.015}_{+0}$ mm. . The corresponding shaft is of dimension $\phi 9^{+0.010}_{+0.001}$ mm. The resulting assembly has **[2011]**

(A) loose running fit (B) close running fit
(C) transition fit (D) interference fit

22. In an interchangeable assembly, shafts of size $25.000^{+0.040}_{-0.020}$ mm mate with holes of size $25.000^{+0.030}_{-0.020}$ mm. The maximum interference (in microns) in the assembly is **[2012]**

(A) 40 (B) 30 (C) 20 (D) 10

23. A metric thread of pitch 2 mm and thread angle 60° is inspected for its pitch diameter using 3-wire method. The diameter of the best size wire in mm is **[2013]**

(A) 0.866 (B) 1.000
(C) 1.154 (D) 2.000

24. Cylindrical pins of $25^{+0.020}_{+0.010}$ mm diameter are electroplated in a shop. Thickness of the plating is $30^{\pm 2.0}$ micron. Neglecting gauge tolerances, the size of the GO gauge in mm to inspect the plated components is **[2013]**

(A) 25.042 (B) 25.052
(C) 25.074 (D) 25.084

25. In a CAD package, mirror image of a 2D point P(5,10) is to be obtained about a line which passes through the origin and make an angle of 45° counterclockwise with the x-axis. The coordinates of the transformed point will be **[2013]**

(A) (7.5, 5) (B) (10, 5)
(C) (7.5, –5) (D) (10, –5)

26. For machining a rectangular island represented by coordinates $P(0, 0)$, $Q(100, 0)$, $R(100, 50)$ and $S(0, 50)$ on a casting using CNC milling machine, an end mill with a diameter of 16 mm is used. The trajectory of the cutter centre to machine the island $PQRS$ is **[2014]**

(A) (–8, –8), (108, –8), (108, 58), (–8, 58), (–8, –8)
(B) (8, 8), (94, 8), (94, 44), (8, 44), (8, 8)
(C) (–8, 8), (94, 0), (94, 44), (8, 44), (–8, 8)
(D) (0, 0), (100, 0), (100, 50), (50, 0), (0, 0)

27. Which one of the following instruments is widely used to check and calibrate geometric features of machine tools during their assembly? **[2014]**
(A) Ultrasonic probe
(B) Coordinate Measuring Machine (CMM)
(C) Laser interferometer
(D) Vernier callipers

28. For the given assembly : 25 H7/g8, match Group A with Group B **[2014]**

Group A		Group B	
(P)	H	(I)	Shaft Type
(Q)	IT8	(II)	Hole Type
(R)	IT7	(III)	Hole Tolerance Grade
(S)	g	(IV)	Shaft Tolerance Grade

(A) P-I, Q-III, R-IV, S-II
(B) P-I, Q-IV, R-III, S-II
(C) P-II, Q-III, R-IV, S-I
(D) P-II, Q-IV, R-III, S-I

29. The flatness of a machine bed can be measured using **[2014]**
(A) Vernier callipers
(B) Auto collimator
(C) Height gauge
(D) Tool maker's microscope

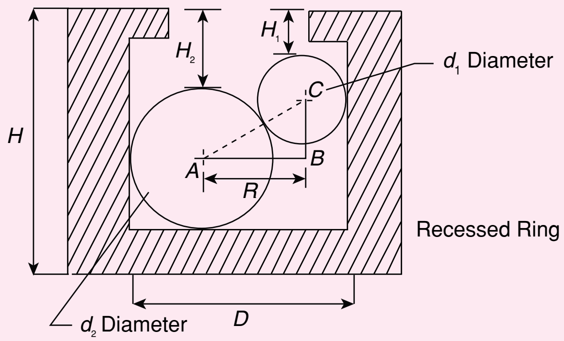
30. A robot arm PQ with end coordinates $P(0, 0)$ and $Q(2, 5)$ rotates counter clockwise about P in the XY plane by 90°. The new coordinate pair of the end point Q is **[2014]**
(A) (–2, 5) (B) (–5, 2)
(C) (–5, –2) (D) (2, –5)

31. For the CNC part programming, match Group A with Group B : **[2014]**

Group A		Group B	
(P)	circular interpolation, counter clockwise	(I)	G02
(Q)	dwell	(II)	G03
(R)	circular interpolation, clockwise	(III)	G04
(S)	point to point countering	(IV)	G00

(A) P-II, Q-III, R-I, S-IV
(B) P-I, Q-III, R-II, S-IV
(C) P-I, Q-IV, R-II, S-III
(D) P-II, Q-I, R-III, S-IV

32. The diameter of a recessed ring was measured by using two spherical balls of diameter $d_2 = 60$ mm and $d_1 = 40$ mm as shown in the figure. **[2014]**



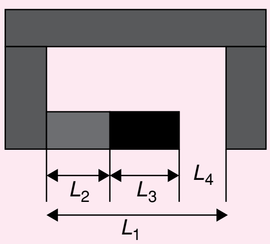
The distance $H_2 = 35.55$ mm and $H_1 = 20.55$ mm. The diameter (D, in mm) of the ring gauge is ____

33. A GO–No GO plug gauge is to be designed for measuring a hole of nominal diameter 25 mm with a hole tolerance of ±0.015 mm. Considering 10% of work tolerance to be the gauge tolerance and no wear condition, the dimension (in mm) of the GO plug gauge as per the unilateral tolerance system is **[2014]**
(A) $24.985^{+0.003}_{-0.003}$ (B) $25.015^{+0.000}_{-0.006}$
(C) $24.985^{+0.03}_{-0.03}$ (D) $24.985^{+0.003}_{-0.000}$

34. Holes of diameter $25.0^{+0.040}_{+0.020}$ mm are assembled interchangeably with the pins of diameter $25.0^{+0.005}_{-0.008}$ mm. The minimum clearance in the assembly will be: **[2015]**
(A) 0.048 mm (B) 0.015 mm
(C) 0.005 mm (D) 0.008 mm

35. The function of interpolator in a CNC machine controller is to **[2015]**
(A) control spindle speed
(B) coordinate feed rates of axes
(C) control tool rapid approach speed
(D) perform Miscellaneous (M) functions (tool change, coolant control etc.)

36. In the assembly shown below, the part dimensions are: **[2015]**
$L_1 = 22.0 \pm 0.01$ mm,
$L_2 = L_3 = 10.0 \pm 0.005$ mm.
Assuming the normal distribution of part dimensions, the dimension L_4 in mm for assembly condition would be:



(A) 2.0±0.008 (B) 2.0±0.012
(C) 2.0±0.016 (D) 2.0±0.020

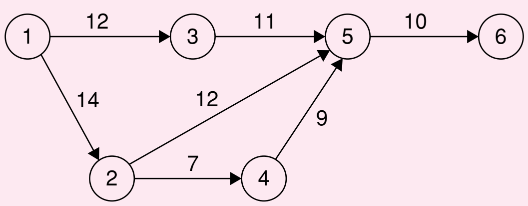
37. A triangular facet in a CAD model has vertices: $P_1(0,0,0)$; $P_2(1,1,0)$ and $P_3(1,1,1)$. The area of the facet is: **[2015]**

(A) 0.500 (B) 0.707
(C) 1.414 (D) 1.732

38. Which one of the following statements is TRUE? **[2015]**

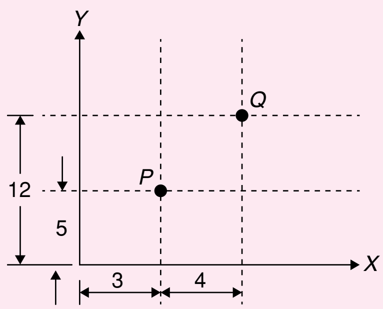
(A) The 'GO' gage controls the upper limit of a hole.
(B) The 'NO GO' gage controls the lower limit of a shaft.
(C) The 'GO' gage controls the lower limit of a hole.
(D) The 'NO GO' gage controls the lower limit of a hole.

39. A project consists of 7 activities. The network along with the time durations (in days) for various activities is shown in the figure.



The minimum time (in days) for completion of the project is _______. **[2015]**

40. A drill is positioned at point P and it has to proceed to point Q. The coordinates of point Q in the incremental system of defining position of a point in CNC part program will be **[2015]**



(A) (3, 12) (B) (5, 7)
(C) (7, 12) (D) (4, 7)

41. In a CNC milling operation, the tool has to machine the circular arc from point (20, 20) to (10, 10) at a sequence number 5 of the CNC part program. If the center of the arc is at (20, 10) and the machine has incremental mode of defining position coordinates, the correct tool path command is: **[2015]**

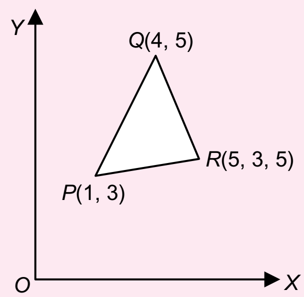
(A) N 05 G90 G01 X-10 Y-10 R10
(B) N 05 G91 G03 X-10 Y-10 R10
(C) N 05 G90 G03 X20 Y20 R10
(D) N 05 G91 G02 X20 Y20 R10

42. Match the following: **[2016]**

P. Feeler gauge	**I.** Radius of an object
Q. Fillet gauge	**II.** Diameter within limits by comparison
R. Snap gauge	**III.** Clearance or gap between components
S. Cylindrical plug gauge	**IV.** Inside diameter of straight hole

(A) P-III, Q-I, R-II, S-IV
(B) P-III, Q-II, R-I, S-IV
(C) P-IV, Q-II, R-I, S-III
(D) P-IV, Q-I, R-II, S-III

43. The figure below represents a triangle PQR with initial coordinates of the vertices as $P(1, 3)$, $Q(4, 5)$ and $R(5, 3, 5)$. The triangle is rotated in the X-Y plane about the vertex P by angle θ in clockwise direction. If $\sin\theta = 0.6$ and $\cos\theta = 0.8$, the new coordinates of the vertex Q are: **[2016]**

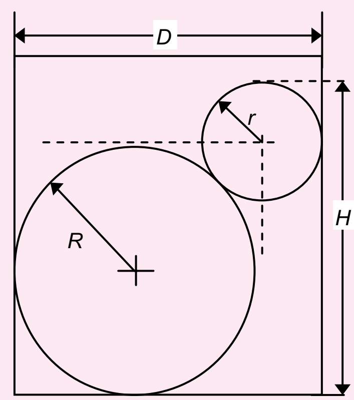


(A) (4.6, 2.8) (B) (3.2, 406)
(C) (7.9, 5.5) (D) (5.5, 7.9)

44. For the situation shown in the figure below the expression for H in terms of r, R and D is : **[2016]**

(A) $H = D + \sqrt{r^2 + R^2}$

(B) $H = (R + r) + (D + r)$



(C) $H = (R + r) + \sqrt{D^2 - R^2}$

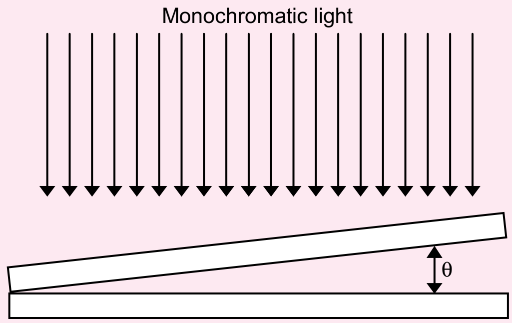
(D) $H = (R + r) + \sqrt{2D(R+r) - D^2}$

45. Match the following part programming codes with their respective functions: **[2016]**

Part Programming Codes	Functions
P. G01	**I.** Spindle stop
Q. G03	**II.** Spindle rotation, clockwise
R. M03	**III.** Circular interpolation, anticlockwise
S. M05	**IV.** Linear interpolation

(A) P–II, Q–I, R–IV, S–III
(B) P–IV, Q–II, R–III, S–I
(C) P–IV, Q–III, R–II, S–I
(D) P–III, Q–IV, R–II, S–I

46. Two optically flat plates of glass are kept at a small angle θ as shown in the figure. Monochromatic light is incident vertically.



If the wavelength of light used to get a fringe spacing of 1 mm is 450 nm, the wavelength of light (in mm) to get a fringe spacing of 1.5 mm is ________. **[2016]**

47. A point P (1, 3, –5) is translated by $2\hat{i}+3\hat{j}-4\hat{k}$ and then rotated counter clockwise by 90º about the z-axis. The new position of the point is: : **[2016]**

(A) (–6, 3, –9) (B) (–6, –3, –9)
(C) (6, 3, –9) (D) (6, 3, 9)

Answer Keys

Exercises

Practice Problems 1

1. B	**2.** C	**3.** A	**4.** D	**5.** D	**6.** B	**7.** D	**8.** C	**9.** A	**10.** D
11. B	**12.** C	**13.** D	**14.** A	**15.** D	**16.** B	**17.** C	**18.** A	**19.** A	**20.** C

Practice Problems 2

1. B	**2.** C	**3.** A	**4.** D	**5.** B	**6.** C	**7.** A	**8.** D	**9.** A	**10.** B
11. C	**12.** A	**13.** D	**14.** B	**15.** C	**16.** A	**17.** D	**18.** D	**19.** B	**20.** A
21. A	**22.** A	**23.** D	**24.** C	**25.** C	**26.** D	**27.** C	**28.** A	**29.** B	**30.** D

Previous Years' Questions

1. D	**2.** A	**3.** D	**4.** C	**5.** C	**6.** A	**7.** A	**8.** B	**9.** A	**10.** A
11. C	**12.** C	**13.** B	**14.** D	**15.** C	**16.** C	**17.** A	**18.** D	**19.** C	**20.** A
21. C	**22.** C	**23.** C	**24.** D	**25.** B	**26.** A	**27.** C	**28.** D	**29.** B	**30.** B
31. A	**32.** 91 to 94		**33.** D	**34.** B	**35.** B	**36.** D	**37.** B	**38.** C	
39. 39 to 40		**40.** D	**41.** B	**42.** A	**43.** A	**44.** D	**45.** C	**46.** 675	**47.** A

Test

Manufacturing Technology

Time: 60 Minutes

Direction for questions 1 to 25: Select the correct alternative from the given choices

1. The condition for interference fit is that the lower limit of the shaft
   (A) Should be greater than the upper limit of the hole
   (B) Should be greater than the lower limit of the hole
   (C) Should be less than the upper limit of the hole
   (D) Should be less than the lower limit of the hole
2. In an assembly of shaft and hole, shaft size is specified as

   $$20^{+0.010}_{-0.040} \text{ mm and hole size as } 20^{-0.000}_{+0.020} \text{ mm.}$$

   The maximum clearance possible in the assembly
   (A) 20 microns (B) 30 microns
   (C) 40 microns (D) 10 microns
3. Cold working of steel means:
   (A) Mechanical working of steel below the lower critical temperature
   (B) Mechanical working of steel below the recrystallisation temperature
   (C) Mechanical working below 2/3 of the melting temperature
   (D) Mechanical working of steel below the upper critical temperature
4. In punching operation the clearance is given:
   (A) On the die
   (B) On the punch
   (C) In the die or punch
   (D) In the die and the punch
5. From a sheet metal of thickness 1 mm a cup of diameter 30 mm and height 150 mm is to be drawn. If limiting draw ratio is 1.8, the number of draws required are
   (A) 2 (B) 3 (C) 4 (D) 5
6. A lead plate is mechanically worked at room temperature. It is
   (A) A cold working process
   (B) A hot working process
   (C) Neither hot working nor cold working
   (D) It is not defined
7. A metal having recrystallisation temperature T_A is cold worked. The recrystallisation temperature of this cold worked item is T_A'. Then
   (A) $T_A = T_A'$ (B) $T_A > T_A'$
   (C) $T_A < T_A'$ (D) Cannot say from this data
8. A rolling mill has rollers of 400 mm diameter. The coefficient of friction is 0.15. In order to reduce the thickness from 150 mm to 10 mm for a strip, the number of passes required are
   (A) 4 (B) 5
   (C) 6 (D) 7
9. Consider tungsten, aluminium, copper and titanium. If they are arranged in the decreasing order of magnitude of forgeability
   (A) Copper, tungsten, aluminium, titanium
   (B) Aluminium, titanium, tungsten, copper
   (C) Aluminium, titanium, copper, tungsten
   (D) Aluminium, copper, titanium, tungsten
10. The pattern allowance for a cylindrical casting of diameter 100 mm and length 150 mm is specified as follows: shrinkage allowance is 2 in 50 and machining allowance is 2 mm/side. The pattern size is
    (A) $d = 110.16$ mm, $d = 170.16$ mm
    (B) $d = 715.32$ mm, $d = 178.56$ mm
    (C) $d = 108.16$ mm, $d = 160.16$ mm
    (D) $d = 112.5$ mm, $d = 163.52$ mm
11. Which of the following gating ratio indicates a pressurised system
    (A) 4:8:3 (B) 1:3:3
    (C) 1:2:4 (D) 3:3:4
12. If 'α' is the rate rake angle of the tool and 'ϕ' the shear angle, then shear strain 'ε' is given by
    (A) $\varepsilon = \cot(\phi - \alpha) + \tan\phi$
    (B) $\varepsilon = \cos(\phi - \alpha) + \tan\phi$
    (C) $\varepsilon = \cos(\phi - \alpha) + \cot\phi$
    (D) $\varepsilon = \tan(\phi - \alpha) + \cot\phi$
13. When chip thickness ratio is 1 and tool rake angle is 12°, shear angle is equal to
    (A) 33° (B) 51°
    (C) 57° (D) 62°
14. 18–4–1 High speed tool steel has the following composition
    (A) 18% molybdenum, 4% tungsten, 1% vanadium
    (B) 18% tungsten, 4% chromium, 1% vanadium
    (C) 18% molybdenum, 4% chromium, 1% cobalt
    (D) 18% tungsten, 4% molybdenum, 1% cobalt
15. Ceramic tools generally have
    (A) Positive rake angle
    (B) Negative rake angle
    (C) Zero rake angle
    (D) Zero or positive rake angle

16. Aspiration effect in gating system is
(A) Due to pressure difference, air flows from the gating system to outside
(B) It is the intake of air from outside atmosphere to the gate due to pressure difference
(C) It is the oxidation of molten metal during pouring
(D) It is the purposeful admission of air into the mould

17. Non-consumable electrodes are used in
(A) TIG welding
(B) MIG welding
(C) Submerged arc welding
(D) Resistance projection welding

18. Two cutting tools are designated as
A: 5, 6, 8 – 3 – 7 – 25 –0.2 mm
B: 5 – 6 – 8 – 3 – 5 – 30 – 0.2 mm
For the same speed and feed, which of the cutting tool gives better surface finish
(A) B has better surface finish
(B) A produces better surface finish
(C) Both A & B give the same surface finish
(D) Data is insufficient

19. Out of the following cutting tools, the one which is hardest next to diamond
(A) Cemented carbide (B) HSS
(C) Cubic boron nitride (D) Ceramics

20. In orthogonal cutting operation the cutting force and thrust force are 950 N and 450 N respectively. The rake angle is zero. The coefficient of friction is
(A) 0.21 (B) 0.32
(C) 0.4 (D) 0.47

21. Two grades of tools (A and B) are used to machine a steel piece. The cutting speed per minute of tool life is 80 for the first tool (A) and cutting speed per minute of tool life for second tool (B) is 100. If Tailors index for first tool (A) is 0.2 and that for second tool (B) is 0.25, the tool which is giving maximum tool life is
(A) Tool A (B) Tool B
(C) Both A & B (D) Data is insufficient

22. During a machining process with 12° rake tool, the chip thickness ratio is found to be 0.4. The shear angle is
(A) 23.1° (B) 31.2°
(C) 34.5° (D) 36.2°

23. In an operation the ratio between thrust force and cutting force is found to be 2.8. Then the operation is
(A) Drilling (B) Turning
(C) Grinding (D) Milling

Direction for questions 24 and 25:
A cylindrical rod of 120 mm diameter is forged from 60 mm height to 40 mm height at 900°C. The flow stress of the material is 75 MPa

24. The work of deformation will be
(A) 51 kNm (B) 61 kNm
(C) 71 kNm (D) 81 kNm

25. If a drop hammer weighing 16 kN is used for forging to be done in one blow, the height of fall for the hammer is
(A) 2.5 m (B) 3.2 m
(C) 4.8 m (D) 5.6 m

Answer Keys

1. A	**2.** B	**3.** B	**4.** A	**5.** B	**6.** B	**7.** B	**8.** C	**9.** D	**10.** C
11. A	**12.** D	**13.** B	**14.** B	**15.** B	**16.** B	**17.** A	**18.** A	**19.** C	**20.** D
21. A	**22.** A	**23.** C	**24.** A	**25.** B					