PHYSICAL PROPERTIES OF BIOMATERIALS LIKE SHAPE, SIZE, VOLUME AND SURFACE AREA

Lecture 3 & 4

PFE-2.4.5

By:

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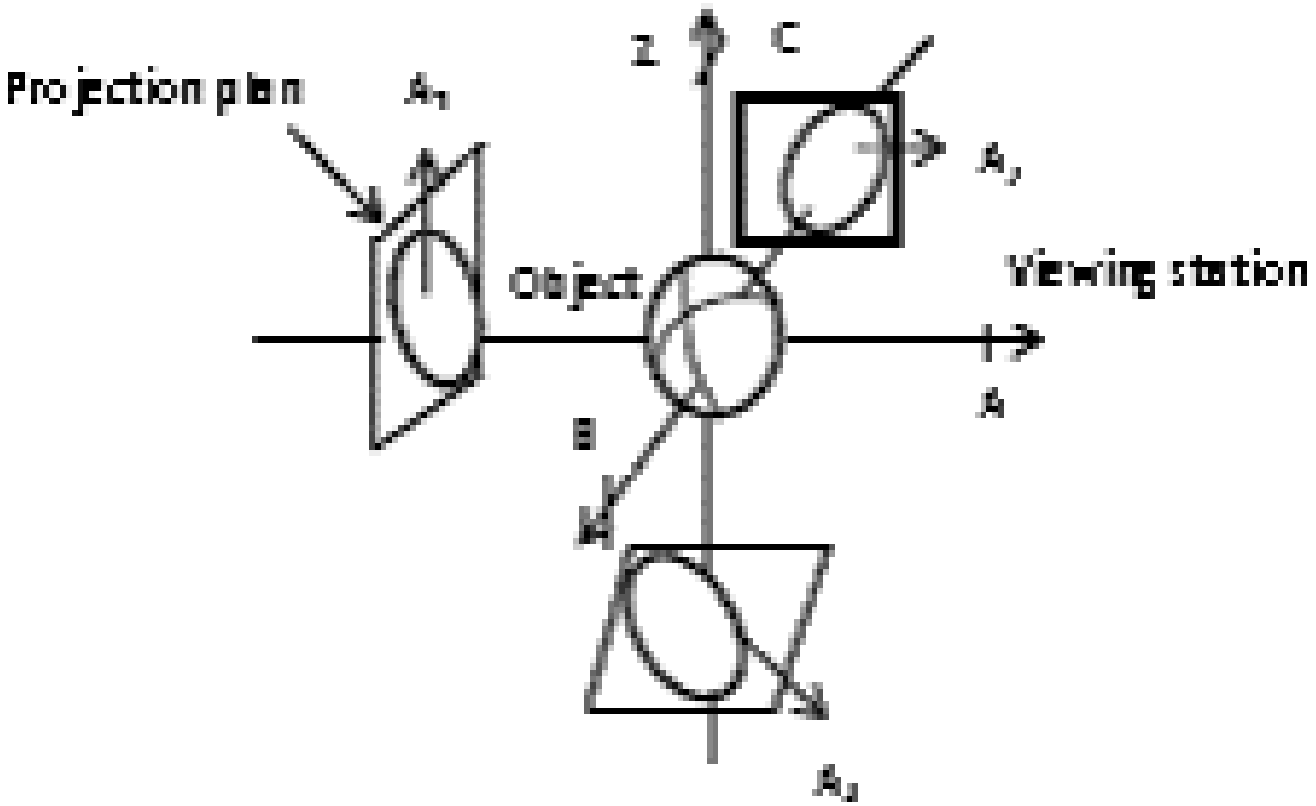
SIZE

- Size is an important physical attribute of foods used in **screening** solids to separate foreign materials**, grading** of fruits and vegetables, and evaluating the **quality** of food materials.
- **Sorting of fresh market** - Pattern packing, higher packing density
- Modern or on-line fruit/ vegetables/ grain/spices density sorting.
- **Surface area** - Quantifying the microbial population
- internal quality (IQ) sensors
- **some primary and secondary processing machines**

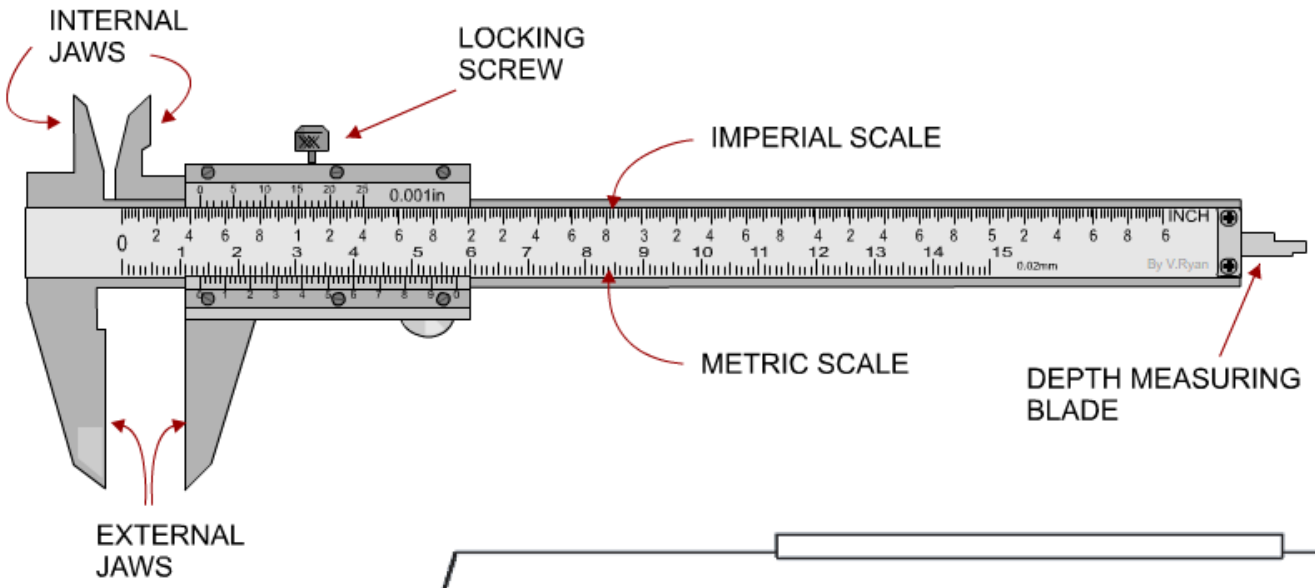
Methods of measurement of size

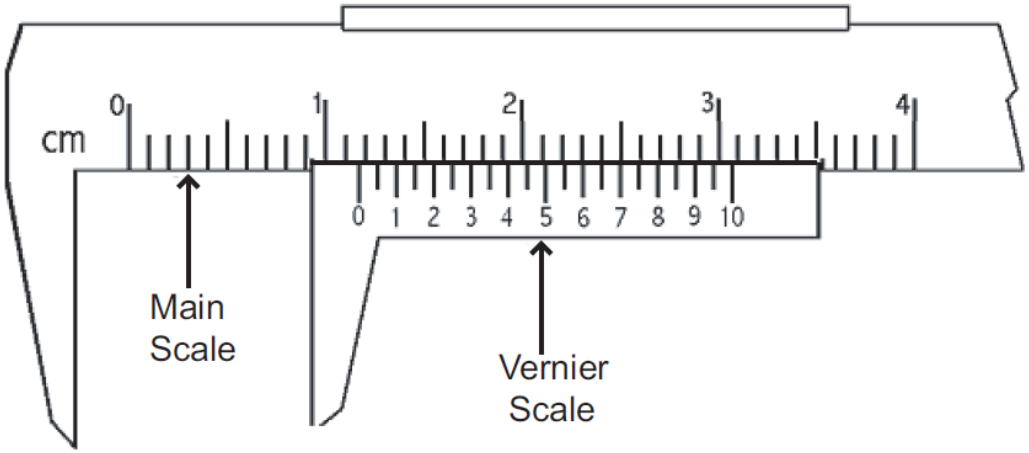
- **Projected area method**
  - **Major diameter,** which is the longest dimension of the maximum projected area
  - **Intermediate diameter**, which is the minimum diameter of the maximum projected area or the maximum diameter of the minimum projected area.
  - **Minor diameter**, which is the shortest dimension of the minimum projected area.

Projected area method

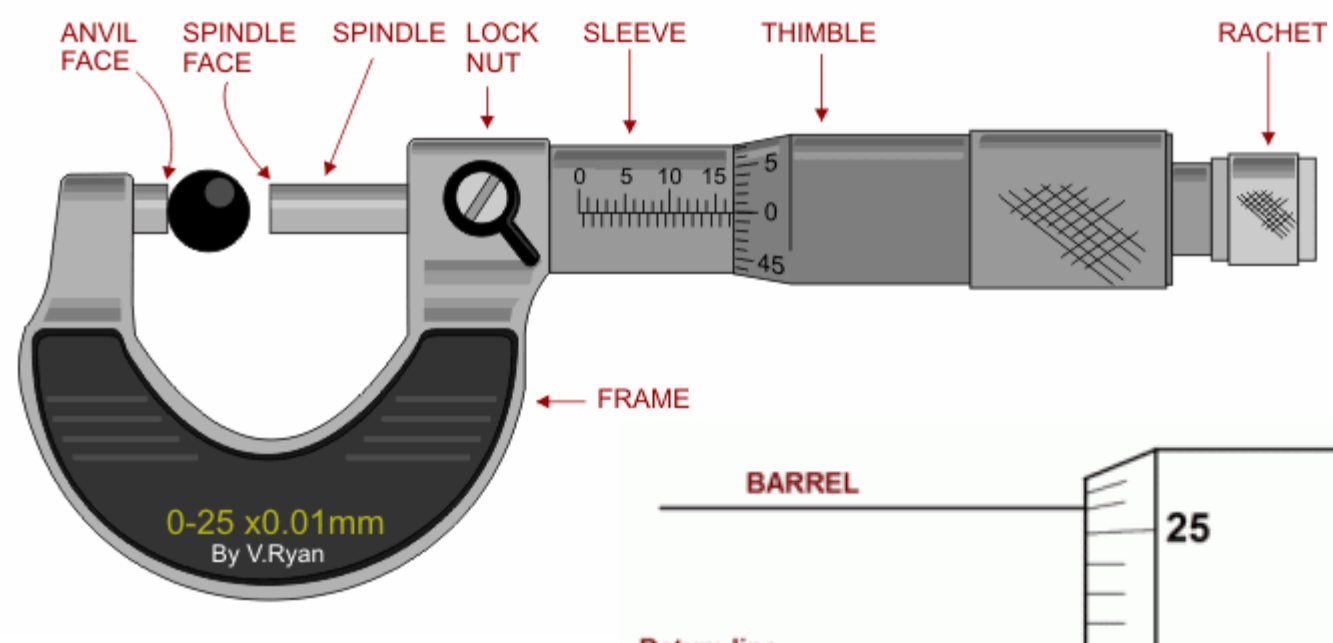


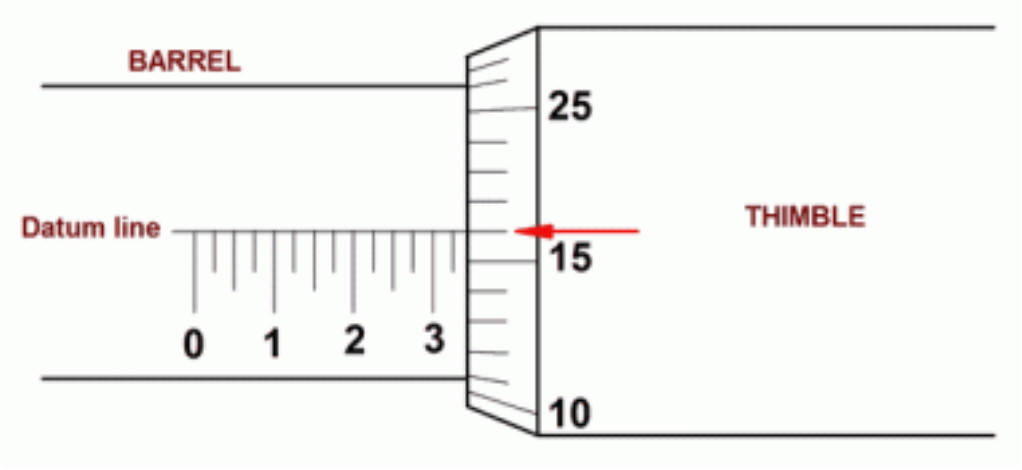
Vernier caliper





Micrometer measurement





Grain shape tester

- Place a small quantity of sample on the plate
- Operate the lever by left hand.
- Holding a pencil by right hand
- Measure the grain length or thickness by moving each grain to the groove.

Electronic system

- Volume of the gap between the fruit and the outer casing of **embracing gauge equipment**.
- Systems that calculate fruit size by measuring the distance between a **radiation source** and the fruit
- Systems that rely on the **obstruction of light barriers**
- Two-dimensional (**2-D**) machine vision systems such as digital images received by **web cameras, CCD cameras**.
- **Three-dimensional (3-D)** machine vision systems such as multi spectral and hyper-spectral imaging system.
- **Computed tomography (CT)-** It is a technology that uses computer-processed x-rays to produce tomographic images (virtual 'slices') of specific areas of the scanned object, allowing the user to see what is inside it without cutting it open**.)**
- **Magnetic resonance imaging (MRI), X-ray, ultrasound** techniques as well as some other approaches not included in the other groups.

SHAPE

- **Heat and mass transfer calculations,**
- **Screening solids to separate foreign materials**
- **Grading of fruits**
- **quality of food materials**

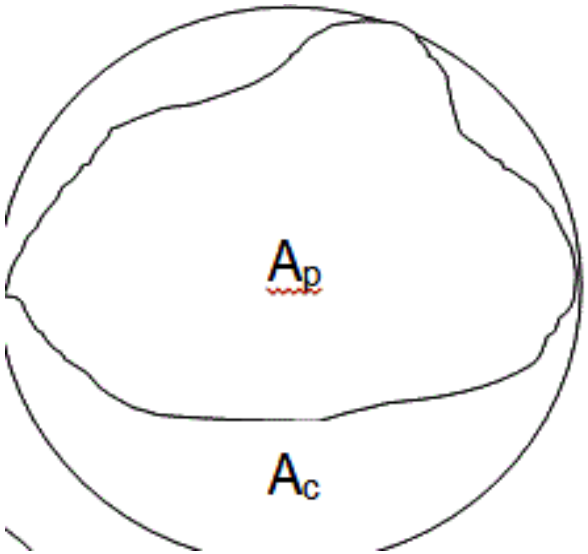
Shape

Shape	Description	Examples
Round	Approaching Spheroid	sapota, cherry tomato, pea
Oblate	Flattened at the stem end and apex	Orange, pumpkin
Oblong	Vertical diameter greater than horizontal diameter	some apple varieties, capsicum, brinjal, rice, wheat
Conic	Tapered towered the apex	ladies finger, carrot, reddish
Ovate	Egg shaped & broad at stem end	Brinjal, apple and guava.
Oblique	Axis connecting stem and apex slated	some apple varieties, tomato.
Obovate	Inverted ovate-broad at apex	Mango, papaya
Elliptical	Approaching ellipsoid	rice, wheat, pointed guard etc
Truncate	Having both hand squared or flattened	capsicum
Unequal	One half larger than the other	mango
Ribbed:	In cross section, sides are more or less angular	plantain, ladies finger
Regular	Horizontal section approaches a circle	orange, apple, guava etc
Irregular	Horizontal section dearth materially from a circle	mango, ladies finger, capsicum etc.

Shape

ROUNDNESS

- Roundness is a **measure of sharpness of the corners** of the solid. Where, the object area in obtained by projection/tracing.



$$Roundness = \frac{A_p}{A_c}$$

A_p = largest projected area of object in natural rest position

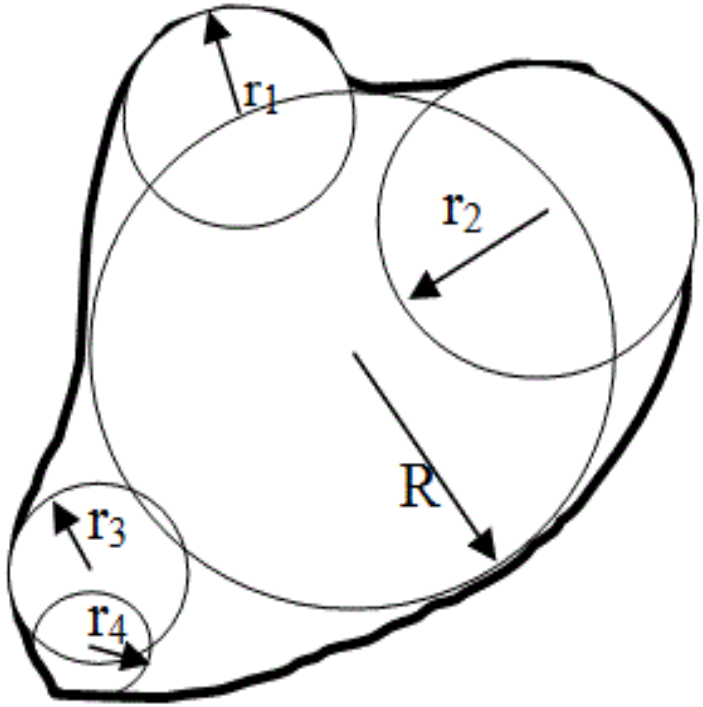
A_c = Area of smallest circumscribing circle

ROUNDNESS

$$Roundness = \frac{\sum^{r}}{NR}$$

Where

- r = radius of curvature of all the corners
- R = Radius of maximum inscribed circle
- **N = total number of corners**



Numerical

Q.1. If projected area of a fruit is 300 cm^2 and the diameter of the smallest circumscribing circle is 10cm. Calculate the Roundness.

Q.2 If the roundness of a vegetable is 0.95 and the radius of the smallest circle is 3cm, calculate the projected area.

Q.3 If the radius of sharp corners are 1, 1, and 1.5 cm, whereas the radius of maximum inscribed circle is 5cm, calculate the roundness.

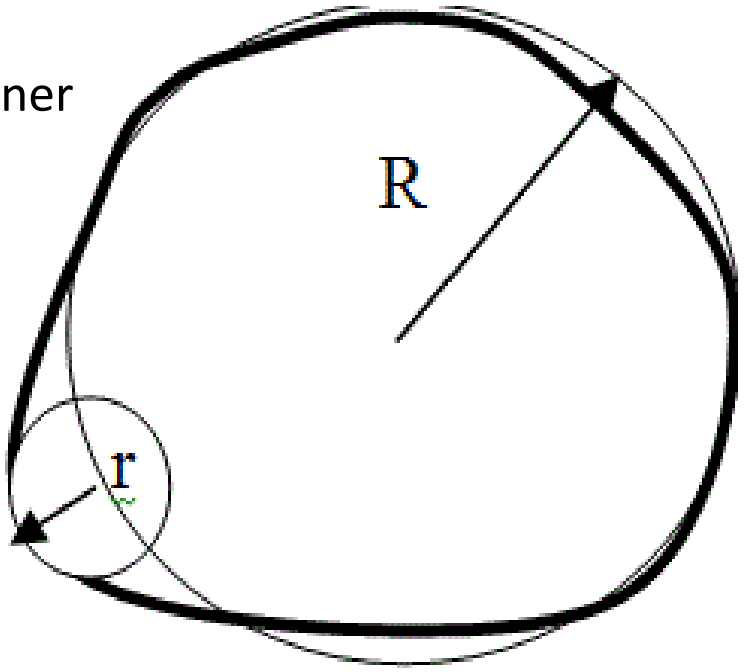
ROUNDNESS RATIO

$$Roundnessratio = \frac{r_n}{R_m}$$

Where

R_m = mean radius of the object

r_n = radius of curvature of the sharpest corner

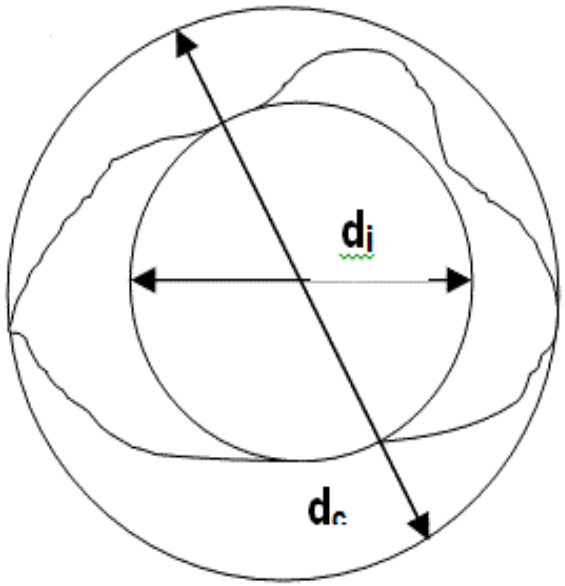


SPHERICITY

- Sphericity is the degree to which an object resembles a sphere.

$$Sphericity = \frac{d_i}{d_c}$$

- d_i = diameter of largest inscribed circle
- d_c = diameter of smallest circumscribed circle



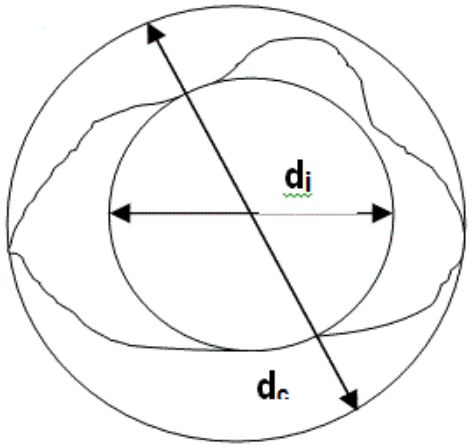
SPHERICITY

- Sphericity is the degree to which an object resembles a sphere.

$$Sphericity = \frac{d_e}{d_c}$$

Where

- d_e= diameter of the sphere of the same volume as the object
- d_c= diameter of the smallest circumscribed sphere or usually the longest diameter of the object.



SPHERICITY

$$Sphericity = \left[\frac{volumeofsolid}{volumeofcircumscribedsphere}\right]^{\frac{1}{3}}$$

$$= \left[\frac{\frac{\pi}{6}abc}{\frac{\pi}{6}a^3}\right]^{\frac{1}{3}} = \left[\frac{bc}{a^2}\right]^{\frac{1}{3}} = \frac{[abc]^{\frac{1}{3}}}{a}$$

Where

- a= largest intercept
- b = longest intercept normal to a
- c = longest intercept normal to a and b

Numericals

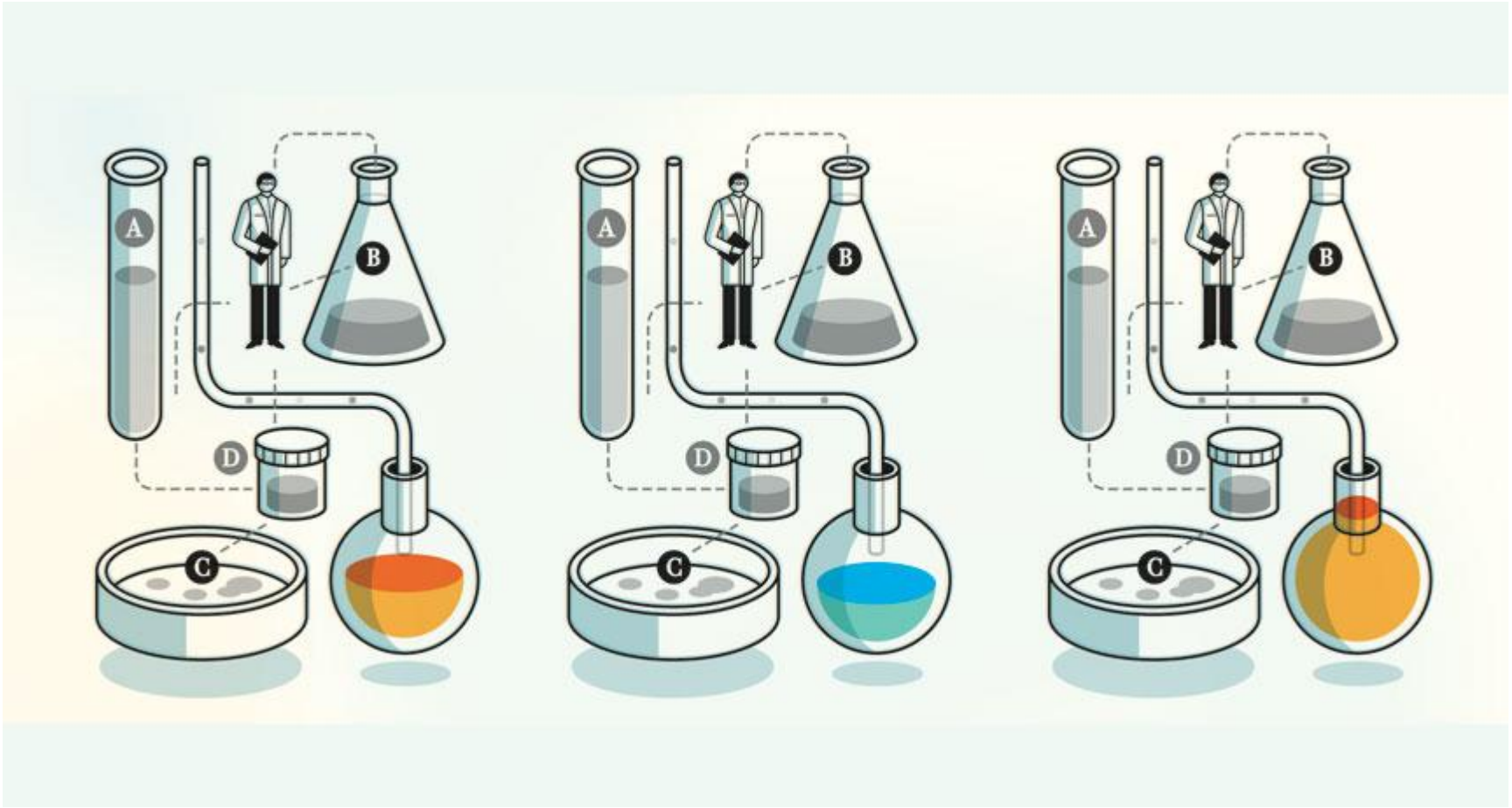
Q.1. If largest inscribed and smallest circumscribed radius of a fruit are 4.2 and 5.4cm respectively, calculate the sphericity of the food material.

Q.2 . If equivalent sphere and smallest circumscribed radius of a fruit are 4.0 and 5.4cm respectively, calculate the sphericity of the food material.

Q.3 If three intercept of cashew nut are 4,2.5 and 2.7cm respectively, calculate the sphericity.

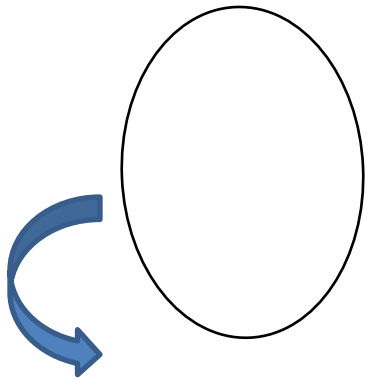
Replications

- Replication is the act of reproducing or copying something, or is a copy of something.



Resemblance to geometric bodies

- **Prolate spheroid** which is formed when an **ellipse rotates about its major axis**.



Prolate spheroid

$$V_{prolatespheroid} = \frac{4}{3}\pi a b^2$$

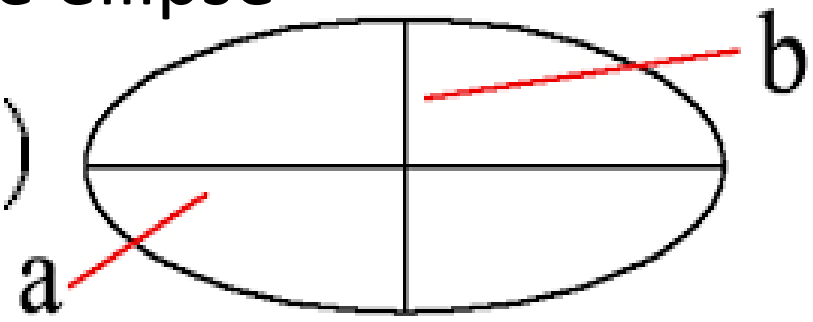
$$S_{prolatespheroid} = 2\pi b^2 + 2\pi \frac{ab}{e}\sin^{-1} e$$

Where

- a = major semi axis of the ellipse
- b = major semi axis of the ellipse

$$e = \sqrt{1 - \left(\frac{b}{a}\right)^2}$$

$$where, e = \left([1 - (b/a)^2]\right)$$

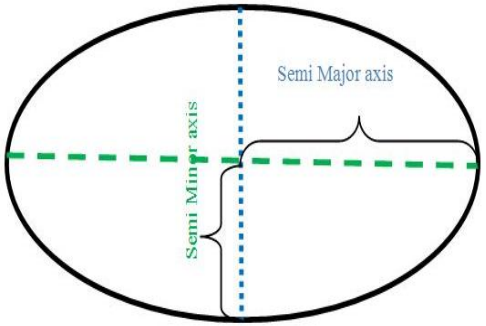


Numerical

Q.1. If largest and smallest dimension of lemon are 5.2 and 3.4 cm respectively, Calculate the volume and surface area of lemon.

Oblate spheroid

- **Oblate spheroid** is formed when an ellipse rotates about its minor axis. An oblate spheroid is a rotationally symmetric ellipsoid having a polar axis shorter than the diameter of the equatorial circle whose plane bisects it. e.g. grape fruit, pumpkin



Oblate spheroid

$$V_{oblatespheroid} = \frac{4}{3}\pi a^2 b$$

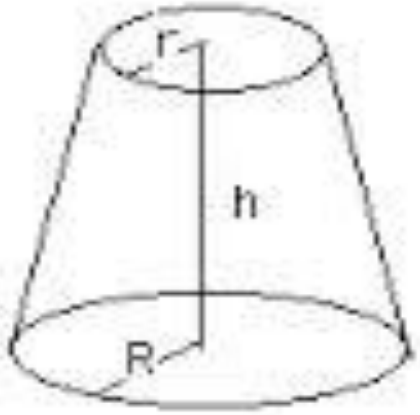
$$S_{oblatespheroid} = 2\pi a^2 + \pi \frac{b^2}{e} \ln \frac{1+e}{1-e}$$

Numerical

Q.1. If largest and smallest dimension of pumpkin are 4.3 and 3.4 cm respectively, Calculate the volume and surface area of pumpkin.

Right circular cone or cylinders

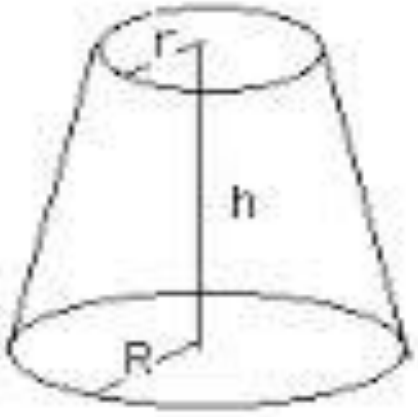
- **Right circular cone or cylinders** is formed when a frustum rotates about its axis e.g. carrot and cucumber.



Right circular cone or cylinders

$$V_{rightcone} = \frac{\pi}{3} h \left[r_1^2 + r_1 r_2 + r_2^2 \right]$$

$$S_{rightcone} = \pi (r_1 + r_2) \sqrt{\left[h^2 + (r_1 - r_2)^2 \right]}$$



Where

r_1 = radius of base

r_2 = radius of top (apex)

h = altitude

Numerical

Q.1. If largest and smallest diameters of carrot are 3.3 and 2.4 cm, whereas the length of carrot is 12 cm, Calculate the volume and surface area of carrot.

Correction factor

- **Actual Volume**

= Correction factor$_1$ X Estimated volume

- **Actual surface area**

= Correction factor$_2$ X Estimated volume

Grading of rice: Interrelations

- Slenderness ratio => Length : width
- Aspect ratio => Width: length

Grading of fruit: Interrelations

- Ellipsoid ratio => Major diameter: minor diameter
- Aspect ratio = >length: major diameter