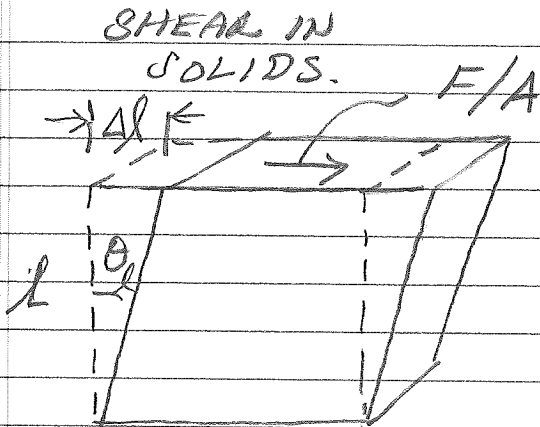


SHEAR, BENDING, TORSIONAL FORCES.

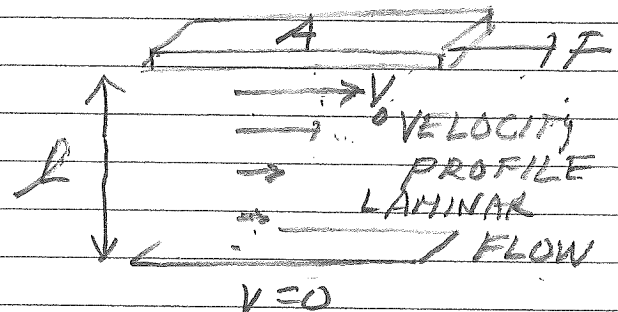
BESIDES ELONGATION & THE ASSOCIATED YOUNG'S ELASTIC MODULUS, THERE IS SHEAR MODULUS.



$$\frac{F}{A} = \frac{Y}{S} \frac{\Delta l}{l} = \frac{Y}{S} \theta$$

↑
SHEAR MODULUS
 $Y/S = G$ (ALSO USED)

SHEAR IN FLUIDS.
FLUIDS DO NOT SUPPORT SHEAR - THEY FLOW.



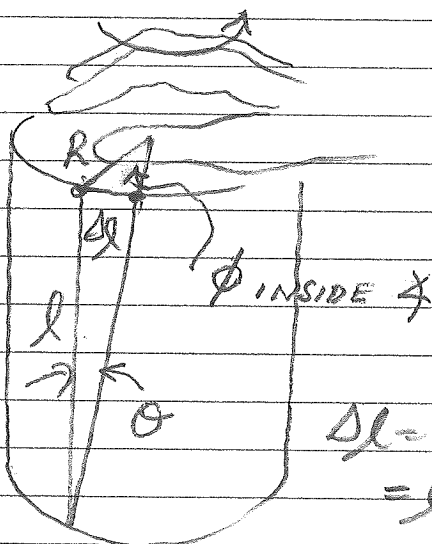
$$\frac{F}{A} = \eta \frac{v_0}{l}$$

η VISCOSITY
UNITS $\frac{N \cdot S}{m^2}$

$$\eta \approx 15 \times 10^{-6} \frac{N \cdot S}{m^2} \text{ AIR}$$

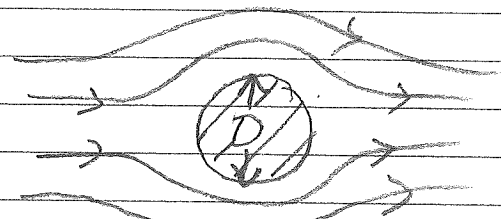
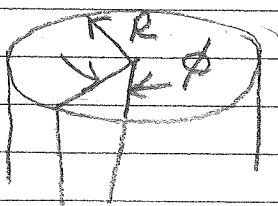
$$\eta \approx 10^{-3} \frac{N \cdot S}{m^2} \text{ WATER}$$

TORSIONAL

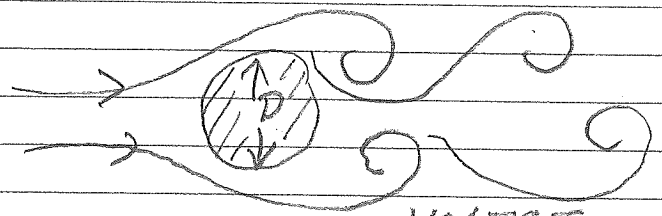


$$\Delta l = R \phi$$

$$= l \theta$$



LAMINAR FLOW



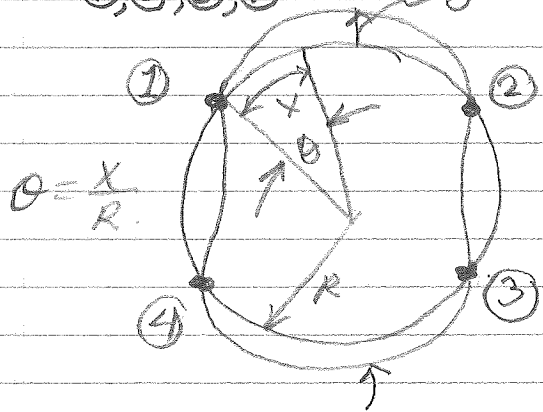
VORTICES
TURBULENT FLOW

BREAKING GLASS DEMO - $2\pi R = n\lambda$ WHOLE # OF λ 'S ON CIRCLE

NODES AT ①, ②, ③, ④

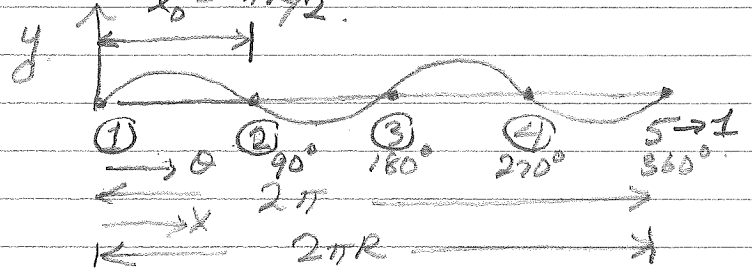
$y(x)$ or $y(\theta)$

$\lambda = \frac{2\pi R}{n}$



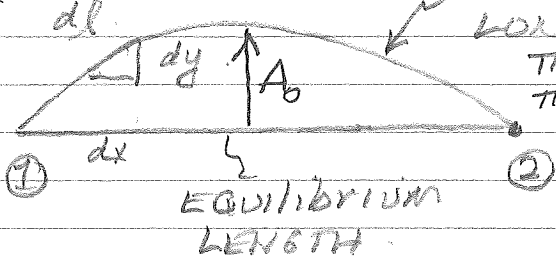
OPEN UP CIRCLE

$l_0 = \pi R / 2$



$n=2$ QUADRUPOLE OSCILLATION
2 λ 'S

$\lambda = \pi R$



HOW MUCH LONGER IS THIS ARC THAN $l_0 = \pi R / 2$

PYTHAGORAS:

$$dl = \sqrt{(dx)^2 + (dy)^2}$$

$$= \sqrt{(dx)^2 \left(1 + \left(\frac{dy}{dx}\right)^2\right)}$$

$$= dx \sqrt{1 + \left(\frac{dy}{dx}\right)^2}$$

$y(x) = A_0 \sin kx$

$k = \frac{2\pi}{\lambda} = \frac{2\pi}{\pi R} = \frac{2}{R}$

$kx = \frac{2x}{R} = 2\theta$

$y(\theta) = A_0 \sin 2\theta$ $0 \leq \theta \leq \pi/2$ FROM ① TO ②

$\frac{dy}{dx} = \frac{dy}{d\theta} \frac{d\theta}{dx} = \frac{dy}{d\theta} \cdot \frac{1}{R} = \frac{2A_0 \cos 2\theta}{R}$ $dx = R d\theta$

$l = \int_{0, \text{①}}^{\pi/2, \text{②}} dl = \int dx \sqrt{1 + \left(\frac{dy}{dx}\right)^2} = \int_0^{\pi/2} R d\theta \sqrt{1 + \left(\frac{2A_0}{R}\right)^2 (\cos 2\theta)^2}$

$\theta' = 2\theta$ $d\theta = d\theta'/2$ $a^2 \equiv \left(\frac{2A_0}{R}\right)^2$

$l = \int_0^{\pi} R \frac{d\theta'}{2} \sqrt{1 + a^2 \cos^2 \theta'} = \frac{R}{2} \left(\text{elliptic } E(-a^2) + \sqrt{1+a^2} \text{ Elliptic } E\left(\frac{a^2}{1+a^2}\right) \right)$
VERY GOOD APPROXIMATION

CHECK $A_0=0$ $l = \frac{\pi R}{2}$ $l \approx \frac{\pi R}{2} \left(1 + \frac{1}{4} a^2\right) = \frac{\pi R}{2} \left(1 + \frac{1}{4} \left(\frac{4A_0}{R}\right)^2\right)$

$l_0 + \Delta l = \frac{\pi R}{2} + \frac{\pi R}{2} \left(\frac{A_0}{R}\right)^2$ $\Delta l / l_0 = \left(\frac{A_0}{R}\right)^2$

BREAKING GLASS DEMO

TENSILE STRENGTH & BREAKING YOUNG'S LAW

$$\frac{F}{A} = Y \frac{\Delta L}{L_0} = Y \left(\frac{\Delta}{R}\right)^2$$

ONLY HAVE TO LOOK FROM ① TO ②

$\frac{\Delta L}{L_0}$ SAME FOR ② TO ③, ③ TO ④, ④ TO ①

Y GLASS - $(50-90) \times 10^9$
DENSITY OF GLASS $\sim 2-3 \times 10^3 \frac{kg}{m^3}$

$$v_{GLASS} = \sqrt{\frac{Y}{\rho}}$$

USE $Y = 50 \times 10^9$ $\rho = 2 \times 10^3$

$$v = \sqrt{25 \cdot 10^6} = 2500 \text{ m/s}$$

$$\frac{F}{A} = 50 \times 10^9 \frac{\Delta L}{L_0}$$

UTS = ULTIMATE TENSILE STRENGTH - DEFINES THE $\frac{F}{A}$ THAT WILL CAUSE MATERIAL TO BREAK

UTS $\sim 50 \cdot 10^6$ NORMAL GLASS $\sim 75 \cdot 10^9$

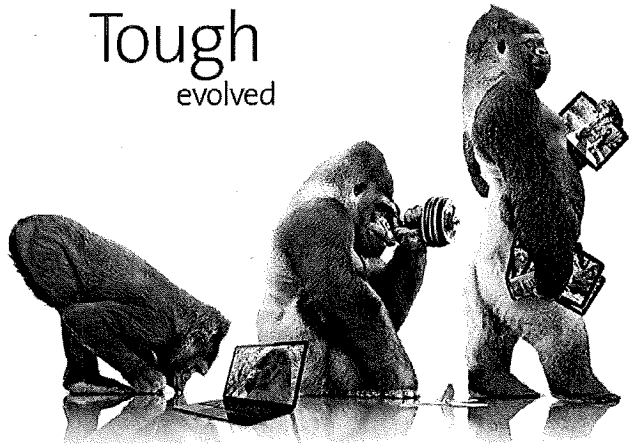
UTS : E-GLASS - (FOR LAMINATES) $\sim 1500 \cdot 10^6$ \uparrow Y?

$$50 \cdot 10^6 = 50 \cdot 10^9 \frac{\Delta L}{L_0} \quad \frac{\Delta L}{L_0} = 10^{-3} = .001 = 0.1\%$$

$$\left(\frac{\Delta}{R}\right)^2 = .001 \quad \frac{\Delta}{R} = .0316 \sim 3\%$$



Tough evolved



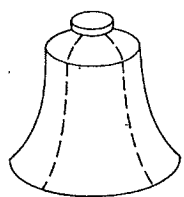
CORNING® GORILLA® GLASS 3 WITH NATIVE DAMAGE RESISTANCE™

Corning is continually looking for ways to improve Gorilla Glass and achieve new levels of toughness. Gorilla® Glass 3 is not only chemically strengthened — its atomic configuration is formulated so that the glass is more durable. Corning® Gorilla® Glass 3 with Native Damage Resistance™ (NDR) is fundamentally tougher and more damage resistant before chemical strengthening.

How tough? Gorilla® Glass 3 with NDR enables improved damage resistance and toughness compared to former glass compositions and is up to three times more resistant than Gorilla Glass 2. This type of Native Damage Resistance is a unique feature of Gorilla® Glass 3. Something Corning is able to provide due to a proper glass composition that is better able to resist the deep scratches that cause glass break.

13.17 ■ BELLS AND CARILLONS

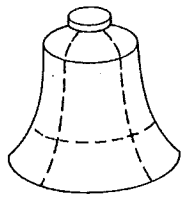
Bells have been a part of nearly every culture in history. Bells existed in the Near E before 1000 B.C., and a number of Chinese bells from the time of the Shang dyna (1600-1100 B.C.) are found in museums throughout the world. A set of tuned bells fr the fifth century B.C. was recently discovered in the Chinese province of Hubei.



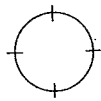
Hum



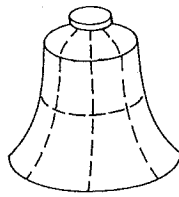
$f/f_s = 0.5$



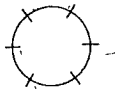
Prime (fundamental)



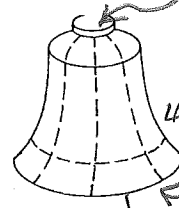
1.0
 $2\pi R = 2\lambda$



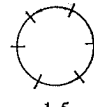
Minor third



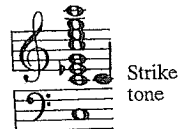
$6/5 = 1.2$



Fifth



$3/2 = 1.5$

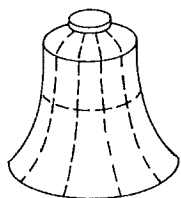


Strike tone

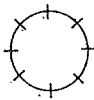
ACTS LIKE THE APEX OF A CONICAL BORE.

NODAL LINES.

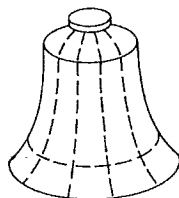
FREE RIM.



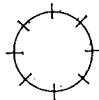
Octave (nominal)



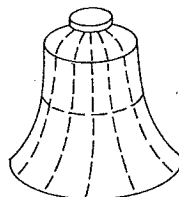
2.0



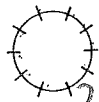
Upper third



2.5

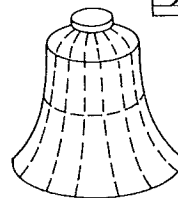


Twelfth

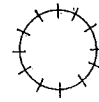


3.0

$2\pi R = 5\lambda$

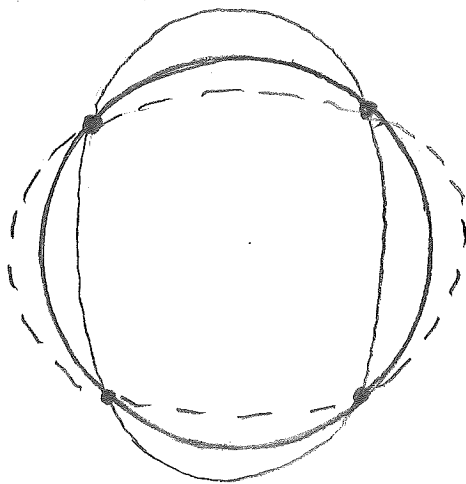


Upper octave



4.0

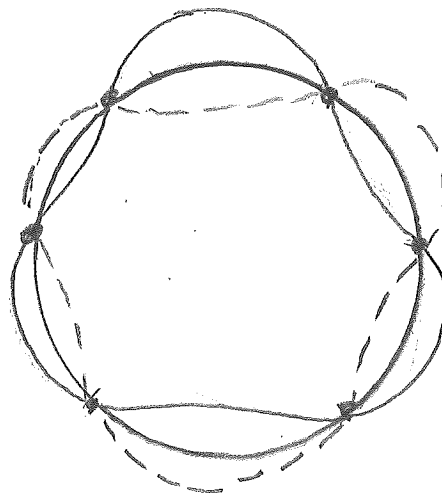
$2\pi R = 6\lambda$



ELLIPTOIDAL VIBRATION
FOOTBALL SHAPE.

$2\pi R = 2\lambda$

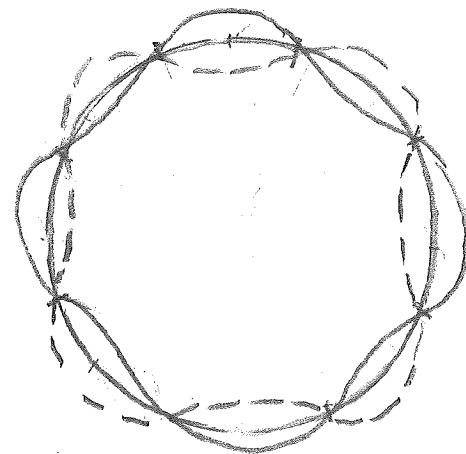
HUM & FUNDAMENTAL.



PEAR SHAPE OSCILLATION.

$2\pi R = 3\lambda$

MINOR THIRD & FIFTH



OCTAVE.

$2\pi R = 4\lambda$

CYMBAL IS A FLATEN VERSION OF BELL.

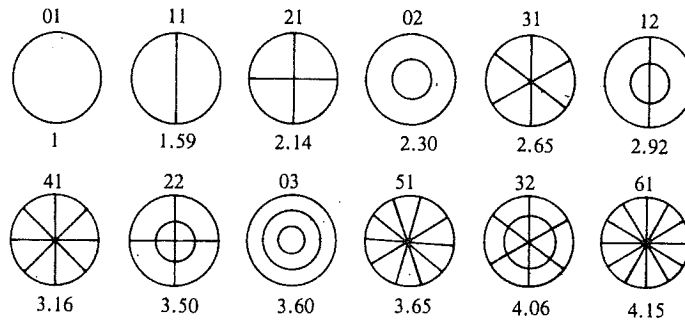
DRUM (MEMBRANE) IS A FLAT VERSION WITH RIM FIXED, NOT FREE



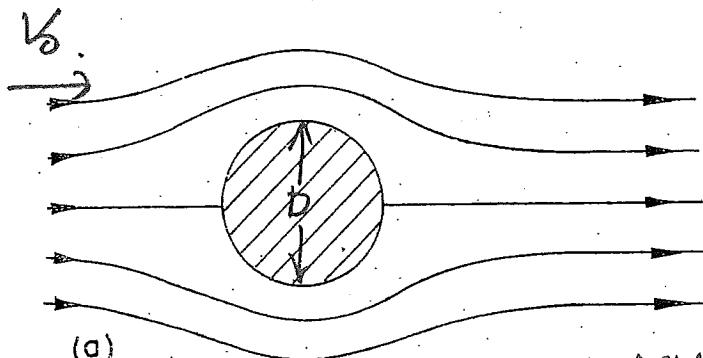
13.7 ■ VIBRATIONS OF MEMBRANES

FIGURE 13.9
 Modes of an ideal membrane, showing radial and circular nodes and the customary mode designation (the first number gives the number of radial modes, and the second number the circular nodes, including the one at the edge). The number below each mode diagram gives the frequency of that mode compared to the fundamental (0, 1) mode.

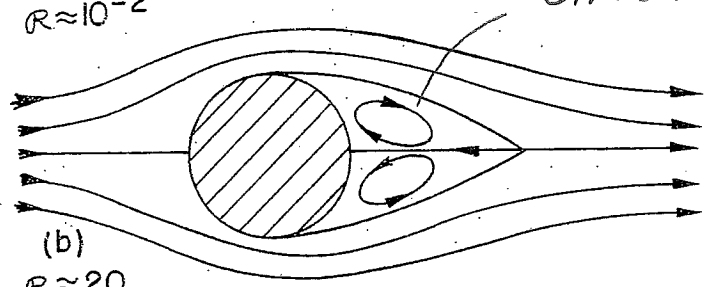
The vibrations of an ideal membrane were discussed briefly in Section 2.6. We pointed out that a membrane may be thought of as a two-dimensional string, in that the restoring force necessary for it to vibrate is supplied by tension applied from the edge. A membrane, like a string, can be tuned by changing its tension. One major difference between vibrations in the membrane and in the string, however, is that the mode frequencies in the ideal string are harmonics of the fundamental, but in the membrane they are not. Another difference is that in the membrane, nodal lines replace the nodes that occur along the string. These nodal lines are circles and diameters, as shown in Fig. 13.9.



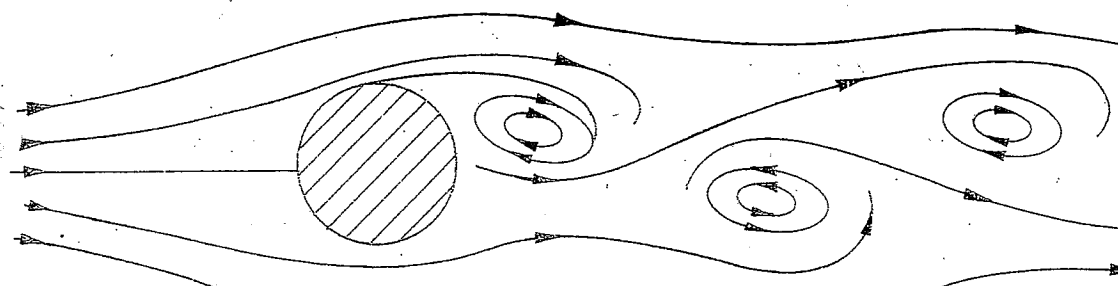
FLOW OF FLUID
AROUND AN OBSTACLE



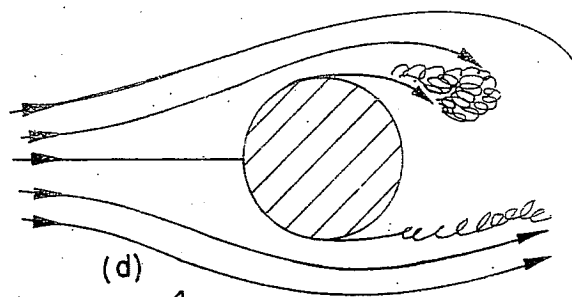
(a)
 $R \approx 10^{-2}$



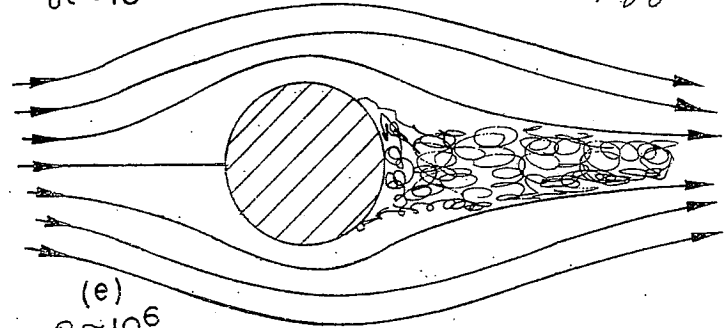
(b)
 $R \approx 20$



(c)
 $R \approx 100$



(d)
 $R \approx 10^4$



(e)
 $R \approx 10^6$

STREAMLINE FLOW
CONDITION FOR
DIFFERENT BEHAVIOR
IS DETERMINED BY
REYNOLDS NUMBER R

ρ DENSITY
 V_0 IS SPEED
 D DIAMETER
 η VISCOSITY
(NUMBER THAT
HAS TO BE GIVEN)

$$R = \frac{\rho V_0 D}{\eta}$$

ONE VORTEX
COMES OFF ONE
SIDE, ANOTHER
OFF OTHER SIDE

CALLED A KARMAN STREET

FREQUENCY OF
VORTEX IS GIVEN
BY STROUHAL #
 St

$$f_{\text{VORTEX}} = St \frac{V}{D}$$

Fig. 41-6. Flow past a cylinder for various Reynolds numbers. $R = \frac{\rho}{\eta} V_0 D$