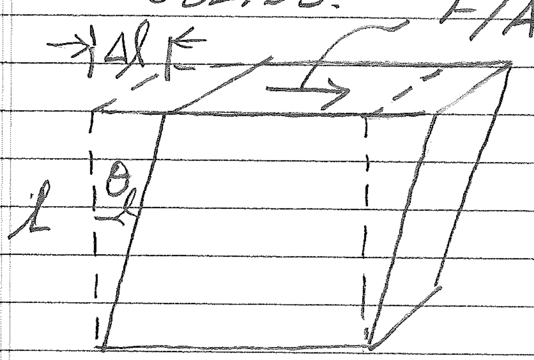
SHEAR, BENDING, TORSIONAL FORCES.

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

SHEAR IN SOLIDS.



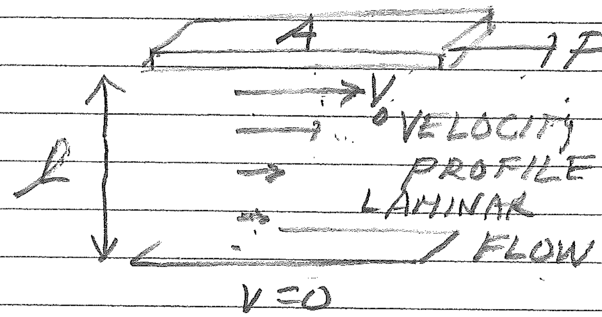
$$\frac{F}{A} = Y_S \frac{\Delta l}{l} = Y_S \theta_l$$

SHEAR MODULUS

$Y_S \equiv G$ (ALSO USED)

SHEAR IN FLUIDS.

FLUIDS DO NOT SUPPORT SHEAR – THEY FLOW



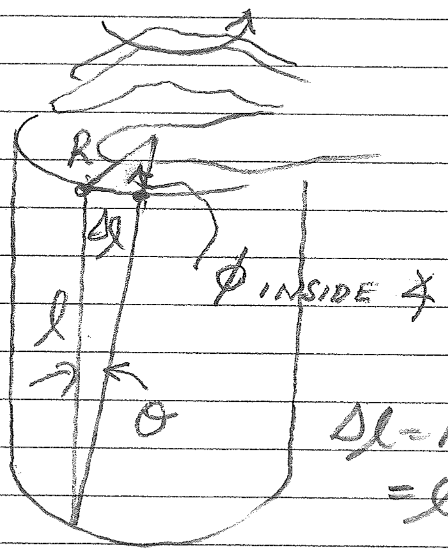
$$\frac{F}{A} = \eta \frac{V_0}{l}$$ η VISCOSITY

UNITS $\frac{N \cdot S}{M^2}$

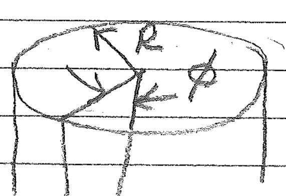
$\eta \cong 15 \times 10^{-6} \frac{N \cdot S}{M^2}$ AIR

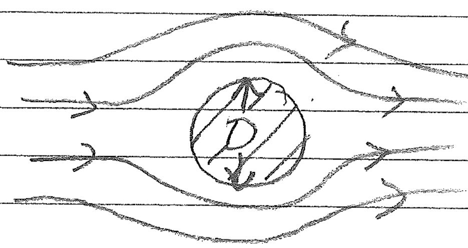
$\eta \cong 10^{-3} \frac{N \cdot S}{M^2}$ WATER

TORSIONAL

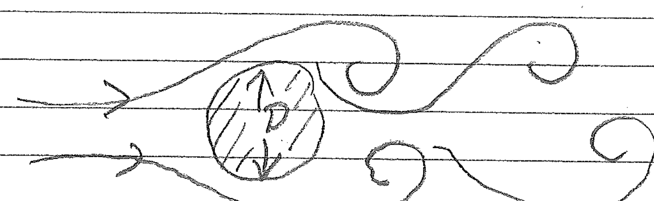


$$\Delta l = R\phi = l\theta$$





LAMINAR FLOW



VORTICES

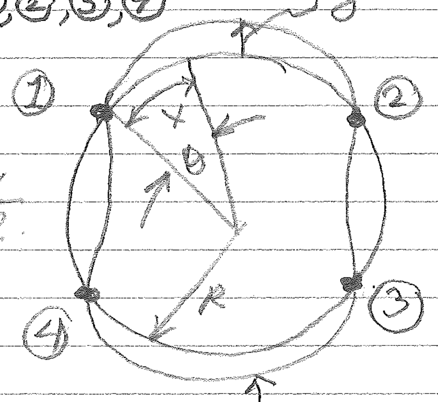
TURBULENT FLOW

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

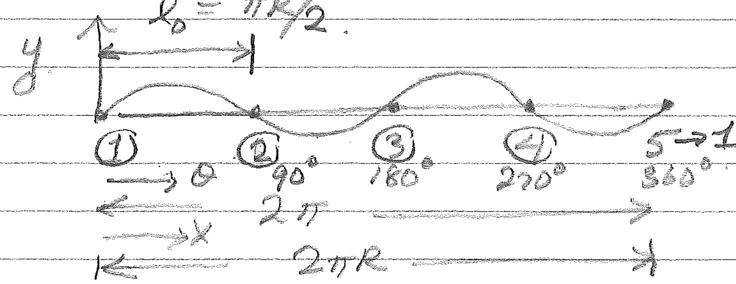
$\lambda = \frac{2\pi R}{n}$

NODES AT 1, 2, 3, 4

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

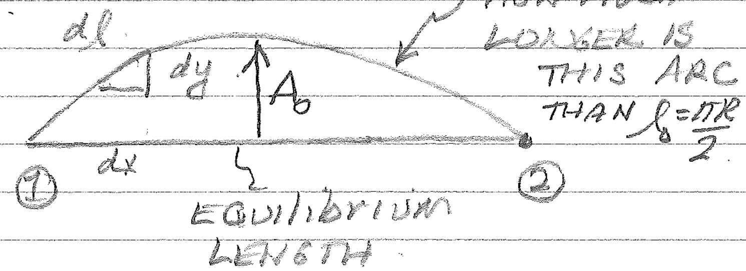


OPEN UP CIRCLE



$x = R\theta$

$n = 2$ QUADRUPOLE
2λ's OSCILLATION
$\lambda = \pi R$



PYTHAGORAS:

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

$$y(x) = A_0 \sin kx$$

$$k = 2\pi/\lambda = \frac{2\pi}{\pi R} = \frac{2}{R} \qquad kx = \frac{2x}{R} = 2\theta$$

$$y(\theta) = A \sin 2\theta \qquad 0 \le \theta \le \pi/2 \text{ FROM (1) TO (2)}$$

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

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

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

$$\ell = \int_0^{\pi} R\frac{d\theta'}{2}\sqrt{1 + a^2\cos^2\theta'} = \frac{R}{2}\left(\text{EllipticE}(-a^2) + \sqrt{1+a^2}\,\text{EllipticE}\left(\frac{a^2}{1+a^2}\right)\right)$$

VERY GOOD APPROXIMATION

$$\text{CHECK } A_0 = 0 \quad \ell = \frac{\pi R}{2} \qquad \ell \cong \frac{\pi R}{2}\left(1 + \frac{1}{4}a^2\right) = \frac{\pi R}{2}\left(1 + \frac{1}{4}\,4\left(\frac{A}{R}\right)^2\right)$$

$$\ell_0 + \Delta\ell = \frac{\pi R}{2} + \frac{\pi R}{2}\left(\frac{A_0}{R}\right)^2 \qquad \boxed{\Delta\ell/\ell_0 = (A_0/R)^2}$$

BREAKING GLASS DEMO

TENSILE STRENGTH & BREAKING

YOUNGS LAW

$$\frac{F}{A} = Y\frac{\Delta l}{l_0} = Y\left(\frac{A}{R}\right)^2$$

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 $-(50-90)\times 10^9$ $\quad v_{GLASS} = \sqrt{\frac{Y}{\rho}} =$

DENSITY OF GLASS $\sim 2-3\times 10^3 \frac{kg}{m^3}$.

USE $Y = 50\times 10^9$ $\rho = 2\times 10^3$ $\quad v = \sqrt{25\cdot 10^6} = 2500\ m/s$.

$$\frac{F}{A} = 50\times 10^9 \frac{\Delta l}{l_0}$$

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

$\sim 75\times 10^9$.

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

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

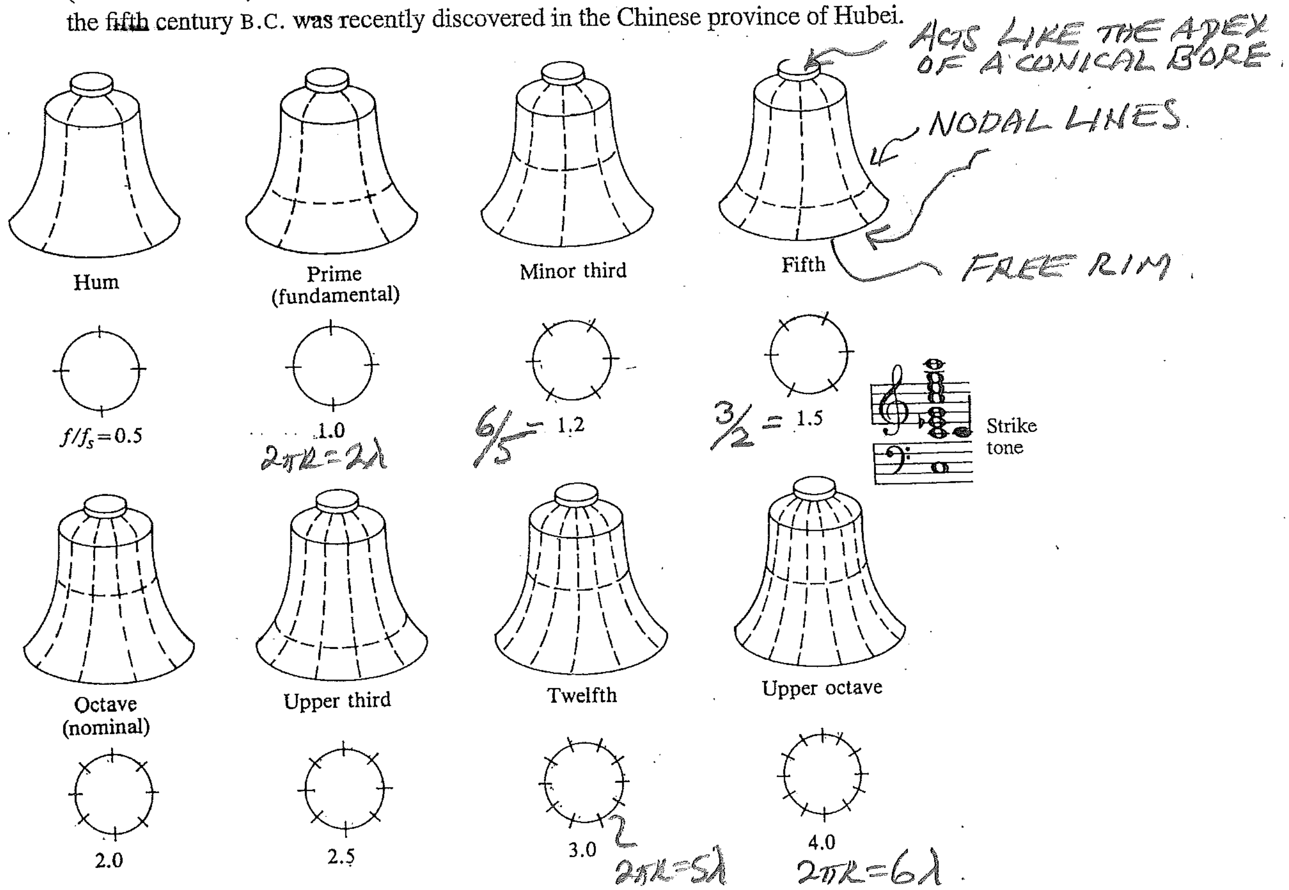
$$50\times 10^6 = 50\times 10^9 \frac{\Delta l}{l_0} \qquad \frac{\Delta l}{l_0} = 10^{-3} = .001$$

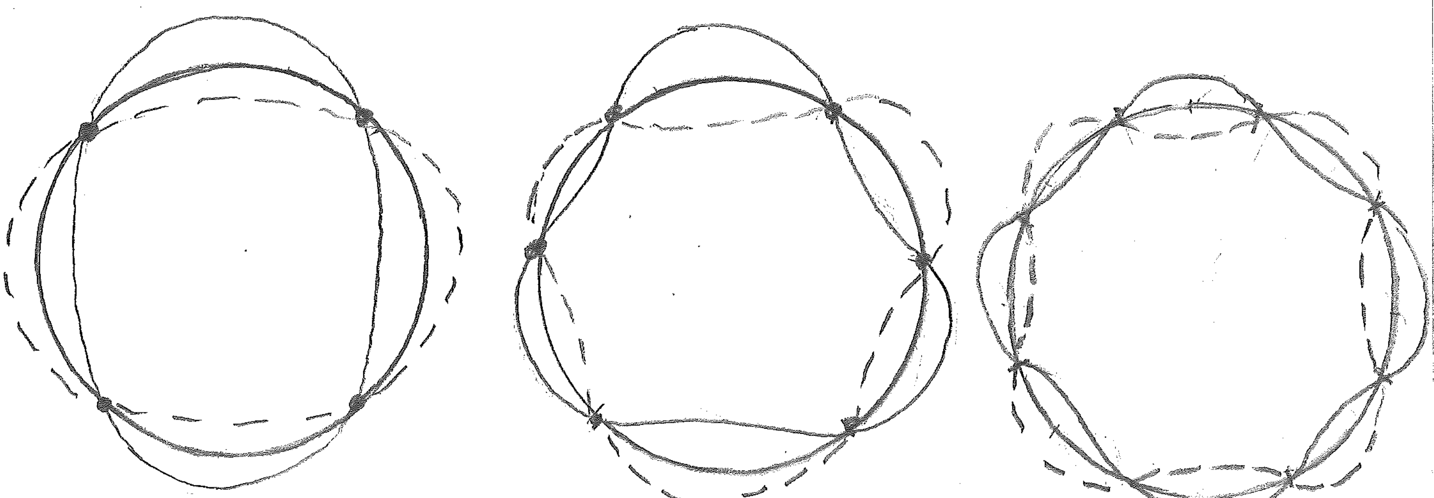
$$= 0.1\%$$

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

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.





ELLIPSOIDAL VIBRATION FOOTBALL SHAPE.

$2\pi R = 2\lambda$

HUM & FUNDAMENTAL.

PEARSHAPE OSCILLATION.

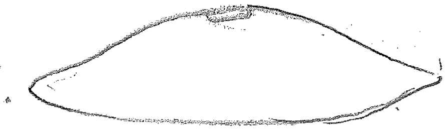
$2\pi R = 3\lambda$

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

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.

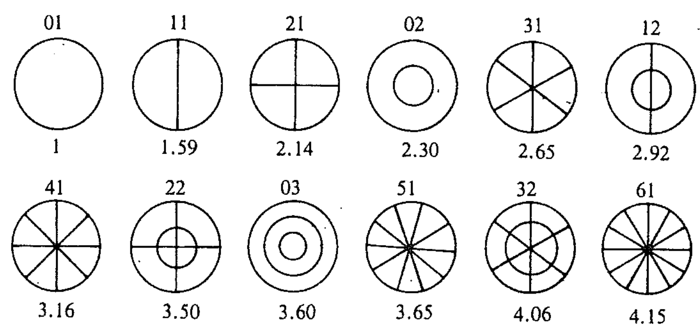
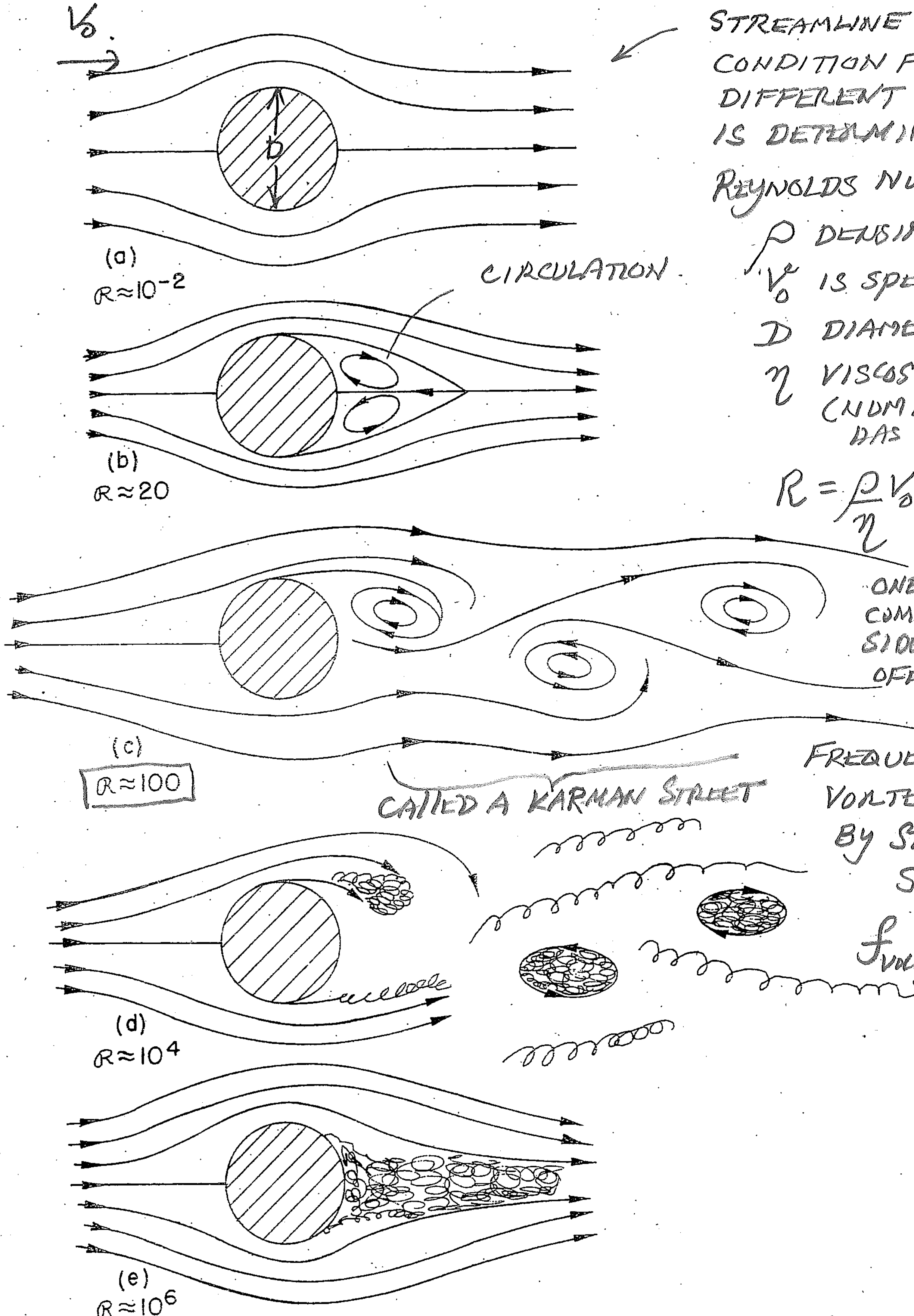


FIGURE 13.9 Modes of an ideal membrane, showing radial and circular nodes and the customary mode designation (the first number gives the number of radial modes, and the second number the circular nodes, including the one at the edge). The number below each mode diagram gives the frequency of that mode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

FLOW OF FLUID
AROUND AN OBSTACLE



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

FREQUENCY OF VORTEX IS GIVEN BY STROUHAL # St

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

Fig. 41–6. Flow past a cylinder for various Reynolds numbers. $R = \frac{\rho}{\eta} v_0 D$