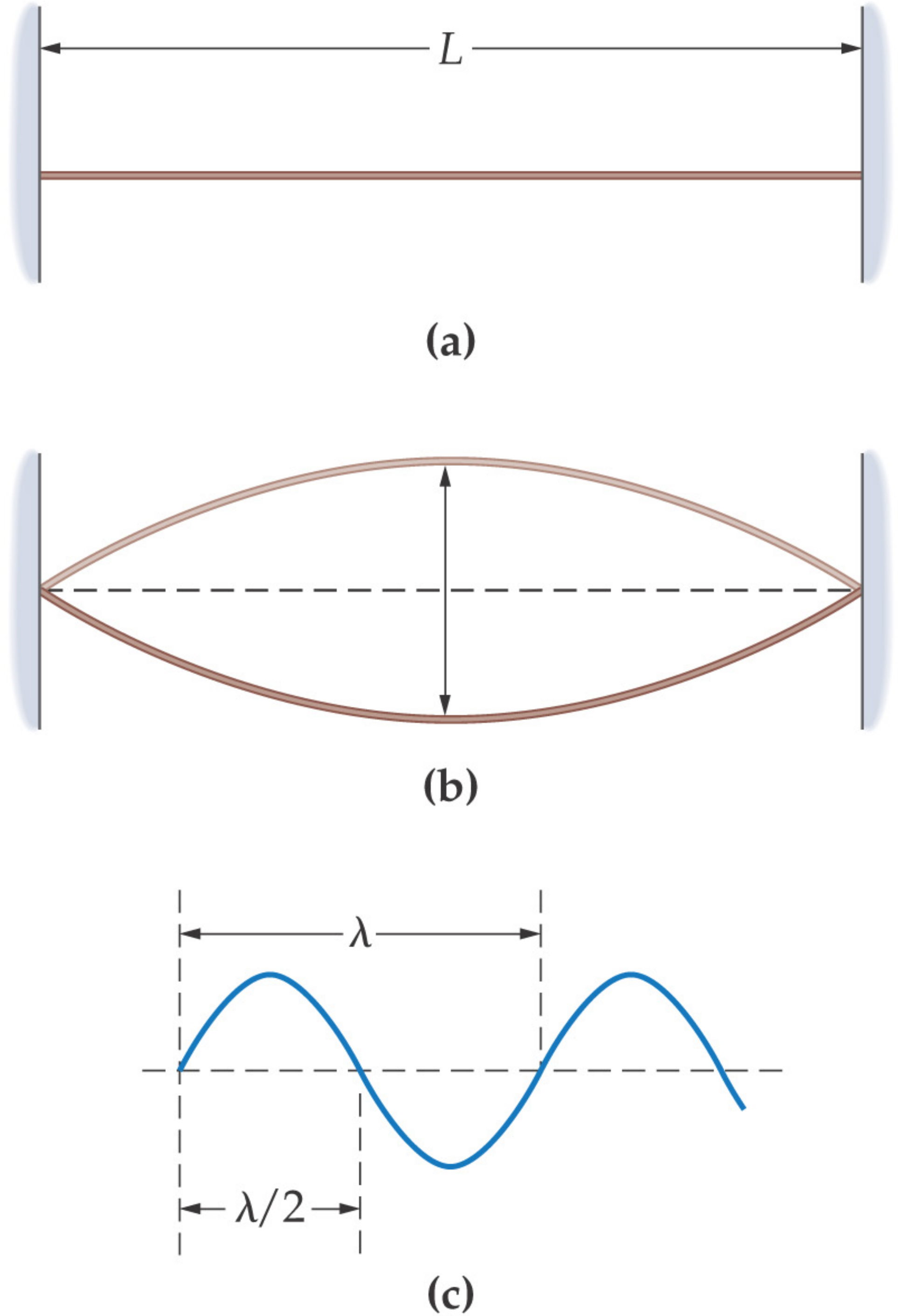
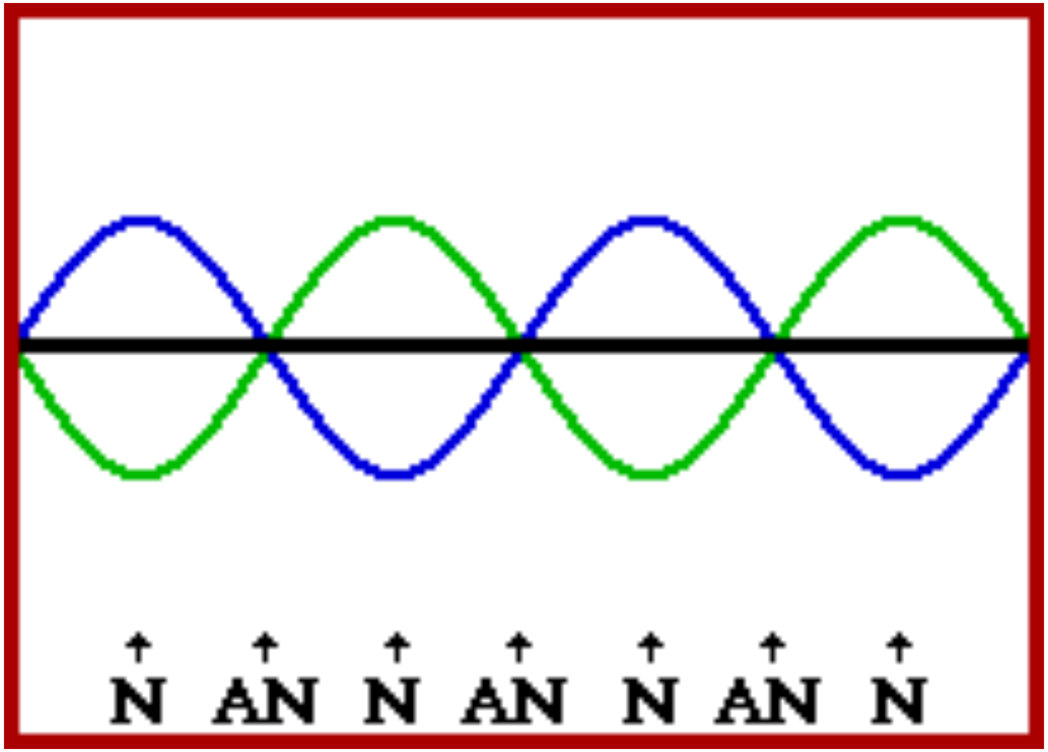
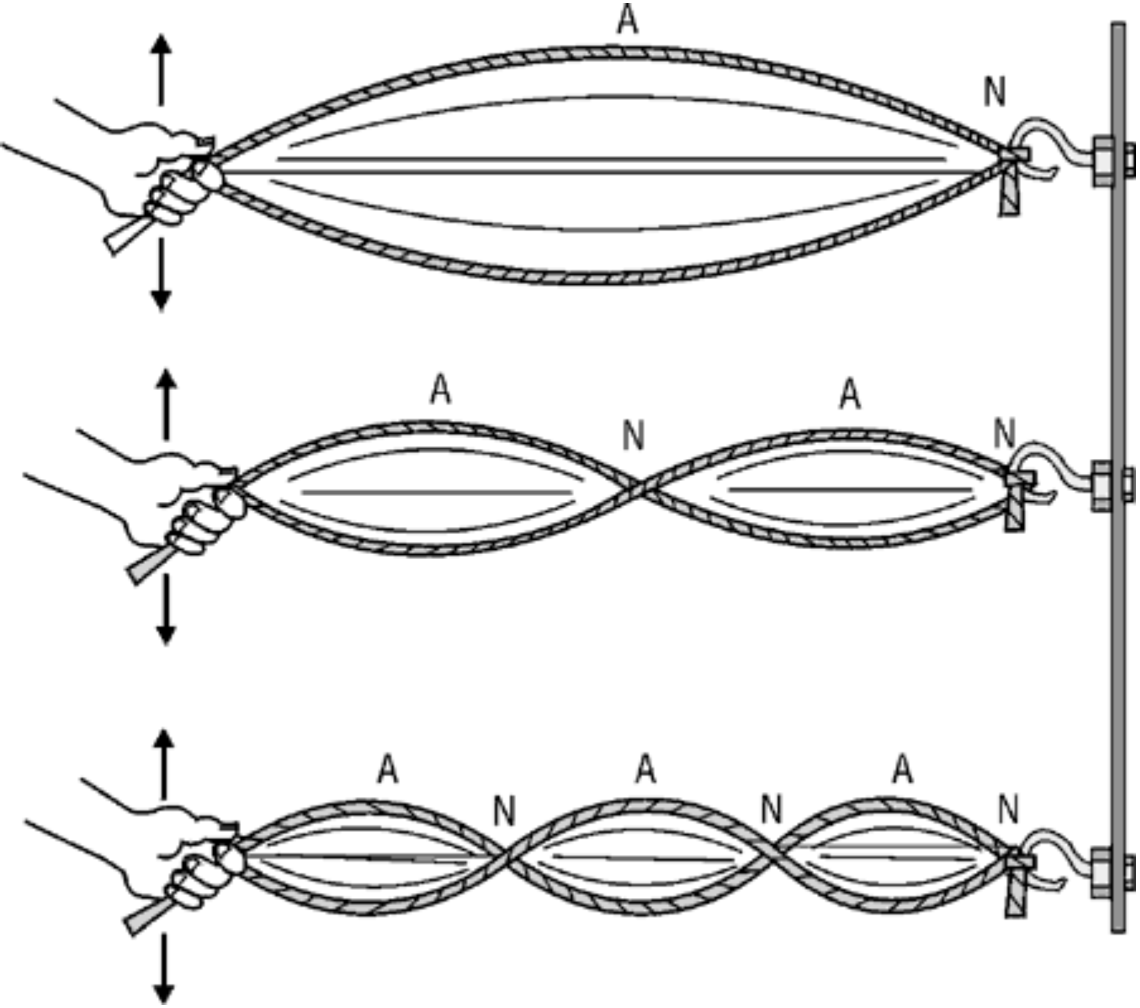
STANDING WAVES IN STRINGS

At certain frequencies standing waves can be produced in which the waves seem to be standing still rather than traveling. This means that the string is vibrating as a whole. This is called resonance and the frequencies at which standing waves occur are called resonant frequencies or harmonics.



A standing wave is produced by the *superposition* of two periodic waves having *identical frequencies* and *amplitudes* which are traveling in opposite directions. In stringed musical instruments, the *standing wave* is produced by waves reflecting off a fixed end and interfering with oncoming waves as they travel back through the medium.

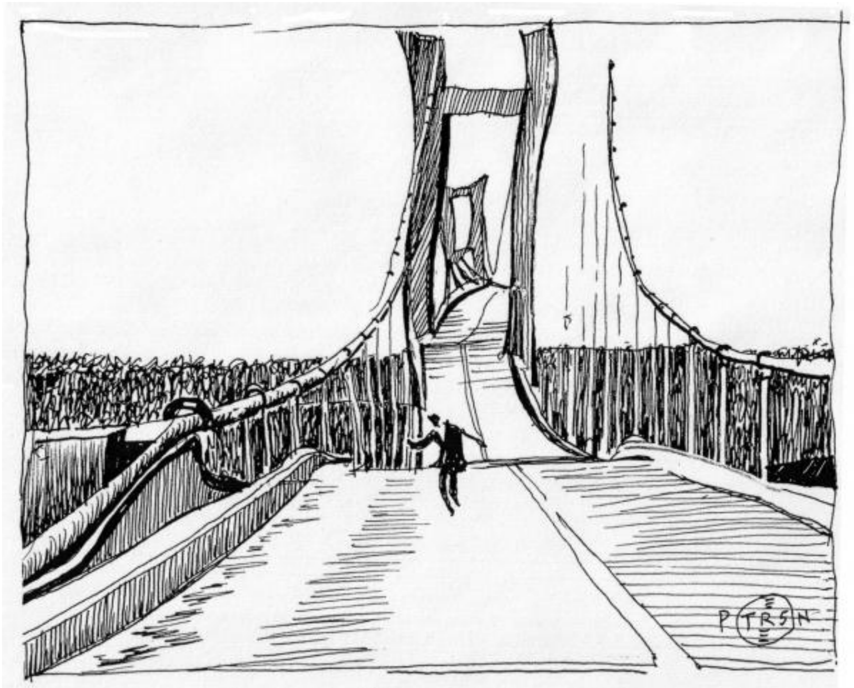


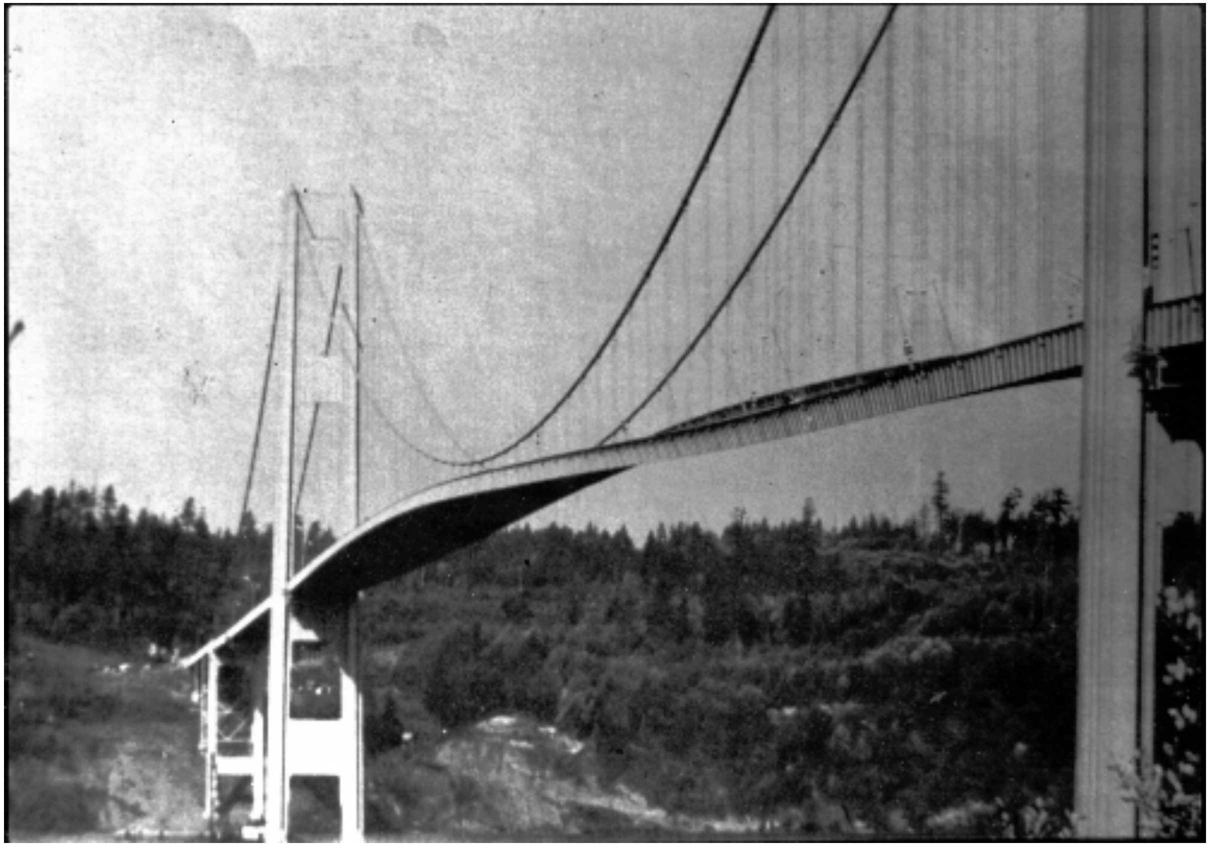


The points of destructive interference (no vibration) are called nodes, and the points of constructive interference (maximum amplitude of vibration) are called antinodes.

Tacoma Narrows Bridge Disaster

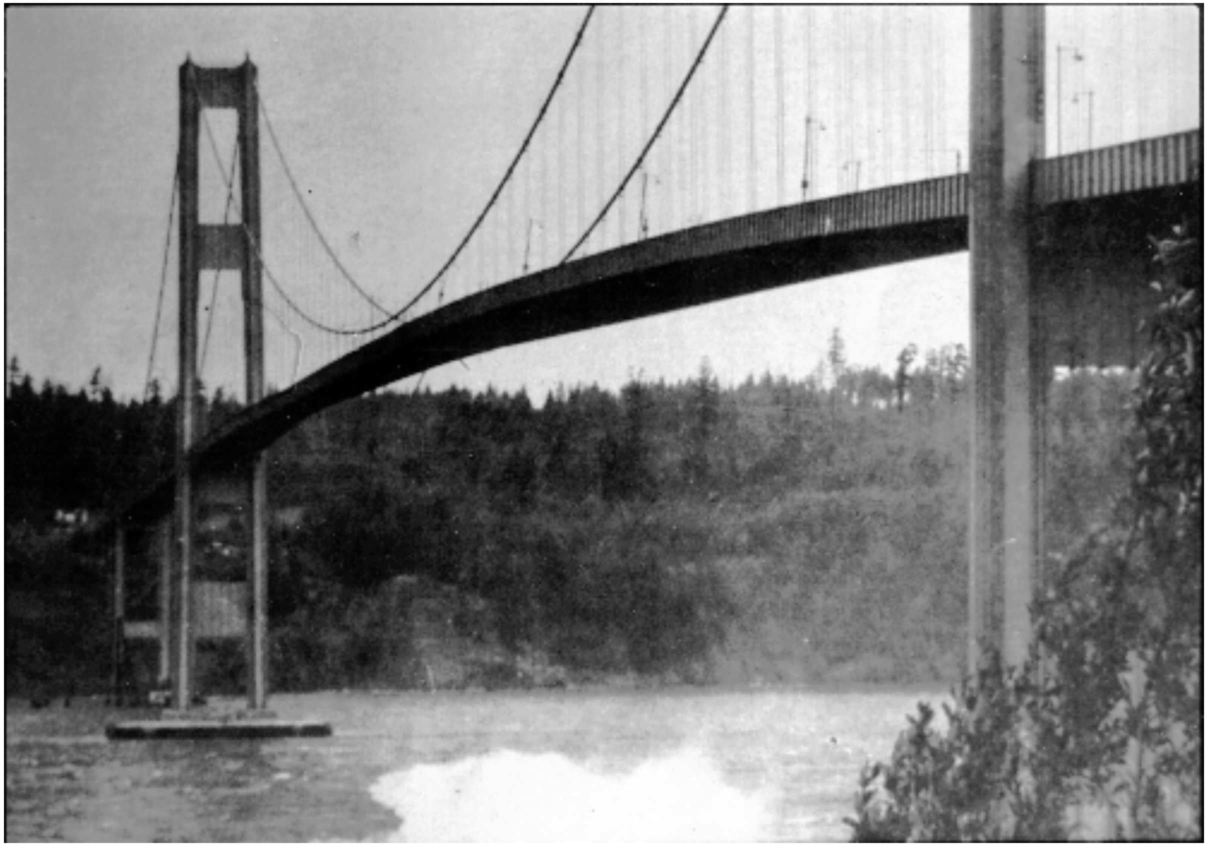
On November 7, 1940, at approximately 11:00 AM, the first Tacoma Narrows suspension bridge collapsed due resonance caused by wind-induced vibrations. The wind speed was 42 mph and the frequency was 0.2 Hz. Situated on the Tacoma Narrows in Puget Sound, near the city of Tacoma, Washington, the bridge had only been open for traffic a few months.



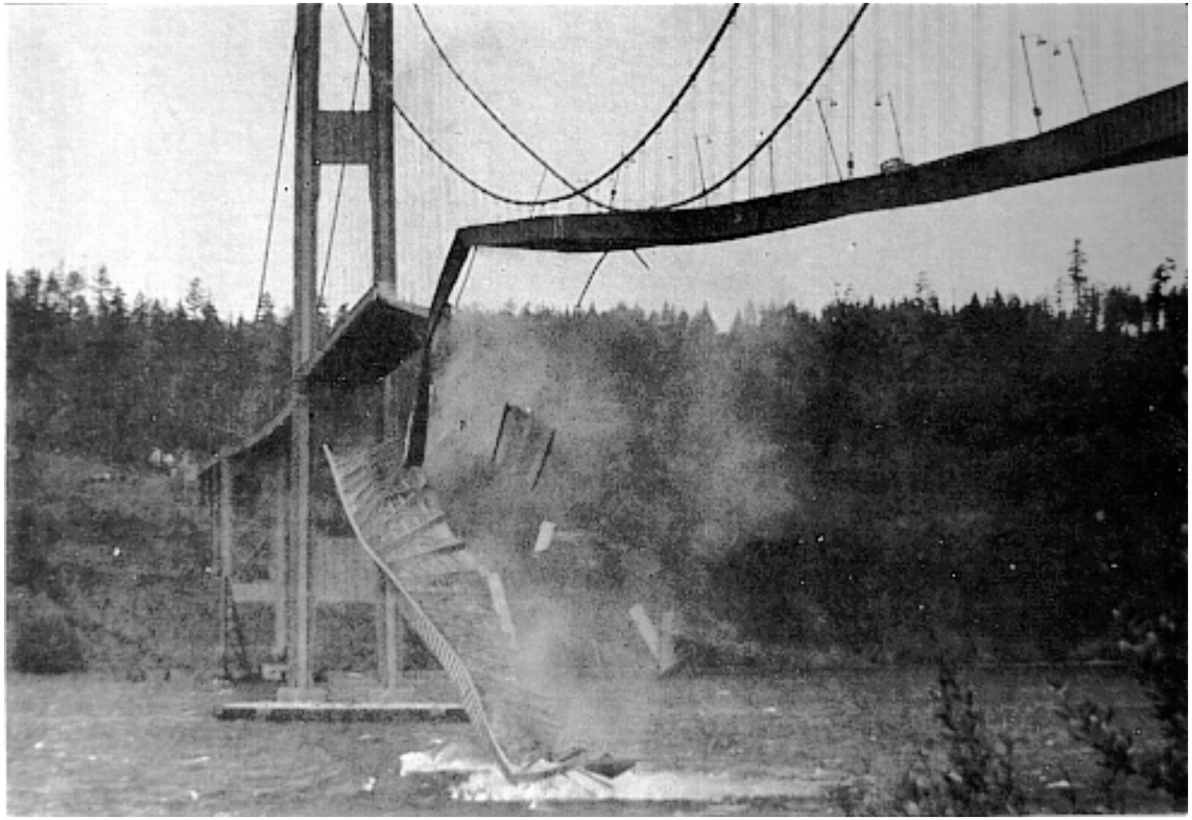


This photograph shows the twisting motion of the center span just prior to failure.

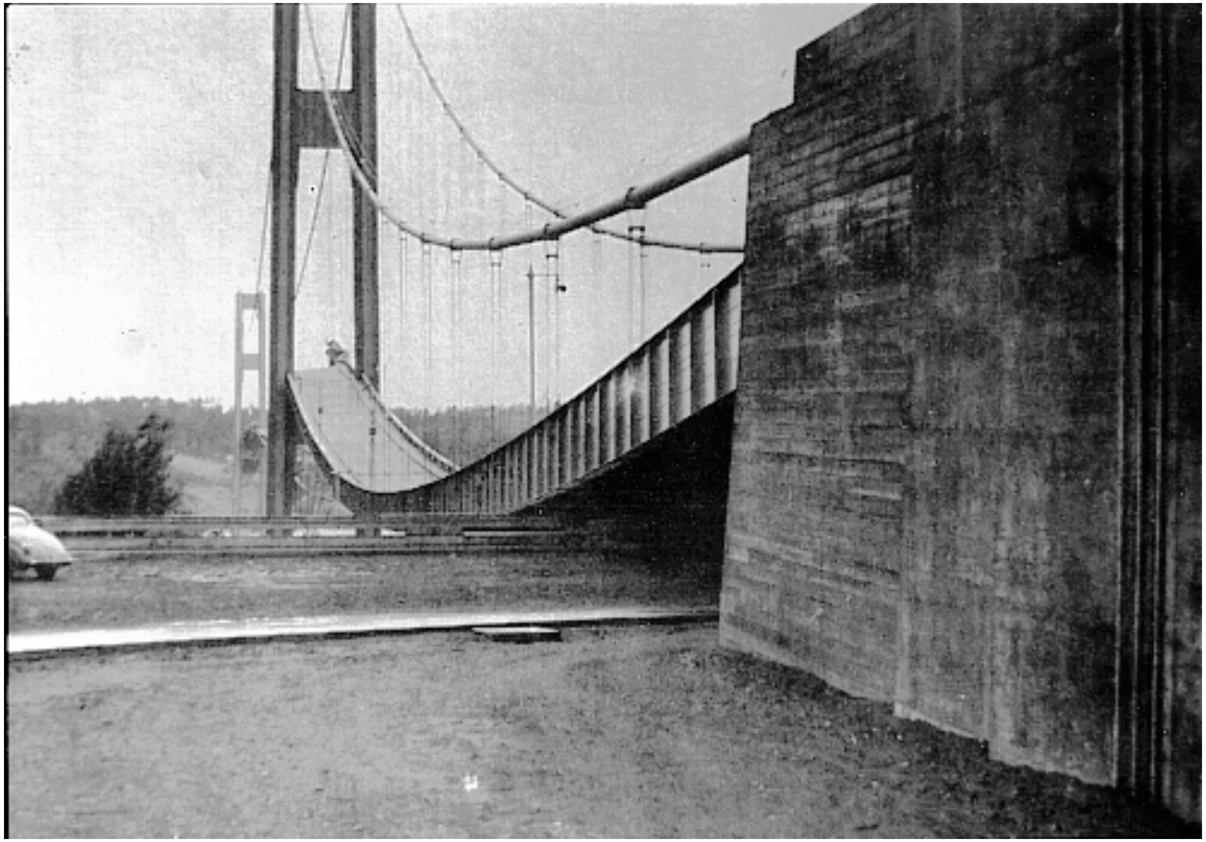
The nature and severity of the torsional movement is revealed in this picture taken from the Tacoma end of the suspension span. When the twisting motion was at the maximum, elevation of the sidewalk at the right was 28 feet (8.5m) higher than the sidewalk at the left.



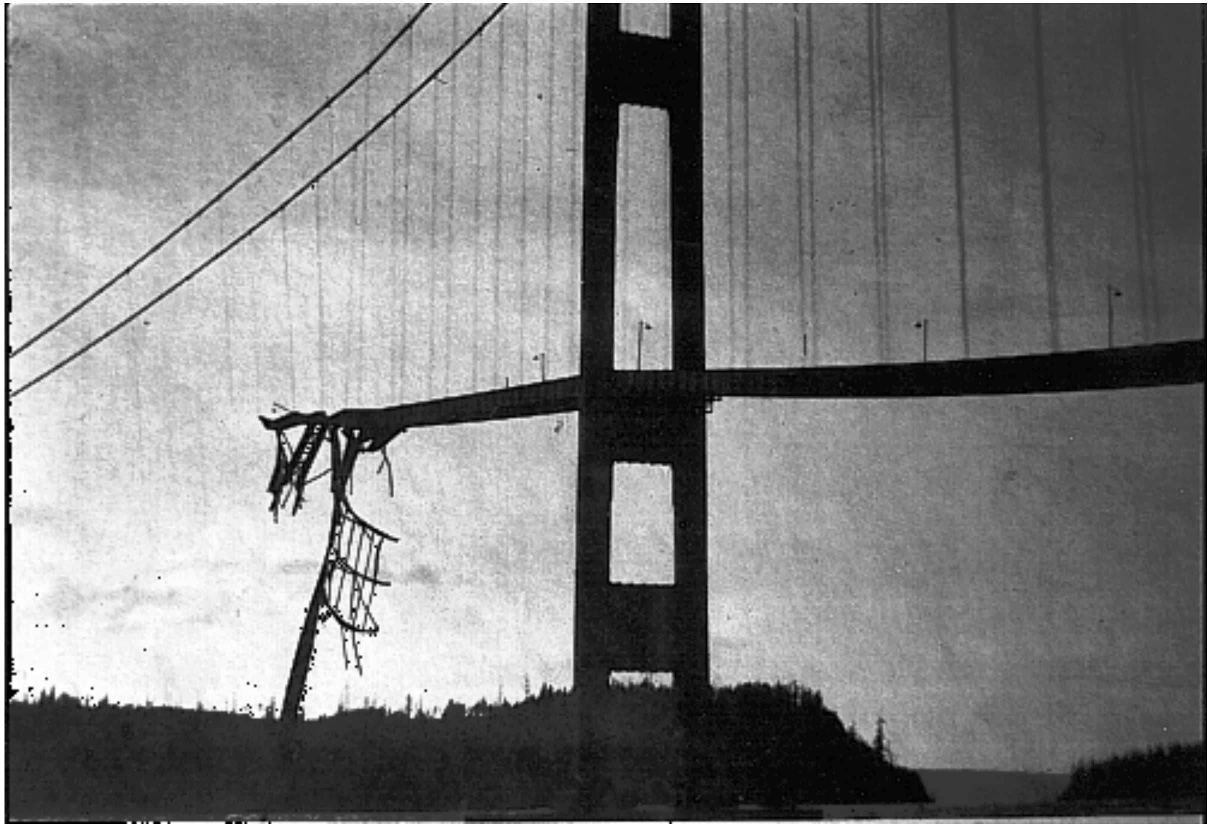
The first failure shortly before 11 o'clock, as the first concrete dropped out of the roadway.



A few minutes after the first piece of concrete fell, this 600 ft section broke out of the suspension span, turning upside down as it crashed in Puget Sound. The floor assembly and the solid girders have been twisted and warped. The square object in mid air is a 25 foot (7.6m) section of concrete pavement. Notice the car in the top right corner.



This photograph shows the sag in the east span after the failure. With the centre span gone there was nothing to counter balance the weight of the side spans. The sag was 45 feet (13.7m).



This picture was taken shortly after the failure. Note the nature of the twists in the dangling remainder of the south stiffening girder and the tangled remains of the north stiffening girder.

Tubby, a cocker spaniel, was the only fatality of the **Tacoma Narrows Bridge** disaster. Leonard Coatsworth, Tubby's owner, was driving with the dog over the bridge when it started to vibrate violently. Coatsworth was forced to flee his car, leaving Tubby behind.

Two people attempted to rescue Tubby, but the dog was too terrified to leave the car and bit one of the rescuers.
Tubby died when the bridge fell, and neither his body nor the car were ever recovered.
Coatsworth received $364.40 in reimbursement for the contents of his car, including Tubby.

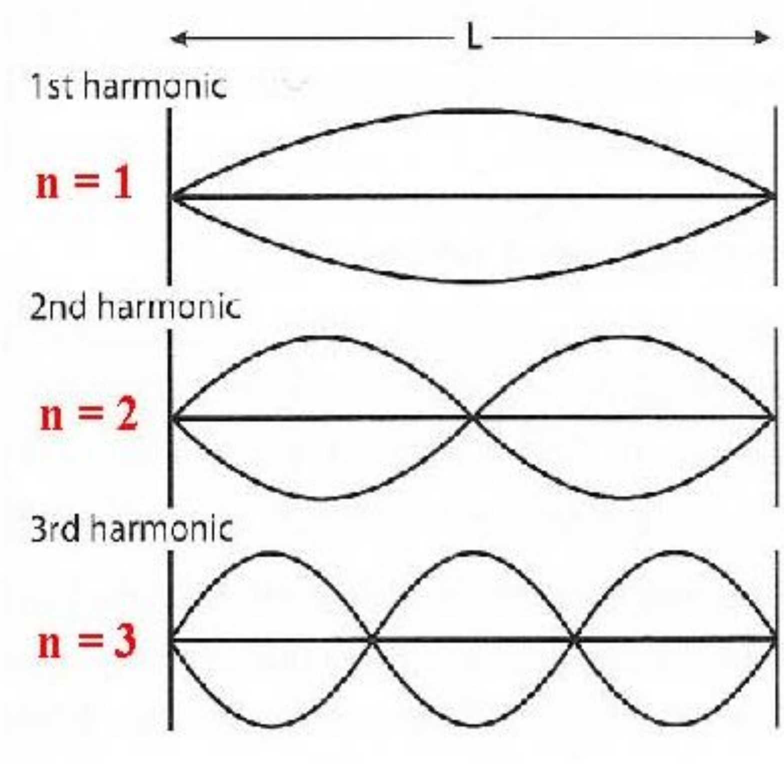
And now the video

- Tacoma Narrows Bridge Collapse

Formula!

Standing wave in a stringed instrument

$\lambda_n = \frac{2}{n}L$ $\qquad f_n = \frac{v}{\lambda_n}$ $\qquad$ where the velocity (v) is the same for all n



One half wave

$\lambda_1 = \frac{2}{1}L \qquad f_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$

Two half waves

$\lambda_2 = \frac{2}{2}L \qquad f_2 = \frac{v}{\lambda_2} = \frac{v}{L} = 2f_1$

Three half waves

$\lambda_3 = \frac{2}{3}L \qquad f_3 = \frac{v}{\lambda_3} = \frac{v}{2/3L} = 3f_1$