

**Today, we will:**

- Do a review problem – hydrostatic forces on submerged bodies
- Discuss buoyancy and stability in hydrostatics
- Discuss fluids in rigid-body motion (linear acceleration and solid-body rotation)

**EXAMPLE 3–8 Hydrostatic Force Acting on the Door of a Submerged Car**

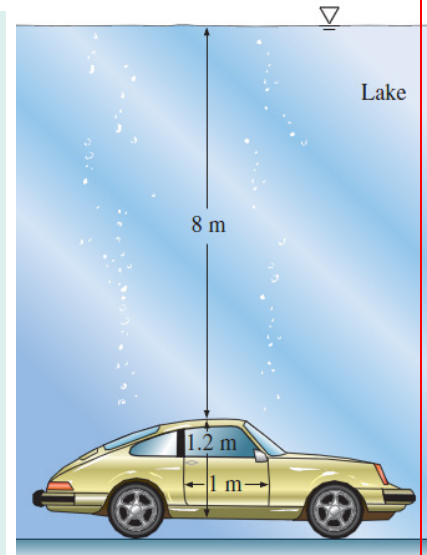
A heavy car plunges into a lake during an accident and lands at the bottom of the lake on its wheels (Fig. 3–34). The door is 1.2 m high and 1 m wide, and the top edge of the door is 8 m below the free surface of the water. Determine the hydrostatic force on the door and the location of the pressure center, and discuss if the driver can open the door.

**SOLUTION** A car is submerged in water. The hydrostatic force on the door is to be determined, and the likelihood of the driver opening the door is to be assessed.

**Assumptions** 1 The bottom surface of the lake is horizontal. 2 The passenger cabin is well-sealed so that no water leaks inside. 3 The door can be approximated as a vertical rectangular plate. 4 The pressure in the passenger cabin remains at atmospheric value since there is no water leaking in, and thus no compression of the air inside. Therefore, atmospheric pressure cancels out in the calculations since it acts on both sides of the door. 5 The weight of the car is larger than the buoyant force acting on it.

**Properties** We take the density of lake water to be  $1000 \text{ kg/m}^3$  throughout.

**Analysis** The average (gage) pressure on the door is the pressure value at the centroid (midpoint) of the door and is determined to be



**Discussion** A strong person can lift 100 kg, which is a weight of 981 N or about 1 kN. Also, the person can apply the force at a point farthest from the hinges (1 m farther) for maximum effect and generate a moment of 1 kN·m. The resultant hydrostatic force acts under the midpoint of the door, and thus a distance of 0.5 m from the hinges. This generates a moment of 50.6 kN·m, which is about 50 times the moment the driver can possibly generate. Therefore, it is impossible for the driver to open the door of the car. The driver's best bet is to let some water in (by rolling the window down a little, for example) and to keep his or her head close to the ceiling. The driver should be able to open the door shortly before the car is filled with water since at that point the pressures on both sides of the door are nearly the same and opening the door in water is almost as easy as opening it in air.

## E. Hydrostatic Forces on Submerged Surfaces (continued)

### 3. Buoyancy and Stability

#### a. buoyancy

#### **Example: Buoyancy**

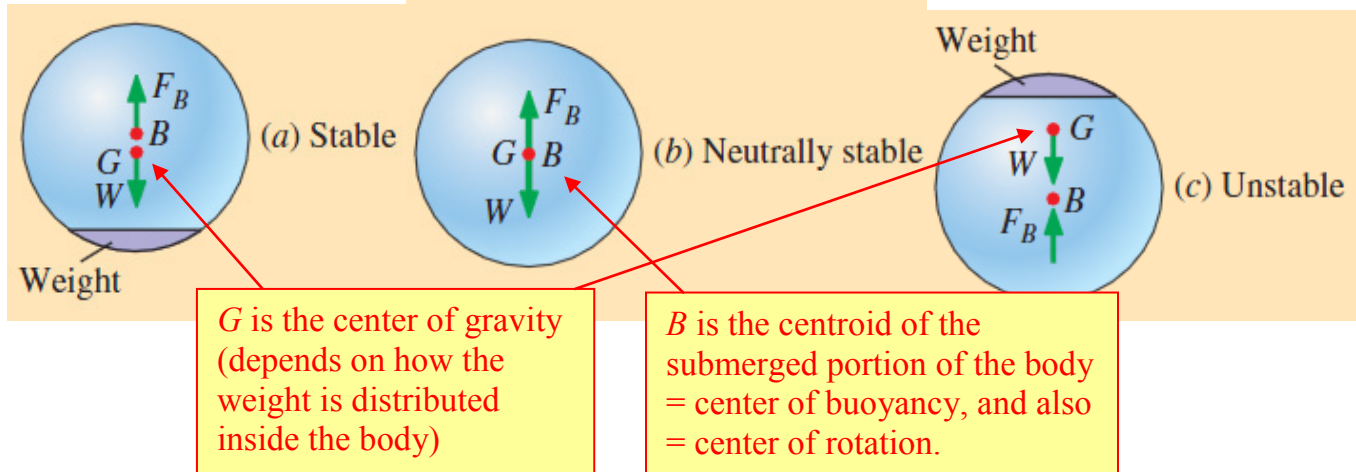
**Given:** A sphere of diameter  $D = 0.0550$  m and density  $\rho_{\text{body}} = 1700$  kg/m<sup>3</sup> falls into a tank of water ( $\rho_f = 1000$  kg/m<sup>3</sup>).

**To do:** Calculate the net downward body force on the sphere due to gravity.

**Solution:**

b. stability

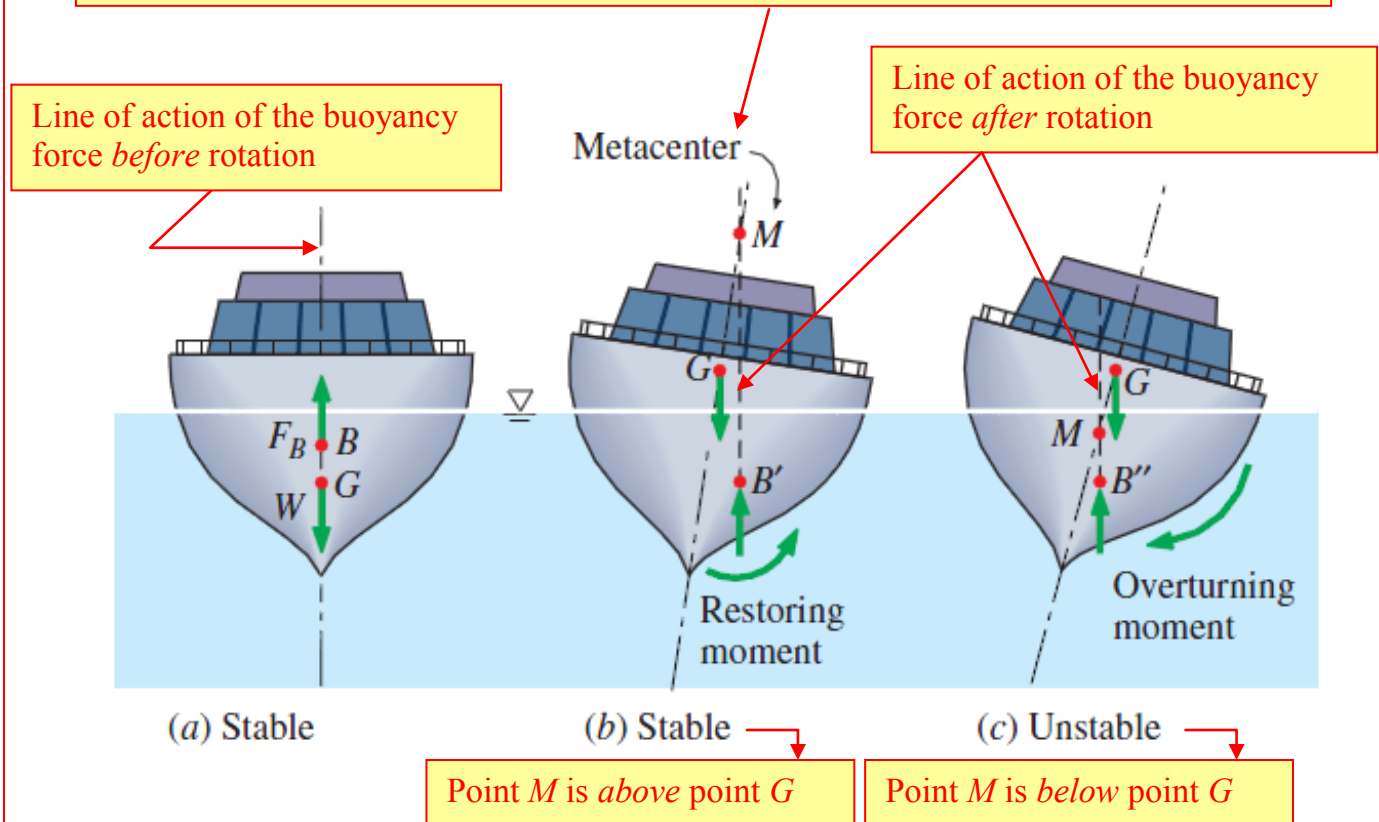
### Stability of a symmetric submerged body



Bottom line: The body is *unstable* if center of buoyancy  $B$  is *below* center of gravity  $G$ .

### Stability of a boat (partially submerged)

Define  $M$  = the **metacenter** = the point where the line of action of the buoyancy force *before* rotation and the line of action of the buoyancy force *after* rotation intersect.



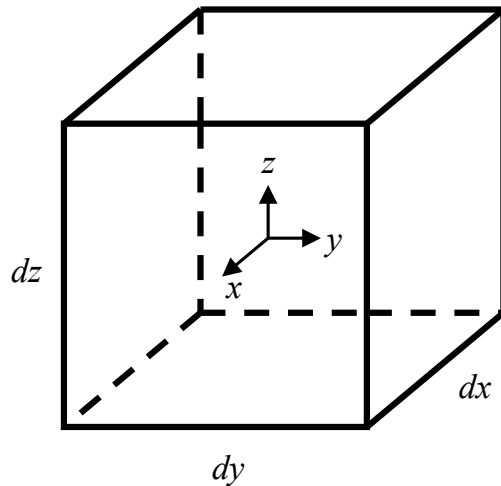
Bottom line: The boat is *unstable* if metacenter  $M$  is *below* center of gravity  $G$ .

## F. Fluids in Rigid-Body Motion (Section 3-7)

### 1. Equations

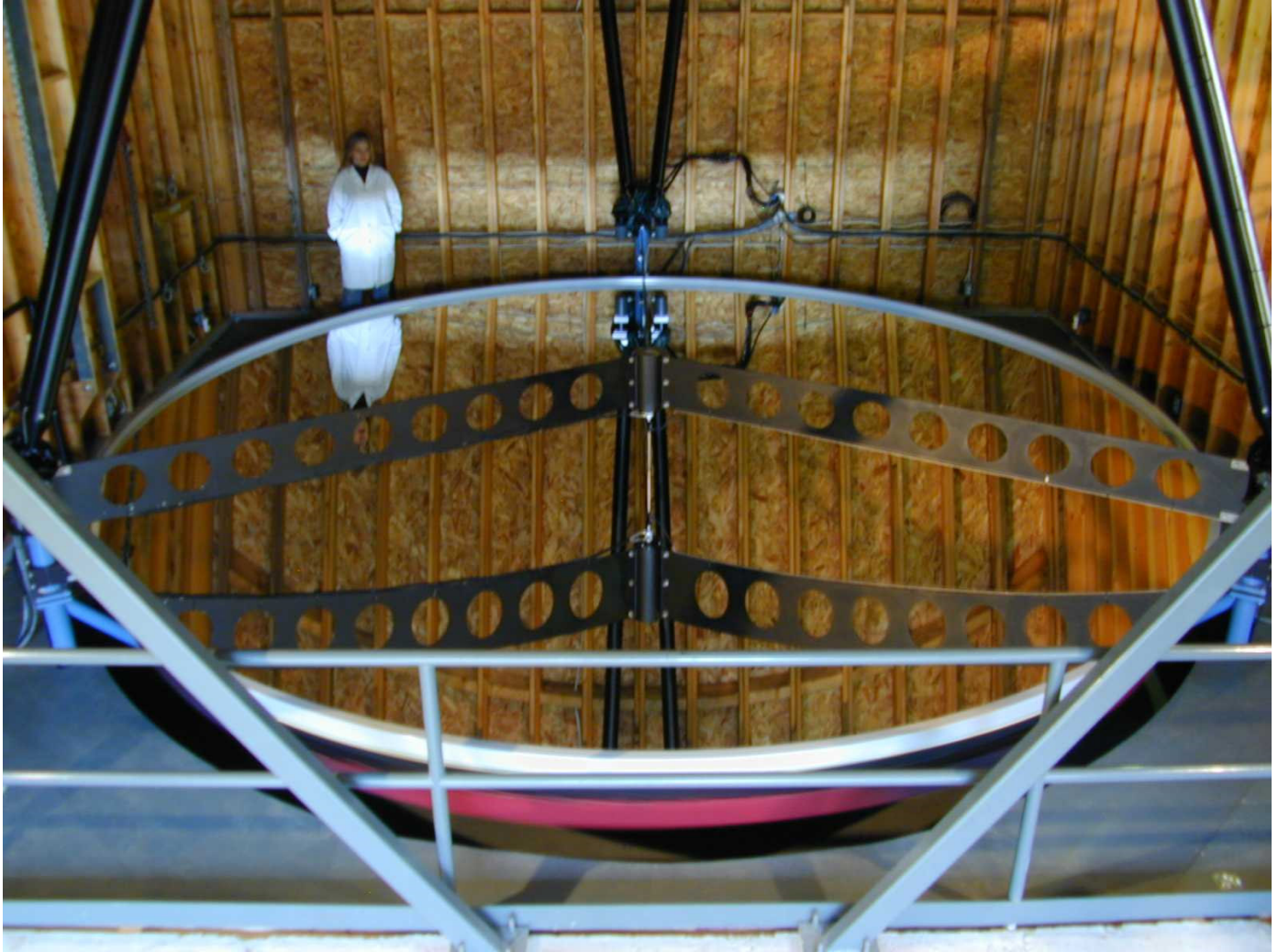
Key: In rigid-body motion, the fluid moves and accelerates as a rigid or solid body – no distortion, and therefore no shear stresses on a fluid element – only pressure and weight.

Consider a small fluid element of dimensions  $dx$ ,  $dy$ , and  $dz$  as sketched previously.



**Liquid mercury mirrors.** By rotating a container of mercury, a nice parabolic mirror can be generated without the need to grind or polish. Unfortunately, it can look only straight up. However, there is some discussion of creating similar mirrors in space – thrust can be used in place of gravity to produce the parabolic shape.

Example: The Large Zenith Telescope in Canada: Photo from <http://www.astro.ubc.ca/LMT/lzt/index.html>.





Mirrors made from spinning molten glass in a furnace, and letting it harden in the paraboloid shape.

Example: The 40-foot (12 meter) diameter spinning furnace used in casting 6.5 meter and 8.4 meter borosilicate glass "honeycomb" mirrors at the Steward Observatory Mirror Lab, University of Arizona. Image from <http://uanews.org>.

