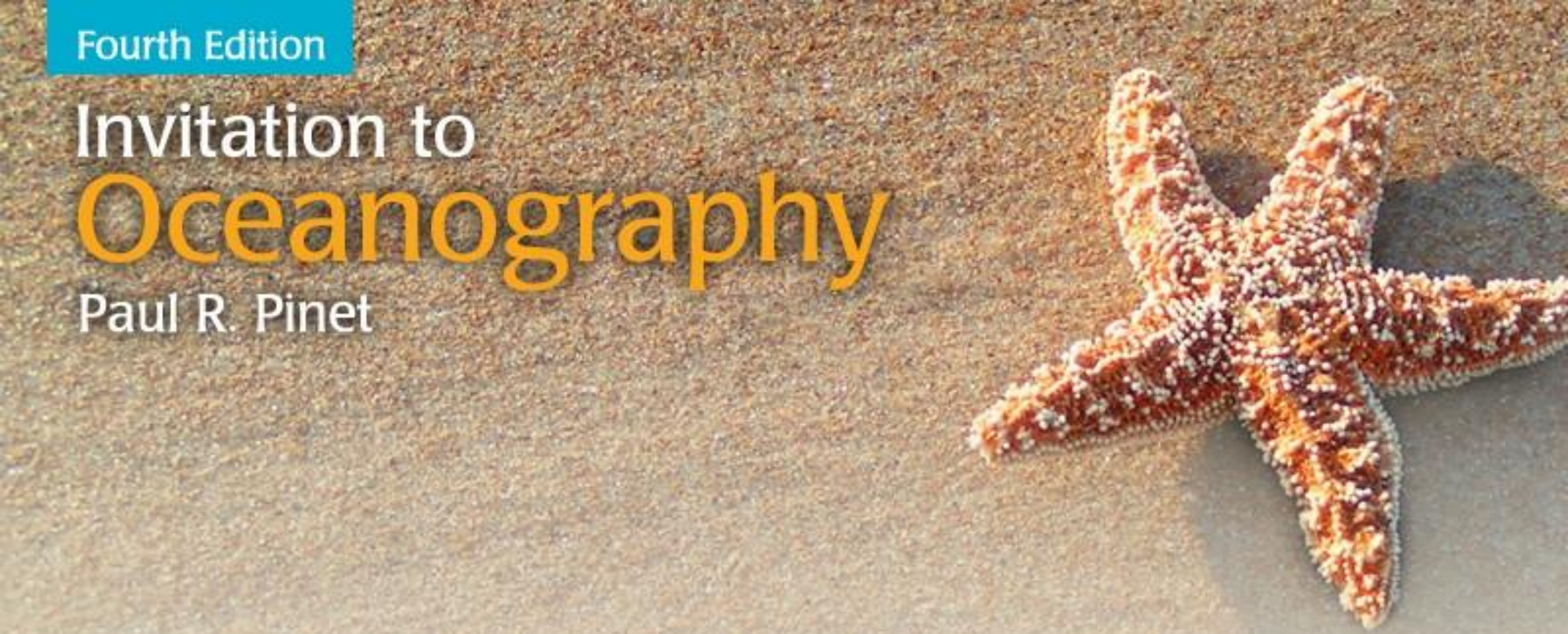
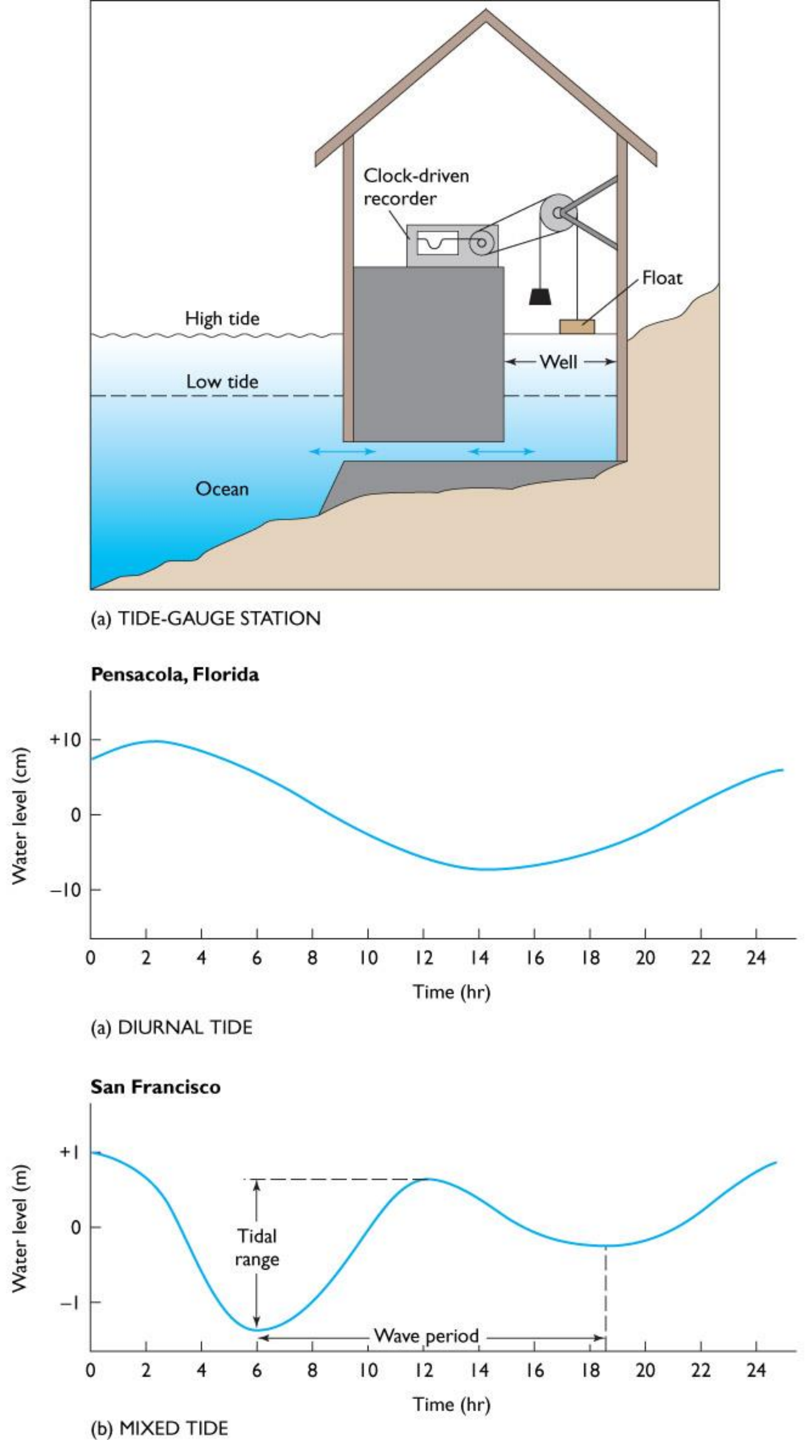


Chapter 8

Tides



The Measurement of Tides

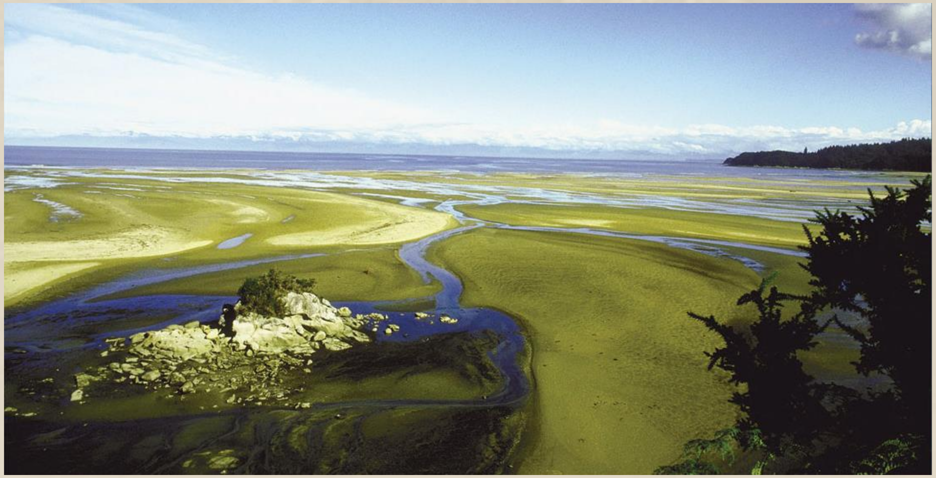


Figure 8-1 The Measurement of Tides

8-1 Tidal Characteristics

- There are three basic types of daily tides defined by their period and regularity:
  - diurnal tides
  - semidiurnal tides
  - mixed tides
- Over a month the daily tidal ranges vary systematically with the cycle of the Moon, causing **spring** and **neap** tides.
- Tidal range is also altered by the shape of a basin and sea floor configuration.

The Measurement of Tides

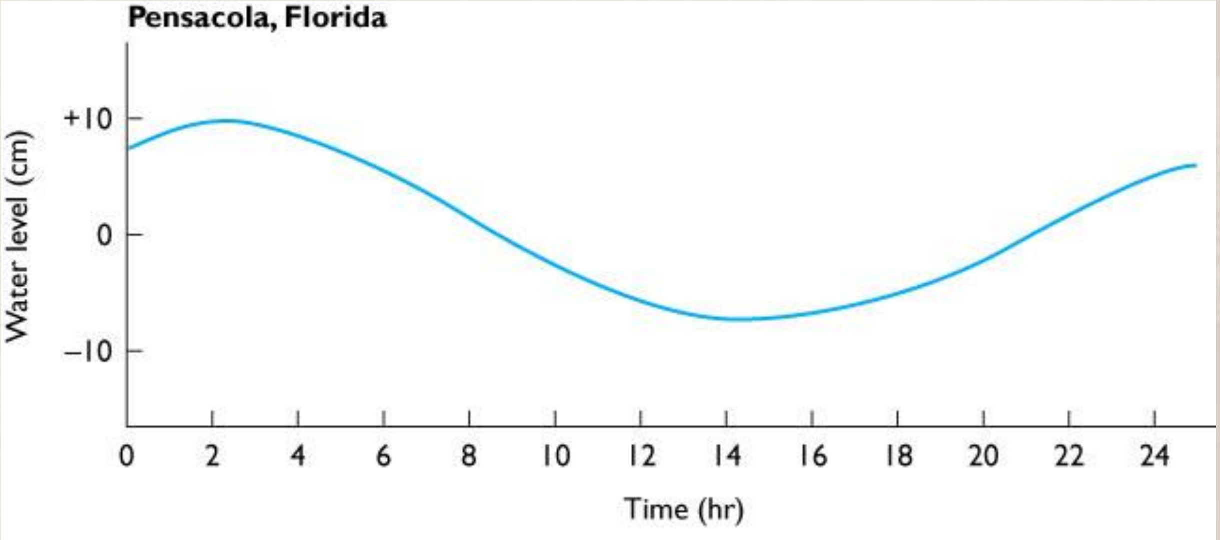


Figure 8-3a Diurnal Tide

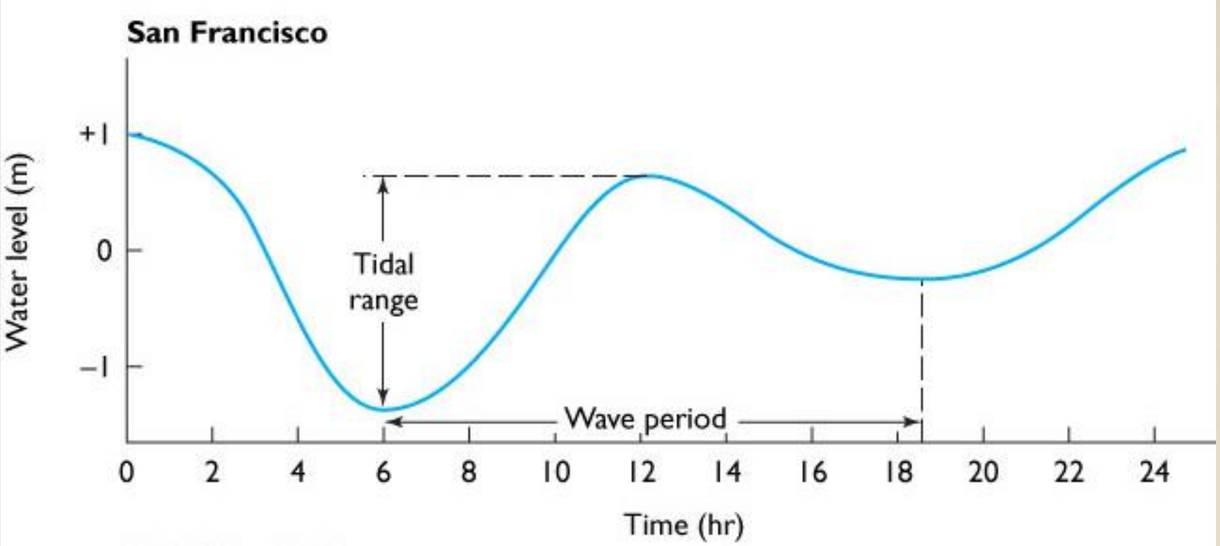


Figure 8-3b Mixed Tide

8-1 Tidal Characteristics

Tides result from gravitational attraction and centrifugal effect.

- Gravity varies directly with mass, but inversely with distance.

- Although much smaller, the Moon exerts twice the gravitational attraction and tide-generating force as the Sun.
  - This is because the Moon is closer.

- Gravitational attraction pulls the ocean towards the Moon and Sun, creating two gravitational **tidal bulges** in the ocean (high tides).

- **Centrifugal effect** is the push outward from the rotation about the center of mass.

Tidal Bulges

Gravitational attraction and centrifugal force produce two tidal bulges of water of about the same size, positioned on opposite sides of the Earth.

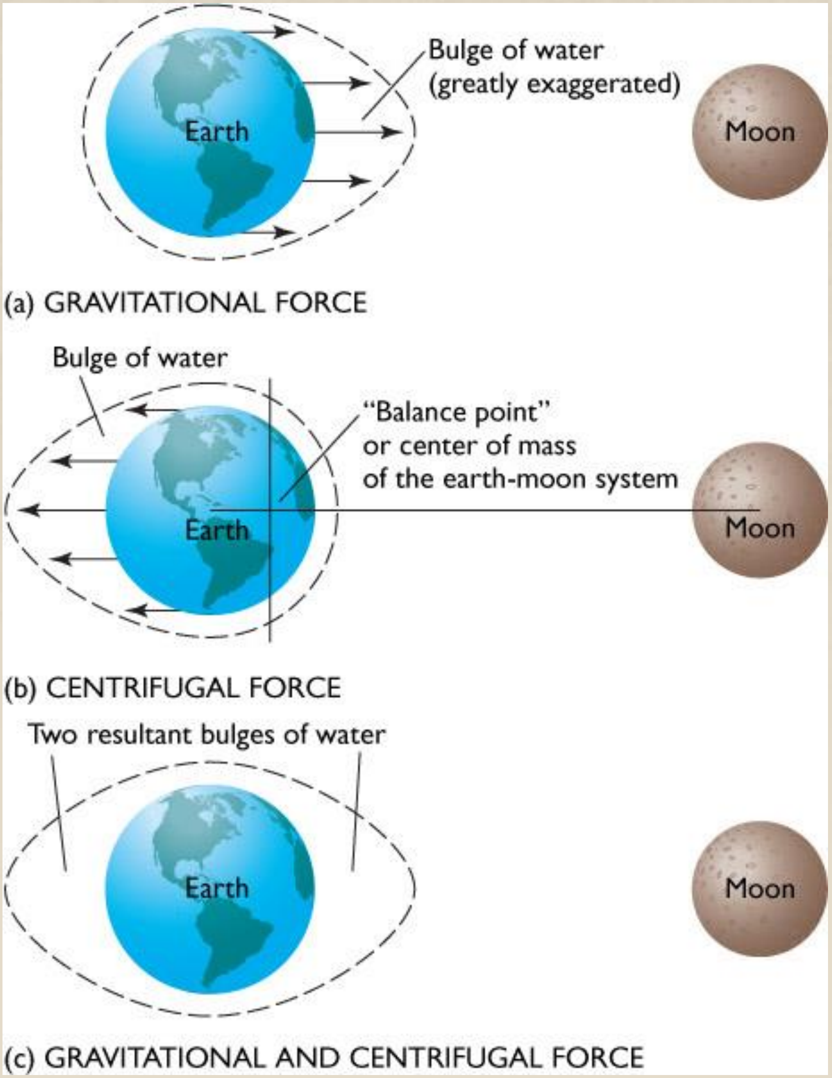
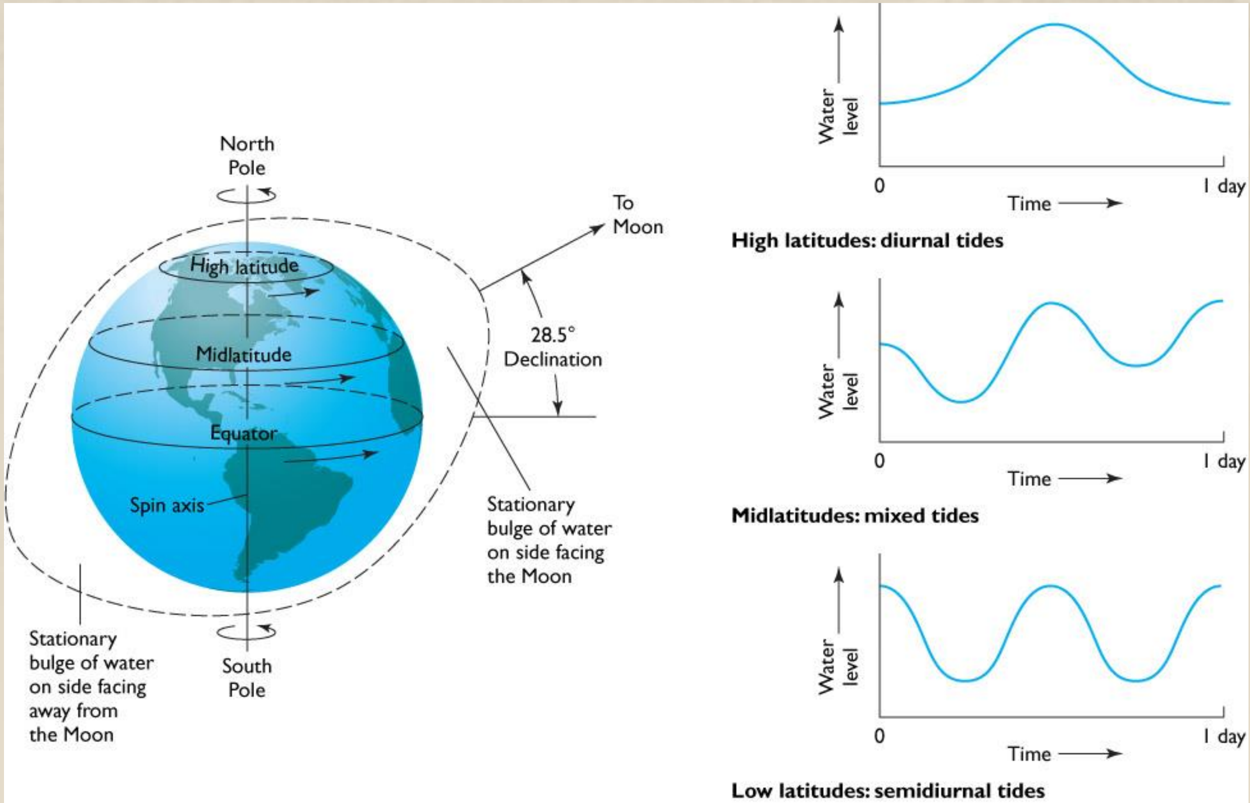


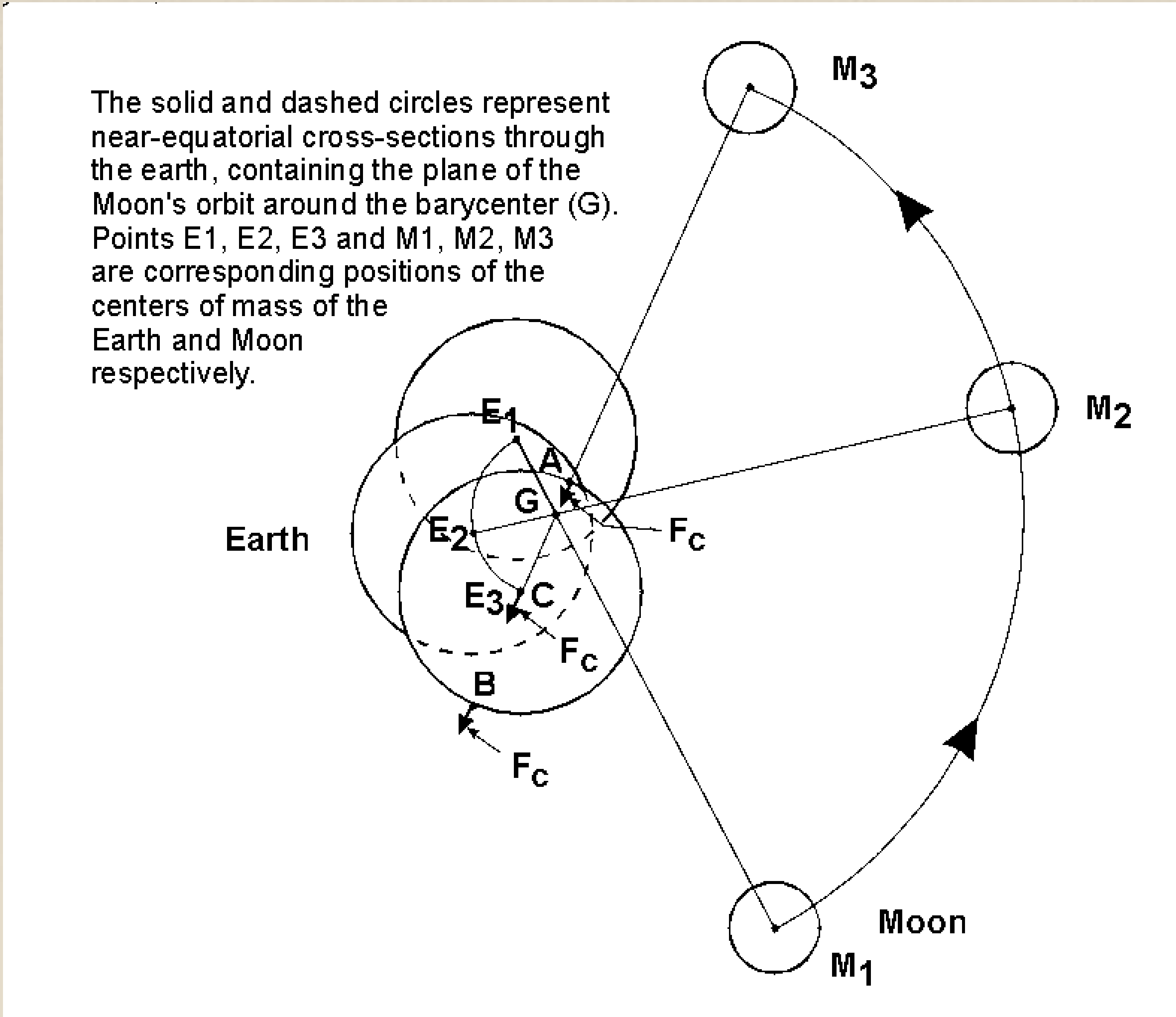
Figure 8-5a Gravitational Force

Figure 8-5b Centrifugal Force

Figure 8-5c Gravitational and Centrifugal Force

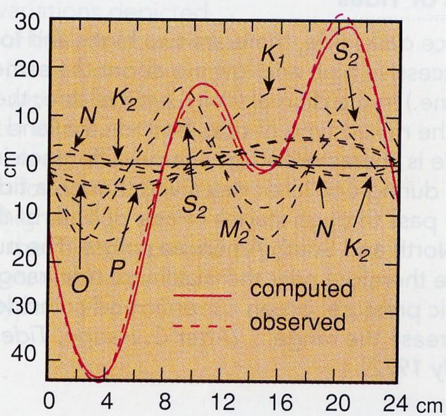
- For equilibrium tides, the latitude of the tidal bulges is determined by the **declination**.
  - Declination is the angle between Earth’s axis and the lunar and solar orbital plane.




The solid and dashed circles represent near-equatorial cross-sections through the earth, containing the plane of the Moon's orbit around the barycenter (G). Points E1, E2, E3 and M1, M2, M3 are corresponding positions of the centers of mass of the Earth and Moon respectively.
M3
M2
Moon
M1
Earth
E1
E2
E3
A
G
C
B
Fc
Fc
Fc

	Symbol	Period in solar hours	Amplitude $M_2 = 100$	Description
Semidiurnal tides	M_2	12.42	100.00	Main lunar (semidiurnal) constituent
	S_2	12.00	46.6	Main solar (semidiurnal) constituent
	N	12.66	19.1	Lunar constituent due to monthly variation in moon's distance
	K_2	11.97	12.7	Soli-lunar constituent due to changes in declination of sun and moon throughout their orbital cycle
Diurnal tides	K_1	23.93	58.4	Soli-lunar constituent
	O	25.82	41.5	Main lunar (diurnal) constituent
	P	24.07	19.3	Main solar (diurnal) constituent

(a) The seven most important partial tides



(b) Partial tides, computed tide, and observed tide at Pula, Yugoslavia (January 6, 1909). Note close fit of computed and observed tides.

- Spring tides occur when:
  - Earth, Moon and Sun are aligned in a straight line
  - the tidal bulges display constructive interference, producing high high tides and low low tides.
    - Spring tides coincide with the new and full moon.

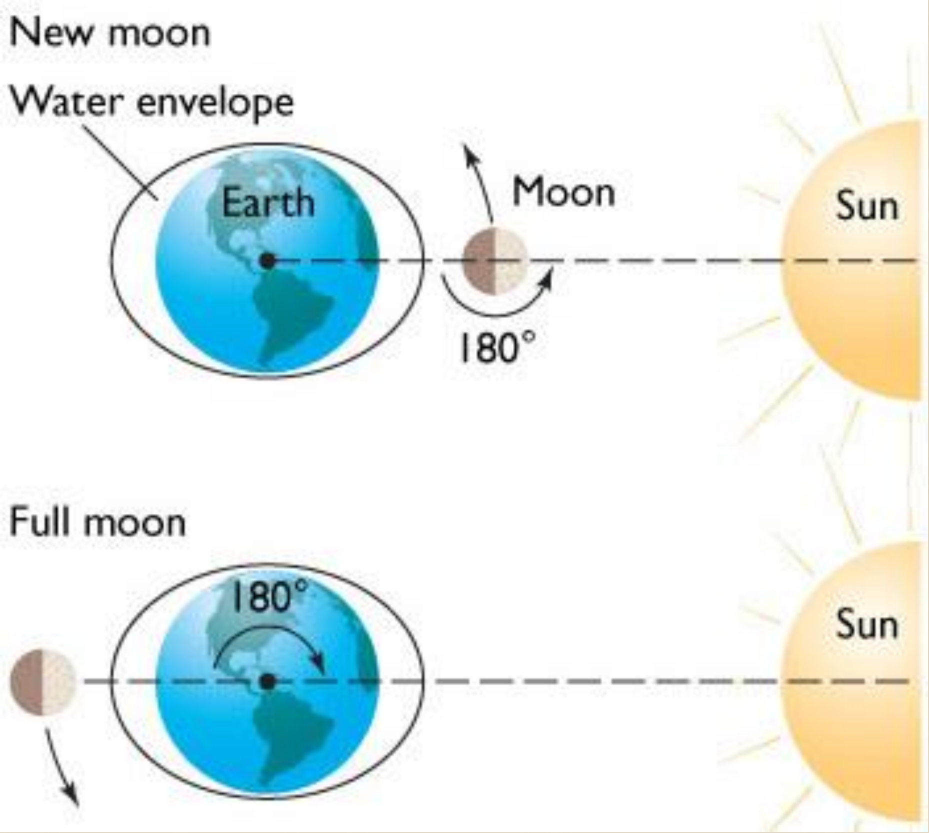


Figure 8-7b Spring Tides

- Neap tides occur when:
  - the Earth, Moon and Sun are aligned forming a right angle
  - tidal bulges display destructive interference, producing low high tides and high low tides.
    - Neap tides coincide with the first and last quarter moon.

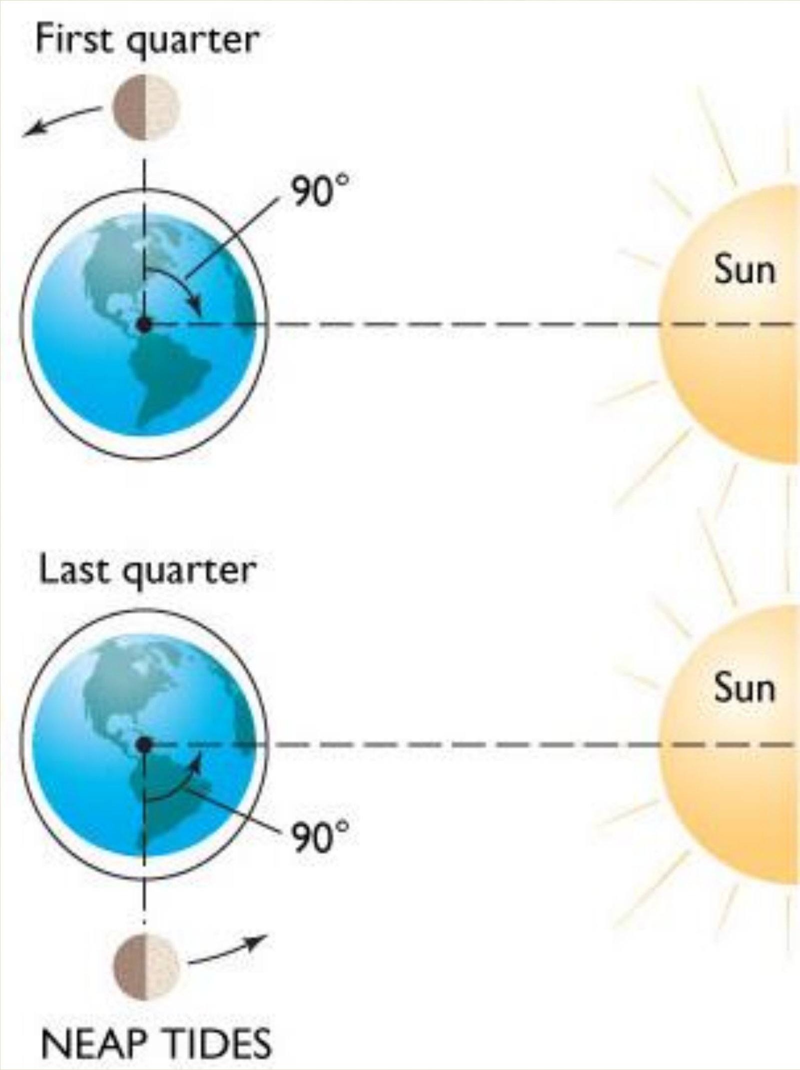


Figure 8-7b

- Earth on its axis and the Moon in its orbit both revolve eastward.
  - This causes the tides to occur 50 minutes later each day.

The Dynamic Model of Tides

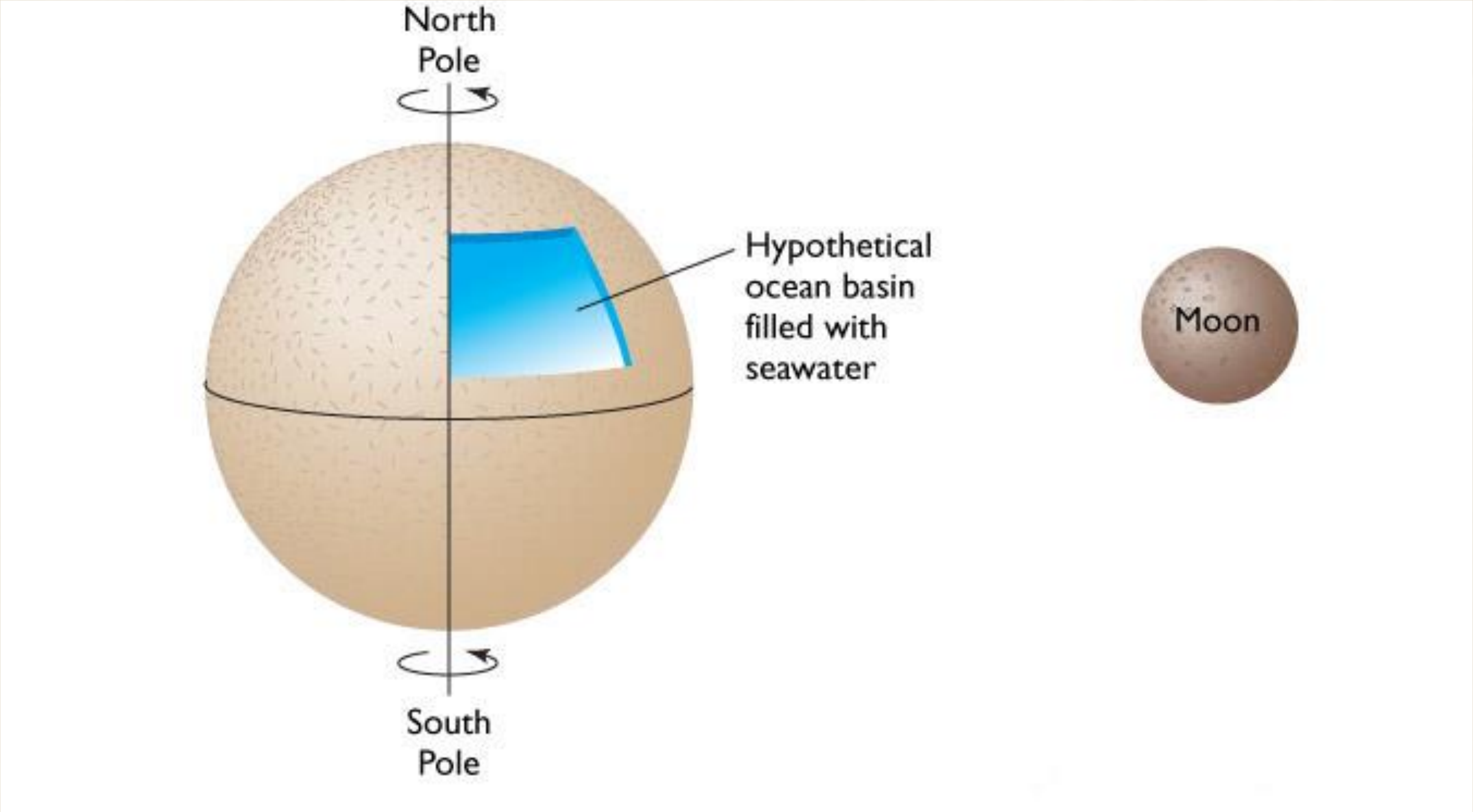


Figure 8-8a The Dynamic Model of the Tides

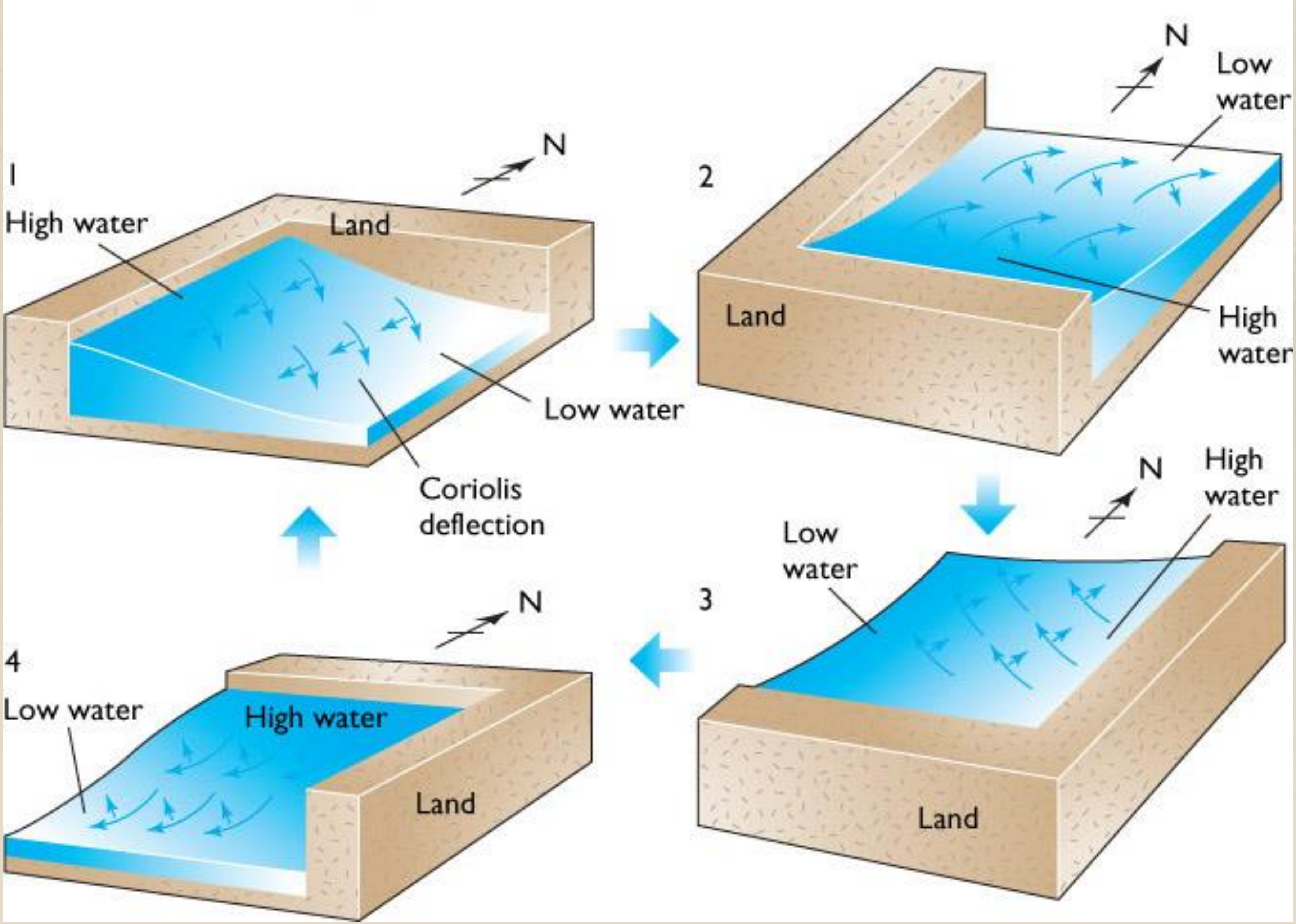


Figure 8-8b The Dynamic Model of the Tides

8-2 The Origin of the Tides

Amphidromic Systems

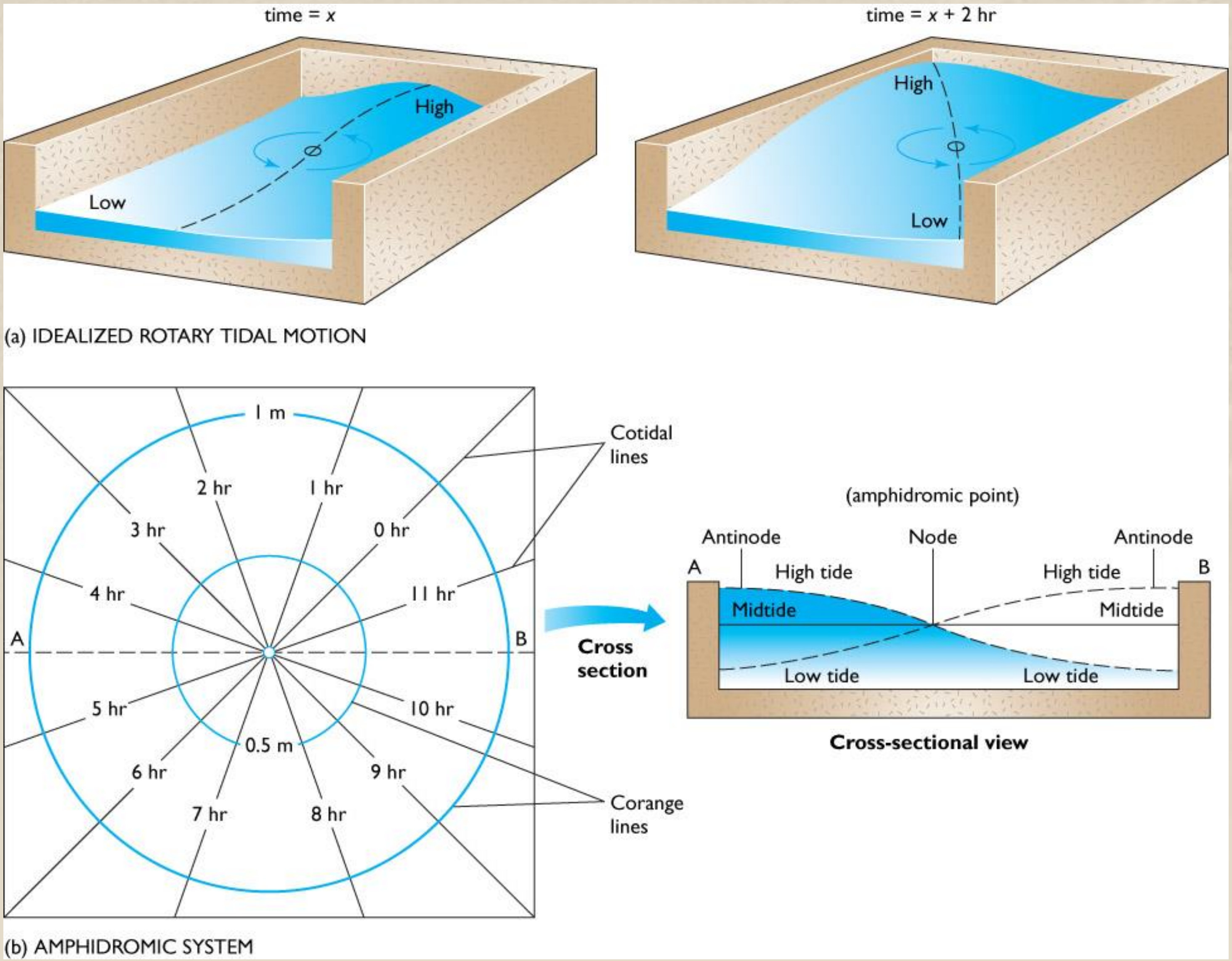


Figure 8-9 Amphidromic Systems

- **Cotidal lines** connect points on the rotary wave that experience high tide at the same time.
  - Cotidal lines are not evenly spaced.
    - This is because tides are shallow water waves and their speed (celerity) depends upon water depth.

- **Corange circles** are lines connecting points that experience the same tidal range.
  - The lines form irregular circles which are concentric about the node.
  - Tidal range increases outward from the node.

- Amphidromic systems rotate clockwise in the southern hemisphere and counterclockwise in the northern hemisphere.

- Irregular coastlines distort the rotary motion.

- Actual tide expressed at any location is a composite of 65 different tidal components.

Global Amphidromic Systems for the Main Lunar Component

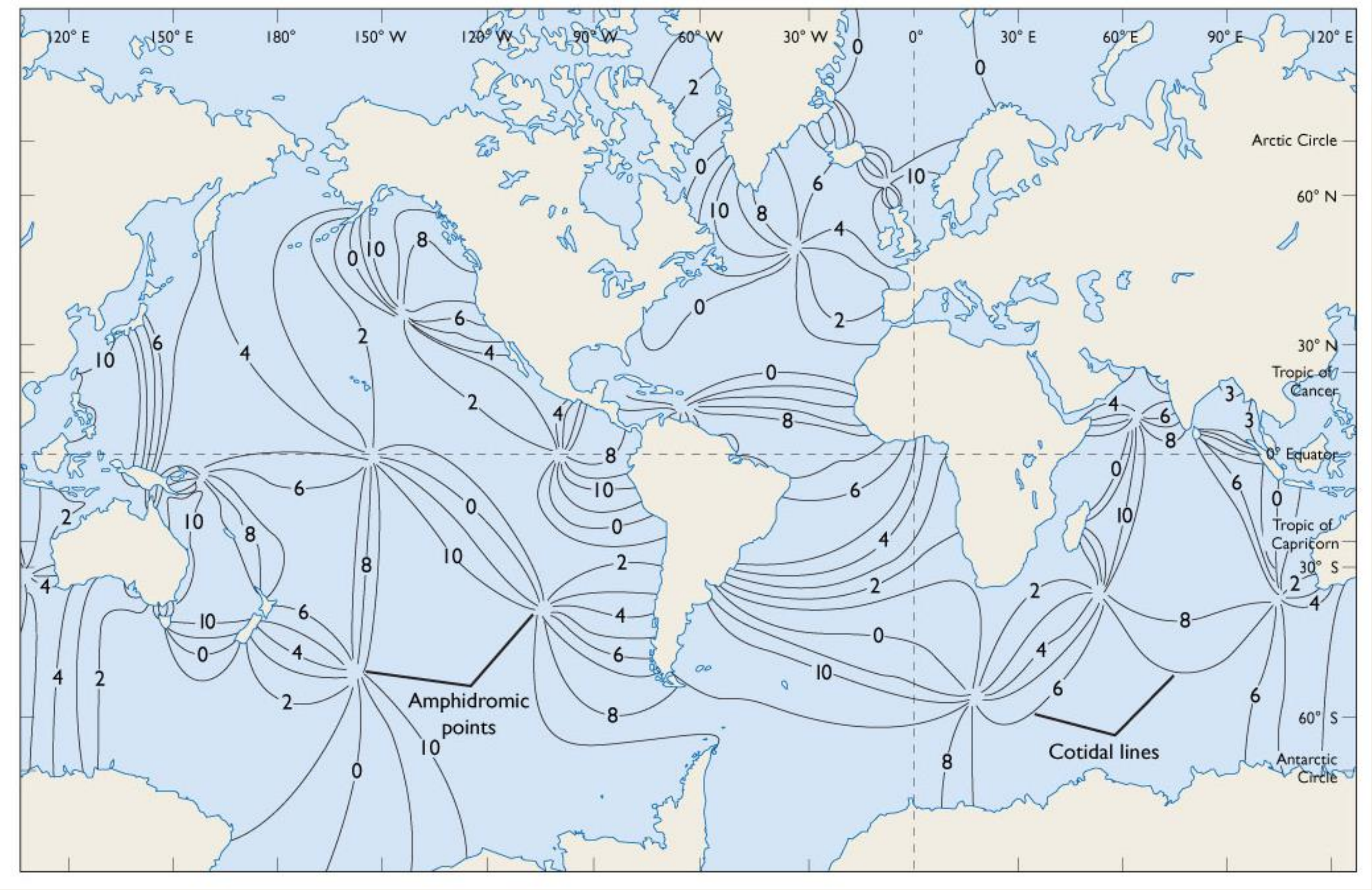


Figure 8-11 Global Amphidromic Systems for the Main Lunar Component

Global Tidal Variations

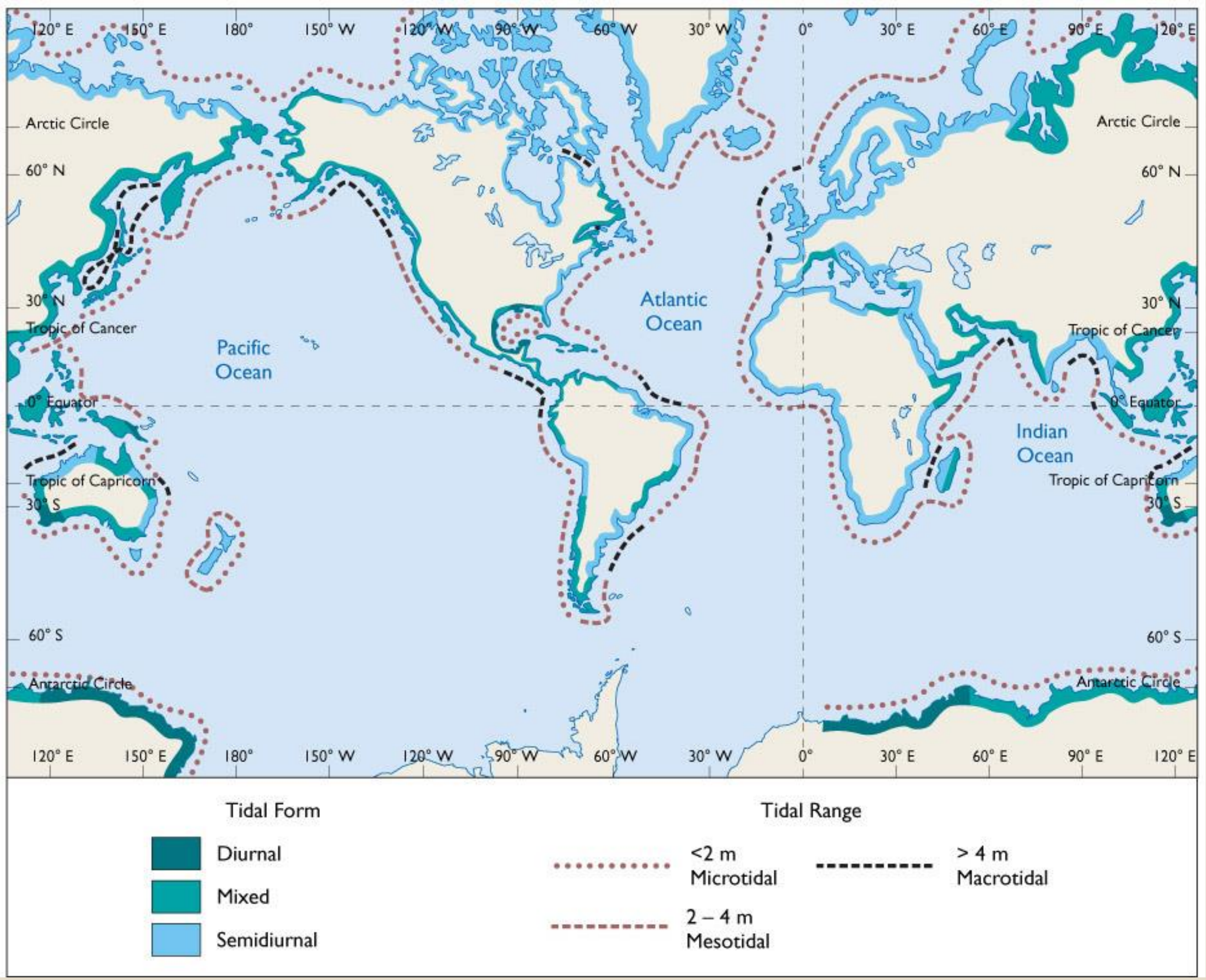


Figure 8-12

In long and narrow basins tides cannot rotate

- Currents in these basins simply reverse direction between high and low tide.
- Cotidal and corange lines are nearly parallel to each other.
- Tidal ranges increase if a bay tapers landward because water is funneled towards the basin’s narrow end.
- **Tidal resonance** occurs if the period of the basin is similar to the tidal period.
    - Resonance can greatly enhance the tidal range.
- A **tidal bore** is a wall of water that surges upriver with the advancing high tide.

Tides in Restricted Basins

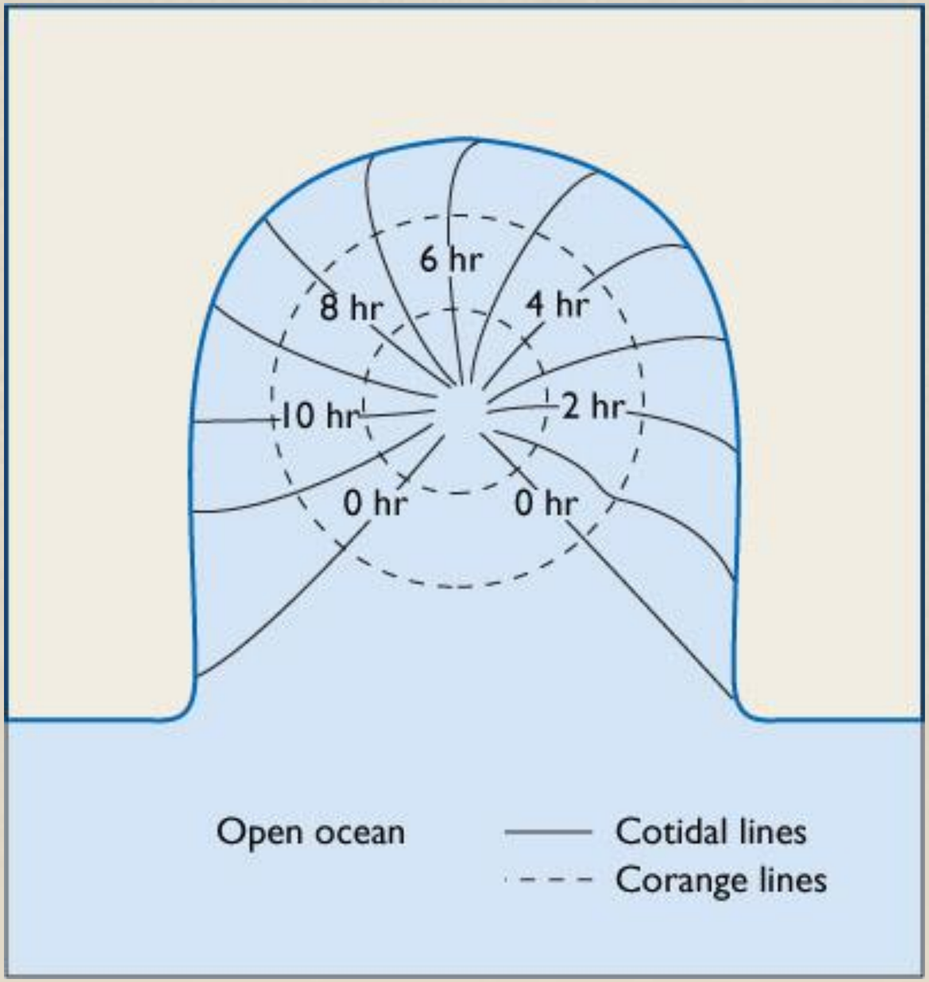


Figure 8-13a Broad Basin

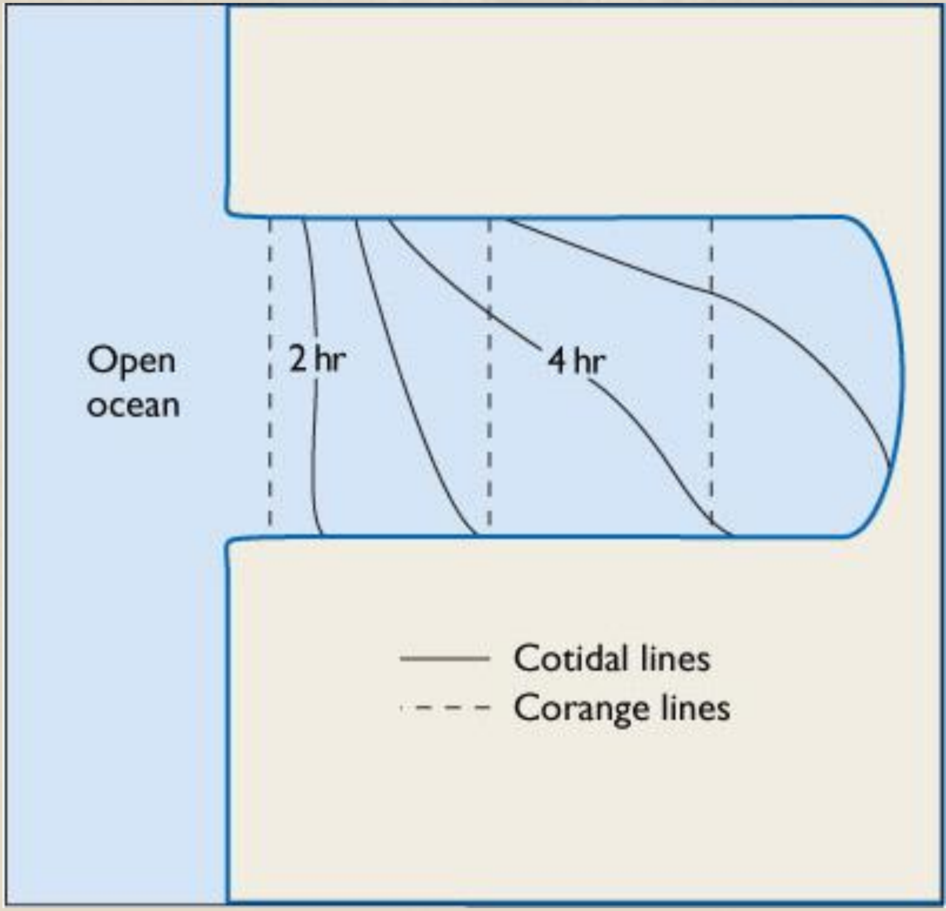


Figure 8-13c Narrow Basin

8-3 Tides in Small & Elongated Basins

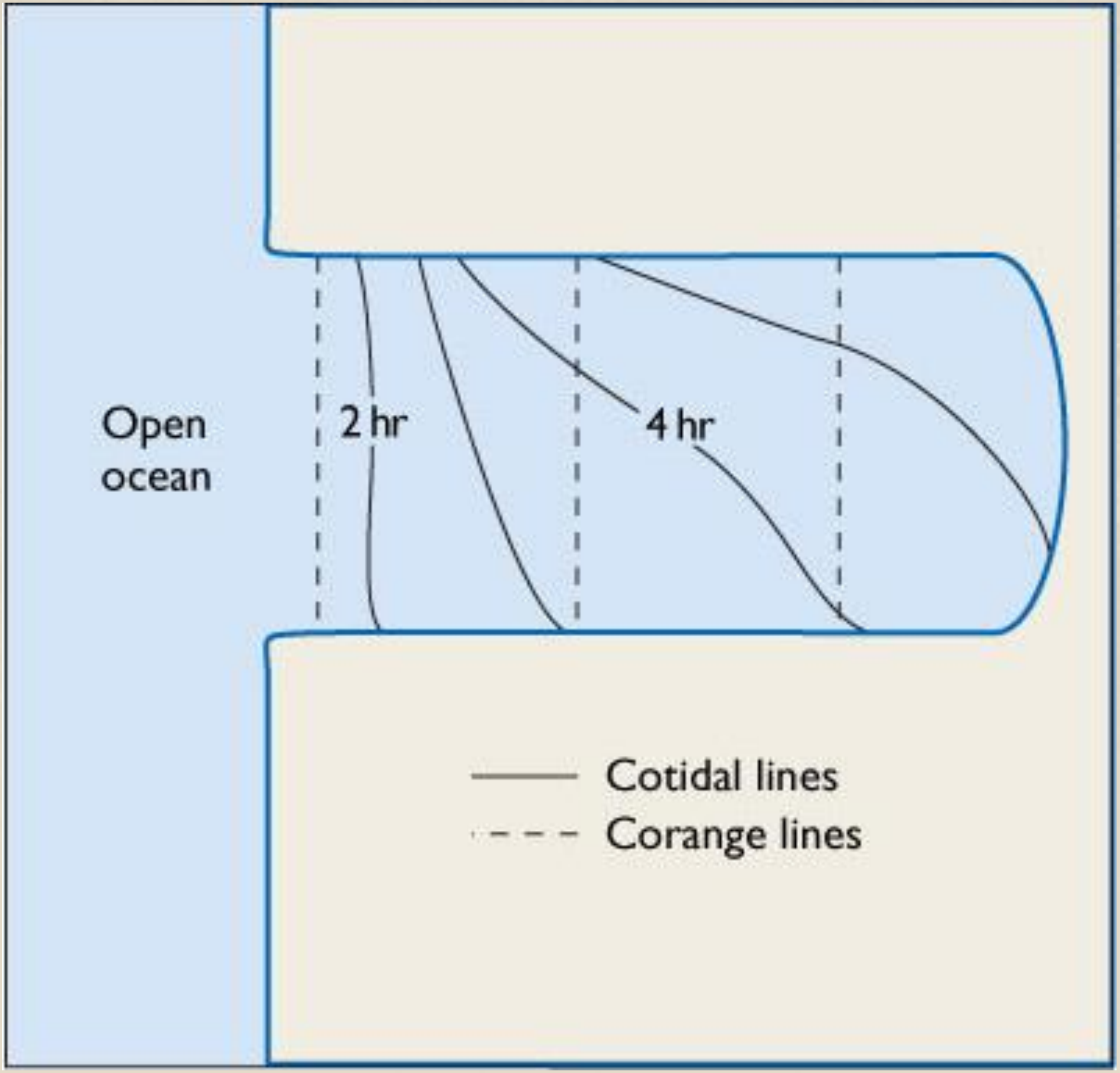
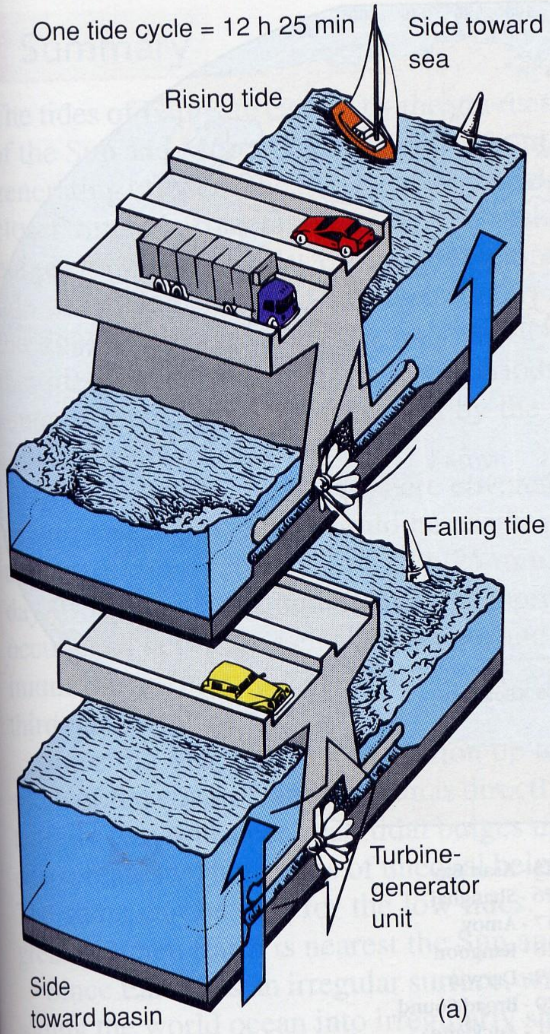


Figure 8-13b Amphidromic System: Gulf of St. Lawrence

8-3 Tides in Small & Elongated Basins


QUÉBEC
ONTARIO
Montréal
Ottawa
Toronto
NEW BRUNSWICK
NOUVEAU-BRUNSWICK
P.E.I.
Î.-P.-É.
NOVA SCOTIA
NOUVELLE-ÉCOSSE
NEWFOUNDLAND
TERRE-NEUVE
U.S.A.
É.-U.
Boston
New York
BAY OF FUNDY



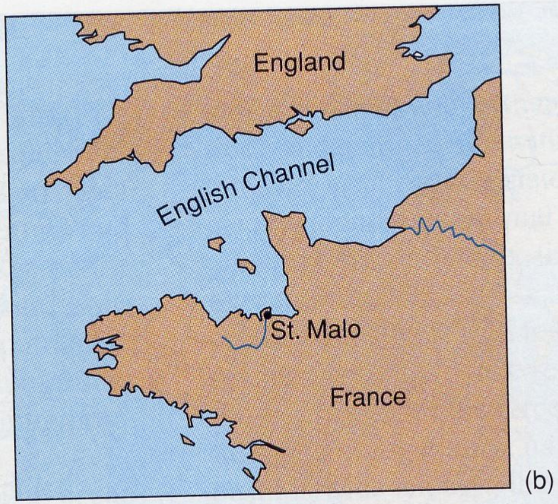


Figure 11-27 **La Rance Tidal Power Plant at St. Malo, France**

Diagram shows the barrier between the open ocean to the right and the La Rance estuary to the left. The relative water levels during rising and falling oceanic tides also are shown. *(Photo courtesy of Phototeque/Electricite de France.)*

- The movement of water towards and away from land with the tides generates tidal currents.

- **Flood current** is the flow of water towards the land with the approaching high tide.

- **Ebb current** is the flow of water away from the land with the approaching low tide.

- Offshore, the tidal currents inscribe a circular path over a complete tidal cycle.

- Nearshore, the tidal currents produce simple landward and then seaward currents.

- If we have a large bay connected to the ocean by a narrow opening, electricity can be generated from tidal currents if the tidal range is greater than 5m.

- A dam is constructed across the opening.

- Water is allowed to flow into and out of the bay, driving turbines and generating power.

Power from the Tides

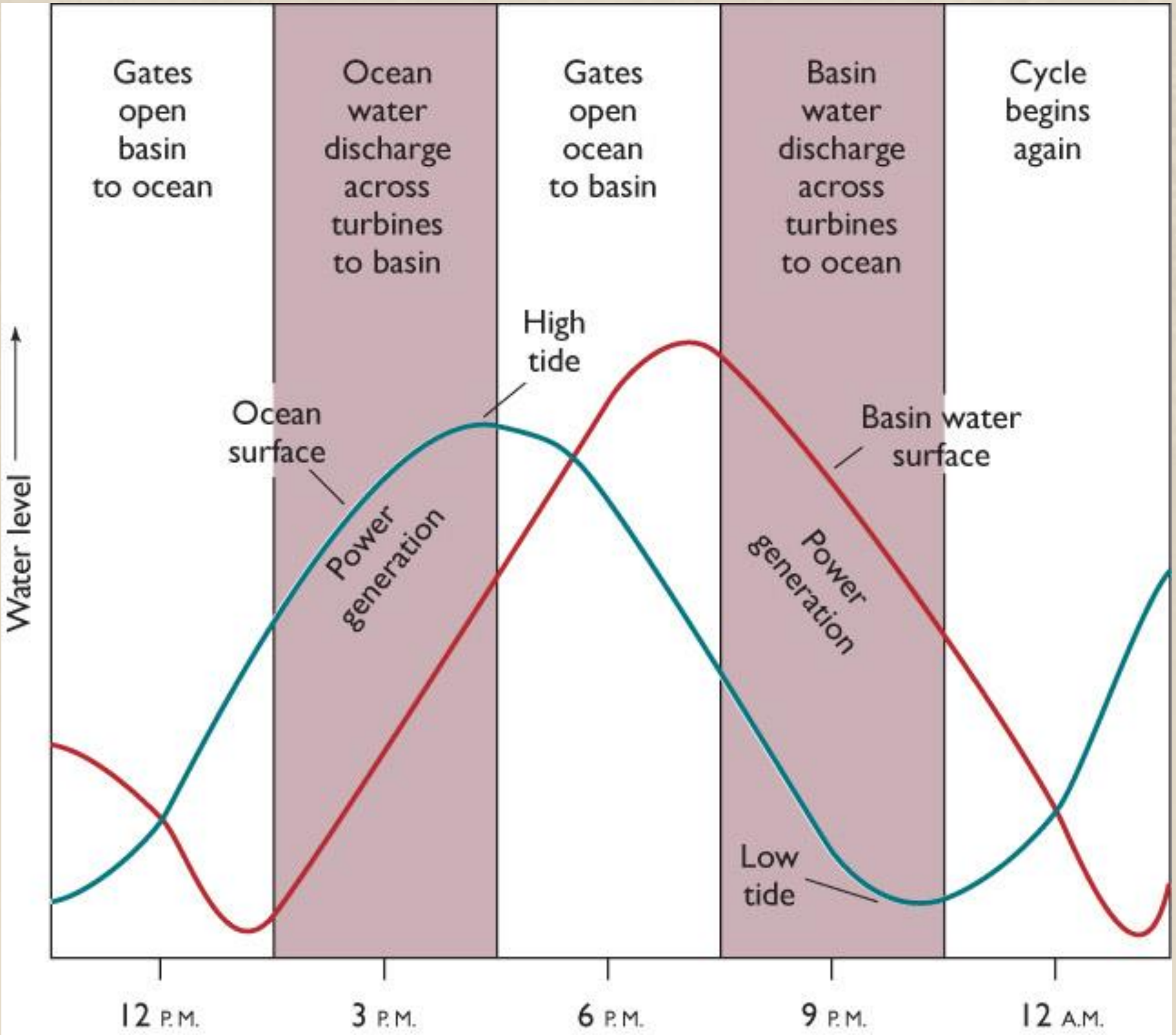


Figure 8-17 Power from the Tides