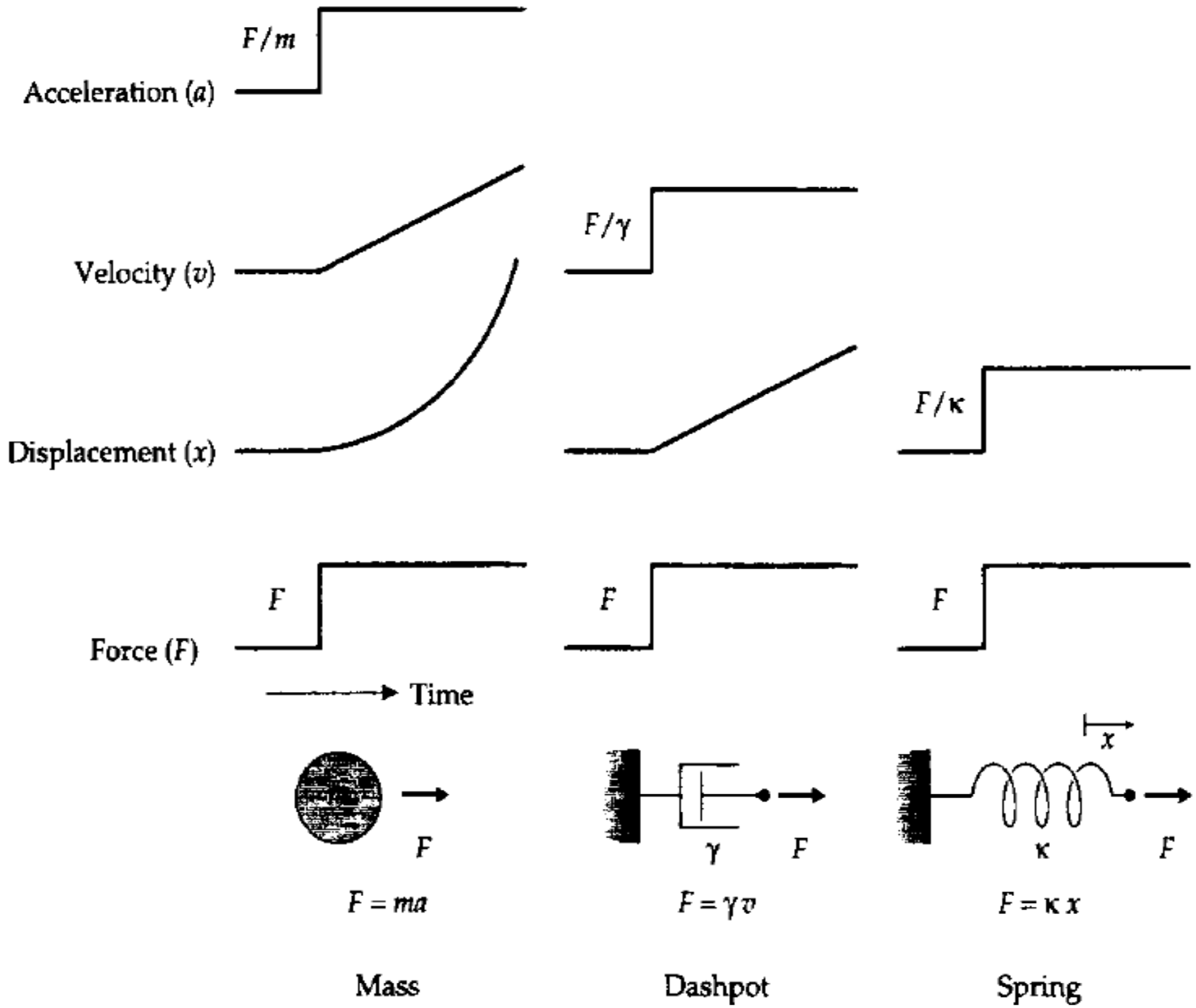


Figure 2.2 Motion of a mass, a dashpot, and a spring under the influence of a constant external force

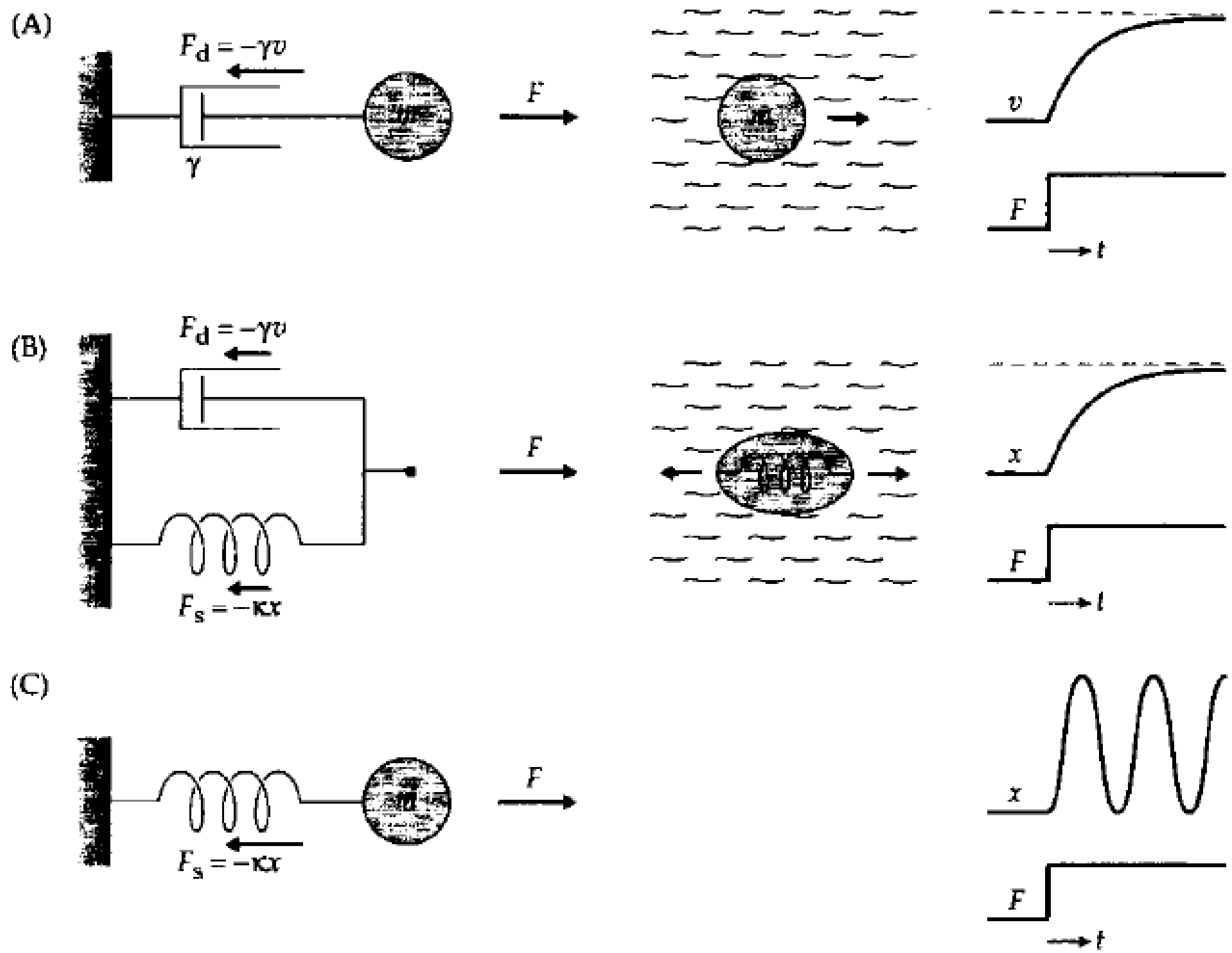
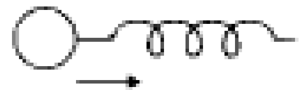
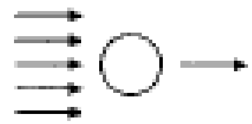
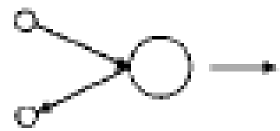
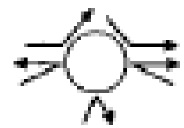
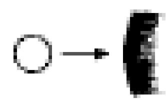
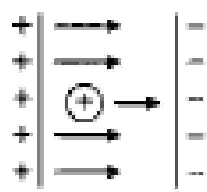


Figure 2.3 Motion of pairs of mechanical elements
(A) The mass and dashpot model represents an object that is damped by a viscous fluid. (B) A spring and dashpot model represents a low-mass object (like a protein) that is deformed in a viscous fluid. (C) The mass and spring model represents an undamped system.

Table 2.1 Examples of forces acting on molecules

Type of force	Diagram	Approximate magnitude
Elastic		1–100 pN
Covalent		10,000 pN
Viscous		1–1000 pN
Collisional		10^{-12} to 10^{-9} pN for 1 collision/s
Thermal		100–1000 pN
Gravity		10^{-9} pN
Centrifugal		$< 10^{-3}$ pN
Electrostatic and van der Waals		1–1000 pN
Magnetic		$<< 10^{-6}$ pN

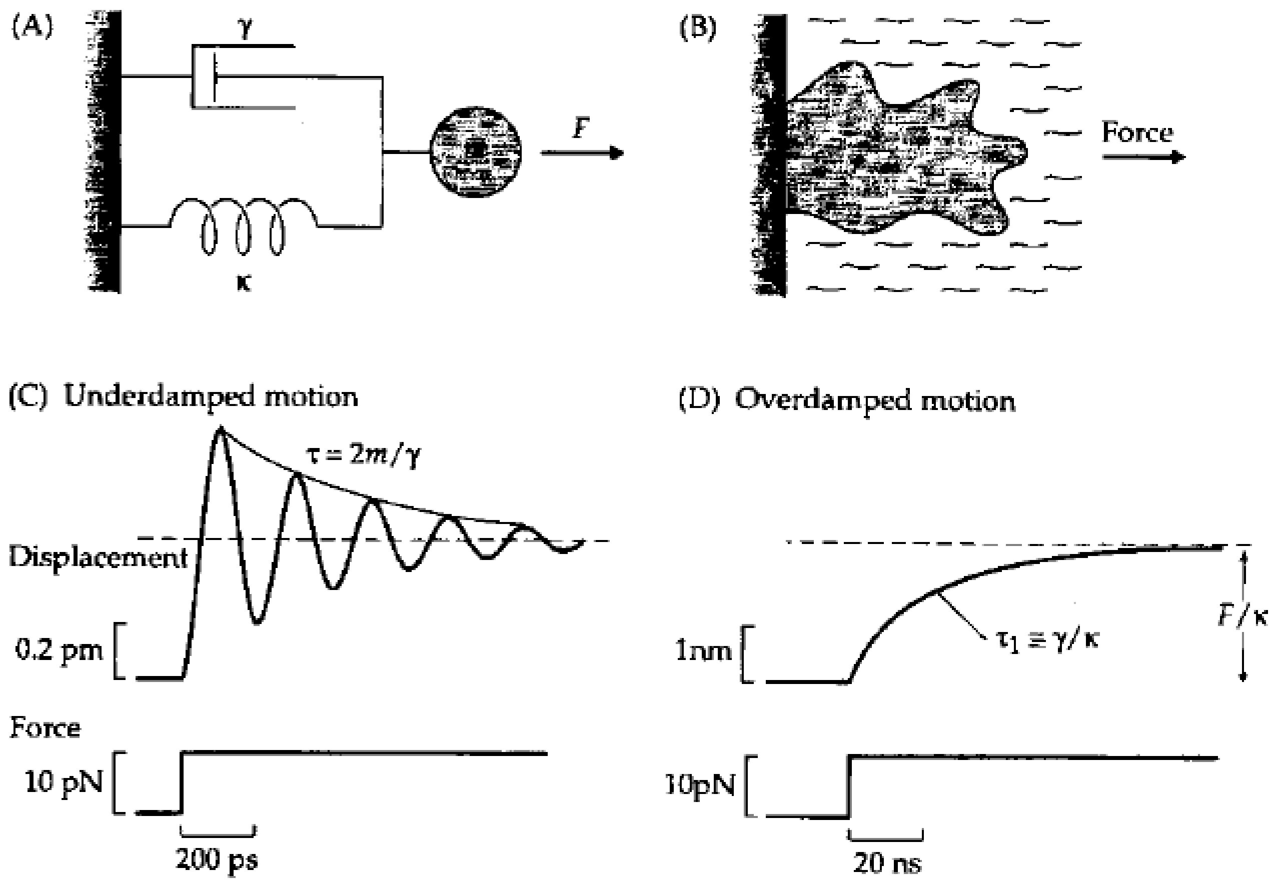


Figure 2.4 Motion of a mass and spring with damping
The mechanical model (A) is used to describe the motion of an elastic solid in a fluid (B). (C) Underdamped motion. In this example, $\gamma^2/4m\kappa \cong 0.007$, and the motion corresponds to that of a hypothetical globular protein that is both very large (16 MDa) and very rigid (stiffness 30 N/m) and experiences unrealistically little damping from the fluid (γ = 150 pN·s/m). (D) Overdamped motion. In this example, $\gamma^2/4m\kappa \cong 1400$, and the motion corresponds to that of a more realistic protein of molecular mass 100 kDa and stiffness 4 pN/nm.

Table 2.2 Physical properties of a globular protein of molecular mass 100 kDa

Property	Value	Comment
Mass	166×10^{-24} kg	Mass of 1 mole/Avogadro constant
Density	1.38×10^{3} kg/m^3	1.38 times the density of water
Volume	120 nm^3	Mass/density
Radius	3 nm	Assuming it is spherical
Drag coefficient[a]	60 pN·s/m	From Stokes' law (Chapter 3)
Diffusion coefficient[a]	67 μm^2/s	From the Einstein relation (Chapter 4)
Average speed[b]	8.6 m/s	From the Equipartition principle (Chapter 4)

Note: 1 nm = 10^{-9} m, but 1 nm^3 = (1 nm)^3 = 10^{-27} m^3.

[a]In water at 20°C

[b]Root-mean-square (the square root of the average value of the square of the velocity)