10.24 During blood transfusion the needle is inserted in a vein where the gauge pressure is 2000 Pa. At what height must the blood container be placed so that blood may just enter the vein ? [Use the density of whole blood from Table 10.1].

10.25 In deriving Bernoulli's equation, we equated the work done on the fluid in the tube to its change in the potential and kinetic energy. (a) What is the largest average velocity of blood flow in an artery of diameter 2×10^{-3} m if the flow must remain laminar ? (b) Do the dissipative forces become more important as the fluid velocity increases ? Discuss qualitatively.

10.26 (a) What is the largest average velocity of blood flow in an artery of radius 2×10^{-3}m if the flow must remain lanimar? (b) What is the corresponding flow rate ? (Take viscosity of blood to be 2.084×10^{-3} Pa s).

10.27 A plane is in level flight at constant speed and each of its two wings has an area of 25 m^2. If the speed of the air is 180 km/h over the lower wing and 234 km/h over the upper wing surface, determine the plane's mass. (Take air density to be 1 kg m^{-3}).

10.28 In Millikan's oil drop experiment, what is the terminal speed of an uncharged drop of radius 2.0×10^{-5} m and density 1.2×10^{3} kg m^{-3}. Take the viscosity of air at the temperature of the experiment to be 1.8×10^{-5} Pa s. How much is the viscous force on the drop at that speed ? Neglect buoyancy of the drop due to air.

10.29 Mercury has an angle of contact equal to 140° with soda lime glass. A narrow tube of radius 1.00 [redacted] ning mercury. By what amount [redacted] he liquid surface outside ? Surf [redacted] eriment is 0.465 N m^{-1}. Density [redacted]

10.30 Two narrow [redacted] together to form a U-tube open [redacted] the difference in its levels in th [redacted] the temperature of the experim [redacted] t to be zero and density of wat [redacted]

Calculator/Compute [redacted]

10.31 (a) It is known [redacted]

where ρ_0 = 1.2 [redacted] ant. This density variation is c [redacted] suming that the temperature of [redacted] ns). Also assume that the value [redacted]
(b) A large He [redacted] 400 kg. Assume that the ballo [redacted] does it rise ?
[redacted]

APPENDIX 10.1 : WHAT IS BLOOD PRESSURE ?

In evolutionary history there occurred a time when animals started spending a significant amount of time in the upright position. This placed a number of demands on the circulatory system. The venous system that returns blood from the lower extremities to the heart underwent changes. You will recall that veins are blood vessels through which blood returns to the heart. Humans and animals such as the giraffe have adapted to the problem of moving blood upward against gravity. But animals such as snakes, rats and rabbits will die if held upwards, since the blood remains in the lower extremities and the venous system is unable to move it towards the heart.

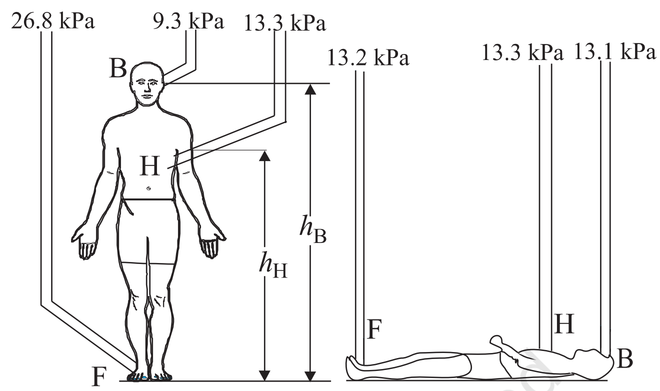

Fig. 10.26 *Schematic view of the gauge pressures in the arteries in various parts of the human body while standing or lying down. The pressures shown are averaged over a heart cycle.*

Figure 10.26 shows the average pressures observed in the arteries at various points in the human body. Since viscous effects are small, we can use Bernoulli's equation, Eq. (10.13),

$$P + \frac{1}{2}\rho v^2 + \rho g y = \text{Constant}$$

to understand these pressure values. The kinetic energy term ($\rho\, v^2/2$) can be ignored since the velocities in the three arteries are small ($\approx$ 0.1 m s^{-1}) and almost constant. Hence the gauge pressures at the brain P_B, the heart P_H, and the foot P_F are related by

$$P_F = P_H + \rho\, g\, h_H = P_B + \rho\, g\, h_B \qquad (10.34)$$

where ρ is the density of blood.

Typical values of the heights to the heart and the brain are h_H = 1.3 m and h_B = 1.7 m. Taking $\rho = 1.06 \times 10^3$ kg m^{-3} we obtain that P_F = 26.8 kPa (kilopascals) and P_B = 9.3 kPa given that P_H = 13.3 kPa. Thus the pressures in the lower and upper parts of the body are so different when a person is standing, but are almost equal when he is lying down. As mentioned in the text the units for pressure more commonly employed in medicine and physiology are torr and mm of Hg. 1 mm of Hg = 1 torr = 0.133 kPa. Thus the average pressure at the heart is P_H = 13.3 kPa = 100 mm of Hg.

The human body is a marvel of nature. The veins in the lower extremities are equipped with valves, which open when blood flows towards the heart and close if it tends to drain down. Also, blood is returned at least partially by the pumping action associated with breathing and by the flexing of the skeletal muscles during walking. This explains why a soldier who is required to stand at attention may faint because of insufficient return of the blood to the heart. Once he is made to lie down, the pressures become equalized and he regains consciousness.

An instrument called the sphygmomanometer usually measures the blood pressure of humans. It is a fast, painless and non-invasive technique and gives the doctor a reliable idea about the patient's health. The measurement process is shown in Fig. 10.27. There are two reasons why the upper arm is used. First, it is at the same level as the heart and measurements here give values close to that at the heart. Secondly, the upper arm contains a single bone and makes the artery there (called the brachial artery) easy to compress. We have all measured pulse rates by placing our fingers over the wrist. Each pulse takes a little less than a second. During each pulse the pressure in the heart and the circulatory system goes through a

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maximum as the blood is pumped by the heart (**systolic pressure**) and a minimum as the heart relaxes **(diastolic pressure)**. The sphygmomanometer is a device, which measures these extreme pressures. It works on the principle that **blood flow in the brachial (upper arm) artery can be made to go from laminar to turbulent by suitable compression. Turbulent flow is dissipative, and its sound can be picked up on the stethoscope**.

The gauge pressure in an air sack wrapped around the upper arm is measured using a manometer or a dial pressure gauge (Fig. 10.27). The pressure in the sack is first increased till the brachial artery is closed. The pressure in the sack is then slowly reduced while a stethoscope placed just below the sack is used to listen to noises arising in the brachial artery. When the pressure is just below the **systolic** (peak) pressure, the artery opens briefly. During this brief period, the blood velocity in the highly constricted artery is high and turbulent and hence noisy. The resulting noise is heard as a **tapping sound** on the stethoscope. When the pressure in the sack is lowered further, the artery remains open for a longer portion of the heart cycle. Nevertheless, it remains closed during the **diastolic** (minimum pressure) phase of the heartbeat. Thus the duration of the tapping sound is longer. When the pressure in the sack reaches the diastolic pressure the artery is open during the entire heart cycle. The flow is however, still turbulent and noisy. But instead of a tapping sound we hear a steady, continuous roar on the stethoscope.

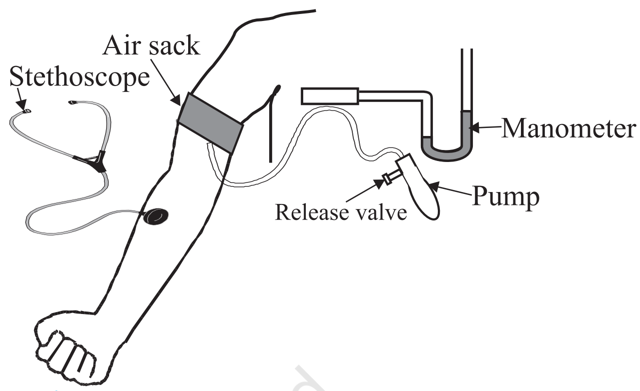

Fig. 10.27 *Blood pressure measurement using the sphygmomanometer and stethoscope.*

The blood pressure of a patient is presented as the ratio of systolic/diastolic pressures. For a resting healthy adult it is typically 120/80 mm of Hg (120/80 torr). Pressures above 140/90 require medical attention and advice. High blood pressures may seriously damage the heart, kidney and other organs and must be controlled.

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