Presentation 1: Pancosmorio Theory Classical Mechanics Clarifications

This supplement provides discussions of classical mechanics topics for which complete, error-free explanations are lacking in the existing literature These discussions also explain connections of these general physics topics to the content of the topics of the paper.

1 Conservation of Momentum and Entropy

The conservation of momentum theorem is derived from Newton's second law and Newton's third law by applying the definitions of momentum and impulse and using the ideal state of the multi-body isolated system. Proof of this theorem can be found in most university physics textbooks. When two objects collide and stick together in a perfectly inelastic collision, the conservation of momentum theorem dictates that total momentum is conserved. The consequence of this conservation is that macroscopic mechanical energy in the form of kinetic energy is lost. Specifically for a two-body perfectly inelastic collision,

$$KE_f^{Tot} = \frac{m_A}{m_A+m_B} KE_o^{Tot}. \tag{P1.1}$$

However, the conservation of energy theorem requires that total energy also be conserved. The lost kinetic energy must go somewhere. Consider the following two-body inelastic collision example:

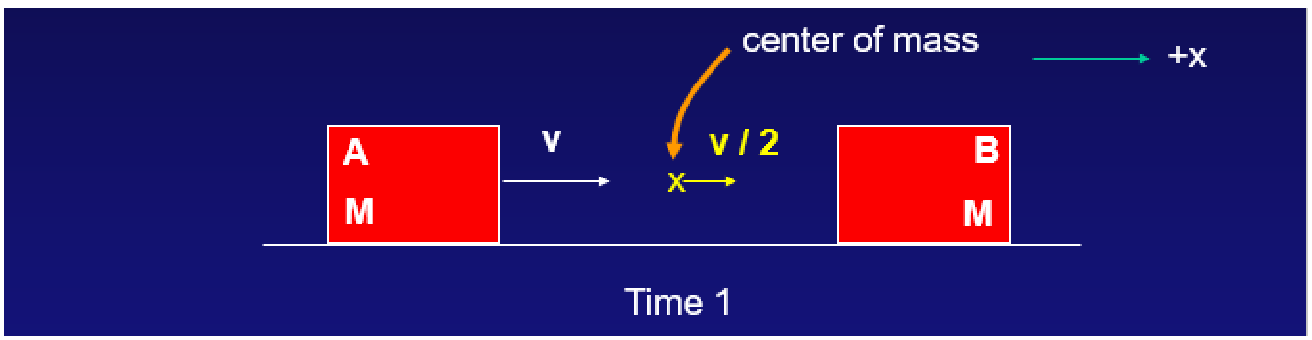

Figure P1.1. Block A is moving a speed v and block B is stationary. Considering the masses of blocks A and B are equal (M), the center of mass moves at half the speed ($v/2$) of block A.

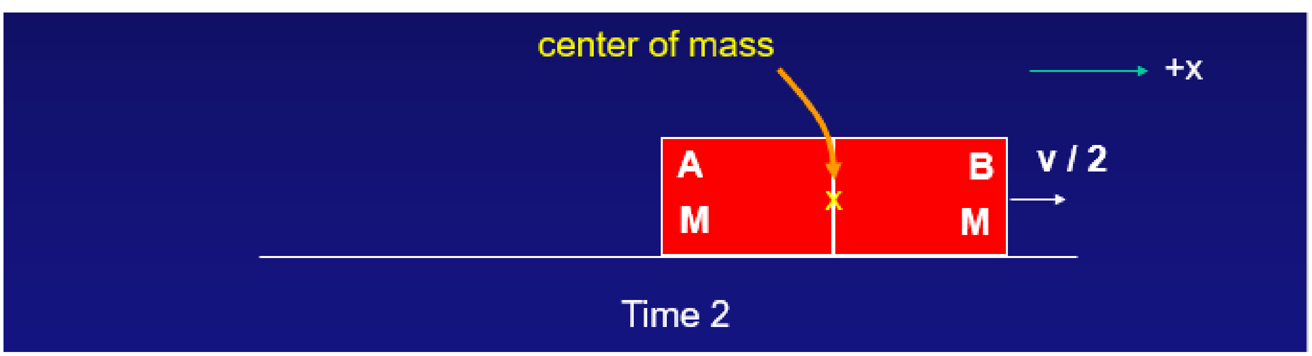

Figure P1.2. When the blocks collide in a perfectly inelastic collision, they continue moving as a joined unit with the same velocity as the center of mass.

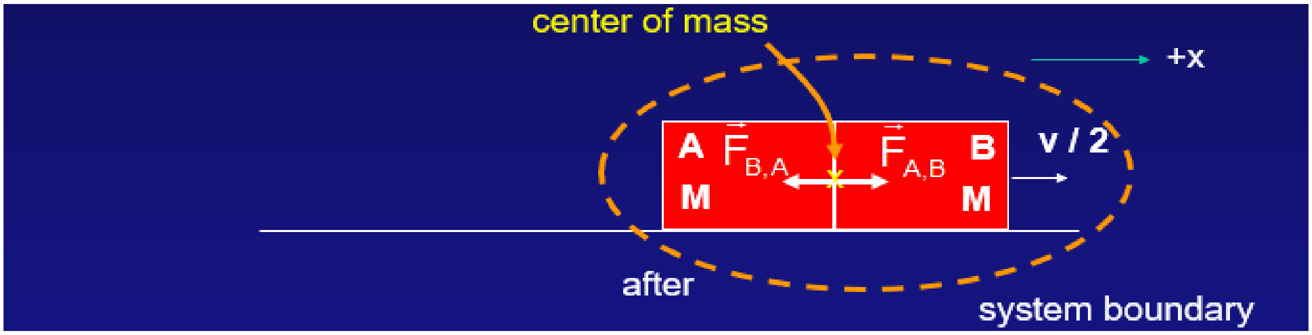

Figure P1.3. When the blocks are viewed as a single system, all forces of collision are force pairs according to Newton's third law and are internal. Newton's first law dictates that if no external forces act on a system, then no acceleration occurs. It is $\overrightarrow{F_{A,B}}$ acting on block B through Newton's second law from which is derived the impulse and momentum theorem that causes block B to increase in speed to $v/2$, as well as $\overrightarrow{F_{B,A}}$ acting on block A that causes block A to decrease in speed to $v/2$.

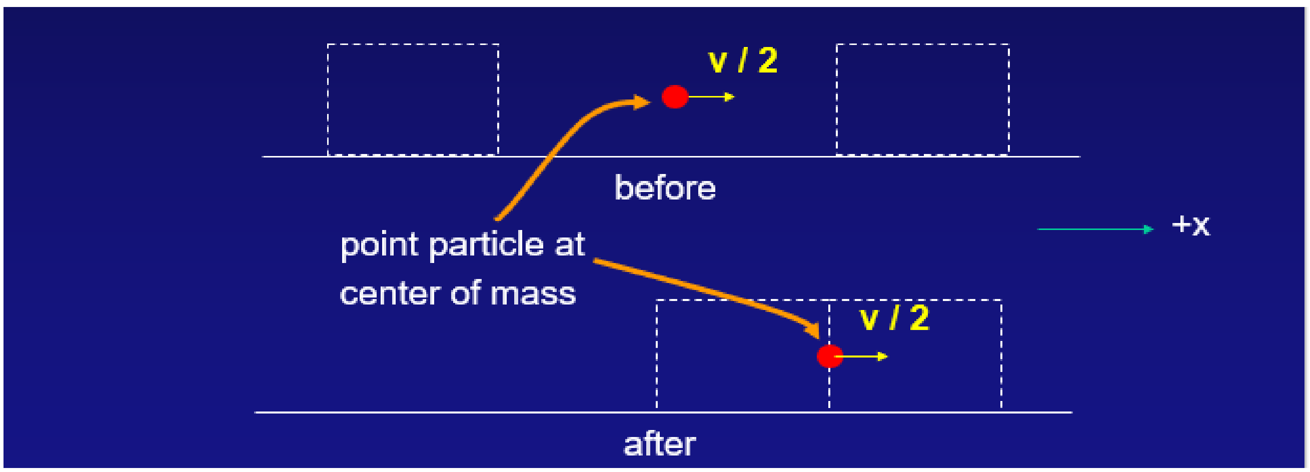

Figure P1.4. Viewing the two-body system as a point particle of mass *2M* located at the center of mass, no change in motion of the point particle occurs.

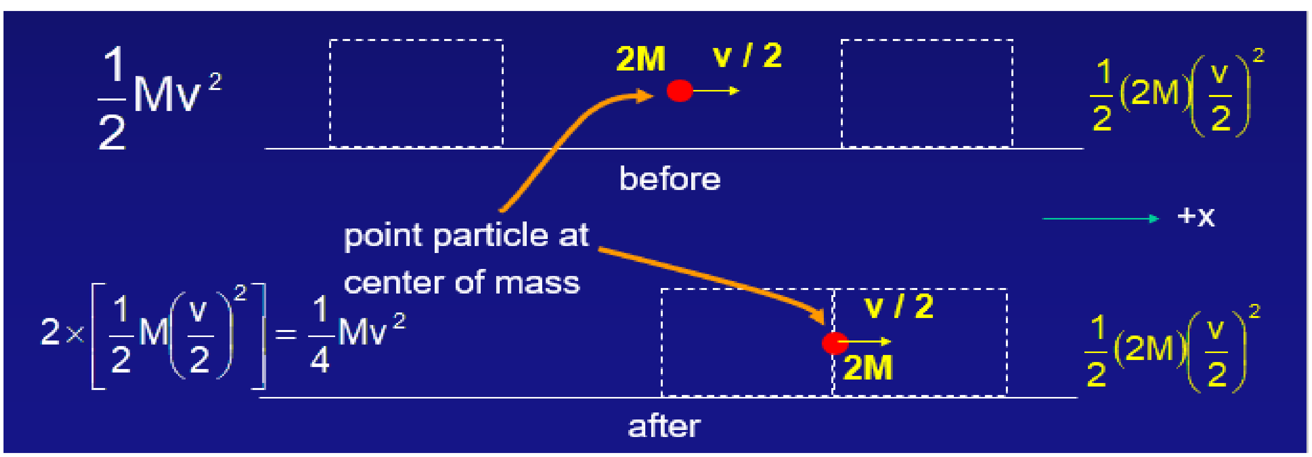

Figure P1.5. Newton's laws require that the two bodies as separate systems lose some kinetic energy to an extent that maintains the kinetic energy of the center of mass constant.

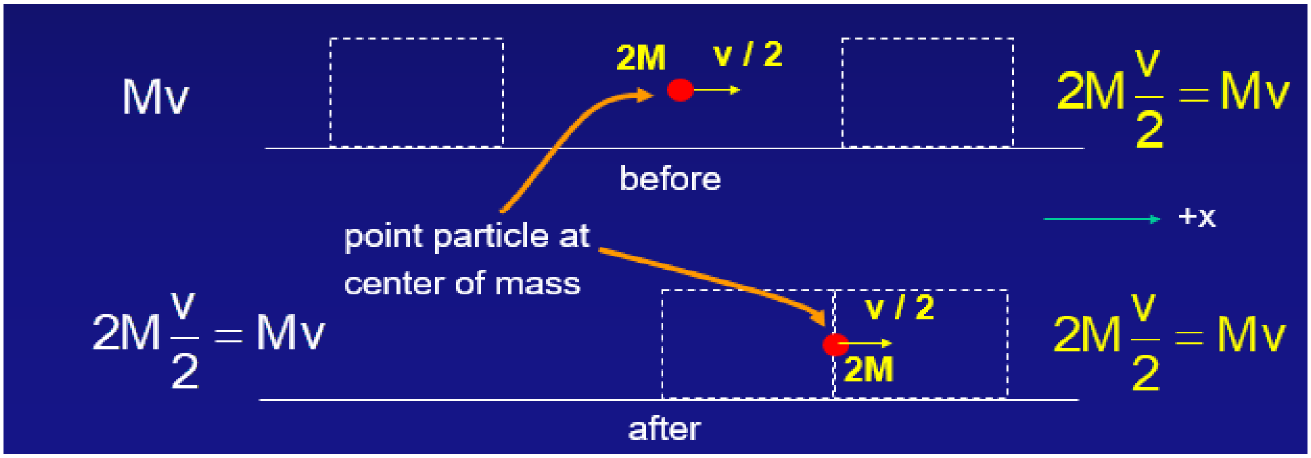

Figure P1.6. Newton's laws also result in the sum of the momenta of the two objects before and after collision to be equal to each other and to the momentum of the center of mass.

Equation (P1.1) and Figures P1.1 through P1.6 reveal that only enough mechanical energy is lost to keep momentum conserved. The implication is that all three of Newton's laws, together, require a fixed proportion of macroscopic mechanical energy to transition toward non-useful energy in the worst-case of a perfectly inelastic collision. Even in an inelastic collision in which the objects do not stick together, some kinetic energy is lost. The lost kinetic energy goes into mechanical vibration and wave energy within the colliding objects that, in turn, is converted into wave energy leaving the objects as pressure and shear wave or internal, thermal energy that raises temperatures and results in conductive, convective, and radiative heat leaving the objects. According to the second law of thermodynamics and the kinetic molecular theory of gases, conductive heat in the form of the thermal motion of particles is driven by momentum differentials between adjacent, elastically colliding particles to pass toward regions of lower temperature, and heat in the form of radiation eventually passes into regions of lower particle densities. When this excess heat is not subsequently used by heat engines, it does not contribute to useful work. This eventually results in heat passing into space beyond Earth, contributing to the overall increase in the entropy of the universe.

The consequence of Newton's laws, the conservation of momentum theorem, and inelastic collisions is the second law of thermodynamics and entropy increasing in the universe.

2 The Apparent Force of Weight

Weight and the force of gravity are not the same thing. In an inertial free-fall reference frame, an object does not experience the phenomenon of weight even though the force of gravity is present and acting on the object. That is because there is no other force acting on the object in free-fall. In contrast, a skydiver falling through the atmosphere is not in free-fall because air applies an upward force of friction in reference to the downward force of gravity. The force of gravity and the force of air friction are not a force pair described by Newton's third law. The equal and opposite force pairs in this example are (i) the gravitational pull of Earth on the object and the gravitational pull of the object on Earth and (ii) the frictional force of the air on the object and the frictional force of the object on the air.

The object will accelerate when the downward force of gravity is greater than the upward force of air friction. Once the object is falling at a great enough speed for the force of air friction to increase to be equal in magnitude to the force of gravity, then the falling object is no longer being accelerated and has reached what is called terminal velocity. The force of air friction on the object creates the phenomenon of the feel of weight on the object, and only feels like the full weight experienced by the object when it is stationary on the surface of Earth once the object reaches terminal velocity while falling. Also of note is the phenomenon of the feel of increased weight on a passenger when an elevator starts rising or when an airplane accelerates while increasing altitude. This increased-weight experience is the result of the force of gravity on the passenger, the normal force of the floor of the elevator or seat of the plane on the passenger, and the additional upward force of the elevator or plane on the passenger due to the elevator or plane accelerating upward. For further explanation, refer to the classical mechanics sections of any general physics textbook.

3 Buoyancy as a Conservative Force

Warming water vapor expands against the cooler surrounding air in order to come into equalized pressure with it. When the differential pressure between the bottom and top of the volume of the water vapor bubble results in a net upward force that exceeds the weight of the volume of water vapor, the volume of water vapor rises.

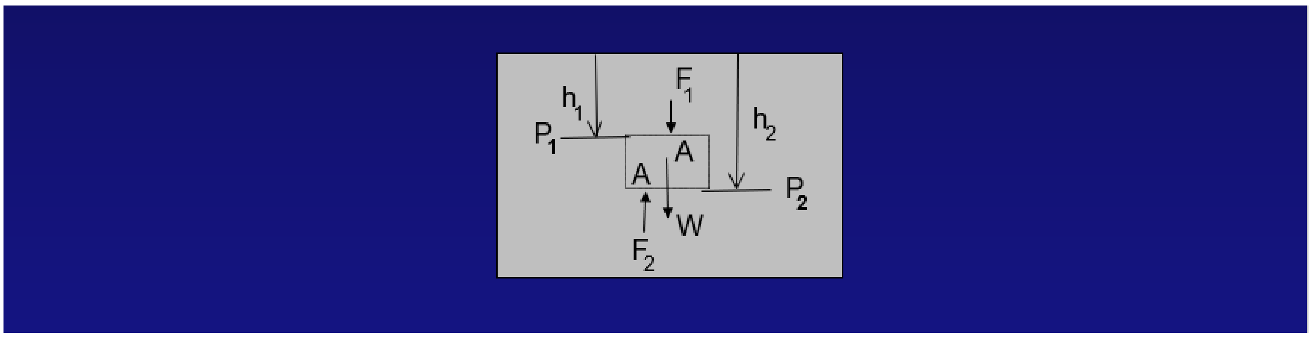

Figure P1.7. When warming, expanding water vapor displaces higher density air, the effect is that an exact volume of the higher density air equal to the volume of the warming air and water vapor is displaced. This results in a higher pressure at the bottom of the bubble of water vapor than at the top, equation (P1.2), by an amount equal to the product of the density of air (ρ_{air}), the local acceleration due to gravity (g), and the depth difference from the top of the atmosphere ($h_2 - h_1$).

$$P_2 = P_1 + \rho_{air} g (h_2 - h_1) \qquad \text{(P1.2)}$$

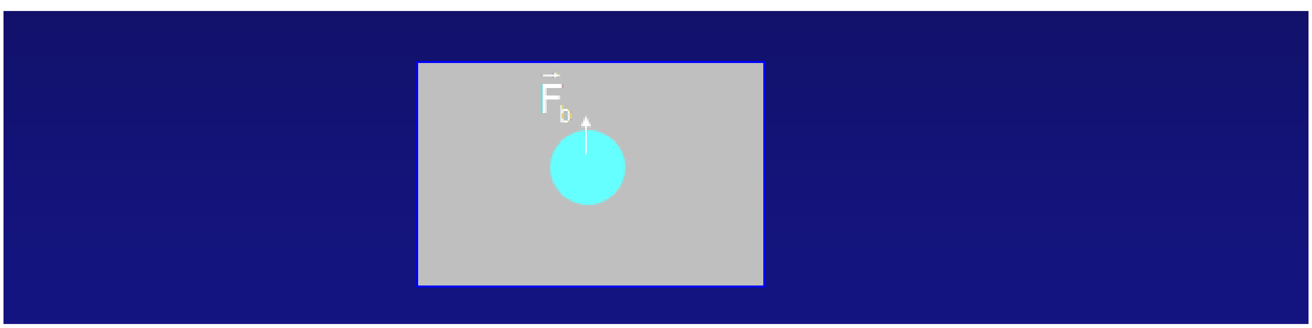

Figure P1.8. Considering the pressure at the bottom of the water vapor bubble is greater than that at the top, the surrounding atmosphere exerts a net upward force on the vapor bubble, the buoyant force, equation (P1.3), equal to the product of the density of air (ρ_{air}), the volume of air displaced by the water vapor bubble ($V_{dis-air}$), and the local acceleration due to gravity (g).

$$\left|\vec{F_b}\right| = \rho_{air} V_{dis-air} g \tag{P1.3}$$

The pressure gradient of a fluid atmosphere in a gravitational force field results in a buoyancy force field contained within the depth of fluid. This buoyant force is conservative, considering its source of energy is the gravitational force. This becomes more apparent by analyzing the phenomenon using a simplified model of a u-tube, Figure P1.9.

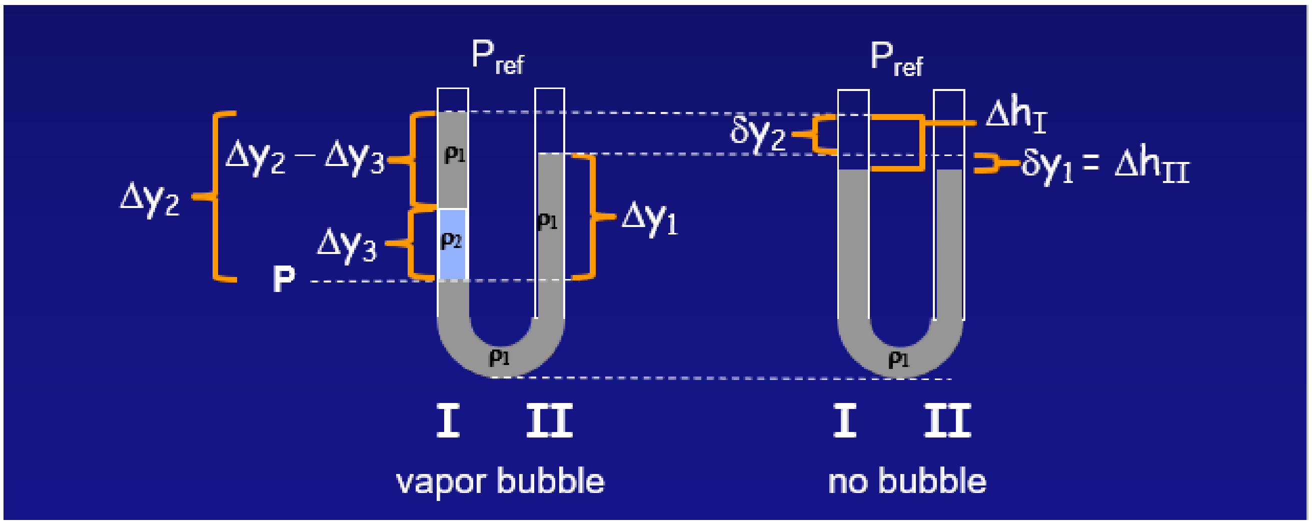

Figure P1.9. The vertical expansion of the vapor bubble results in the air in columns I and II displacing upward in summation by an equivalent amount. This relationship can be put in terms of two separate expressions, equation (P1.4) and equation (P1.5).

$$\Delta y_3 = \Delta h_I + \Delta h_{II} \tag{P1.4}$$

$$\Delta y_3 = (2 \cdot \delta y_1) + \delta y_2 \tag{P1.5}$$

The air pressure in each column at the depth of the bottom of the water vapor is equal, equation (P1.6).

$$P = P_{ref} + \rho_1 g(\Delta y_2 - \Delta y_3) + \rho_2 g \Delta y_3 = P_{ref} + \rho_1 g \Delta y_1 \tag{P1.6}$$

$$\Delta y_3(\rho_2 - \rho_1) + \Delta y_2 \rho_1 = \Delta y_1 \rho_1$$

Solving equation (P1.6) for the depth of the bottom of the water vapor bubble results in equation (P1.7).

$$\Delta y_2 = \Delta y_1 + \left(1 - \frac{\rho_2}{\rho_1}\right) \Delta y_3 \tag{P1.7}$$

Comparing equation (P1.7) to Figure P1.9, equation (P1.8) becomes visibly apparent.

$$\delta y_2 = \left(1 - \frac{\rho_2}{\rho_1}\right) \Delta y_3 \tag{P1.8}$$

Using equation (P1.8) in equation (P1.5) leads to equation (P1.9).

$$\Delta y_3 = 2 \cdot \delta y_1 + \left(1 - \frac{\rho_2}{\rho_1}\right) \Delta y_3 \quad \text{(P1.9)}$$

Solving equation (P1.9) for the amount of upward displacement if column II results in equation (P1.10).

$$\Delta h_{II} = \delta y_1 = \frac{1}{2}\frac{\rho_2}{\rho_1} \Delta y_3 \quad \text{(P1.10)}$$

The amount of upward displacement of column I is shown in equation (P1.11).

$$\Delta h_I = \delta y_1 + \delta y_2 = \left(1 - \frac{1}{2}\frac{\rho_2}{\rho_1}\right) \Delta y_3 \quad \text{(P1.11)}$$

In the real situation, column I represents the half of Earth atmosphere under solar insolation during the day with the ongoing geophysical evaporation of water from the surface and the biophysical transpiration of water from plants, column II is other half of Earth atmosphere on the night side that is cooling with water condensing out of the atmosphere, and the top of the atmosphere all around Earth remaining level as water vapor forms and expands on the day side, a result of the naturally self-leveling nature of a fluid in the presence of gravity. The self-leveling results in the day side atmosphere being shifted below energy equilibrium and the night side atmosphere being shifted above energy equilibrium according to equations (P1.12).

$$\Delta h_{self-leveling} = \frac{1}{2} \delta y_2 = \frac{1}{2}\left(1 - \frac{\rho_2}{\rho_1}\right) \Delta y_3 \quad \text{(P1.12)}$$

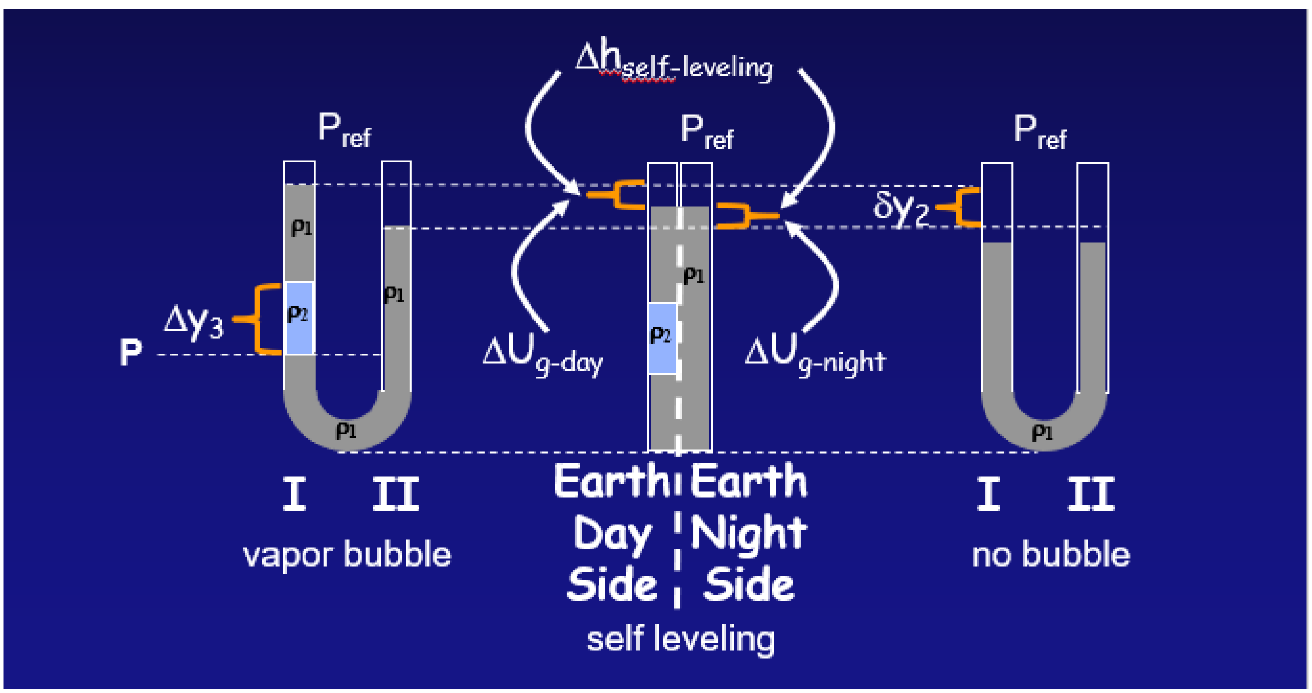

Figure P1.10. This results in the day side of Earth atmosphere having a gravitational potential energy deficit and the night side of Earth atmosphere having a gravitational potential energy excess equivalent to equation (P.13). The amount of atmospheric mass displaced downward on the day side and upward on the night side because of the self-leveling is estimated in equation (13), in which

R_{atm} is the radius of the top of the atmosphere as measured from the center of Earth. Combining equation (P1.13) and equation (P1.14) results in equation (P1.15) for the a gravitational potential energy excess on the night side. This simplifies to equation (P1.16), in which Δy_3would be the vertical extent of all of the water vapor in the atmosphere on the day side if merged into a single bubble that is spread evenly throughout the entire day-lighted hemisphere.

$$\Delta U_{g-night} = -\Delta U_{g-day} = m \cdot g \cdot \Delta h_{self-leveling} \tag{P1.13}$$

$$m \approx \rho_1 \cdot \frac{1}{2}\left[4 \cdot \pi \cdot R_{atm}^2 \cdot \frac{1}{2}\left(1 - \frac{\rho_2}{\rho_1}\right)\Delta y_3\right] = \pi \cdot R_{atm}^2 \cdot (\rho_1 - \rho_2)\Delta y_3 \tag{P1.14}$$

$$\Delta U_{g-night} = [\pi \cdot R_{atm}^2 \cdot (\rho_1 - \rho_2)\Delta y_3] \cdot g \cdot \frac{1}{2}\left(1 - \frac{\rho_2}{\rho_1}\right)\Delta y_3 \tag{P1.15}$$

$$\Delta U_{g-night} = \pi \cdot R_{atm}^2 \cdot g \cdot \frac{1}{2}\left(\rho_1 - 2\rho_2 + \frac{{\rho_2}^2}{\rho_1}\right){\Delta y_3}^2 \tag{P1.16}$$

The resulting total available gravitational potential energy is the difference between these shifts in potential energy. That is double the quantity of equation (P1.16), shown in equation (P1.17). This total available gravitational potential energy is what couples the buoyancy force field to the gravitational force field, making the buoyancy force field a conservative force field just as the gravitational force field.

$$\Delta U_{Avail}^{Tot} = \Delta U_{g-night} - \Delta U_{g-day} = \pi \cdot R_{atm}^2 \cdot g \cdot \left(\rho_1 - 2\rho_2 + \frac{{\rho_2}^2}{\rho_1}\right){\Delta y_3}^2 \tag{P1.17}$$

4 Forces on the Human Body in the Free-Fall of Space

To understand what is happening to the human body in space, it is important to understand the forces that are present. What follows is a physical analysis of the forces.

An object in an inertial free-fall reference frame does have Earth gravity pulling on it, but it does not experience the apparent force of weight, described earlier, considering it is not being pulled by gravity against an opposing force, such as air friction or the normal force of a surface. Even though this environment is often called “micro gravity,” the force of Earth's gravity is not actually at a *micro* level in either low-Earth orbit (LEO) or geosynchronous-Earth orbit (GEO). What is true about these orbits is that objects are in free-fall. They do experience the force of Earth gravity at an amount just a little less than the force of gravity at the surface of Earth, and this force pulls objects in orbit toward Earth (inward), causing them to experience falling. However, an object in orbit is also moving at a great enough tangential velocity to Earth that it falls around the Earth in an elliptical orbit, never reaching the surface of the Earth as it falls. As a result, objects in an inertial free-fall reference frame do not experience a normal force. For further explanation of the force of gravity, refer to the classical mechanics section of any general physics textbook.

The inertial free-fall reference frame of gravitational orbit is also a special type of circular motion that exhibits the phenomenon of a centripetal (i.e., toward the center) force that has no associated apparent centrifugal force (i.e., away from the center). No one on a space station is being held against the wall of the space station as it moves around Earth at about 7.8 kilometers per second. This is quite different from the phenomenon of centrifugal force experienced by a passenger in an automobile or on an amusement park ride moving around a curve. For further explanation of orbit, centripetal force, centrifugal force, and apparent forces in general, refer to the classical mechanics section of any general physics textbook.

Objects in an inertial free-fall reference frame do experience micro-forces. As humans move about on a space station by pushing off surfaces, as electromechanical prime movers engage in action (e.g., motors, mechanical linkages), and as impulse rockets correct the attitude and altitude of the space station, these result in micro-forces (i.e., literally units of micro-Newtons, μN). These micro-forces move through the station in impulse waves, causing experiments onboard the space station to experience micro-accelerations (i.e., units of $\mu m/sec^2$). This is an important aspect of the environment that experiment designers need to know is present, and thus it has been given a name. The shorthand symbol used for “micro-acceleration” is “μg,” which comes from the language that aerospace engineers and structural engineers use when they talk of pilots or structures experiencing accelerations in terms of the “number of g’s,” meaning the number (i.e., n) of equivalent units of the Earth-surface-acceleration-due-to-gravity (i.e., 9.8 m/sec^2 at Earth’s surface). The “number of g’s” (i.e., n x 9.8 m/sec^2) is equivalent to saying “the multiple of the apparent weight increase” experienced by an object being accelerated. The symbol “μg” looks like shorthand for “micro-gravity.” Thus, even though objects in gravitational orbit experience near-full Earth surface gravity, “micro-gravity” has become the misnomer for what is more aptly named “an inertial free-fall reference frame experiencing micro-accelerations.”

With a slightly lower gravitational force than Earth surface gravity, no apparent weight force, no apparent centrifugal force, and micro-accelerations in random directions, the result is that there are no consistent or significant fluid pressure gradients in gravitational orbit, including in the human body. Therefore, the dissipative structures in the human body misfunction, resulting in a breakdown of exergy in the human body.

An inertial free-fall reference frame is present anywhere in space where the only force acting on the human body (other than micro-accelerations) is the gravity resulting from the sum of all gravitational fields of planetary masses present in the surrounding space. Human physiology evolved in the context of fluid pressure gradients on Earth resulting from gravity and a lithosphere normal force. Resistance exercise performed against springs in space does induce stress in bones and muscle that simulates gravity but does not produce a consistent fluid pressure gradient in the body. This is likely a major factor in the dysfunction of human physiology. The same is true for other life forms. The physiological functions of the human body and of other biotic elements of an ecosystem are a form of resource utilized directly by humans. All of this suggests that sustainability might be difficult to meet for the biotic elements of an ecosystem in an inertial free-fall reference frame in space.