General Physics Spring 2020

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Name:

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1. State the units (the **dimension**) in the cgs system of the following quantities:

- D, the size of an oxygen molecule O_2.
- G, Newton's constant.
- ω, angular velocity of Earth.
- p, the momentum of a rain droplet.

2. Consider the pendulum of a mass M attached to a rope of length L in the Earth's gravitational field g. The pendulum swings at an angle θ relative to the vertical with oscillation period P.

- State the dimensions of g, L, m and P.
- By dimensional analysis, give an expression for P.
- Give an expression for the total energy H in terms of the sum of kinetic energy E_k and potential energy U.
- Comparing periods at different locations, state whether $P_e > P_n$ or $P_e < P_p$, where P_e (P_n) the period of the pendulum at the equator (north pole).

3. Consider a binary of masses M_i with Newtonian gravitational binding energy U and kinetic energies E_i $(i = 1, 2)$.

- State the total energy H of the two body system.
- State the condition on H for the system to be bound. Can you think of an example? Sketch the orbit in this case.
- State the condition on H for the system to be unbound. Can you think of an example? Sketch the orbit in this case.

4. The cantilever of length L_0 is an example of a Hooke's spring in nanotechnology, whose force

$$F = -k_0 z \tag{1}$$

is linear for small deflections z at the tip, where k_0 is Hooke's constant. [1] Consider changing k with a cantilever N times longer, i.e., $L = 10L_0$. What is k in terms of k_0 in (1)?

[1] F arises from bending, i.e., a curvature $d\theta/dx$ proportional to z, where $\tan\theta$ denotes the slope of the tangent to the cantilever as a function of x ($0 \leq x \leq L$), where L denotes the length of the cantilever.

5. Über-Air Inc. is studying an air-frame suitable for both lighter-than-air and hot-air balloon technologies. Recall examples like the Hindenburg airship and, respectively, J. Charles' balloon of 1783. Given such air-frame, what would be the required temperature of the hot-air balloon to have the same buoyancy as when filled with hydrogen? Is hot-air technology a realistic competitor for lighter-than-air technology?