Instructions

- Write the names and student ids of all members of the group on the first answer sheet. You should show your work carefully – most of the points depend on your problem solving process.

- Solutions to the problems should begin from the following basic physical principles:
  - If $\vec{x}(t)$ is the position of the object as a function of time than velocity is $\vec{v}(t) = \frac{d\vec{x}}{dt}$ and acceleration is $\vec{a}(t) = \frac{d^2\vec{x}}{dt^2}$.
  - When the acceleration is a constant $\vec{a}$ then $\vec{x}(t) = \vec{x}_0 + \vec{v}_0 t + \frac{1}{2} \vec{a} t^2$.
  - Newton’s Laws: $\vec{F} = m \vec{a}$ and $\vec{F}_{12} = -\vec{F}_{21}$
  - Common forces include static friction ($F \leq \mu_s F_N$), kinetic friction ($F = \mu_k F_N$), gravitational force ($F = mg$), drag ($F = \frac{1}{2} \rho AC_D v^2$) and the spring force ($F = -kx$).
  - Kinetic energy is $\frac{1}{2} m v^2$, work is $W = \int \vec{F} \cdot d\vec{x}$, gravitational potential energy is $U_g = mgh$, and spring potential energy is $U_s = \frac{1}{2} kx^2$.

- Show all steps in the derivation of the answers. Make sure you write neatly and orderly. It is YOUR RESPONSIBILITY to make sure that the grader understands your solution. S/he will not give full points if they can not follow the solution, even if the final answer is correct.

- The acceleration due to gravity on Earth is 9.8 m/s$^2$.

- The solutions to the quadratic equation $0 = ax^2 + bx + c$ are given by $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$.

- The following derivatives and integrals may be useful:
  - If $y(x) = Ax^m$, where $A$ and $m$ are constants, then
    $$\frac{dy}{dx} = Amx^{m-1}$$
    $$\int y \, dx = \frac{A}{m+1}x^{m+1}, \text{ for } m \neq -1$$

- You can use a calculator.

- You can discard this page – it does not need to be handed in.

Problem on back side of sheet


**Problem (25 points)**

Because of your physics background, you have been hired as a member of the team the state highway department has assigned to evaluate plans for new transportation projects. The officials in Cottonwood county would like to rebuild a section of Highway 30 which is essentially a quarter-circle with a radius of 600 m. The officials would like the road redesigned so that cars will not slide off the outside of the curve at 20 mph (9 m/s) even under icy conditions when the coefficient of static friction is just 0.001. The officials claim this can be achieved with a banking angle of just 3°. Your boss would like to determine if this is correct (assuming standard passenger cars with a mass of 1000 kg). She indicates that you only need to consider the car sliding out of the curve – cars sliding into the center of the curve can be handled in another manner. She would also like to know the maximum safe speed under summer conditions when the coefficient of kinetic friction is 0.70 and the coefficient of static friction is 0.80 between the tires and the road. This information will allow her to evaluate the cost and benefits of the project.
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