Homework 1

Physics 5A

Due Fr 9 / 13 / 24 @ 5:00PM

There are 7 problems worth a total of 80 points. The clearer your presentation is, the easier it is for us to give you points! Please turn in your solutions using Gradescope by 5:00 PM on Friday, September 13. "K.K." refers to the 2nd edition of the textbook "An Introduction to Mechanics" authored by Kleppner & Kolenkow. Remember, you are encouraged to work together, but please make sure the work you turn in is your own.

1. Vectors and relative velocity (20 pts)
   If the air velocity (velocity with respect to the air) of an airplane is $\mathbf{u}$, and the wind velocity with respect to the ground is $\mathbf{w}$, then the ground velocity $\mathbf{v}$ of the airplane is $\mathbf{v} = \mathbf{u} + \mathbf{w}$. An airplane flies a straight course (with respect to the ground) from P to Q and then back to P, with a constant airspeed $|\mathbf{u}| = U_0$, regardless of the wind. If the distance from P to Q is L, find the time t required for one round trip, under the following conditions:
   (a) No wind.
   (b) Wind of speed W_0 blowing from P to Q .
   (c) Wind of speed W_0 blowing perpendicular to a line connecting P and Q .
   (d) Wind of speed W_0 blowing at an angle θ from a line connecting P and Q .
   (e) Show that the round trip flying time is always the least for the condition in part (a).
   (f) What happens to the answers to (b)-(d) when $W_0 > U_0$? Interpret this limiting condition physically.
   (g) Since airplanes typically fly much faster than the wind blows, i.e. $U_0 >> W_0$, use a Taylor expansion to obtain an expression for part (d) valid to second order in W_0 (e.g., keep terms up to and including W_0^2). The expansions $\sqrt{1+x} = 1 + \frac{x}{2} + \cdots$ and $\frac{1}{1-x} = 1 + x + \cdots$ may prove useful, or refer to KK Note 1.3.

2. (10 pts) K.K. 1.16

3. (10 pts) K.K. 1.23

4. (10 pts) K.K. 1.24 (Note: these quantities should be given as vectors)

5. (10 pts) K.K. 1.26

6. (10 pts) K.K. 1.27

7. (10 pts) The time derivative of acceleration is called ‘jerk’.
   (a) if we are using a Cartesian coordinate system to describe the motion of the particle, i.e. $\mathbf{r}(t) = x(t)\hat{\mathbf{x}} + y(t)\hat{\mathbf{y}} + z(t)\hat{\mathbf{z}}$, derive the expression for the jerk vector.
   (b) if we are using a polar coordinate system to describe the motion of the particle, i.e. $\mathbf{r}(t) = r(t)\hat{\mathbf{r}}(\theta(t))$, derive the expression for the jerk vector, i.e. find the coefficients j_r and j_θ in $\mathbf{j} = j_r\hat{\mathbf{r}} + j_\theta\hat{\theta}$.
   (c) what is the jerk vector for moving uniformly in a circle of radius R with angular velocity ω ?