Physics 24A – Problem Set 1

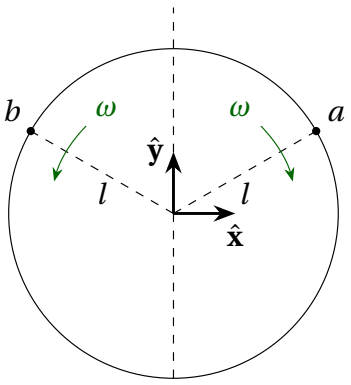
Name _____

Due: Monday, 22 January 2024

For full credit, include words explaining your reasoning, diagrams, as well as calculations. You must provide the full problem statement with your solution.

Problem 1 – Elevator and falling marble* (KK 1.18) At $t = 0$, an elevator departs from the ground with uniform speed. At time T_1 a child drops a marble through a hole in the floor. The marble falls with uniform acceleration $g = 9.8\,\mathrm{m/s^2}$, and hits the ground at time $t = T_2$. Find the height of the elevator at time T_1. (Note: The hint in the back of the book should have $T_1 = T_2 - T_1 = 4\,\mathrm{s}$.)

Problem 2 – Relative velocity (KK 1.19) By relative velocity we mean velocity with respect to a specified coordinate system. (The term velocity, alone, is understood to be relative to the observer's coordinate system.)



(a) A point is observed to have velocity $\vec{v}_A$ relative to coordinate system A. What is its velocity relative to coordinate system B, which is displaced from system A by distance $\vec{R}$? ($\vec{R}$ can change in time.)

(b) Particles a and b move in opposite directions around a circle with angular speed ω, as shown. At $t = 0$ they are both at the point $\vec{r} = l\hat{y}$,where l is the radius of the circle. Find the velocity of a relative to b.

Problem 3 – Particle with constant radial velocity* (KK 1.21) A particle moves in a plane with constant radial velocity $\dot{r} = 4\,\mathrm{m/s}$, starting from the origin. The angular velocity is also constant and has magnitude $\dot{\theta} = 2\,\mathrm{rad/s}$. When the particle is 3 m from the origin, find the magnitude of (a) its velocity and (b) its acceleration.

Problem 4 – Jerk (KK 1.22) The rate of change of acceleration is know as "jerk." Find the direction and magnitude of jerk for a particle moving in a circle of radius R at constant angular velocity ω. Draw a vector diagram showing the instantaneous position, velocity, acceleration, and jerk.

Problem 5 – Smooth elevator ride* (KK 1.23) For a smooth ("low jerk") ride, an elevator is programmed to start from rest and accelerate according to

$$a(t) = \frac{a_m}{2}\left[1 - \cos\left(\frac{2\pi t}{T}\right)\right] \cdot \begin{cases} 1, & 0 \le t \le T \\ -1, & T \le t \le 2T \end{cases}$$

where a_m is the maximum acceleration and $2T$ is the total time for the trip.

(a) Draw sketches of $a(t)$ and the jerk, $\dot{a}(t)$ as functions of time.

(b) What is the elevator's maximum speed?

(c) Find an approximate expression for the speed at short times near the start of the ride, $t \ll T$.

(d) What is the time required for a trip of distance D?

Problem 6 – Peaked Roof* (KK 1.27) A Peaked Roof is symmetrical and subtents a right angle, as shown. Standing at a height of distance h below the peak, with what initial speed must a ball be thrown so that it just clears the peak and hits the other side of the roof at the same height?