

your name _____

Physics 321 Midterm #1 - Wednesday, Oct. 5, 2022

Some integrals:

$$\begin{aligned}\int \frac{dx}{1+x^2} &= \tan^{-1}(x), \\ \int \frac{dx}{1-x^2} &= \tanh^{-1}(x), \\ \int \frac{dx}{\sqrt{1-x^2}} &= \sin^{-1}(x), \\ \int \frac{dx}{\sqrt{1+x^2}} &= \sinh^{-1}(x), \\ \int dx \tan(x+\phi) &= -\ln(\cos(x+\phi)) \\ \int dx \tanh(x+a) &= \ln(\cosh(x+a)).\end{aligned}$$

Write your name on EVERY page!

80 points possible

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1. Aliyah and her iceboat have a mass M_0 and are gliding on a frictionless lake straight toward a long line penguins with initial speed v_0 . Each penguin has a mass m , and there are λ penguins per unit length. The penguins jump straight up (the only direction they can jump due to the frictionless surface) as the boat approaches and land on the boat.
 - (a) (5 pts) What is the momentum of the boat, including Aliyah and her penguin passengers, as a function of time t ? The time is measured from the moment she first reaches the line of penguins.
 - (b) (5 pts) What is Aliyah's velocity as a function of the distance x ? The distance is measured from the point she first reaches the penguins.
 - (c) (10 pts) Find Aliyah's position as a function of time.

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2. A particle of mass m and charge q moves in the $x - y$ plane under the influence of a magnetic field $\vec{B} = B\hat{z}$. At $t = 0$ the particle is at the origin with velocity $v_x(t = 0) = v_0$ and $v_y(t = 0) = 0$.
- (a) (15 pts) Solve for the velocity, both v_x and v_y , as a function of time.
 - (b) (10 pts) Solve for the position as a function of time.

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3. Two bicyclists of the same size and shape, with the same drag coefficient, travel down the road. Cyclist *A* travels at 15 mph and cyclist *B* travels at 20 mph. Assume all the work goes into fighting air resistance (force scales as v^2).
- (a) (5 pts) If cyclist *A* requires 150 Watts to maintain his speed, how much power does cyclist *B* require?
 - (b) (5 pts) If both cyclists travel the same distance, and if Cyclist *A* expends a net energy of 1 kilowatt-hour due to the biking, how much energy does Cyclist *B* expend?

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4. Bill the cat, who has mass m , is fired straight upward from a cannon with muzzle velocity v_0 . The drag force on Bill has magnitude bAv^2 , where A is the cross sectional area. Assume $v_0 < v_t$, where v_t is the terminal velocity.

- (a) (5 pts) What is the terminal velocity? Give answer in terms of b, A, m and the acceleration of gravity g .
- (b) (10 pts) Solve for Bill's velocity as a function of time on the way up. Give your answer in terms of v_0, g and v_t .
- (c) (5 pts) How much time is required to reach the top of the trajectory?
- (d) (5 pts) If, after landing on his feet, Bill was fed heavy marbles, then fired from the cannon again, with the same initial muzzle velocity, would Bill go higher? or lower? – than on his first trip. Justify your answer.
- (e) (5 pts, extra credit) What is the maximum height of Bill's trajectory?
- (f) (5 pts, extra credit, contingent on previous answer being correct) When Bill passes the cannon on the way down, is his speed greater, or less than, or equal to v_0 ? Justify your answer.

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