Answer-key 2 for Calculus-Based Physics-1: Mechanics (PHYS150-01)

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1 Vectors and Newton's Laws

1. Let $\vec{F}_1 = -\frac{3}{2}\hat{x} + 2\hat{y}$ N, and $\vec{F}_2 = -2\hat{x} + \frac{3}{2}\hat{y}$ N. a) Give the magnitude of each force. b) What is the net force? c) What is the angle between these two forces?

2. Imagine you are sitting in an airplane that has just lifted off with an acceleration vector 45 degrees with respect to horizontal. Draw a free-body diagram corresponding to you, showing all forces acting on you.

3. Imagine you are riding a skateboard down a hill. Draw a free-body diagram corresponding to you, showing all forces acting on you.

2 Newton's Laws, and Circular Motion

1. When banking, the free-body diagram of a jet-fighter resembles Fig. **??**. To bank while maintaining altitude, the lift force $\vec{L}$ must *both* balance the weight $\vec{w}$ and provide the centripetal force $\vec{f}_{\rm C}$. Let the mass of the aircraft be m, the radius of the turn be r, and the angle between $\vec{L}$ and horizontal be θ.

   - Show that the angular velocity of the turn, ω, is $\omega = \sqrt{\frac{L\cos\theta}{rm}}$

   - If ω is the angular velocity, then the *period* is $T = 2\pi/\omega$. This is the time required to fly in a complete circle. Show that one-half period is $\frac{T}{2} = \pi\sqrt{\frac{rm}{L\cos\theta}}$. This is the time required to turn.

- Let $L = 8 \times 10^5$ N, $m = 2 \times 10^4$ kg, $r = \frac{1}{2}$ km, and $\theta = 60$ degrees. How long does it take the jet fighter to turn?

- What is the speed of the jet fighter?
  - A: 10 m/s
  - B: 20 m/s
  - C: 100 m/s
  - D: 120 m/s

3 Frictional Forces

1. There is a spill of a mystery toxic liquid on a shop floor, and no one wants to touch it. Someone gets the bright idea that they can identify it by the coefficient of kinetic friction and a steel plate. Draw a free body diagram corresponding to a steel plate sliding along the liquid/floor, with friction decelerating it.

2. What is the coefficient of kinetic friction, μ_{k}, if a steel plate with an initial speed of 5 m/s comes to a stop after 2.5 seconds, assuming $g = 10$ m/s^2? (Use the definition of acceleration $\Delta v/\Delta t = a$).

   - 0.1
   - 0.2
   - 0.5
   - 1.2

3. Suppose they get a sample of the mystery liquid in a vile. They assume the drag force is given by Stoke's Law, $F_{\mathrm{D}} = 6\pi r\eta v$, where v is the velocity of a particle moving through they fluid, r is the radius of the particle, and η is the *viscosity*. They drop a bead with $r = 1$ mm and a mass of one gram into the fluid, and observe the bead sink with a constant (terminal) velocity of 1 m/s. What is the viscosity of the fluid? Units: kg/(m s).

   The net force is zero, because the bead is moving at constant velocity. This implies that the force of gravity is balanced by the force of drag from Stoke's Law. $mg = 6\pi\eta rv$. All parameters are measured, so we may calculate η: $\eta = mg/(6\pi rv)$. Using $g = 10$, we find $\eta = 5/(3\pi)$ kg/(m s).

   - $5/(3\pi)$ kg/(m s) (Correct). Also, we can estimate our way to this one by noticing that it is closer to 1 than the other answers. This liquid is less sticky than honey, but more sticky than blood, and way stickier than water.
   - $5/(30\pi)$ kg/(m s)
   - 10 kg/(m s)
   - 5 kg/(m s)