AP Physics C

Unit 1: Kinematics Test

Direction: You must show all steps required to arrive at the correct answer for the problem below, including any relevant free body/pseudo free body diagrams. You are graded for your demonstration of physics and problem-solving methods, and not for simply writing the correction answer. A correct answer with no justification will receive no more than one point. All numeric answers must be given with correct units.

1. (25 points) At time t = 0 s, a tortoise is at the origin (x = 0) moving right (positive x-direction) with a speed of 2 m/s and an acceleration of 0.1 m/s^2. Meanwhile, a hare is located at x = -200 m at time t = 0 s and is moving in the negative x-direction with a velocity of -20 m/s and acceleration given by $a(t) = +0.6t$.

a) Write functions to the represent the positions of the tortoise, $x_T(t)$, and hare, $x_H(t)$ as functions of time starting from t = 0 s.

b) At some point the hare switches directions. Calculate at which time this occurs.

c) Find the position where the hare catches the tortoise ($x_T = x_H$).

d) Calculate the velocity of the tortoise and hare at the position in c).

e) Sketch a graph of the velocity of tortoise (solid line) and hare (dotted line). Label any maximum or minimum values.

2. (28 points) The height of a helicopter is given by $h(t) = 8 + 20t - 2t^2$. It also moves horizontally at a constant velocity of 4.00 m/s. At takeoff, the x position of the helicopter is x = 0 m.

a) Write an expression for the displacement, velocity, and acceleration of the helicopter as a function of time. Leave all expressions in vector form.

b) Find the helicopter's minimum speed.

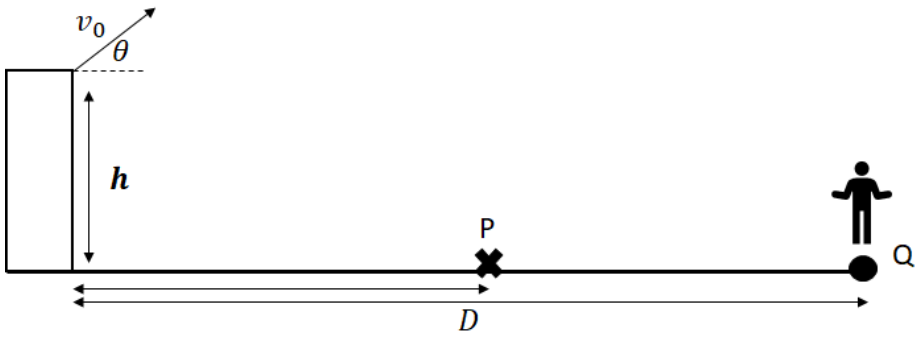
c) At some point, the helicopter hits the ground and crashes. Find the horizontal distance covered by the helicopter while in flight.

d) A separate helicopter is hovering a height h above the ground.

i. A stapler is dropped from the helicopter and hits the ground at a speed of v_1. Another stapler is thrown directly down out of the helicopter at a speed of v_1 and hits the ground at a speed of v_2. Determine the value of the ratio $\frac{v_2}{v1}$.

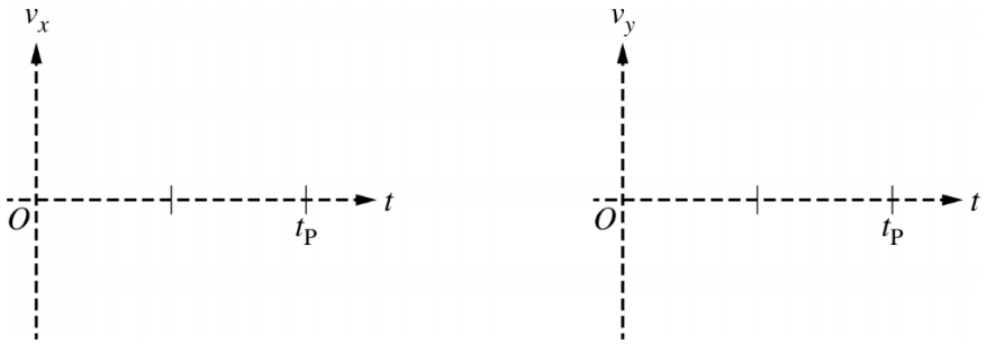
ii. In another case of destroying office equipment, the helicopter is hovering at a very large height and there is significant air resistance. Calculator A is thrown straight up at a speed of 20 m/s. Calculator B (identical to calculator A) is dropped out of the helicopter. Which calculator has the larger terminal velocity: (Calculator A, Calculator B, equal terminal velocities)? Justify your answer.

3. (22 points) A football is launched the top of a cliff of height h, as shown. At time t = 0, the football is launched with speed v_0 at an angle θ above the horizontal. The football lands at point P. Point P is a unknown distance of D from the base of the cliff.



a) Derive an expression for the time t_p at which the projectile reaches point P. Express your answer in in terms of the given quantities and physics constants.

b) Sketch horizontal component and the vertical component of the velocity of the football as a function of time t from $t = 0$ until $t = t_p$. **Explicitly label the vertical intercepts.**



c) Donnie the Dude is at point Q, a distance of D from the base of the cliff. The second the football is launched, he runs at constant speed from point Q to point P and makes a diving catch (has the same position as the football when it hits the ground at P). Determine an expression for the constant speed Donnie the Dude would have to run at.

d) The football hits the ground at point P and makes an angle of ϕ_p with the horizontal. Suppose the projectile were launched at such at speed (with launch angle unchanged) that is lands point Q. In this case, the football makes an angle of ϕ_Q with the horizontal. Is ϕ_Q greater than, less than, or equal to ϕ_p? Justify your answer.