香港中文大學(深圳)
The Chinese University of Hong Kong, Shenzhen

PHY1001: Mechanics

Each academic week, we have 10 or 11 homework problems. Note that the problem difficulty is ranked by the three-star ranking system. Three-star $***$ labels are assigned to the most difficult ones.

Show steps in your homework. Correct answers with little or no supporting work will not be given credit.

Due date: 23: 59:00, January 21st, 2024.

1 Homework Problems for Week 1 Chapter 1-4

1. $*$ A rock is thrown vertically upward from ground level at $t = 0$. At $t = 1.5$s it passes the top of a tall tower, and 1.0 s later it reaches its maximum height.

   (a) What is the height of the tower?
   Answer: 25.7m.

   (b) What is velocity when it first passes the top of the tower?
   Answer: 9.8m/s

2. $*$ (1-D motion) The initial velocity of a car is 0 at $t = 0$, and the acceleration is $a = \beta t^2$ with $\beta = 1\text{m/s}^4$.

   (a) What's the velocity v of the car at $t = 10$s?
   Answer: 333m/s.

   (b) What's the displacement x of the car at $t = 10$s?
   Answer: 833m.

3. $***$ (1-D motion) The initial velocity of a car is v_0 at $t = 0$ with its position at the origin $x = 0$. The acceleration of the car is $a = dv/dt = -kv^3$ with $k > 0$. Find the velocity of the car as the function of x, i.e., $v(x)$. **Answer:** $v(x) = v_0/(1 + kv_0x)$.

4. $**$ An object moves from point A with velocity $5m/s$ upon the north direction, after 2s, it reaches point B, which is 20m away from A, and its direction is 60° east of north relative to A. Suppose we know acceleration is constant.

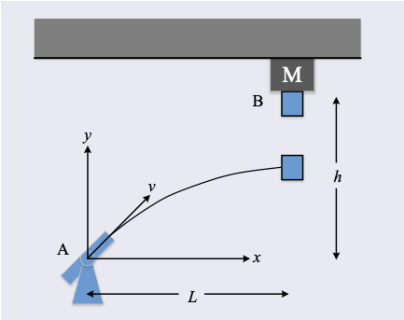
   (a) Find out the acceleration of the object and its velocity at point B.
   Answer: $\vec{a} = 8.66\hat{i}\text{m/s}^2$; $\vec{v} = (17.32\hat{i} + 5\hat{j})\text{m/s}$.

   (b) Check that the trajectory of the object is a parabola.

5. $*$ A magnet (M) sticks with an iron can together at point B, you can blow out a ball with the gun in order to hit the can at point A, the angle and magnitude of the velocity of the ball can be adjusted. At the time you trigger the gun, electric circuit stops and the magnet loses its magnetism so that the can immediately fall freely.

   (a) To hit the can, what should be the angle and magnitude of the launch velocity.

   (b) Given the initial velocity v, how much time does it take to hit the can?



6. $*$ (Halliday,C1-P28) Einstein's mass-energy equation relates mass m to energy E as $E = mc^2$, where c is speed of light in vacuum. The energy at nuclear level is usually measured in MeV where $1\text{MeV} = 1.60218 \times 10^{-13}J$; the masses of atoms are measured in unified atomic mass unit (u), where $1u = 1.66054 \times 10^{-27}$kg. Prove that the energy equivalent of $1u$ is 931.5MeV.

7. $*$ You are writing an adventure novel in which the hero escapes across the border with a billion dollars' worth of gold in his suitcase. Could anyone carry that much gold? Would it fit in a suitcase?
   (Hint: The problem is about the order-of-magnitude estimate. You will need to find out the gold price (As of January 2022, 1 gram of gold costs 60 dollars.) and choose a reasonable size for the suitcase, etc., but you do not have to get the exact number for the final answer.) **Answer:** Absolutely NO.

8. $*$ (Halliday,C2-P20)

   (a) If the position of a particle is given by $x = 25t - 6.0t^3$, where x is in meters and t is in seconds, when, if ever, is the particle's velocity v zero? (Note that t can be negative.)

   (b) When is its acceleration a zero?

9. $*$ (Halliday,C3-P36) Consider two vectors $\vec{p}_1 = 4\hat{i} - 3\hat{j} + 5\hat{k}$ and $\vec{p}_2 = -6\hat{i} + 3\hat{j} - 2\hat{k}$. What is $(\vec{p}_1 + \vec{p}_2) \cdot (\vec{p}_1 \times 5\vec{p}_2)$? **Answer:** 0.

10. $*$ **Bond Angle in Methane.** In the methane molecule, CH_4, each hydrogen atom is at a corner of a regular tetrahedron with the carbon atom at the center. In coordinates where one of the **C-H** bonds is in the direction of $\hat{i} + \hat{j} + \hat{k}$, and an adjacent **C-H** bond is in the $\hat{i} - \hat{j} - \hat{k}$ direction. Calculate the angle between these two bonds. **Answer:** $\cos\theta = -1/3$.