Physics 101H

General Physics 1 – Honors

Lecture 6 – 9/9/22

1D and 2D motion

Summary

Topics

This week
- Vectors
- Kinematics in 1D

Next week
- 2D motion
- Circular motion
- Forces

Yesterday: kinematics in 1D
- Vector products
- Describing motion in 1D
- Position, velocity, acceleration

Today: kinematics in 1D [chapters 3/4]
- Examples in 1D

Announcements

Wednesday: Problem set 1 due
Problem set 2 assigned

Quick quiz

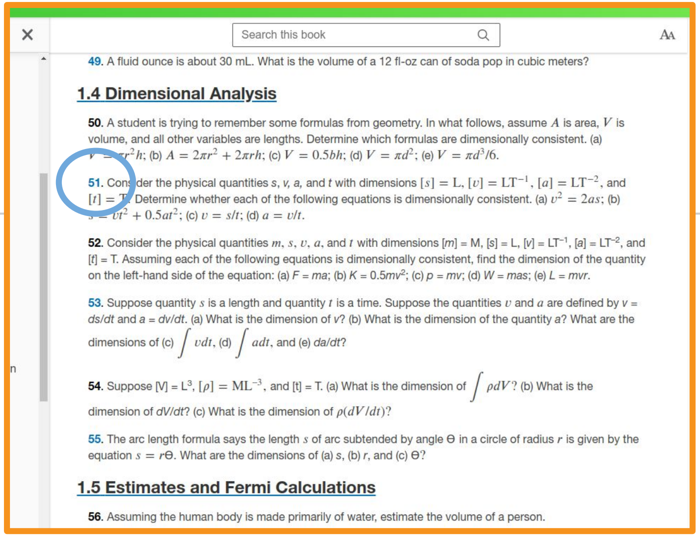
*Quick quizzes incorporate *retrieval practice* and *interleaving*, in which we revisit older material to reinforce your understanding. By keeping track of answers that you can and can't write down without reference to your notes, these quizzes help you identify which topics and concepts you understand best and which you may need to keep reinforcing.

Instructions: This quiz is for your own learning. There are four questions and each question has two columns. Write your own solution, without reference to your notes, the textbook, or your neighbour, **in the first column**. Once you have tried to answer all the questions, discuss the questions with a neighbour and fill in any incomplete answers **in the second column**. Keep your sheet for future reference.

SCAN ME

Want more practice?

Check out the following problems in the textbook



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49. A fluid ounce is about 30 mL. What is the volume of a 12 fl-oz can of soda pop in cubic meters?

1.4 Dimensional Analysis

50. A student is trying to remember some formulas from geometry. In what follows, assume A is area, V is volume, and all other variables are lengths. Determine which formulas are dimensionally consistent. (a) $V = \pi r^2 h$; (b) $A = 2\pi r^2 + 2\pi r h$; (c) $V = 0.5bh$; (d) $V = \pi d^2$; (e) $V = \pi d^3/6$.

51. Consider the physical quantities s, v, a, and t with dimensions $[s] = \mathrm{L}$, $[v] = \mathrm{LT}^{-1}$, $[a] = \mathrm{LT}^{-2}$, and $[t] = \mathrm{T}$. Determine whether each of the following equations is dimensionally consistent. (a) $v^2 = 2as$; (b) $s = vt^2 + 0.5at^2$; (c) $v = s/t$; (d) $a = v/t$.

52. Consider the physical quantities m, s, v, a, and t with dimensions $[m] = \mathrm{M}$, $[s] = \mathrm{L}$, $[v] = \mathrm{LT}^{-1}$, $[a] = \mathrm{LT}^{-2}$, and $[t] = \mathrm{T}$. Assuming each of the following equations is dimensionally consistent, find the dimension of the quantity on the left-hand side of the equation: (a) $F = ma$; (b) $K = 0.5mv^2$; (c) $p = mv$; (d) $W = mas$; (e) $L = mvr$.

53. Suppose quantity s is a length and quantity t is a time. Suppose the quantities v and a are defined by $v = ds/dt$ and $a = dv/dt$. (a) What is the dimension of v? (b) What is the dimension of the quantity a? What are the dimensions of (c) $\int v\,dt$, (d) $\int a\,dt$, and (e) da/dt?

54. Suppose $[V] = \mathrm{L}^3$, $[\rho] = \mathrm{ML}^{-3}$, and $[t] = \mathrm{T}$. (a) What is the dimension of $\int \rho\,dV$? (b) What is the dimension of dV/dt? (c) What is the dimension of $\rho(dV/dt)$?

55. The arc length formula says the length s of arc subtended by angle Θ in a circle of radius r is given by the equation $s = r\Theta$. What are the dimensions of (a) s, (b) r, and (c) Θ?

1.5 Estimates and Fermi Calculations

56. Assuming the human body is made primarily of water, estimate the volume of a person.

In Chapter 3:

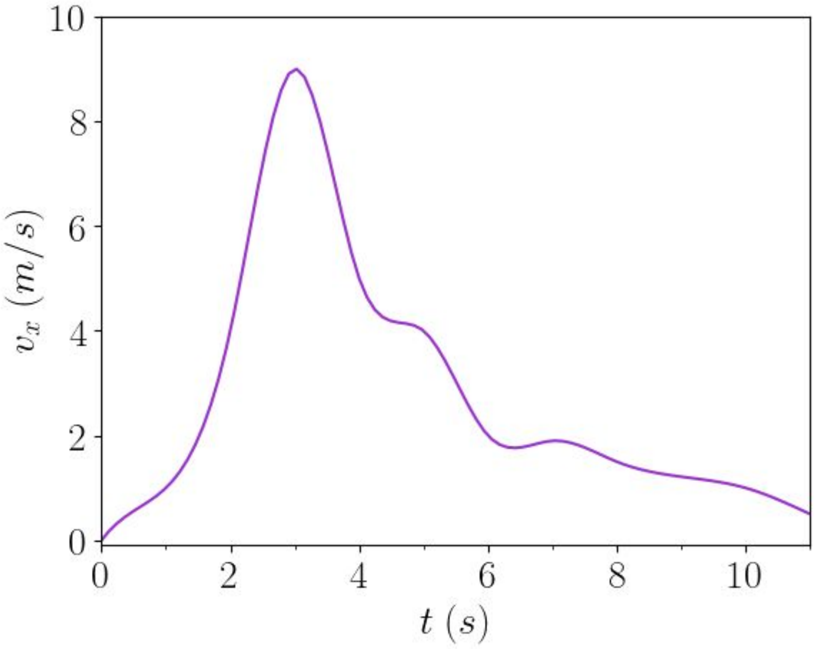
- Conceptual questions: 5, 7, 15, 19
- Problems: 27, 31, 37, 63, 69, 79, **113**

Note that answers are provided for questions with blue numbers (odd numbered)

Click on the number to be taken to the answer.

But make sure you at least **try** the problem first!

Example: Find the average acceleration between t = 0 and t = 6 s. Estimate the time at which the acceleration has its greatest positive value. When is the acceleration zero?



Example: A particle moves along the x-axis according to the equation $x(t) = 2 + 3t - t^2$. At $t = 3$ s, find the position, velocity and acceleration of the particle.

Example: A speedboat moving at 30.0 m/s approaches a no-wake buoy 100 m ahead. The pilot slows the boat with a constant acceleration of $-3.5\ m/s^2$. How long does it take the boat to reach the buoy? What is the speed of the boat when it gets there?

Practice in pairs

*Solving problems together helps you clarify your own understanding, as well as helping others learn. You may also learn new tips and techniques from your peers.

Instructions: Discuss the following question with a neighbour. Your answers will not be graded; your discussion is for your own learning*.

Question: A ball is dropped from a height *h*. Another ball is simultaneously thrown down with a speed *v* from a height of *2h*. What value does *v* need to take so that the two balls hit the ground at the same time?

(a) $\sqrt{gh}$ (b) $\frac{\sqrt{gh}}{2}$ (c) $\sqrt{\frac{gh}{2}}$ (d) $\sqrt{2gh}$ (e) $2\sqrt{gh}$

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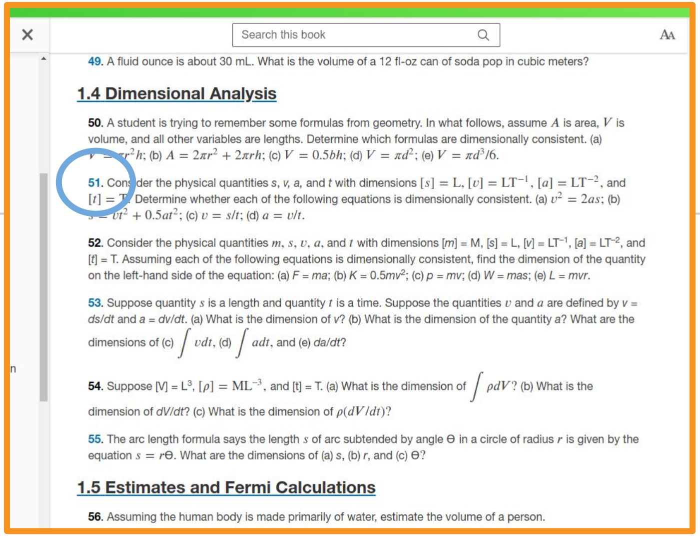

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Summary

Kinematics is the description of the motion of objects

Dynamics is the explanation of the cause of the motion of objects

Position – vector describing where object is relative to some reference frame

Displacement – change in position [a vector]

Distance – total length of journey [a scalar]

Velocity – rate of change of position [a vector]

Speed – the magnitude of the velocity [a scalar]

Acceleration – rate of change of velocity [a vector]

PHYSICS 101 - HONORS

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Kinematic equations

From definitions (or differential equations)

(*) $v = v_0 + at$

(**) $x = \frac{1}{2}at^2 + v_0 t + x_0$

$x = \frac{1}{2}(v + v_0)t + x_0$ ← or $\Delta x = \left(\frac{V_1 + V_0}{2}\right) t$

↑ substitute $a = \frac{v - v_0}{t}$ into (**)

$v^2 = v_0^2 + 2a(x - x_0)$ ← see Problem Set 1 !

Acceleration example

$a_{ave} = \frac{v_f - v_i}{t_f - t_i} = \frac{2-0}{6-0} = \frac{1}{3}\ m/s^2$ $a_{max} \sim t = 2.5s$

$a = 0$ at $t = 3s, 4.5s, 6.5s, 7s$

Position example

$x(t) = 2 + 3t - t^2 \Rightarrow x(t=3) = 2 + 3 \cdot 3 - 3^2 = 2m$

$v(t) = \frac{dx}{dt} = 3 - 2t \Rightarrow v(t=3) = 3 - 2 \cdot 3 = -3\ m/s$

$a(t) = \frac{dv}{dt} = -2 \Rightarrow a(t=3) = -2\ m/s^2$

Boat example

$x(t) = \frac{1}{2}at^2 + v_0 t + x_0$ ← $= 0$

Know $x = 100m$ at $t = t$, $a = -3.5\ m/s^2$ $v_0 = 30.0\ m/s$

Want t, so solve quadratic!

to solve $ax^2+bx+c=$

$x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$

Quadratic formula $t=\frac{-v_0\pm\sqrt{v_0^2-4\left(\frac{1}{2}a\right)(-x)}}{2\left(\frac{1}{2}a\right)}$

$$=\frac{-v_0}{a}\pm\frac{1}{a}\sqrt{v_0^2+2ax}$$

$$\Rightarrow t=\frac{-30}{(-3.5)}\pm\frac{1}{(-3.5)}\sqrt{(30)^2+2(-3.5)(100)}$$

$$=8.57\pm\frac{1}{(-3.5)}\sqrt{900-700}$$

$t=8.57\pm(-4.04)=$ **4.53 s** or 12.61 s

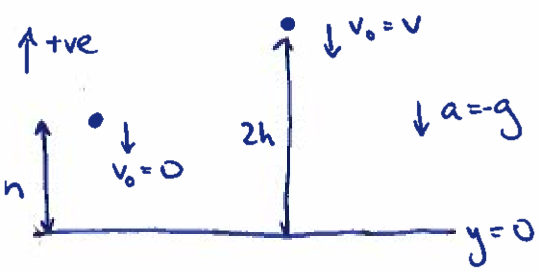
Then $v(t)=at+v_0$

$=(-3.5)\cdot 4.53+30$

$=$ **14.15 m/s**

Ball example

1st ball :



$y(t)=\frac{1}{2}at^2+v_0t+y_0$

$\Rightarrow y-y_0=-h=\frac{1}{2}(-g)t_1^2+0\cdot t_1$

or $\frac{gt_1^2}{2}=h \Rightarrow t_1=\sqrt{\frac{2h}{g}}$

2nd ball :

$y(t)=\frac{1}{2}at^2+v_0t+y_0$

$\Rightarrow y-y_0=-2h=\frac{1}{2}(-g)t_2^2+(-v_0)t_2$

or $2h=\frac{gt_2^2}{2}+v_0t_2$

Now we have two equations

$$2h = \frac{g}{2} t_2^2 + v_0 t_2 \quad \text{and} \quad t_1 = \sqrt{\frac{2h}{g}}$$

But $t_1 = t_2 \Rightarrow$ substitute for t_2

$$\Rightarrow 2h = \frac{g}{2}\left(\sqrt{\frac{2h}{g}}\right)^2 + v_0 \sqrt{\frac{2h}{g}} \quad \leftarrow \text{solve for } v_0$$

So $$2h = \frac{g}{2}\frac{2h}{g} + v_0 \sqrt{\frac{2h}{g}}$$

$$2h = h + v_0 \sqrt{\frac{2h}{g}}$$

$$\Rightarrow v_0 = \frac{h}{\sqrt{\frac{2h}{g}}} = \boxed{\sqrt{\frac{gh}{2}}}$$