PHY131H1F Summer –
Introduction to Physics I
Class 2

Today:
- Error Analysis
- Significant figures
- Constant Velocity Motion
- Constant Acceleration Motion
- Freefall
- Motion on an inclined plane

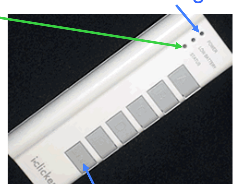
The "Clickers"

Status Light

When I start asking clicker questions:

- Will flash green when your response is registered
- Will flash red if your response is not registered

Power Light



On/Off Switch

Please turn on your clicker now

2

Your First Clicker Question!

**Which car is going faster, A or B?
(Assume these are both motion diagrams.)**

A B

Note: If you vote multiple times, only your ***last*** vote is registered.

After you've made your choice, you can discuss with your neighbours to see if they agree!

Course Syllabus
PHY131H1F – Summer "Introduction to Physics I"
Summer 2011, University of Toronto St. George Campus

Did you read the Course Syllabus?

MasteringPhysics Problem Sets, due twice per week, are

A. strongly recommended, but not worth marks.
B. not worth marks, but you will be tested on the material via "pop-quizzes" delivered in Practicals, worth 10% of your mark.
C. worth 5% of the course mark.
D. worth 10% of the course mark: 5% for the online part, and 5% for the "pop-quizzes" on the exact same material, done in Practicals.
E. worth 30% of the course mark.

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If you have one unexcused absence from Practicals,

A. it will not affect your mark, as Practicals are optional.
B. you will have an opportunity to make-up the activities you missed later in the semester.
C. you will receive a warning, but you will begin losing marks if you miss two Practicals.
D. you will get a zero on that day's activities, and that is the only penalty.
E. you will get a zero on that day's activities, plus you will receive a 1-cubed, or 1% penalty on your overall Practicals mark.

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These Clicker In-Class Discussion Quizzes

A. are for fun only, and are not worth marks in this course.
B. are worth 2% of the course, for participation only.
C. are worth 5% of the course, but in the end your clicker mark will be replaced with your final exam mark if that helps improve your grade.
D. are worth 10% of the course, and accuracy counts.
E. may be excused if you have a medical certificate.

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Did you read the Course Syllabus?

One day, you arrived to class half an hour late, so you missed the first 2 clicker questions. You voted in all the remaining 5 questions, and got 4 of them correct. What was your clicker score for that day?

A. 4 out of 7 (57%)
B. 9 out of 14 (64%)
C. 19 out of 24 (79%)
D. 29 out of 34. (85%)
E. 1 out of 1 (100%)

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Did you read the Course Syllabus?

What are the possible sanctions you can receive for using more than one clicker in order to vote for an absent friend?

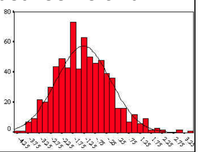
A. A zero on your clicker mark for the whole course (5% penalty on final mark)
B. A zero in the entire course
C. A record of an academic offense committed listed on your transcript for five years
D. Suspension from the university for 12 months
E. All of the above

Last day I asked at the end of class:

- If your friend says, "My height is 150 cm," is there an implicit error in that number? ANSWER: YES! Almost every measured number has an error, even if it is not stated. If you told me your height was 150 cm, I would guess the error is probably between 1 and 5 cm. [But there is no way to know this, unless you investigate how the 150 was measured.]

± Errors

- Why are errors so important to scientists and engineers?
- Errors eliminate the need to report measurements with vague terms like “approximately” or “≈”.
- Errors give a *quantitative* way of stating your confidence level in your measurement.
- Saying the answer is 10 ± 2 means you are about 68% sure that the actual number is between 8 and 12.
- It also implies that you are 95% confident that the actual number is between 6 and 14 (the 2-σ range).



Period of a Pendulum

- Procedure: Measure the time for 5 oscillations, t_5.
- The period is calculated as $T = t_5 / 5$.

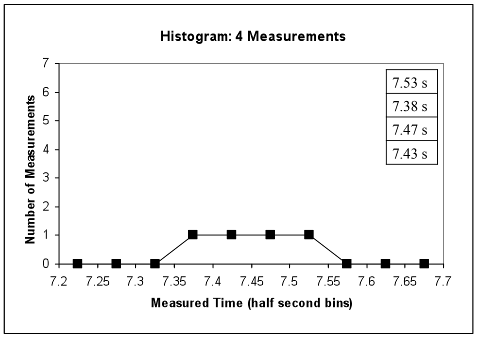
t_5 data: 7.53s
7.38s

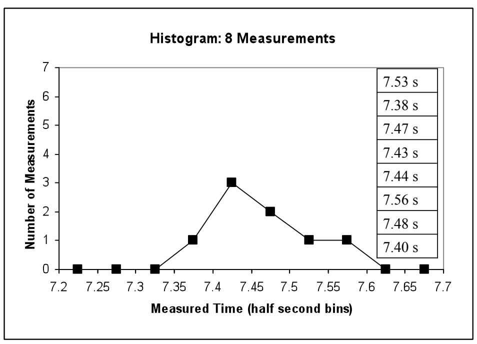
Here were Harlow’s measurements of t_5:

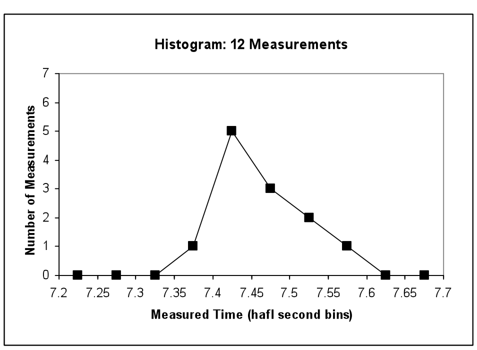
7.53 s
7.38 s
7.47 s
7.43 s

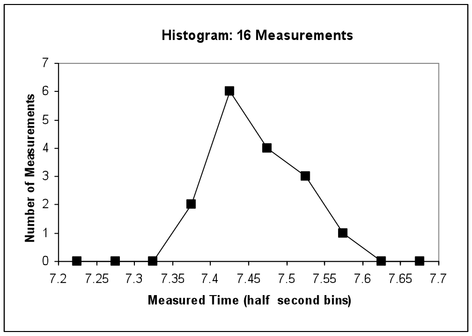
Which of the following might be a good estimate for the error in Harlow’s first measurement of 7.53 seconds?

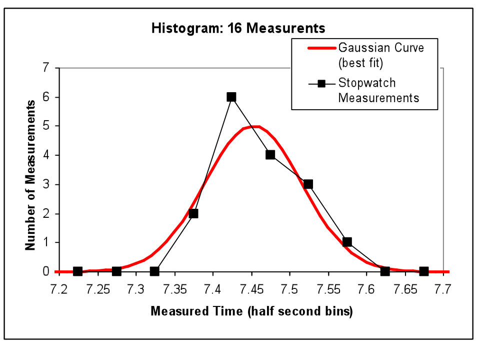
A. 0.005 s
B. 0.05 s
C. 0.5 s
D. 5 s
E. Impossible to determine


Histogram: 4 Measurements
7.53 s
7.38 s
7.47 s
7.43 s
Number of Measurements
Measured Time (half second bins)


Histogram: 8 Measurements
7.53 s
7.38 s
7.47 s
7.43 s
7.44 s
7.56 s
7.48 s
7.40 s
Number of Measurements
Measured Time (half second bins)

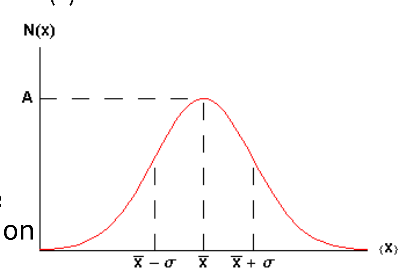

Histogram: 12 Measurements
Number of Measurements
Measured Time (hafl second bins)





The Gaussian:

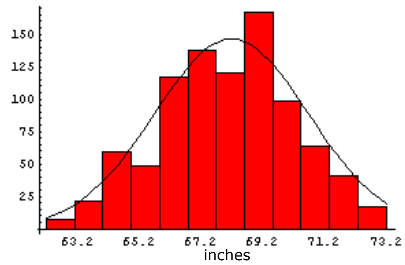
$$N(x) = A\, e^{\frac{-(x-\bar{x})^2}{2\sigma^2}}$$



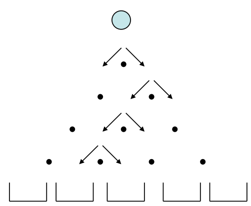
68% of data between the dotted lines on the graph.

Gaussian Distributions turn up everywhere!

Heights of some People (London, 1886)



Random Walk



Where does an object end up, if it takes N steps randomly left or right?

The final distribution is described by a Gaussian function!

The t_5 data

7.53 s $\pm$ 0.06 s
7.38 s $\pm$ 0.06 s
7.47 s $\pm$ 0.06 s
7.43 s $\pm$ 0.06 s

Numerically:

$\bar{t}_{5,est} = 7.45250$ s

$\sigma_{est} = 0.0634429$ s

$\sigma_{est} = 0.06$ s

Propagation of Errors

$$z = x + y \quad z = x - y \qquad \Delta z = \sqrt{\Delta x^2 + \Delta y^2}$$

$$z = x * y \quad z = x / y \qquad \frac{\Delta z}{z} = \sqrt{\left(\frac{\Delta x}{x}\right)^2 + \left(\frac{\Delta y}{y}\right)^2}$$

$$z = A\,x \qquad \Delta z = A\,\Delta x$$

$$z = x^n \qquad \Delta z = |\, n\, x^{n-1}\, \Delta x \,|$$

Repeated Measurements

- Repeated **n** times
- Each individual measurement has an error of precision Δ**x**

$$\Delta \bar{x}_{est} = \frac{\Delta x}{\sqrt{n}}$$

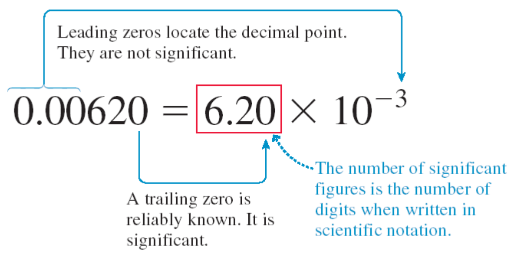
- You wish to know the time it takes to travel from Finch station to Yonge/Bloor by subway. You ask 10 people to take a stopwatch and time the trip. After analyzing all the data you find that it takes an average of 26 minutes and 40 seconds, with an error in this average of ± 100 seconds.
- If you expand your survey and ask 1000 people to time the trip, when you analyze the data, what would you expect to be the error in the average time?

A. 100 seconds
B. 50 seconds
C. 10 seconds
D. 1 second
E. 0.05 seconds

Significant Figures

- Discussed in Section 1.9 of Knight Ch.1
- Rules for significant figures follow from error propagation
  - Assume error in a quoted value is half the value of the last digit.
  - Errors should be quoted to 1 or 2 significant figures
  - Error should be in final displayed digit in number.
- Example: If a calculated result is (7.056 +/- 0.705) m, it is better to report (7.1 +/- 0.7) m.

FIGURE 1.25 Determining significant figures.



- The number of significant figures ≠ the number of decimal places.
- Changing units shifts the decimal point but does not change the number of significant figures.

Rank in order, from the most to the least, the number of significant figures in the following numbers.

a. 8200 b. 0.0052 c. 0.430 d. 4.321×10^{-10}

A. a = b = d > c
B. b = d > c > a
C. d > c > b = a
D. d > c > a > b
E. b > a = c = d

Instantaneous Acceleration

The instantaneous acceleration a_s at a specific instant of time t is given by the derivative of the velocity

$$a_s \equiv \lim_{\Delta t \to 0} \frac{\Delta v_s}{\Delta t} = \frac{dv_s}{dt} \qquad \text{(instantaneous acceleration)}$$

Note: Knight uses "s" to denote a distance in a general direction. Usually in problems we substitute x or y instead of s.

$$a_s \equiv \lim_{\Delta t \to 0} \frac{\Delta v_s}{\Delta t} = \frac{dv_s}{dt} \qquad \text{(instantaneous acceleration)}$$

- If an object is stopped, then

A. its acceleration is negative.
B. its acceleration is zero.
C. its acceleration is positive.
D. its acceleration could be any of the above.

Acceleration in 1-D (along a line)

- Velocity is the time-derivative of position.
- Acceleration is the time-derivative of velocity.
- S.I. unit of acceleration is m/s ***per second***, also called m/s^2.
- Acceleration is like the "speed of the speed"
- Acceleration is "how fast fast changes!"
- It is possible to be momentarily stopped (v=0) with a non-zero acceleration!

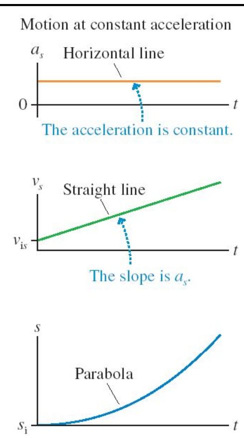
Finding Velocity from the Acceleration

If we know the initial velocity, v_{is}, and the instantaneous acceleration, a_s, as a function of time, t, then the final velocity is given by

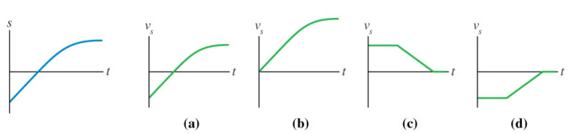
$$v_{fs} = v_{is} + \lim_{\Delta t \to 0} \sum_{k=1}^{N} (a_s)_k \Delta t = v_{is} + \int_{t_i}^{t_f} a_s \, dt$$

Or, graphically,

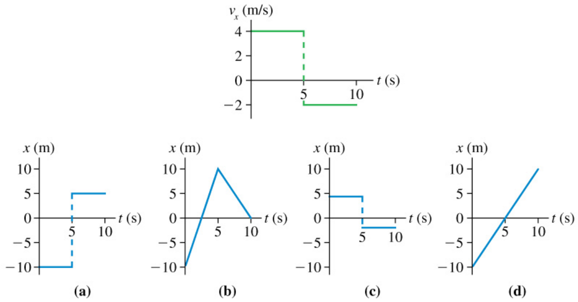
$v_{fs} = v_{is}$ + area under the acceleration curve a_s between t_i and t_f



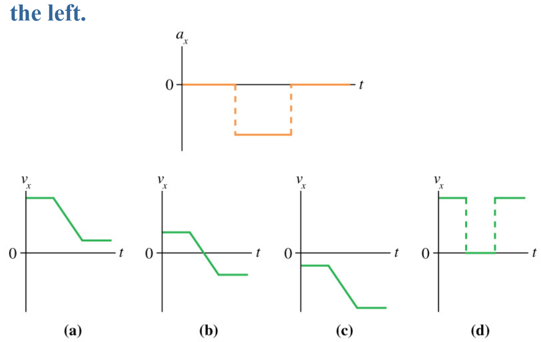
Which velocity-versus-time graph goes best with the position-versus-time graph on the left?



Which position-versus-time graph goes with the velocity-versus-time graph at the top? The particle's position at $t_i = 0$ s is $x_i = -10$ m.



Which velocity-versus-time graph or graphs goes with this acceleration-versus-time graph? The particle is initially moving to the right and finally to the left.



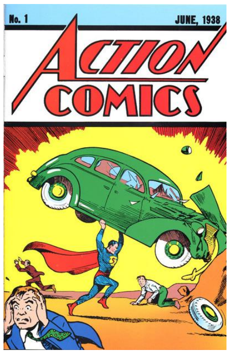
The 4 Equations of Constant Acceleration:

1. $v_f = v_i + a\Delta t$ — Does not contain position!
2. $s_f = s_i + v_i\Delta t + \frac{1}{2}a(\Delta t)^2$ — Does not contain v_f!
3. $v_f^2 = v_i^2 + 2a(s_f - s_i)$ — Does not contain Δt !
4. $s_f = s_i + \left(\frac{v_i + v_f}{2}\right)\Delta t$ — Does not contain a ! (but you know it's constant)

Strategy: When a = constant, you can use one of these equations. Figure out which variable you don't know and don't care about, and use the equation which doesn't contain it.

The Physics of Superheroes

©2009 by James Kakalios available at Chapters.ca for $15



- In the original comic, Superman only had super-strength and very tough skin!
- He could "leap tall buildings in a single bound."
- It was not until the 1940s that the writers changed his abilities to included guided flying.

Example Question.

Superman's parents came from a planet where the gravity was much stronger. His race has legs strong enough to jump to a maximum height of 1.0 m on planet Krypton.

On Earth, Superman can jump to a maximum height of 25 m. (a tall building in 1938!)

What was the acceleration due to gravity on planet Krypton?

Example Question & Demo – using Error Analysis.

A small object is dropped from a height of $y_i = 3.00 \pm 0.01$ m. $y_f = 0$ m.

The time of flight is $\Delta t \pm \sigma_t$.

Estimate g in this room.

MODEL: Neglect air resistance: $a = -g$.
This is called "free-fall"

Before Next Class:

- Read Chapter 3 of Knight.
- Read Sections 4.1 through 4.4 of Chapter 4 of Knight.
- Complete MasteringPhysics.com Problem Set 1, due by May 23 at 11:59pm
- Something to think about: Can you add a scalar to a vector? Can you multiply a vector by a scalar?