Welcome to PHYS-170

Mechanics I

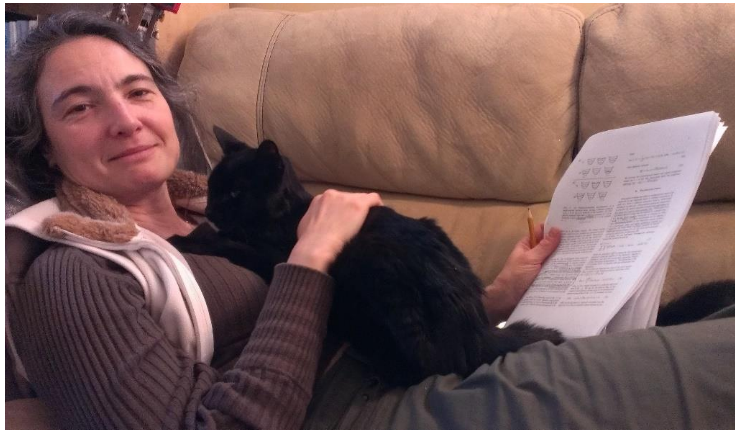
Section 201 (Mon Wed Fri 12:00 – 13:00)

Dr. Marina Litinskaya

Please pick up a worksheet from the front of the class!

Instructor: Dr. Marina Litinskaya

(left in this picture)



Email: mlit@phas.ubc.ca

Office: Henn 334

Office hours:

- Thu 5:30 – 6:30 pm (Zoom)
- or by appointment via email

Research interests: Optics and spectroscopy of atoms, molecules and nanostructures (theory)

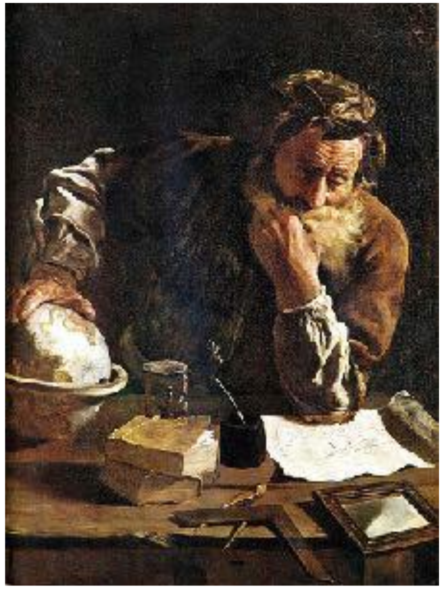
- Same said in a different way: I use light to learn about what's going on inside gases and solids, and to manipulate various processes in atoms and molecules.

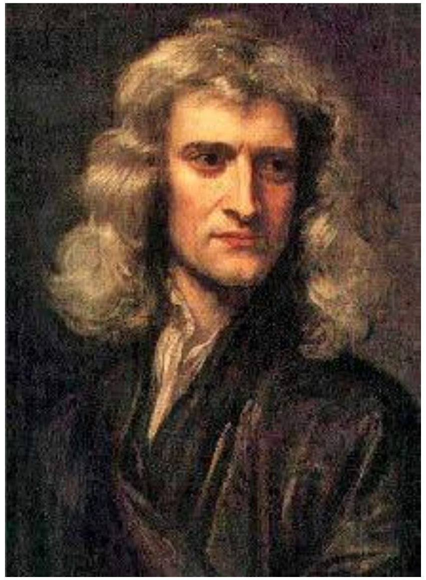
Teaching: PHYS 100, 131, 118, 157, 158, 159, 170, 333

MECHANICS:

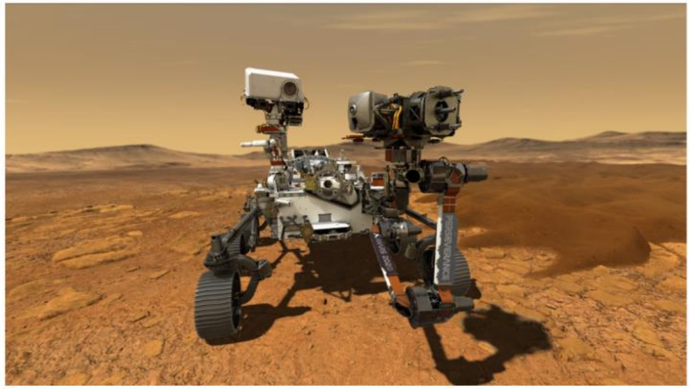
Yesterday, Today, Tomorrow

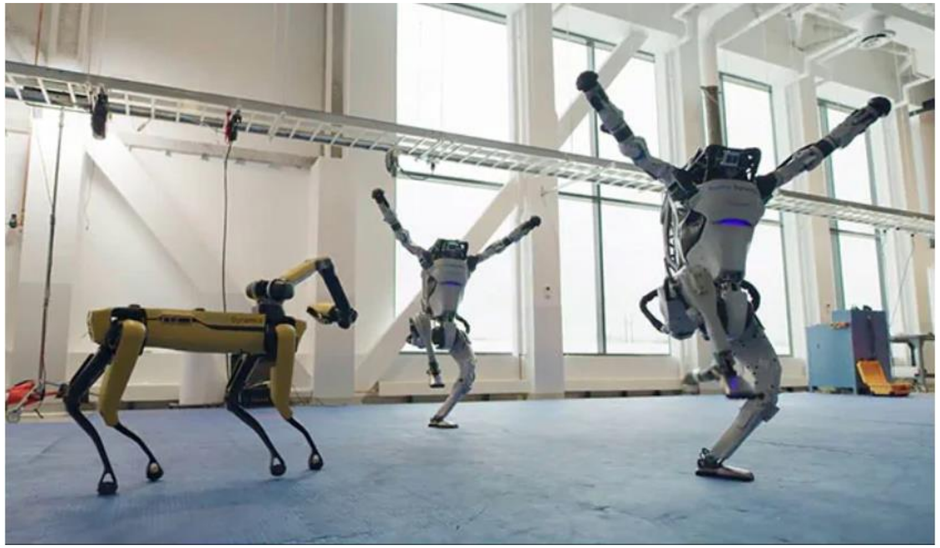
This course will use physics that was discovered hundreds (even thousands) of years ago by Archimedes, Aristotle and Newton (and others).





One of the joys on engineering is to use well understood physics in the most innovative ways possible.





COURSE OVERVIEW

Text: R.C. Hibbeler, *Engineering Mechanics: Statics and Dynamics*

Chap. 1: General Principles
Chap. 2: Force Vectors
Chap. 3: Equilibrium of a Particle
Chap. 4: Force System Resultants
Chap. 5: Equilibrium of a Rigid Body
Chap. 8: Friction

Statics

(how and why objects refrain from motion)

March exam (Thursday, March 7^{th}, 6:00-7:00 pm)

Chap. 12: Kinematics of a Particle
Chap. 13: Kinetics of a Particle: Force and Acceleration
Chap. 14: Kinetics of a Particle: Work and Energy
Chap. 15: Kinetics of a Particle: Impulse and Momentum

Dynamics

(how and why objects move)

Schedule: https://canvas.ubc.ca/courses/132391/files/30479780?module_item_id=6270206

WHAT ARE WE ACTUALLY GOING TO LEARN?

- Learning to solve multi-step problems that require planning and exploring various routes

- Seeing how various pieces of this course work together.

FUTURE PLANS

- Kinematic characteristics (velocity, position)

$$\vec{F}_R = m\vec{a}$$

- Free-body diagrams
- 3rd Newton's law pairs
- Kinetic friction
- .....

- Cartesian coordinates
- Tangential-normal coordinates
- Cylindrical coordinates
- ...

- Dependent motion
- Relative motion
- .....

HOW ARE WE ACTUALLY GOING TO LEARN IT?

- Text: R.C. Hibbeler, *Engineering Mechanics: Statics and Dynamics*
  (15th Edition / earlier editions: OK, but check problem #)
  - ➢ I recommend reading it before the lectures (at least preview the key ideas and definitions), and coming back to it after the lectures if need be;
  - ➢ Check the weekly reading material in Course Outline and Marks on Canvas, or in posted lecture materials.

- Course package: (purchase in the UBC Bookstore, not on Pearson website!!)
  - ➢ Mastering Engineering (= homework) + eText: ISBN 9780134867243 ($119.60)
  - ➢ Mastering Engineering (= homework) only: ISBN 9780138111823 ($60.40)
    - ❖ Used textbook is recommended with the no-eText option
  - Valid for 2 years
  - More information in Text & Register for Mastering Engineering Assignments on Canvas

HOW ARE WE ACTUALLY GOING TO LEARN IT?

- Lectures
  - ➢ Why do I need lectures if I have purchased the text and can read and understand it?
    - ❖ "Physics is best approached not by listening or reading, but by doing things"
    - ❖ Lecture notes: summary of the text (theory)
    - ❖ Clicker questions (please register at "iClicker Sync" on Canvas)
    - ❖ Worksheets (please pick up or download)
    - ❖ "Checklists": on your own, at the end of the week

Week 1. Introduction & Force Vectors in 2D (Text 1.1-1.6, 2.1-2.4)

Lecture notes (Week 1) Checklist 1 : what you need to know

Lecture 1 (Mon, Jan 8)

Inked slides Recording

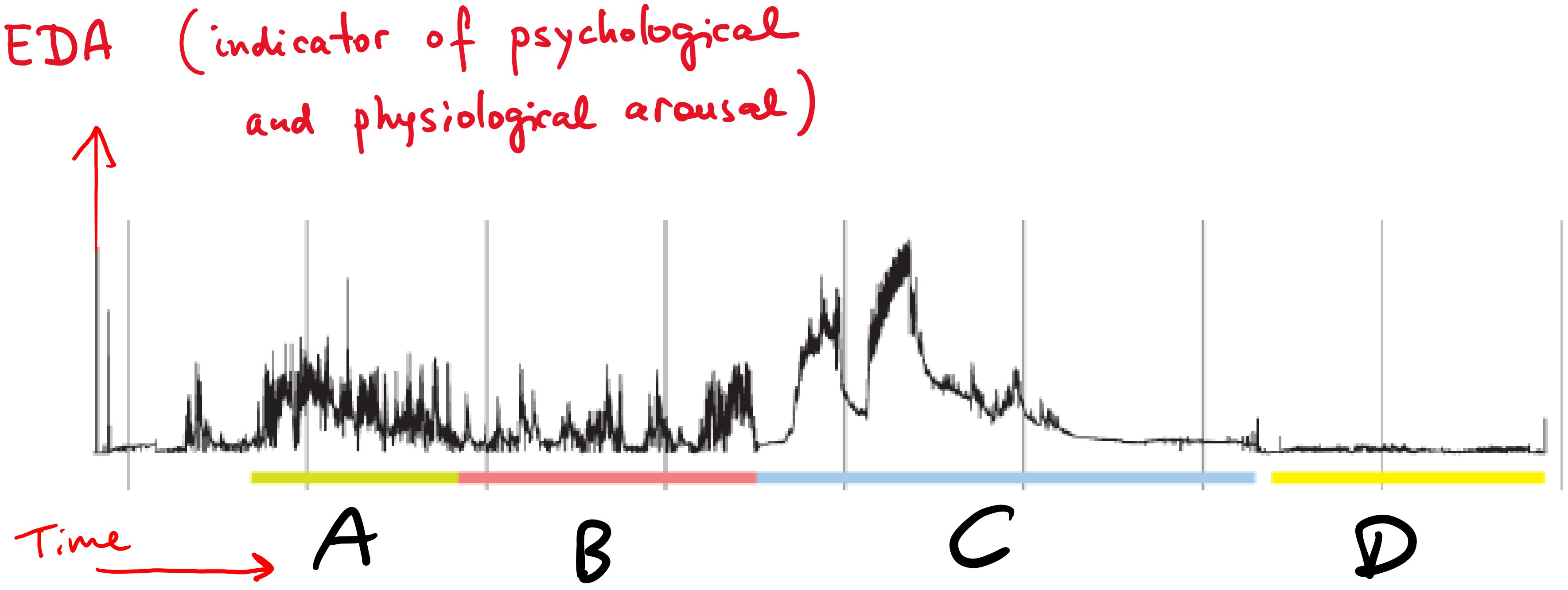
Week 1. Introduction & Force Vectors in 2D (Text 1.1-1.6, 2.1-2.4)

Worksheet 01 Check your solutions here .

Worksheet 01-Extra Practice . (see second opinion here)

  - ➢ Why do I need to attend lectures if they are recorded and posted?
    - ❖ It is much more difficult to get involved when you are watching a recording than when you are physically in the class, and when you can discuss with your peers

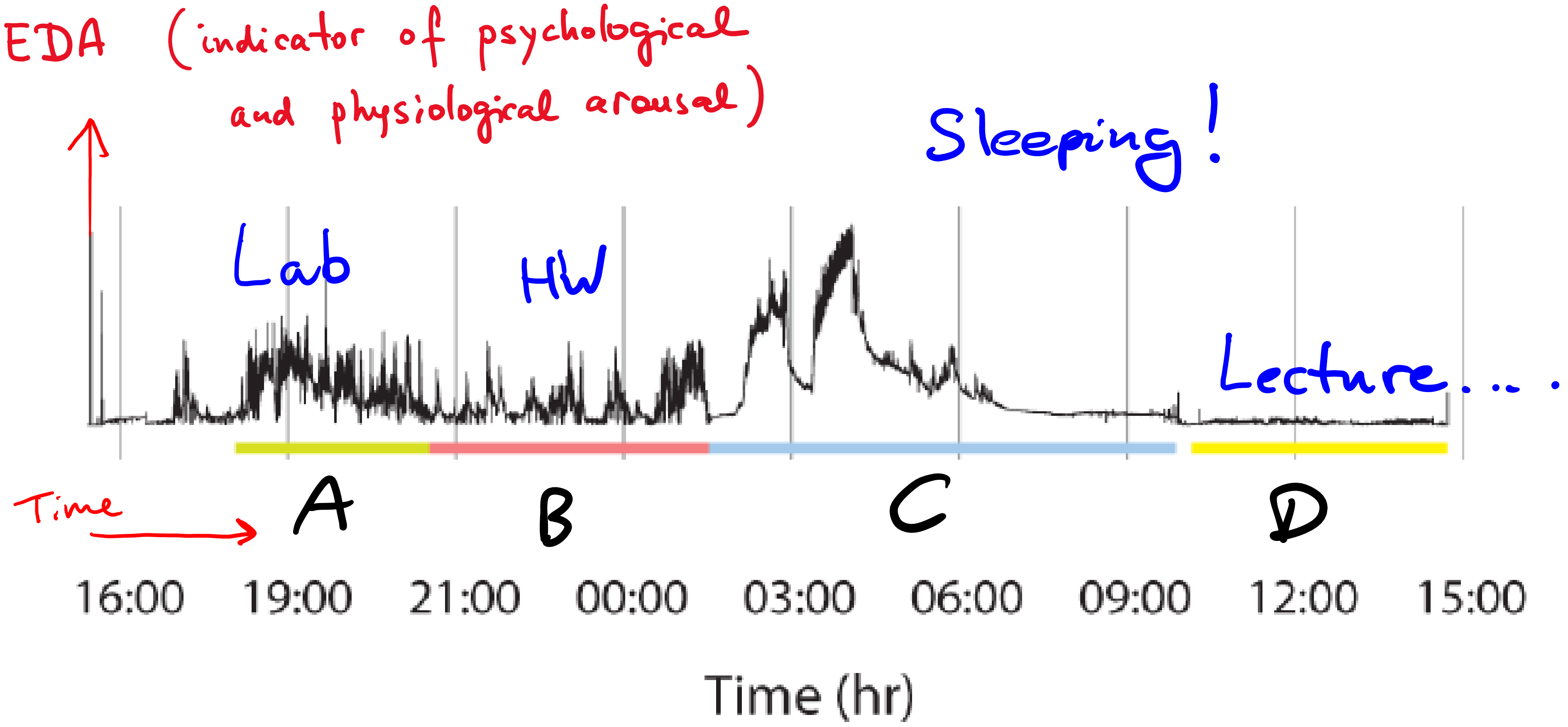
active lectures



Q: Which segment shows EDA during class time?

Poh, M.Z., Swenson, N.C., Picard, R.W., IEEE Transactions on Biomedical Engineering, vol.57, no.5, pp.1243-1252, May 2010

active lectures



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WHAT DO WE NEED?

- Vectors and manipulations with them – now, right away!
  - Vector components
  - Projections => elements of trigonometry
  - Dot (scalar) product of two vectors
  - Cross (vector) product of two vectors

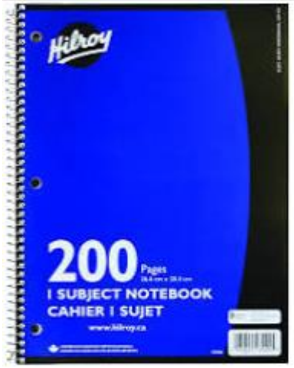
- Systems of linear equations
  - System of N linear equations in N unknowns has one unique solution
  - Know how to find that solution using a calculator (see “Additional Information” on Canvas)

- Elements of calculus (later in the term)

GRADING SCHEME

Final Exam	60
March Exam	30
Mastering Engineering Assignments	5
Tutorial Assignments	5
Total	100

- Exams: Problem solving (you can check past exams here).
- Mastering Engineering Assignments:
  - Due Sundays 10:00 pm
- Tutorials:
  - Check the information carefully, and know your tutorial section
  - Practice in solving problems, and in writing them up
  - A straightedge and a calculator (linear systems of 6x6 eqs)!!!
  - "How to write your solutions" (here). Please read it carefully and take it literally (yes, you will need a straightedge, 3 sig figs, units, and prefixes!!)



The recommended calculator is **TI 84+**, but there are other options with similar functionality.

ACADEMIC HONESTY

- Carefully check the details here (Academic Honesty page in Course Information module on Canvas). It lists the resources, which you can / cannot use for each type of the assignments, and what you can / cannot discuss with other students.
- It is never acceptable to use a resource which provides, in whole or in part, a solution to one of the problems you are solving in this course (Homework, Tutorials, Exams)
- Complete mandatory academic honesty quiz by Jan 21st. You just need to confirm that you know the rules, and will follow them. Doing this is necessary for your marks for homework and tutorials to count.

RESOURCES

- Office hours: schedule
- Study groups
- Piazza. Register asap (the link is on Canvas)

PHYS 170

Week 1: Force Vectors in 2D

Section 201 (Mon Wed Fri 12:00 – 13:00)

General Principles

Text: 1.1-1.6

Content:

- Mechanics, Statics, Dynamics…
- Fundamental quantities & fundamental laws of mechanics
- Units: SI and FPS systems
- Dimensional analysis

MECHANICS / STATICS / DYNAMICS

mechanics, science concerned with the motion of bodies under the action of forces, including the special case in which a body remains at rest.

Britannica

Mechanics

- Statics: the analysis of loads (force and torque, or "moment") on physical systems in static equilibrium (i.e., nothing moving).
- Dynamics: the study of forces and torques and their effect on motion (particularly acceleration).

- Immediate applications in Mechanical Engineering and Civil Engineering

FUNDAMENTAL CONCEPTS

- Idealizations (“model”):
  - Point particle (mass, negligible size)
  - Rigid body (mass, finite size, does not deform under load) ← Torques!
  - Concentrated force (acts at a point)
  - Ideal cords (massless, no stretching)
  - Ideal pulleys (massless, no friction…)

Q: When a car can be considered as a point particle, and when cannot?

FUNDAMENTAL LAWS

- Newton's 1st law:

A particle which is originally at rest or is moving in a straight line with a constant velocity, will remain in this state provided the particle is not subjected to unbalanced forces (or *motion with a constant velocity along a straight line is a natural state and it does NOT require a constant force to maintain this velocity* – very counter-intuitive, since we live in the world where we always cause motion by applying a force to compensate for friction/drag)

- Newton's 2nd law:

A particle acted upon by an unbalanced force experiences an acceleration in the same direction as the net force with a magnitude proportional to the force (or $\vec{F}_{net} = m\vec{a}$)

- Newton's 3rd law:

The mutual forces of "action" and "reaction" between particles are equal and opposite (or "all forces appear in pairs", or *you cannot touch without being touched*).

- Newton's law of gravitation:

Gravity force due to two masses (magnitude): $F_G = G\,\frac{m_1 m_2}{r^2}$ $\Rightarrow$ on the Earth: $W = mg$

UNITS OF PHYSICAL QUANTITIES

- Basic and derived quantities:
  - length, time, mass: independent (basic)
  - force, moment of force, … can be derived; example: $\vec{F} = m\vec{a} = \underbrace{m}_{kg}\underbrace{\frac{d^2\vec{r}}{dt^2}}_{\frac{m}{s^2}}$
  - Or you can say that **force** is an independent quantity, and derive **mass** from it
    - This is exactly what makes a difference between SI and FPS units systems!

UNITS OF PHYSICAL QUANTITIES

Name	Length	Time	Mass	Force
International System of Units (SI)	meter (m)	second (s)	kilogram (kg)	newton* (N) $\left(\frac{\text{kg}\cdot\text{m}}{\text{s}^2}\right)$
U.S. Customary (FPS)	foot (ft)	second (s)	slug* $\left(\frac{\text{lb}\cdot\text{s}^2}{\text{ft}}\right)$	pound (lb)

*Derived unit.

- SI (Le Système International d'Unités)
- FPS (Foot-Pound-Second)

- Note: kg (or slug) are units of mass, while lb (or newton) are units of force.
- Weight is a force! You absolutely cannot say "my weight is 60 kg".
  - ➢ Weight in Newtons = mass in kg * 9.81
  - ➢ Mass in slugs = weight in lbs / 32.2.

$$\boxed{W = mg}$$

$$\boxed{g = 9.81\,\frac{m}{s^2} = 9.81\,\frac{m}{s^2} \times \frac{1\text{ ft}}{0.3048\,m} = 32.2\,\frac{\text{ft}}{s^2}}$$

UNITS OF MEASUREMENT

Los Angeles Times

Mars Probe Lost Due to Simple Math Error

By ROBERT LEE HOTZ

OCT. 1, 1999 | 12 AM

TIMES SCIENCE WRITER

NASA lost its $125-million Mars Climate Orbiter because spacecraft engineers failed to convert from English to metric measurements when exchanging vital data before the craft was launched, space agency officials said Thursday.

A navigation team at the Jet Propulsion Laboratory used the metric system of millimeters and meters in its calculations, while Lockheed Martin Astronautics in Denver, which designed and built the spacecraft, provided crucial acceleration data in the English system of inches, feet and pounds.

In a sense, the spacecraft was lost in translation.

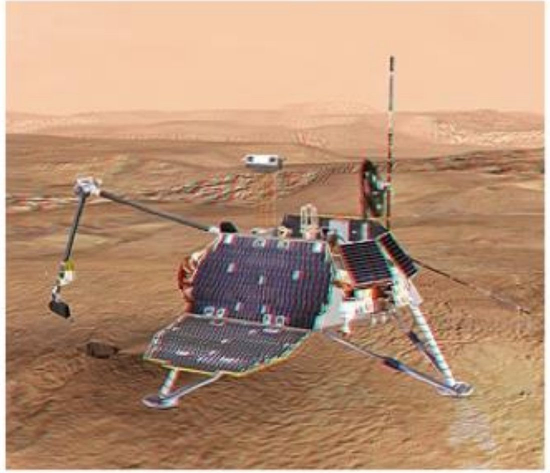
Update

- On Sept. 23, 1999 the orbiter crashed during its approach to Mars because it came in too low to the planet.

Metric error caused Crash of Mars Orbiter

ASSOCIATED PRESS

WASHINGTON - Failure to convert English measures to metric values caused the loss of the Mars Climate Orbiter, a spacecraft that smashed into the planet instead of reaching a safe orbit, a NASA investigation confirmed Wednesday.



NASA VIA AP

The Mars Climate Orbiter, shown in an artist's rendering, was to relay information from another spacecraft on the planet's surface.

The orbiter, a key craft in the space agency's exploration of the red planet, vanished after a rocket firing Sept. 23 that was supposed to put the spacecraft on station around Mars.

An investigation board concluded that NASA engineers failed to convert English measures of rocket thrusts to newtons, a metric system measurement of rocket force. One English pound of force equals 4.45 newtons. A small difference between the two values caused the spacecraft to approach Mars at too low an altitude.

The investigation board found that the error went undetected in ground-based computers. Also, the mission's navigation team had an imperfect understanding of how the craft was pointed in space.

NUMERICAL CALCULATIONS

- **Significant figures (sig. figs.):** accuracy of a number
  - Default for final answers: **3 sig. figs.** (generally carry 4 [or more] for intermediate values, best to keep full precision in calculator)

- **Rounding numbers** (check your textbook):
  - If the "tail" that you drop starts with {0,1,2,3,4} the last digit you keep does not change (round down);
  - If the "tail" starts with {5,6,7,8,9} add 1 to the last digit you keep (round up)

    2.34475 => 2.34;   2.34575 => 2.35

  - If the "tail" consists of one digit, 5: look at the last number you keep:

    only one digit, and this digit is 5!

    2.365 -> 2.36 (even => round down),
    but 2.335 -> 2.34 (odd => round up)
    "**Round to even digit rule**"

$\boxed{F = 5.63\ kN}$

$F = 5627\ N = 5630\ N = 5.63 \cdot 10^3\ N$

- **Engineering notations:**
  - Express everything in multiples of 10^3 using prefixes

SI prefixes

Exp. form	Prefix	SI symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n

DIMENSIONAL HOMOGENEITY

- All terms in equation must have same physical dimension (same units)
- For example, you know that force is measured in Newtons, but you don't remember what a Newton is. Use $F = ma$ to figure out that

$$[F] = [m] \cdot [a] = kg \cdot \frac{m}{s^2} = 1\ N$$

- Making sure that your units are consistent can get you very far

DIMENSIONAL ANALYSIS IS YOUR FRIEND

Q: Physical drag of something being pushed through the air depends on the ***mass density*** ρ of air, the ***frontal area*** A of the thing being pushed, and ***velocity*** v at which it's being pushed.

Which expression for the magnitude of the ***drag force*** $\boldsymbol{F}$ is dimensionally correct?

A. $\rho A v$
B. $(\rho/A)\ v$
C. $\rho A^{2/3} v^2$
D. $\rho A v^2$
E. Not sure

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E. Not sure

$$[\rho] = \frac{kg}{m^3} \qquad [A] = m^2 \qquad [v] = \frac{m}{s}$$

$$[F] = N = \frac{kg \cdot m}{s^2} \qquad \left(F = ma = kg \cdot \frac{m}{s^2}\right)$$

$$\frac{kg\, m}{s^2} = \frac{kg}{m^3} \cdot \frac{m^2}{s^2} \cdot m^2$$

"proportional to"

$$F \propto \rho \cdot v^2 \cdot A \rightarrow \boxed{F \propto \rho v^2 A}$$