Get Real! -
Appropriate Values for Teaching Physics

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A simple mechanics problem

Pastiche of MC problems I have been reviewing

A student using a force probe exerts an average force of 24 N on a 6 kg laboratory cart for 5 seconds. The cart travels on a straight track, and the cart wheels have negligible drag.

Find the change in the cart's momentum.

Analysis

$$\Delta p = F\Delta t = 120 \text{ N-s}$$

is the the correctly calculated result

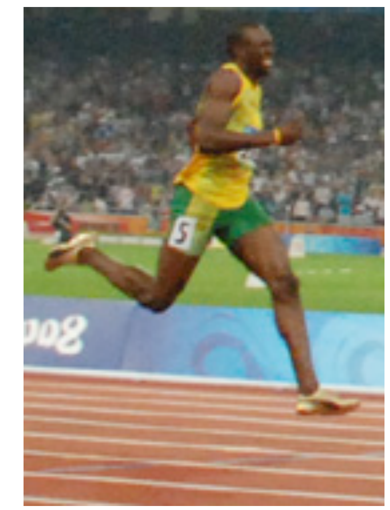
Let's look further!

Acceleration = 4 m/s^2
Starting from rest, after 5 s
v = 20 m/s and d = 50 m.

Nice, simple numbers
No calculator required.
Basic kinematics and dynamics

BUT CONSIDER:

13 pound lab cart!
(12 pound load on 1/2 pound PASCO™ lab cart?)



final speed of cart and student :
72 km/h = 44 mph = 1.6 Usain Bolt top speed

distance traveled in classroom: 60 yards
classroom size > 0.5 football field

track = 23 PASCO™ 2.2 meter tracks end to end

Student hopes to stop safely

50 college track coaches beating down the door to reach him first

Do we worry? Why?

Simple concept, easy numbers, what's the issue?

Issue: Physics is more than crunching numbers in equations
Physics is building, testing & using plausible models of real world.

Can we use easy numbers?

For novices, numbers should be as simple as possible, but not simpler (paraphrasing Einstein)

On mastery exams, we should reward robust knowledge.

Students should reject vertical leap height of 20 m, accept 20 cm.
If 20 m is the "correct" answer, we are cheating good students.

Proposed principles for problem preparation.

Physically reasonable values and units should provide experience with real world magnitudes.

Problem values situated in class or lab context should be consistent with readily achievable results in class and lab context.

If values are from some other context, that should be clearly stated.

If unrealistic values are used, clear notice should be given or students should be cued to challenge the realism of the given values.

Problems in electrostatics

Many authors have little feel for realistic values of charges, fields, size & mass of charged objects on classroom scale.

In past, few tools at hand to measure charge

Now we have Vernier™ & PASCO™ charge sensors

Texts give electric breakdown strength of air 3 x 10^6 N/C
Many calculate breakdown surface charge density 27 μC/m^2

Minimum radius of sphere for given charge

$$R_{\min} = 55\left(\frac{\mathrm{m}}{\mathrm{C}^{\frac{1}{2}}}\right)\sqrt{Q}$$

Maximum charge for given radius

$$Q_{\max} = 3.3\times10^{-4}\left(\frac{\mathrm{C}}{\mathrm{m}^2}\right)R^2$$

Realistic values

Charge & R_{min}

Charge	R_{min}
1 C	55 m
1 mC	1.7 m
1 μC	5.5 cm
1 nC	1.7 mm

Measured charges in lab

Styrofoam cup	60 - 90 nC
soda can charged on VDG	70 nC
plastic straw	20 nC
4 cm dia ping pong ball rubbed with acrylic	20 nC
4 cm Scotch™ tape	8 nC
Al foil cylinder 5 mm x 1cm	5 nC

Example: A charge too large

One microcoulomb sounds small but is not small at lab scale

Many examples of object dimensions too small for the charge

Find the net force exerted on a 1μC test charge halfway between 5 μC and 2 μC charged spheres with centers 10 cm apart.

R_{min} of spheres must be 5.5 cm, 12.3 cm, 7.8 cm respectively.

Place 5 μC and 2 μC objects in contact, centers are 20 cm apart, twice the specified separation, so no room for 1 μC , 11 cm diameter object in between.

Compare	15 cm diameter Van De Graaff 2 μC
maximum	30 cm diameter 450 kV VDG 7 μC
charges	1 cm diameter pith ball only 8.3 nC

Example: A field too strong

Find the field strength to exert a 15 N force on a small pellet with a 3nC charge?

Result: $E = 5\times10^9$ N/C

~1700 times $E_{breakdown}$

15 N force is huge!

3 nC styrofoam pellet has R_{min} about 3 mm.

Styrofoam density100 kg/m^3 gives mass of 0.11 μg,

acceleration if released is 140×10^6 m/s^2

speed after 1 cm is 1.7 km/s

comparable to high velocity rifle bullet

don't let go of that in the lab

Impossible materials

Common situation: a 10 gram sphere with a 60 μC charge hangs from a string. Its center is 30 cm from the other end of the string which is attached to a charged vertical wall.

Stop right there.

R_{min} for 60 μC is 42 cm so the string ends inside the object!

From mass and R_{min}, volume is 0.32 m^3 & density 0.031 kg/m^3

At STP, densities of air and hydrogen gas are 1.3 & 0.090 kg/m^3.

What material can we use to make a 2 foot diameter ball with average density a third that of hydrogen gas?

Suggestions

<u>Authors</u> - TAKE CARE -
Choose realistic values. Test your assumptions.

<u>Teachers</u> - with most present texts you might need to revise at least electrostatics problems to have them make sense.

For now, could enlist students to check problems and devise realistic replacement values.

Finding mistakes in authoritative texts is BOUND to have student appeal.

(<u>Students</u> - if writing authors, please do it most politely.)

We all make mistakes
Writing good books and good problems is hard.