2210 General Student Difficulties

(** means it’s prevalent/serious among our students)

Some math difficulties noticed:
- Don’t know how to apply the chain rule**
- Complex numbers: students not comfortable with re^(i theta) notation, much prefer to convert to x +iy and do calculations with this form (even when an expert would call that a much more difficult approach)**
- Is \( \cos(nx) = \cos(-nx) \)?
- How to write a sum of 1-1/3+1/5-1/7 since it is alternating odds. Some just left it as sin(n Pi/2), but a few figured out (or told each other) \((-1)^{(n+1)/2}\)
- Not immediately clear to some students that \( d\phi/dr = \text{constant} \) means \( \phi = \text{constant} \ r \), or not immediately clear that \( \text{integral(\text{constant } dr}) = r*\text{constant} \.
- Students don’t always know how to integrate complicated expressions - they had trouble recognizing whether they should use sub or use an integral already written in the front of the book. Also, they seemed to have trouble factoring out the constants in a useful way (so that the integral resembles something that they can actually integrate).

Basic Algebra difficulties
- Divide by a variable instead of factoring it out (lose the solution \( x=0 \))
- Don’t know what to do when \( \ln(\text{blah}) = \text{blahdeblah} \) (not experienced with taking the exponent of each side)
- not comfortable with \( \ln(a)-\ln(b) = \ln(a/b) \)
- not comfortable with \( e^a*e^b = e^{(a+b)} \)
- One or two students think that \( 1/(a+b) = 1/a+1/b \)

Some general problem solving difficulties
- Don’t know what are constants/parameters and what are variables in a given problem*
- Students don’t choose limiting cases on their own, may not understand when we ask them to check using a limiting case.**
- Students may not know what “checking units” means or how to determine the units of a given variable/parameter.**
- Trouble picking the best coordinate system – visualizing coordinate systems
- Trouble breaking vector in to components, adding component visually (some students may just put in a cosine or sine term without using the geometry to justify which)**

Air resistance/ODEs:
- do not see Newton’s law as a differential equation
- do not see differential equation as a way to get \( x(t) \)
- incorporating initial conditions: students may not recognize that the arbitrary constant they added is determined by an initial condition. They may neglect this constant completely. Some students try to use integration limits but don’t know what to use.**
- Moving words to criteria: e.g. is “when the ball hits the ground” when \( v_y=0 \) or when \( y=0 \)?
- Trouble separating separable ODEs. Some students do not understand what separating variables mean and have some terms that are not multiplied by \( d\_\text{anything} \). Some students have trouble with the actual mechanics of separating an equation and use addition/subtraction to move terms between sides rather than division.**
-Getting the sign for the drag term right in the ODE for both linear and quadratic drag (addressed by intermediate mechanics tutorial).

**Momentum and Rockets/ Center of Mass:**
- Students want to equation/variable match and use the rocket equation for releasing a discrete chunk of mass (e.g. an empty fuel tank).
- Vector equations as 3 equations, particular vector equations involving an integral (e.g. center of mass equation expressed as a vector relation - students don’t recognize this as 3 equations)
- Difficulty with the idea of combining a vector in Cartesian with an integral in spherical.
- Equation-variable matching to solve an equation without thinking about what the variables in an equation mean physically.

**Taylor series: (XXX We have more here now)**
- Unfamiliarity with the mathematical form of the Taylor series.
- Do not understand for what conditions a few terms of the Taylor series are a good approximation for the functions (i.e. epsilon <<1).
- Do not know how to choose the right variable or group of variables to expand in
- Thinking that if we assume a variable is small that means we will take it to be zero
- Do not recognize when to use a Taylor series (e.g. if the problem says “approximate the solution” in some regime)
- Difficulties with terminology: leading order, first correction, etc.

**Potential Energy/Conservative forces/curl/grad:**
- Thinking a rotational field is associated with curving lines in the field
- Confusing derivative (curl) and value when the value is zero, want the curl to also be zero
- Line integrals – lose track of what the dot product means inside the integral.
- Imprecision in thinking/writing in what is a scalar and what is a vector

**Gravity/Gauss’s law:**
- Don’t think of integrals as adding up little chunks of stuff** (Math classes do not treat integrals this way, it’s just a formal operation, or perhaps ”area under a curve”)
- Don’t know how (and when) to apply Gauss’s law.
- Don’t know difference between surface and volume integrals
- Don’t know dA indicates you are doing an area integral
- Don’t know Gauss’ s law is an integral over a surface rather than a volume.
- May not have encountered problems with non-constant density before- do not know that they need to integrate to get M_enclosed
- Trying to remember rather than reason.
- Don’t realize r-hat points a different direction for each little dA
- Trouble making rigorous symmetry arguments
- Want to neglect mass outside of Gaussian surface even when symmetry doesn’t justify this.
- Think field should be zero if enclosed mass is zero. **
- See Singh, AJP, 2005 - [http://link.aip.org/link/?APCPCS/79/65/1](http://link.aip.org/link/?APCPCS/79/65/1) for more.

**SHM:**
- Think about the spring constant as just a number rather than the ratio of force to extension of the spring – don’t always realize that they can figure out k from some physical information.
- students did not realize that only the under-damped oscillator actually oscillates back and forth (the others can't have a period), so they weren't sure whether it was valid to choose that one in a problem where the description includes a frequency.
- were not sure how to get $A_1\sin(\omega t) + B_1\cos(\omega t) = C_1\sin(\omega t + \delta)$
- When looking at $\sin(blah^*t-\delta)$ were not confident the frequency was $blah$
- not confident with relationships between $omega$, $f$, and $T$
- Some trouble getting real or imaginary parts of complex expressions
- not thinking about what the different terms in the damped/driven differential equation represent physically

**Fourier Series/Transforms**
- Students are good at applying formula in books, weak when period is not $2\pi$ – they don’t know what to modify or why.
- Some students have trouble with a regular $\sin$ or $\cos$ equation recognizing what is the amplitude, period, and phase.
- not confident with relationships between $omega$, $f$, and $T$
- Students do not recognize that $a_0$ in the FT was the shift of the function up from the origin.
- Students not comfortable with formal definition and application of even and odd (though many seem to have an intuitive feel that often, but not always, will lead them to the correct conclusions).
- Odd and even function combinations not understood. One student (who I believe is probably among the best in the course) had memorized that $(odd+odd)/even$ was odd, and $odd/even$ is odd, had a few examples involving $\sin$ and $\cos$, but didn’t know how to understand/derive these relations without memorizing. Another student asked me if $e^{ikx}$ was even or odd.
- Students unfamiliar with idea of orthogonal function, do not recognize functions as orthogonal inside integrals, and do not apply to help them solve problems.
- One student I talked to didn’t see the equivalence of transform and inverse transform (trying to remember whether it was position or momentum that was the fourier transform, and which one got narrower if the other was broad)
- One student thought that $g(\alpha)$ [the Fourier transform] couldn’t have $i$ in it (i.e. couldn't be complex). I got the sense at least one other student was thinking this as well.

**Separation of Variables**
- Several students seemed not to understand that the general method was to use the boundary conditions to figure out the arbitrary constants
- Students do not know the general solution (i.e. may have $Y(y)$ and $X(x)$ added instead of multiplied, and do not always include the necessary arbitrary constants)
- In general it seemed that many students aren’t satisfied with this method because you don’t get a “real” answer (instead, you get an infinite sum).
- Students don’t initially understand how to apply the boundary conditions. Some want to set the constant in the term that is zero on the boundary to zero, or say that term “drops out” instead of setting the constant on the other term to zero. (e.g. $X(x) = A \cos(kx) + B \sin(kx)$, and $X(0)=0$, students would set $B=0$ rather than $A=0$)