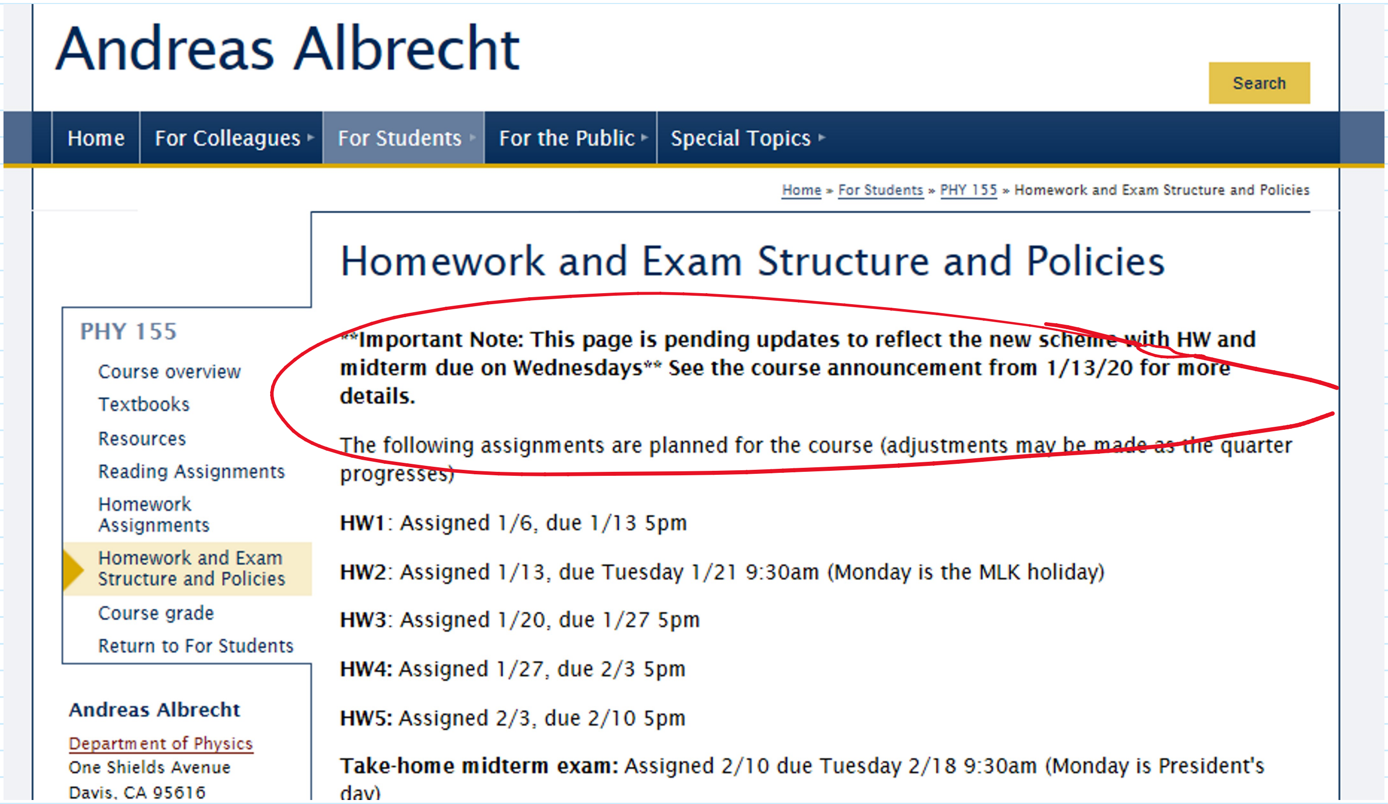
Lecture 3a

Monday, January 13, 2020 9:06 PM

Discuss: New Rules for HW due dates

Also: Midterm will also have a Wed due date



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Homework and Exam Structure and Policies

****Important Note: This page is pending updates to reflect the new scheme with HW and midterm due on Wednesdays** See the course announcement from 1/13/20 for more details.**

The following assignments are planned for the course (adjustments may be made as the quarter progresses)

HW1: Assigned 1/6, due 1/13 5pm

HW2: Assigned 1/13, due Tuesday 1/21 9:30am (Monday is the MLK holiday)

HW3: Assigned 1/20, due 1/27 5pm

HW4: Assigned 1/27, due 2/3 5pm

HW5: Assigned 2/3, due 2/10 5pm

Take-home midterm exam: Assigned 2/10 due Tuesday 2/18 9:30am (Monday is President's day)

<u>Reminder from Lecture 2:</u>

- "A dual vector dotted with a vector is a scalar" (Less formal than Carroll)
  - This is a generalization of

$$\vec{A}\cdot\vec{B} = \text{Scalar} \quad \text{(under 3d rotations)}$$

which is simpler because $R^T = R^{-1}$

<u>TENSORS</u>

Under 3D rotations:

$$\vec{A}\,T\,\vec{B} = T_{ij}A_iB_j = \text{Scalar}$$

Now let's extend the same idea to tensors (Also staying less formal than Carroll (section 1.6)):

$$T^{\mu}{}_{\nu}\,\omega_{\mu}A^{\nu} = \text{Scalar}$$

Lower ==> dual vector, contracts with upper on tensor
Upper ==> vector, contracts with lower on tensor

$T^{\mu}{}_{\nu}$ Is a "type" (or "rank") (1,1) tensor

$T^{\mu\nu}$ Is type (2,0)

$T_{\mu\nu}$ Is type (0,2)

More formal stuff from Carroll:

tensor. Just as a dual vector is a linear map from vectors to **R**, a tensor T of type (or rank) (k, l) is a multilinear map from a collection of dual vectors and vectors to **R**:

$$T: \underbrace{T_p^* \times \cdots \times T_p^*}_{(k \text{ times})} \times \underbrace{T_p \times \cdots \times T_p}_{(l \text{ times})} \rightarrow \mathbf{R}. \tag{1.56}$$

of ordered pairs of vectors. Multilinearity means that the tensor acts linearly in each of its arguments; for instance, for a tensor of type (1, 1), we have

$$T(a\omega + b\eta, cV + dW) = acT(\omega, V) + adT(\omega, W) + bcT(\eta, V) + bdT(\eta, W). \quad (1.57)$$

space, we need to define a new operation known as the **tensor product**, denoted by $\otimes$. If T is a (k, l) tensor and S is an (m, n) tensor, we define a $(k + m, l + n)$ tensor $T \otimes S$ by

$$\begin{aligned} T \otimes S(\omega^{(1)}, \ldots, \omega^{(k)}, \ldots, \omega^{(k+m)}, V^{(1)}, \ldots, V^{(l)}, \ldots, V^{(l+n)}) \\ = T(\omega^{(1)}, \ldots, \omega^{(k)}, V^{(1)}, \ldots, V^{(l)}) \\ \times S(\omega^{(k+1)}, \ldots, \omega^{(k+m)}, V^{(l+1)}, \ldots, V^{(l+n)}). \end{aligned} \quad (1.58)$$

As with vectors, we will usually take the shortcut of denoting the tensor T by its components $T^{\mu_1 \cdots \mu_k}{}_{\nu_1 \cdots \nu_l}$. The action of the tensors on a set of vectors and dual vectors follows the pattern established in (1.48):

$$T(\omega^{(1)}, \ldots, \omega^{(k)}, V^{(1)}, \ldots, V^{(l)}) = T^{\mu_1 \cdots \mu_k}{}_{\nu_1 \cdots \nu_l} \omega^{(1)}_{\mu_1} \cdots \omega^{(k)}_{\mu_k} V^{(1)\nu_1} \cdots V^{(l)\nu_l}.$$

(our $T^{\mu}{}_{\nu} \omega_{\mu} A^{\mu}$)