Strategies for Assessment in MOOCs

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Aim to provide a broad range of MS&E courses on edX

- MOOC resources are used in our MIT classrooms

**3.012: Fundamentals of Materials Science and Engineering**

**3.022: Microstructural Evolution in Materials**

**3.024: Electronic, Optical and Magnetic Properties of Materials**

**3.072: Symmetry, Structure, and Tensor Properties of Materials**

**3.091: Solid State Chemistry**

**3.032: Mechanical Behavior of Materials**

**3.15: Electrical, Optical and Magnetic Properties of Materials and Devices**

**3.086: Innovation and Commercialization of Materials Technology**

**3.054: Cellular Solids: Structure, Properties, Applications**

**3.MatSelx: Structural Materials: Selection and Economics**
Moving Beyond Multiple Choice

Multiple choice questions are highly prevalent in MOOCs and sometimes play an important role in learning.

We also want to consider approaches to problem design that allow us to engage and assess higher cognitive skills: assessing, analyzing, evaluating, and creating.

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1. Bloom’s Taxonomy of Learning Domains
Problem: A slab of intrinsic GaAs, 3 cm long, 2 cm wide, and 0.3 cm thick, is exposed to light. The light is absorbed with an absorption coefficient $\alpha = 500 \text{cm}^{-1}$ (this means that the light intensity decreases in the material exponentially with distance $t$, and is proportional to $\exp(-\alpha t)$). The light is monochromatic with a wavelength of 750 nm and an intensity of $5 \times 10^{-4} \text{W/cm}^2$. (Photon energy (eV) is given by $1.24/\text{wavelength (\mu m)}$.)

What is the excess carrier concentration due to the light? You may assume a recombination time of $2 \times 10^{-4}$ sec.

<table>
<thead>
<tr>
<th>Rounding errors</th>
<th>Different formatting</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta n$ (in $\text{cm}^{-3}$):</td>
<td>$\Delta n$ (in $\text{cm}^{-3}$):</td>
</tr>
<tr>
<td>1.22e12</td>
<td>1.2e12</td>
</tr>
<tr>
<td>$1.22 \times 10^{12}$</td>
<td>$1.2 \times 10^{12}$</td>
</tr>
</tbody>
</table>
Problem 4.1

2/2 points (graded)

The energy-separation curve for two atoms, a distance, r, apart is: \( U(r) = \frac{-A}{r^m} + \frac{B}{r^n} \)

Derive an expression for the equilibrium spacing, \( r_0 \), as a function of \( A, B, m, \) and \( n \). Explicitly indicate multiplication with a * symbol.

\( r_0 = \)

\[ \left( \frac{Bb}{A^m} \right)^{\frac{1}{n-m}} \]

Derive an expression for the stiffness of the bond at the equilibrium spacing, in terms of \( A, B, m, n, \) and \( r_0 \).

\( S = \frac{dF}{dr} \text{ at } r = r_0: \)

\[ \frac{-A^m(m+1)}{r_0^{m+2}} + \frac{Bn(n+1)}{r_0^{n+2}} \]
Fill-in-the-Blank Derivations

If we pick a lattice point \( A \), and translate it by \( T \) (a unit vector), we will get another lattice point \( A' \).

Then we rotate \( AA' \) counter-clockwise about axis \( A_\alpha \) by angle \( \alpha \) to point \( B' \), and clockwise about axis \( A'_\alpha \) by angle \( \alpha \) to point \( B' \).

\( B \) and \( B' \) should both be lattice point in this 2D crystal.

Therefore:

\[
BB' = \frac{mT}{m \cdot T}
\]

where \( m \) should be an integer number. Also, we know from geometry that:

\[
BB' = AA' - \frac{2T \cdot \cos(\alpha)}{2 \cdot T \cdot \cos(\alpha)} = \frac{T(1 - 2 \cdot \cos(\alpha))}{T \cdot (1 - 2 \cdot \cos(\alpha))}
\]

Therefore:

\[
mT = \frac{T(1 - 2 \cdot \cos(\alpha))}{T \cdot (1 - 2 \cdot \cos(\alpha))}
\]

\[
m = \frac{1 - 2 \cdot \cos(\alpha)}{1 - 2 \cdot \cos(\alpha)}
\]

(And this continues…)
You are given two semiconductors, A and B. A has a band gap of 1eV and B has a band gap of 2eV. The band offset $\Delta E_c$ is 0.3eV (the electron energy level steps down as you go down as you go from the conduction band of B to the conduction band of A).

Complete the band diagram:

Response template:

Correct response:

From Ross, C.A. “3.15.1x: Electronic Materials and Devices.” MOOC offered by MIT on edX. Retrieved April 20, 2018
Consider the pattern shown below. Drag and drop the appropriate symmetry elements onto the cell shown below:

Response template:

Correct response:

Self-Graded Short Answers

Please write a brief definition of each of the following terms in the text box below. Then click on the Show Answer button and evaluate the following: Did your answer match the one in the Solution. (Exact matches are not required, though your answer should contain the main points indicated in the instructor-generated answer.)

Conduction Band:

The lowest unfilled energy band in a semiconductor. (Contains no electrons at 0K.)

Submit

Show Answer

Your answers were previously saved. Click 'Submit' to grade them.

problem

0.25/0.25 points (graded)

Does your Conduction Band definition match the Instructor's Definition?

- Yes ✔
- No
How does Instructor Grading compare to Self-Grading?

• How accurately do students assess themselves when compared to instructors?

• We compared the grades self-assigned by students in the 2016 version of 3.15.1x: Electronic Materials and Devices to grades assigned by two instructors.

• We evaluated three of these definition-style questions: conduction band, valence band, and band gap.

• We considered a total of 1248 student responses.
How do student-assigned grades compare to instructor-assigned grades?
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Table 1: Additional Analysis of Self-Graded Problems

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<thead>
<tr>
<th></th>
<th>Conduction Band</th>
<th>Valence Band</th>
<th>Band Gap</th>
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<tbody>
<tr>
<td>Total non-blank responses</td>
<td>427</td>
<td>421</td>
<td>400</td>
</tr>
<tr>
<td>Cases where both instructors</td>
<td>60 (14.05%)</td>
<td>68 (16.65%)</td>
<td>10 (2.50%)</td>
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<tr>
<td>gave a grade of 0 but student</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gave a grade of 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cases where both instructors</td>
<td>4 (0.94%)</td>
<td>1 (0.23%)</td>
<td>4 (1.00%)</td>
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<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gave a grade of 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cases where students and both</td>
<td>19 (4.45%)</td>
<td>6 (1.43%)</td>
<td>1 (0.25%)</td>
</tr>
<tr>
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- On average, 11.1% of the students gave themselves credit for a question that neither instructor judged correct
We use the peer-grading functionality to create short answer-style quizzes.

Short answer questions account for 50% of the Final Exam grade in the course.

During the first week, students are asked to answer several of these short answer questions.

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**Figure A: Example Prompt and Response**

The prompt for this section

(b) Name at least four properties of graphene that are important in this solar cell design.

Your response (required)

Graphene is cheap, abundantly available, highly conductive, flexible, robust, and transparent.

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Peer-Graded Short Answer

- We use the peer-grading functionality to create short answer-style quizzes
- Short answer questions account for 50% of the Final Exam grade in the course
- During the second week, we give the correct answer to the students and ask them to evaluate their peers

Figure B: Example Grading Rubric

- Part B: Graphene is cheap, abundantly available, highly conductive, flexible, robust, and transparent.

Does the answer identify at least four of the above factors?

- Good
  Yes, the answer identifies at least four of these factors
  2 POINTS

- Fair
  The answer only identifies some of these factors
  1 POINTS

- Poor
  The answer doesn't identify any of these factors
  0 POINTS

From Ross, C.A. “3.15.2x: Optical Materials and Devices.” MOOC offered by MIT on edX. Retrieved April 20, 2018
How does Instructor Grading compare to Peer-Grading

• How accurately do students assess their peers when compared to instructors?

• We compared the grades self-assigned by students in the 2016 version of 3.15.2x: Optical Materials and Devices to grades assigned by two instructors.

• Students were asked to read an article entitled Nanowires and graphene: Keys to low-cost, flexible solar cells from the Autumn 2013 issue of Energy Futures and answer three questions:
  
  – What are the two problems that researchers are trying to solve?

  – Name at least four properties of graphene that are important in this solar cell design.
  
  – What properties of ZnO nanowires are important for this solar cell design?
How do peer-assigned grades compare to instructor-assigned grades?

- On average, out of six points, learners rated their colleagues 0.246 (4.1%) points higher than instructors.
Difference in Instructor A and Instructor B Scoring

<table>
<thead>
<tr>
<th>Question</th>
<th>Instructor A</th>
<th>Instructor B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question A Average</td>
<td>1.89781 (94.9%)</td>
<td>1.883212 (94.2%)</td>
</tr>
<tr>
<td>Question B Average</td>
<td>1.89781 (94.9%)</td>
<td>1.912409 (95.6%)</td>
</tr>
<tr>
<td>Question C Average</td>
<td>1.364964. (68.2%)</td>
<td>0.992701. (49.7%)</td>
</tr>
</tbody>
</table>

- Question C was open to a more broad interpretation than the other questions. One instructor was more liberal with their interpretation of the rubric than the other.
Take-aways from self-grading analysis:

- Students consistently grade themselves more generously than the instructors
  - On average, 11.1% of the students gave themselves credit for a question that neither instructor judged correct
- Students grade their peers only slightly more generously than instructors
  - On average, peer grades are 4.1% higher than instructor assigned grades
- There are large gaps between Instructor A’s grade and Instructor B’s grade, in both analyses
- Reducing any potential ambiguity in the rubric is important for consistent grading
- A correct-or-incorrect rubric makes grading difficult
  - How do you treat an answer that is 80% correct?
- However, a simplified rubric may offer other advantages
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