Unifying Lectures, Recitations & Laboratories as a part of the Humanized Physics Project

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As a part of our work in the Humanized Physics Project, we have made the content of the physics laboratories the keystone of our physics content coverage. After having selected an appropriate human application of physics for the laboratory each week, we have shaped the lecture, recitation and homework assignments to support the laboratory. Our poster will provide examples from both semesters of our general physics course.

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(2) Humanized Physics Project co-PIs:
   Nancy L. Beverly, Mercy College
Rationale:

- The students in this course are intending to have a career based on science and the students have had a college course in chemistry.
- The course must be responsive to the needs of students intending to have careers in biological or medical-related fields.
- The laboratory activities are the keystone of the course with the other course components such as lectures, recitations and examinations supporting the laboratory activities.

Structure at UNL:

There are...
- three 50 minute lectures per week of up to 167 students taught by a faculty member
- one 50 minute recitation per week in sections of not more that 32 students each taught by graduate teaching assistants
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- one 3 hour **laboratory** per week in sections of not more than 18 taught by graduate, or undergraduate, teaching assistants.
Humanized Physics Project at the University of Nebraska - Lincoln

Laboratory (LAB)

Lectures

Student Reasoning & Attitudes

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First Semester of Humanized Physics

The sequence of topics:

- **How Do We Move?**  
  (Kinematics and Dynamics, 5 weeks)
- **How Do We Use Energy?**  
  (Energy and Momentum, 5 weeks)
- **How Do We Transform Energy?**  
  (Heat and Fluids, 3 weeks)
- **How Do We Make and Hear Sound?**  
  (Waves and Sound, 2 weeks)

Second Semester of Humanized Physics

The sequence of topics:

- **How Do We Sense, Think, and Move?**  
  (Electricity and Magnetism, 5 weeks)
- **How Do We See Color?**  
  (Light and Optics, 6 weeks)
- **How Can We See Inside Ourselves?**  
  (Radiation, 3 weeks)
- **How Can We Compare Our Senses?**  
  (Overview, 1 week)
Poiseuille's Law

When a liquid of viscosity $\eta$ flows in a tube of radius $R$ (m) and of length $L$ (m) with a pressure difference $\Delta P$ (Pa), the flow rate in $m^3/ s$ may be given by:

$$\text{Flow rate} = \left(\frac{\pi}{8} \eta \right) \left( \frac{\Delta P}{L} \right) R^4$$

$$\text{Flow rate} = \frac{\pi (P_1 - P_2) R^4}{8 \eta L}$$

Dimensional analysis:

$$(m^3/s) = \frac{(Pa) m^4}{\eta m}$$

so $\eta$ has the units of Pa•s or poise (CGS) conversion factor $1 \text{Pa} \cdot \text{s} = 10 \text{poise}$
Recitation Class activity:
In your small group, based on Poiseuille's Law, discuss and answer the following questions:

1) The flow of viscous blood through the human circulatory system may be constricted by a narrow portion of the system. As a person ages, the constriction may expand. Assume the diameter of the constriction increases by only 8%.

   a) How much does the flow rate increase?

   b) If the person's blood pressure is adjusted so that the flow remains constant, what happens to the person's blood pressure, assuming that it was originally 120 mm of Hg.

2) Assume a person with hardening of the coronary arteries can survive an effective diameter decrease of his arteries of 20%. Under these conditions, how must the blood pressure change to keep the rate of blood flow constant?
"Blood is one of the most interesting organs in the body. It has two unique properties: it is a liquid and it is always on the move."

From How the Body Works by John Lenihan.

Here is an engineer's sketch of the blood circulation system of a human body.
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Studying Flow Rate as a Function of Pressure, Length, & Diameter

Conduct experiments to determine how the flow rate changes as a function of pressure, tube length, and inside tube diameter.

Data Collection:

• Keep the height of the water surface constant.
• Capture the water flowing out of the container for a set time.
• Calculate the flow rate.

Data Analysis:

(a) Determine mathematical models for each variable.
(b) Describe the physical meaning of these models.
(c) Poiseuille (1799-1869) was interested in the physics of blood circulation. He found that the flow rate of a fluid undergoing laminar flow in a cylindrical tube is:

\[ \text{Flow rate} = \frac{\pi \cdot \text{pressure} \cdot (\text{radius})^4}{8 \cdot \text{viscosity} \cdot \text{length}} \]
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Compare the class results to this predicted mathematical model.
Sample Student Data

Flow Rate vs. Length

Flow Rate vs. Diameter

Expected: $F = A^0L^{-1}$

Expected: $y = C x^3.39$

$R^2 = 0.9973$

$R^2 = 0.9999$
2nd semester lecture content example:

**Bouguer's Law**

Absorption of light by a medium of thickness $t$:

$$I_x = I_0 \exp(-at) = I_0 e^{-at}$$

where $t$ is distance (m)

and $a$ is the absorption coefficient (m$^{-1}$)

**Beer's Law**

Absorption of light by a medium with a concentration of $c$:

$$I_x = I_0 \exp(-bc) = I_0 e^{-bc}$$

$c$ is concentration (g/L)

$b$ is the absorption coefficient (L/g)

Take the logarithms (base 10) of both sides and combine:
Recitation Content

Skin Burning Intensity of Sunlight

Human skin is not equally sensitive to all types of ultraviolet (UV) radiation. The Erythemal Response Spectrum is a scientific expression that describes human skin sensitivity to UV radiation.

Skin Sensitivity to Ultraviolet Radiation

UV Radiation Contained in Solar Light at the Earth's Surface for Different Ozone Thicknesses

The Effective UV Spectrum - "Skin Burning Intensity"

The Effective UV Spectrum is the mathematical product of Solar UV Spectrum and the Erythemal Response Spectrum. It can be interpreted as the "skin burning intensity" of individual wavelengths of sunlight.
1. Determine the relative "Skin Burning Intensity' as a function of UV wavelength for 2 ozone thicknesses.

2. Compare quantitatively the skin burning intensity for the two different ozone thicknesses.

Reference:  www.safesun.com/ scientific.html
Lab - Sunglasses and Other Optical Filters

Effect of Sunglasses as Perceived by Your Eyes

- Using your eyes as light detectors, examine how these sunglasses affect the light that passes through them.

Effect of Sunglasses as Perceived by MBL Light Sensors

- Using the MBL light sensor(s), examine how these sunglasses affect the light that passes through them. Measure the light intensity with and without the sunglasses with each sensor.

\[
\text{Absorbance} = \text{Optical Density} = \log_{10} \frac{I_0}{I}
\]

- Using your 2 different data sets, calculate the optical density of one pair of sunglasses.

Effect of Colored Filters as Perceived by Your Eyes

- Using your eyes as light detectors, examine how the different color filters affect the light that passes through them.

Effect of Colored Filters as Perceived by a Light Sensor

- Using the light sensor, measure the light intensity for 0 filters to 20 filters for a single color of filter.
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• Create mathematical models of Percent Transmitted vs. Filter Thickness and Optical Density vs. Filter Thickness.
Spectral Response Curves for Different Light Detectors

- Pasco Light Sensor

![Graphs showing spectral response curves for different light detectors.](image-url)
Spectral Response - Human Eye

Wavelength of Light (nm) vs. Relative Sensitivity
Sample Data for Colored Filters

Absorption by Color Filters

\[
y(y) = 87.8\% e^{-0.195x} \\
R^2 = 0.984
\]

\[
y(red) = 87.8\% e^{-0.195x} \\
R^2 = 0.984
\]

\[
y(blue) = 95.4\% e^{-0.246x} \\
R^2 = 0.993
\]
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The sequence of topics:

• How Do We Move? (Kinematics and Dynamics, 5 weeks),
• How Do We Use Energy? (Energy and Momentum, 5 weeks),
• How Do We Transform Energy? (Heat and Fluids, 3 weeks)
• How Do We Make and Hear Sound? (Waves, 2 weeks)

Second Semester of Humanized Physics

The sequence of topics:

• How Do We Sense, Think, and Move? (Electricity and Magnetism, 5 weeks),
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• How Can We Compare Our Senses? (Overview, 1 week).

For more complete details visit our website:

http://www.doane.edu/hpp/
Modeling the Circulatory System

Conduct experiments to determine how the flow rate changes as a function of pressure, of tube length, and of inside tube diameter. Create graphical and functional models for each of these variables.

1. Poiseuille (1799-1869) was interested in the physics of blood circulation. He found that the flow rate of a fluid undergoing laminar flow in a cylindrical tube is:

\[
\text{Flow rate} = \frac{\pi \cdot \text{pressure} \cdot (\text{radius})^4}{8 \cdot \text{viscosity} \cdot \text{length}}
\]

Compare the class results to this predicted mathematical model.

Sunglasses and Other Optical Filters

![Spectral Response - Human Eye](image)

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- Study effect of sunglasses on white light as perceived by your eyes and by the MBL light sensor.
- Study effect of different colored filters on white light as perceived by your eyes and by the MBL light sensor.
- Study the absorption of light by different thicknesses of colored filters.
- Create mathematical models for Transmission vs. # of filters and for Optical Density vs. # of filters.

![Absorption by Color Filters](image)

- $y(yellow) = 87.8\%e^{-0.085x}$
  - $R^2 = 0.996$
- $y(red) = 87.8\%e^{-0.195x}$
  - $R^2 = 0.984$
- $y(blue) = 95.4\%e^{-0.246x}$
  - $R^2 = 0.993$