Phys 123

Review & Analysis of Exam 1 & Hints on Exam 2

- Thursday Evening February 8
- Kane Hall 210, 5:00 pm

- Tonight We Review Exam 1 Solutions Then Prepare for Exam 2 (Chapters 33, 34, 18)

Exam 1 Q5 (17%)

A uniform thin rod of length $\ell = 1.8\ \text{m}$ and mass $M = 3.6\ \text{kg}$ is attached to a horizontal pivot (•) at distance $\ell/4 = 0.45\ \text{m}$ below the top of the rod as shown. A cylinder of radius $r = 15\ \text{cm}$ and mass $m = 1.8\ \text{kg}$ is attached to the rod at distance $\ell/12 = 0.15\ \text{m}$ above the bottom of the rod. The rod-cylinder combination is pulled back so that the rod makes an angle of 15° to the vertical as shown, and released. Use $g = 9.8\ \text{m/s}^2$.

Ignoring friction and air drag, which choice best represents the period of oscillation of this pendulum?

A. 2.7 s **B.** 1.9 s **C.** 2.3 s **D.** 1.6 s **E.** 2.1 s

NOT a simple pendulum, so must use:

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{I}{m\ell_{\text{cm}}g}}$$

$$I = \frac{1}{12}M\ell^2 + M\left(\frac{\ell}{4}\right)^2 + \frac{1}{2}mr^2 + m\left(\frac{2\ell}{3}\right)^2 = 4.31\ \text{kg}\cdot\text{m}^2$$

$$\ell_{\text{cm}} = \frac{M(\ell/4) + m(2\ell/3)}{M+m} = 0.7167\ \text{m}$$

Total mass = 5.4 kg

Exam 1 Q6 (42%)

Ignore friction and air drag. Which change(s) would increase the period?

A. Move the cylinder up toward the center of the rod.
B. Move the cylinder down toward the bottom of the rod.
C. Double the mass of both rod and cylinder.
D. Either B or C.
E. None of these.

Choice A decreases period

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{I}{m\ell_{\text{cm}}g}}$$

$$I = \text{doubled by C, increased noticeably by B}$$

$$\ell_{\text{cm}} = \text{unaffected by C, increased slightly by B}$$

Doubled by C

Exam 1 Q7 (22 %)

1. Which choice best summarizes the effects of air drag during the first 15 cycles of the motion of the pendulum?

A. Amplitude, energy and period of oscillation all decrease as $e^{-\alpha t}$.

B. Amplitude and energy decrease as $e^{-\alpha t}$, period of oscillation increases as $e^{+\alpha t}$.

C. Amplitude decreases as $e^{-\alpha t}$, energy decreases as $e^{-2\alpha t}$, constant period = T_1 .

D. Amplitude decreases as $e^{-\alpha t}$, energy decreases as $e^{-2\alpha t}$, constant period > T_1.

E. None of these is correct.

Examine the equation sheet, substituting $\alpha = 1/2\tau$:

$$x(t) = Ae^{-t/2\tau}\sin(\omega_{\mathrm{d}}t + \phi_{\mathrm{i}})$$

$$E(t) = E_0 e^{-t/\tau}$$

Exam 1 Q15 (38%)

1. Which choice best represents the variation in intensity with time that occurs at any point where maximum constructive interference is observed?

A. No variation, the intensity has a constant value.
B. Intensity varies between almost zero and maximum 340 times per second.
C. Intensity varies between almost zero and maximum 680 times per second.
D. Intensity varies between almost zero and maximum 1360 times per second.
E. None of these.

At any maximum, the two waves add constructively at each point in time because they are in phase. But each wave varies from maximum positive, to zero, to minimum, to zero, etc. When one wave is zero, so is the other, so the amplitude varies from +2A to –2A at the same frequency as each wave, but there are TWO zeroes for every cycle, and intensity is proportional to amplitude squared (so positive or negative amplitudes contribute equal intensities).

Basic Principles:

PHYS 123: Waves, Optics & Thermal Physics

- Oscillations Produce Waves of the Same Frequency
- Superposed Sine Waves Can Represent Any Wave
- Waves Diffract & Interfere
- The Ray Model Works for Waves When Diffraction & Interference Are Negligible
- The Building Blocks of Nature Share Wave & Particle Properties
- The Values of Physical Quantities Are Quantized
- The Laws of Thermodynamics Arise from the Statistics of Large Systems, and Constrain the Transfer of Energy (and All Interactions) Within and Between Such Systems

Review: Basic Principles

PHYS 122: Electromagnetism

- Conservation of Electric Charge
- Gauss' Law for Electric Fields
- Definition of Electric Potential Difference
- Ampere's Law *(Modified by Maxwell)
- Gauss' Law for Magnetic Fields
- Faraday's Law of Electromagnetic Induction

Other General Principles:

- Principle of Superposition
- Principle of Symmetry

Basic Principles

PHYS 121: Mechanics

- Relations Among $\vec{r}, \vec{v}$ and $\vec{a}$
- Principle of Relativity
- Newton's Three Laws of Motion
- Conservation of Energy:
  - The Work - Energy Principle
    - Special Case: Mechanical Energy is Constant
- Conservation of Linear Momentum
  - The Impulse – Momentum Principle
    - Special Case: Linear Momentum is Constant
- Conservation of Angular Momentum
  - The Angular Impulse – Angular Momentum Principle
    - Special Case: Angular Momentum is Constant

And Their Rotational Analogues

Problem Solving Approach

- Getting started:

  Only Shortcut This if Obvious

  - Organize your thoughts; examine which **principles** are applicable; make relevant diagrams; note assumptions
- Devise plan:

  If You Have Been Doing This for 3 Quarters, You Should Be Able to Shortcut a Lot By Now

  - Construct equations **from principles** based on diagrams; no numbers, just symbols; count equations and unknowns; decide on ordered plan of attack.
- Execute plan:
  - Do the calculations; check vectors / all questions answered / no unknowns in answers / units / sig digs.
- Evaluate result:
  - Matches your diagrams? Compare to known values; Check limiting cases; check signs and order of magnitude; try a different method.

Universal Procedure

- Write the Generic Equation for a Principle
- Check Validity of That Principle for the Problem
- Draw Pictures Illustrating Left & Right Sides of Equation
- Choose Coordinates *(Not Needed for Energy)
- Use Pictures to Help in Getting Each Term Right in Equation(s) for the Particular Problem
- Substitute Known Values & Special Case Formulae
- Count Unknowns & Equations
- Enough Equs? $\Rightarrow$ Do the Algebra
- Otherwise Try Another Principle

Review: Polarization

- Linear: ***E*** Oscillates Along One Direction (Transmission Axis of Polarizer)
  - Of Course ***B*** Also Along One (Perpendicular) Direction

$$\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B} \qquad \left(\left|\vec{S}\right| = I = uc\right)$$

  - First Polarizer Transmits 50% of Incident (Unpolarized) Intensity.
  - If Already Polarized, Law of Malus Gives Transmitted Intensity:

$$I = I_0 \cos^2\theta$$

θ = Angle Between Original ***E*** Direction & Transmission Axis

Review: Reflection & Refraction

- Reflection Angle = Incidence Angle
  - Reflection From Larger Index of Refraction is Upside Down (Phase Shift of $\lambda/2$ or π).
- Refraction Angle by Snell's Law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

  - Total Internal Reflection Occurs When There is NO Solution to Snell's Law for the Refracted Angle in the Medium of Smaller n.
  - Complete Polarization (***E*** Parallel to Surface) Upon Reflection at Brewster Angle:

$$\tan\theta_P = \frac{n_2}{n_1} \qquad (n_2 > n_1)$$

Review: Images

- Straight Line Ray Tracing, Backwards.
- Image Where Rays from Common Source Point Cross (or Appear to Cross).
  – Real = Actually Cross, Virtual = Only Appear to Cross.
- Mirror/Lens That Brings Parallel Rays to a Focus = Converging.
- Mirror/Lens That Brings Parallel Rays Apart (as if from Focus on Wrong Side) = Diverging
- Locate Images by Ray Diagram or Lens/Mirror Equation. For Multiple Lenses/Mirrors, Apply in Order Using Image as "Object" for Next.

Review: Ray Diagrams

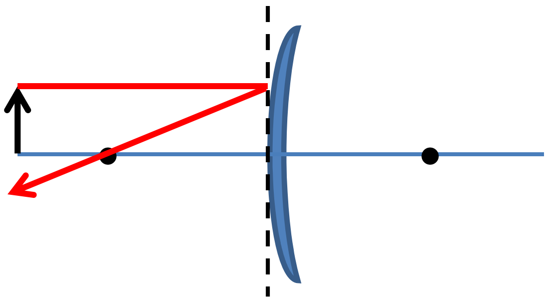
- There Are Thousands of Rays… Draw the Easy Ones for Lens or Mirror:

  1. Ray Comes In Parallel to Axis, Goes Out Through (Converging) <u>or</u> As If It Came Through (Diverging) the Focal Point.
  2. Reverse Logic of Ray #1.
  3. Ray Straight Toward Center (Flat Portion) of Mirror/Lens Goes Out at Same Angle.

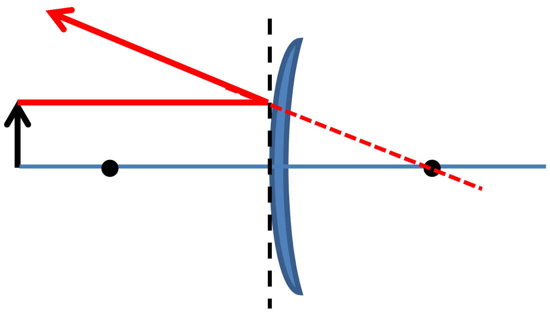
- Draw Rays to**/**from Mirror Surface
- Draw Rays to/from Centerline for Lenses, <u>Not</u> Lens Surface.

Which Ray is NOT Correct for This Mirror?

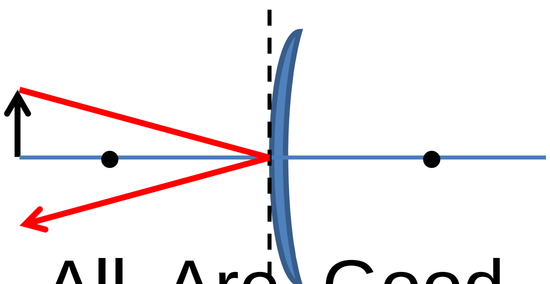
A.



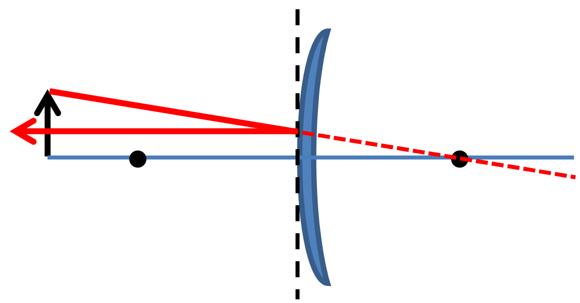
B.



C.



D.



E. All Are Good

Not Done in Class

Review: Lens / Mirror Equation

$$\frac{1}{o}+\frac{1}{i}=\frac{1}{f}$$

$o =$ object distance, $i =$ image distance, $f =$ focal length

- All Distances Measured From Centerline
- Focal Length:
  - f = Positive for Converging, Negative for Diverging
- Object Distance:
  - o = Positive if Object on <u>Same</u> Side of Centerline as the <u>Incoming</u> Light. Otherwise Negative.
- Image Distance:
  - i = Positive if Image on <u>Same</u> Side of Centerline as the <u>Outgoing Light</u>. Otherwise Negative.

Review: Magnification

- Linear, Single Lens or Mirror: $$m = \frac{h_i}{h_o} = -\frac{i}{o}$$
  - Negative m Means

  Inverted Image (Rel. to Object)
- Combinations of Lenses / Mirrors:

$$m = m_1 * m_2 * \ldots$$

- Angular, Single Lens or Mirror: $$M = \frac{\theta_i}{\theta_{\mathrm{ref}}}$$
- Angular Multiplication for

  Lens / Mirror Combos: $$M = M_1 * M_2 * \ldots$$
- Special Cases:

Telescope: $M = -\dfrac{f_{\mathrm{o}}}{f_{\mathrm{e}}}$ Microscope: $M = -\dfrac{\left(L - f_{\mathrm{e}}\right)N}{f_{\mathrm{o}}\, f_{\mathrm{e}}}$

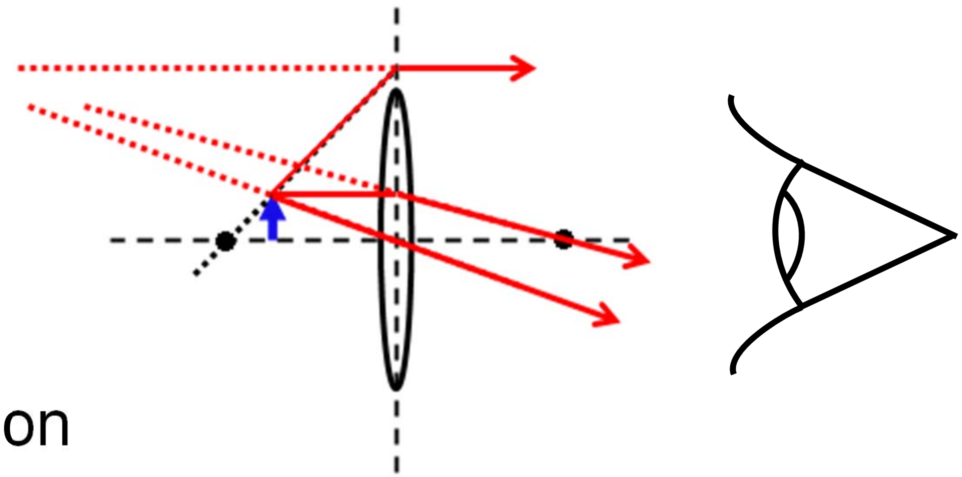
A Farsighted Person Would Need Which Type of Lens to Correct Her Vision?

A. Diverging
B. Converging
C. Inverting
D. Polarizing
E. None of These

Not Done in Class

Review: Magnifying Glass

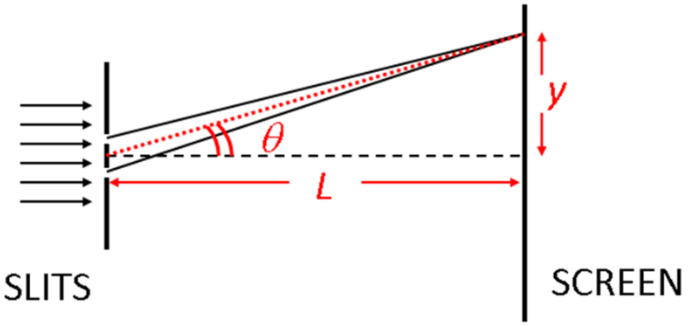
- Single Converging Lens, Object Placed Near Focal Point (or Closer to Lens Than f)
  - Result is Magnified, Upright, Virtual Image Somewhere Between Near Point and Infinity
    - **Near Point** is Closest Distance Eye Can Focus On
  - Can Use the Mirror / Lens Equation to Find the Image
  - Angular Magnification



$$M = \frac{\theta_i}{\theta_{\text{ref}}} \qquad \theta_{\text{ref}} = \frac{h_o}{N} \qquad N = \text{ Near Point}$$

Review: 2-Source Interference

- 2 Thin Slits, Phase Change Due to Path Difference



  - Constructive: $d\sin\theta = m\lambda$
  - Destructive: $d\sin\theta = \left(m+\frac{1}{2}\right)\lambda$
  - Position on Screen: $y = L\tan\theta$

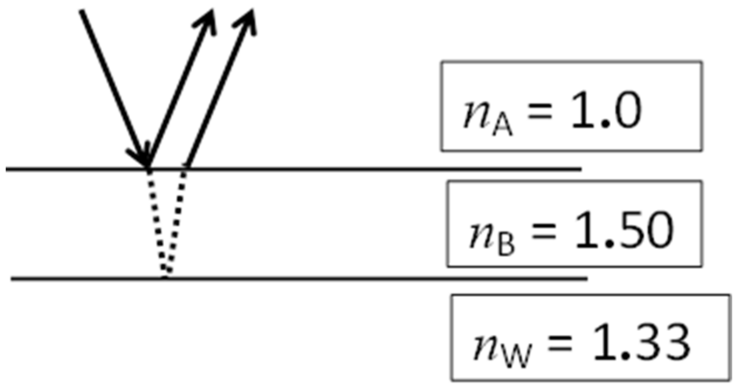
- Thin Film, 2 Surfaces, Phase Change Due to Path Difference AND Reflection

  - Cross Thickness Twice $\Rightarrow$ 2***t*** :
  - Reflect off Large n: Add $\lambda/2$

Constructive: $$2t \pm \left(\frac{\lambda_{\text{mat}}}{2} \text{ if needed}\right) = m\lambda_{\text{mat}} = m\frac{\lambda_{\text{air}}}{n_{\text{mat}}}$$

Solution

What is the Thinnest Film of Benzene (n = 1.50) on Water (n = 1.33) That Will Cause Bright Reflection for λ = 500 nm ?



– Reflect at Top:

Phase Shift λ_{mat} / 2

– Reflect at Bottom:

No Phase Shift

– Path Difference $2t$ Must Provide Additional λ_{mat} / 2 For Total of One Wavelength (or Zero) Phase Diff.

$$2t = \frac{\lambda_{mat}}{2} \Rightarrow t = \frac{\lambda_{mat}}{4} = \frac{\lambda_{air}}{4n_{mat}} = \frac{500}{4(1.50)} = 83.3 \text{ nm}$$

More Exam Topics

- Interference & Diffraction for Single & Multiple Slits, Diffraction Gratings
  - Use of Phasors to Determine Intensity
- Circular Openings
  - Rayleigh's Criterion, Resolving Power
- Energy & Momentum of Photons
  - Photoelectric Effect
  - Also Wavelength of Electrons
- Static Fluids and Pressure versus Depth
  - Archimedes, Pascal, Surface Tension, Wetting
- Moving Fluids
  - Bernoulli, Viscosity, Poiseuille, Laplace