Great Problems in Physics

2-D Motion - Projectile Motion

Dr. Jennifer Carter is an assistant professor at Susquehanna University where she teaches both astronomy and physics courses. Her main research interests are in astrophysics and data analysis. Currently her focus is on exoplanet research, in which she is using Bayesian data analysis techniques to test current models of reflected light and thermal emissions of exoplanets against novel models she is developing.

> “I chose this problem because many students struggle with the quadratic and symmetric nature of projectile motion. In particular, they may struggle in choosing which of the two possible solutions applies to a given situation. This problem will require students to use the context of the problem statement to determine which of two possible solutions to choose, but what makes this problem unique compared to many other problems is that there will be two positive solutions to the amount of time that has passed; therefore, students cannot rely on eliminating the negative time as being physically unreasonable and must instead carefully consider the context of the problem”

Read more about Dr. Carter and her research here.
View Dr. Carter's LinkedIn profile here.

Problem

Some children are practicing baseball and accidentally throw a ball onto the roof of one of their houses. Suppose that the baseball was thrown at an angle of 51° above the horizontal at a speed of 25 m/s. The ball rises to its maximum height before falling onto the roof of the house 4.5 m above the level at which it was thrown.

Part a: Determine the total amount of time, in seconds, the baseball spends in the air.
t = ____

Part b: Calculate the horizontal distance, in meters, between the baseball's launch point and its landing point.
x = ____

Great Problems in Physics

Work and Kinetic Energy

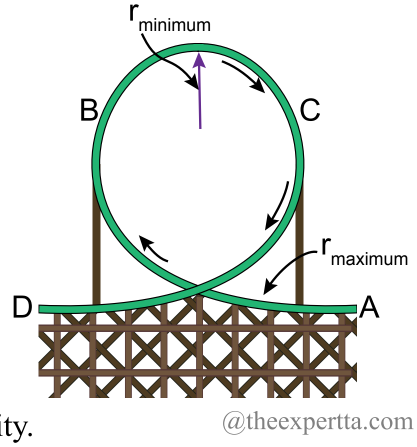
Dr. Cindy Schwarz earned a BS in Mathematical Physics at the State University of New York at Binghamton. Five years later she was awarded her doctorate in experimental particle physics from Yale University for her research done on CP-Violation at Brookhaven National Laboratory.

> "I really like this problem because it shows the most sensible design for modern roller coasters. The shape that is ideal is called a clothoid and this problem uses an approximation to the shape. The clothoid is a curve that is characterized by its curvature being proportional to its length. This property makes it very useful as a transition curve when designing roller coasters. To approximate, the radius of curvature at the bottom of the loop is greater than the radius of curvature at the top of the loop. This assures a smaller (safer) acceleration at the bottom of the loop."

Read more about Dr. Schwarz and her research here.

Problem

Modern roller coasters have vertical loops like the one shown in the figure. The radius of curvature is smaller at the top than on the sides so that the downward centripetal acceleration at the top will be greater than the acceleration due to gravity, keeping the passengers pressed firmly into their seats.



Part a: What is the speed, in meters per second, of the roller coaster at the top of the loop if the radius of curvature there is 12 m and the downward acceleration of the car is 1.8g? Note that g here is the acceleration due to gravity.
v = ____

Part b: The beginning of this roller coaster is at the top of a high hill. If it started from rest at the top of this hill, how high, in meters, above the top of the loop is this initial starting point? You may assume there is no friction anywhere on the track.
h = ____

Part c: If it actually starts 6.5 m higher than your answer to the previous part (yet still reaches the top of the loop with the same velocity), how much energy, in joules, did it lose to friction? Its mass is 1900 kg.
E_{lost} = ____

Potential Energy and Mechanical Energy

Dr. Kimberly Shaw is a professor and the UTeach Science Co-Director at Columbus State University. She earned a bachelor's degree in physics from Vanderbilt University, then a master's degree in physics and a doctorate in experimental condensed matter physics from Florida State University. She is a member of the American Physical Society, the American Association of Physics Teachers, the National Science Teachers Association and the Association for Women in Science. She was named as the 2015 Georgia Professor of the Year by the Council for Advancement and Support of Education. She was also honored as the 2018-2019 CSU Scholarship of Teaching & Learning Award Winner.

“This is a problem relating fusion energy to the energy consumption needs of our community. By applying conservation of energy ideas to potential solutions for community problems such as developing alternative energy sources, students can better see how fundamental ideas in physics can be used to solve practical problems that matter to them.”

Problem

The use of hydrogen fusion to supply energy is a dream that may be realized in the next century. This represents a relatively clean and almost limitless supply of energy. For example, there is enough hydrogen in the ocean to create 10^{34} J of energy via fusion.

Calculate how many years the energy needs of the world could be supplied by one millionth of the oceans’ hydrogen fusion energy, assuming the future world will use 5.5 times the energy we do now. (The world's yearly energy usage now is around 4×10^{20} J).
t = ____

EXPERT ta

Momentum, Impulse, and Collisions

Dr. Kimberly Shaw is a professor and the UTeach Science Co-Director at Columbus State University. She earned a bachelor's degree in physics from Vanderbilt University, then a master's degree in physics and a doctorate in experimental condensed matter physics from Florida State University. She is a member of the American Physical Society, the American Association of Physics Teachers, the National Science Teachers Association and the Association for Women in Science. She was named as the 2015 Georgia Professor of the Year by the Council for Advancement and Support of Education. She was also honored as the 2018-2019 CSU Scholarship of Teaching & Learning Award Winner.

> "This is a ballistic pendulum problem. This problem is a simplified way that someone could calculate the muzzle velocity of a gun - and hence has ties to forensic science applications. However, I feel that a problem like this one ties together ideas from kinematics and forces to ideas of energy and momentum, allowing students to reflect on the interconnected nature of these concepts."

Problem

A bullet is fired horizontally into an initially stationary block of wood suspended by a string and remains embedded in the block. The bullet's mass is m = *0.0065* kg, while that of the block is M = *0.99* kg. After the collision the block/bullet system swings and reaches a maximum height of h = *0.95* m above its initial height. Neglect air resistance.

Part a: Enter an expression for the speed of the block/bullet system immediately after the collision in terms of defined quantities and g.

Expression :

v_f = ____

Select from the variables below to write your expression. Note that all variables may not be required.

β, γ, θ, b, c, d, g, h, j, k, m, M, n, P, S

Part b: Find the speed of the block/bullet system, in meters per second, immediately after the collision.

v_f = ____

Part c: Enter an expression for the initial speed of the bullet in terms of defined quantities and g.

v_i = ____

Select from the variables below to write your expression. Note that all variables may not be required.

β, γ, θ, b, c, d, g, h, j, k, m, M, n, P, S

Continued on next page

Problem

Continued from previous page

Part d: Find the initial speed of the bullet, in meters per second..

v_i = ____

Part e: Find the initial kinetic energy of the bullet, in joules.

KE_i = ____

Part f: Enter an expression for the kinetic energy of the block/bullet system immediately after the collision, in terms of defined quantities and g.

Expression :

KE_f = ____

Select from the variables below to write your expression. Note that all variables may not be required.

β, γ, θ, b, c, d, g, h, j, k, m, M, n, P, S

Part g: Calculate the ratio, expressed as a percent, of the kinetic energy of the block/bullet system immediately after the collision to the initial kinetic energy of the bullet.

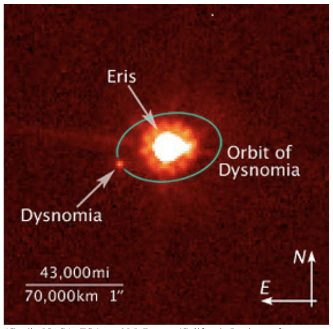
$KE_f / KE_i(\%)$ = ____

Gravitation

Dr. Kathleen Blackett earned her B.S. in physics from the University of Michigan-Dearborn, and her Ph.D. in experimental particle physics from the University of Tennessee. Kathy's career includes participating in searches for mesons with exotic quantum numbers as a postdoc at Brookhaven National Laboratory, working as systems/test engineer for AT&T, and taking some time to raise her family. In addition, Kathy taught physics and math for several years at the University of South Florida, St. Petersburg College and Eckerd College. Currently Kathy is a content author on the Expert TA team and volunteers for NASA as a Solar System Ambassador.

"The following problem, while not especially complicated, is powerful. Like most individuals of my generation, I grew up believing that there were nine planets in our solar system. Period. This problem has convinced me otherwise. Sorry Pluto! You will always be special to me!"

Problem



(Credit: NASA, ESA, and M. Brown (California Institute of Technology))

Pluto was discovered in 1930, and was unquestionably considered a planet until the discoveries of many other trans-Neptunian objects (TNOs) in the 1990's and early 2000's. As more TNOs were being discovered, it was looking like Pluto had much more in common with these objects than the other eight planets. In 2006, it was decided by the International Astronomical Union (IAU) that Pluto be reclassified as a dwarf planet.

One of these trans-Neptunian objects is the dwarf planet, Eris, discovered by the team of Michael Brown, David Rabinowitz and Chad Trujillo in 2005. Later that same year, the team discovered Dysnomia, a moon of Eris. Eris and Dysnomia are pictured to the right. The discovery of Dysnomia was fortunate, because it allowed scientists to calculate the mass of Eris. After careful observation, it was determined that Dysnomia has an orbit that is approximately circular with a radius of about 37,350 km and a period of about 15.79 days.

Part a: Determine the mass, in kilograms, of Eris.
M_{Eris} = ____

Part b: Pluto has a mass of 1.309×10^{22}kg. Which is more massive, Pluto or Eris?
MultipleChoice :
1) Pluto
2) Eris

Great Problems in Physics

Gravitation

Dr. Colette Salyk is an Assistant Professor of Astronomy at Vassar College where she teaches courses in planetary science, observational astronomy, and introductory physics. She earned a Bachelors of Science degree at the Massachusetts Institute of Technology; she earned a Masters of Science and a PhD at the California Institute of Technology. She studies the formation of planets using both ground- and space-based telescopes. In particular, she studies the relationship between protoplanetary disk properties (including chemical composition) and planetary diversity.

"I really like this question because it gets you to think about how different constants or physical values might actually be measured. I teach classes about planetary science, and I really enjoy discussing how we actually measure the properties of planets (masses, sizes, distances) that appear in textbooks. As noted in part (b), the centripetal acceleration of the moon, v2/r, is not that easy to measure. The easiest thing to measure is the moon's orbital period around the Earth (approximately 27 days, which is why a month is called a mo(o)nth), since all we have to do is go outside each night and look at the moon. But it was historically challenging to measure the distance to the moon. Today, this distance is measured with incredible precision thanks to mirrors placed on the moon's surface by the Apollo astronauts. Lasers on Earth are bounced off of the moon, and the amount of time it takes the laser light to get to the moon and reflect back tells you the distance to the moon."

Read more about Dr. Salyk and her research here.

Problem

In this problem, you are going to explore three different ways to determine the gravitational constant, G.

Part a: By observing that the centripetal acceleration of the Moon around the Earth is ac=2.69×10^{-3}m/s^2, what is the gravitational constant, *G*, in cubic meters per kilogram per squared second? Assume the Earth has a mass of ME=5.96×10^{24}kg, and the mean distance between the centers of the Earth and Moon is $r_m = 3.81 \times 10^8$m.
G = ____

Continued on next page...

Problem

Continued from previous page

Part b: Measuring the centripetal acceleration of an orbiting object is rather difficult, so an alternative approach is to use the period of the orbiting object. Find an expression for the gravitational constant in terms of the distance between the gravitating objects, r_m, the mass of the larger body (the earth), M_E, and the period of the orbiting body, *T*.
G = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, φ, π, θ, d, g, h, m, ME, n, P, rm, T, vi

Part c: The gravitational constant may also be calculated by analyzing the motion of an object, launched from the surface of the earth at an initial velocity of v_i. Find an expression of the gravitational constant from the initial velocity, mass of the earth, M_E, and the initial and final heights. Use the parameter $\varphi = 1/r_{initial} - 1/r_{final}$ to simplify your final answer.
G = ____

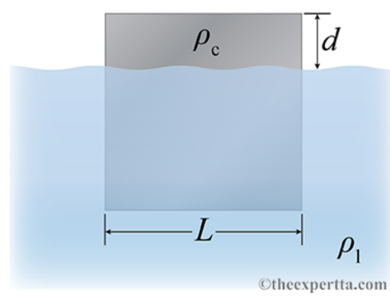
Fluid Mechanics

Anne J. Cox has a B.S. in physics from Rhodes College and a Ph.D. in physics from the University of Virginia. She was awarded Eckerd's Staub Distinguished Teacher of the Year Award in 2004 and named a Fellow of the American Association of Physics Teachers in 2014. Her current research interests are pedagogical strategies to enhance student learning and developing mentoring programs for women physics faculty. She is a contributing author of Physlet Physics: Interactive Illustrations, Explorations, and Problems for Introductory Physics and co-author of Physlet Quantum Physics. She has served as a co-PI on NSF grants to support women in physics, provide scholarships for science students, and to develop simulations for teaching introductory and upper-level physics.

> "Floating is a nice application of static equilibrium problems. This problem makes this more explicit by requiring an expression first. It also provides an "is it reasonable" check on the expression found by considering a case where you can easily figure out the answer. Checking answers against known situations, is an important skill to develop to be successful in physics."

Read more about Dr. Cox and her research here.

Problem



A cube with edge length *L = 0.19* m and density ρc = 0.87×10³ kg/m³ floats in equilibrium in a liquid of density $\rho_1 = 1.5\times10^3$ kg/m³, with the top of the cube a distance d above the liquid's surface, as shown in the figure.

Part a: Enter an expression for the distance d, in terms of the defined quantities.
Expression :
d = ____

Select from the variables below to write your expression. Note that all variables may not be required.
β, γ, ρc, ρl, θ, d, g, h, j, k, L, m, n, P, S

Part b: If the density of the cube is equal to the density of the liquid, how high, in meters, will the top of the cube be above the surface of the liquid?
d = ____

Part c: The given values of edge length and densities are *L = 0.19 m, ρc = 0.87×10³ kg/m³,* and $\rho_1 =$ *1.5*×10³ kg/m³. With these values, how high, in meters, is the top of the cube above the liquid's surface.
d = ____

Great Problems in Physics

Sound Waves

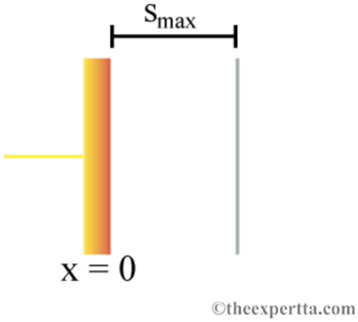
Dr. Kimberly Riegel is an Assistant Professor of Physics at Queensborough Community College. She earned a Bachelor of Arts in Physics at Vassar College, and she was awarded a Masters of Engineering and a PhD in accoustics from The Pennsylvania State University. She studies acoustics, the physics of sound, with a focus on noise control, and she has considerable experience in both academic and commercial environments. In addition to teaching introductory physics and the physics of sound classes, Dr. Riegel is a faculty mentor for the women in science club which works to promote participation and equality of women in science. She is also dedicated to providing research opportunities for undergraduates. She does work with supersonic aircraft using computer simulations to propagate sonic booms in urban areas. She also works with classroom and building acoustics to ensure good acoustic environments for musicians and students.

> “I like this problem because it is a great summary of the relevant topics of Acoustics. It starts with general calculations of wave properties and then builds that into the total equation for the traveling wave. Then the problem takes it one step further and applies the concepts of the mechanical pressure wave to concepts that were previously covered like force. I find a lot of students get confused by trying to create the equations of motion for a wave, and this helps provide that step by step instruction.”

Read more about Dr. Riegel and her research here.

Problem

A periodic vibration at $x = 0$, $t = 0$ displaces air molecules along the x direction by s_{max} = *2.4E-05* m. The motion produces a sound wave that travels at a velocity of v = 350 m/s with a frequency of f = 75 Hz. Take the density of air as $\rho_a = 1.20$ kg/m^3.



Part a: Calculate the wavelength λ of the sound wave, in meters.
λ = ____

Part b: Calculate the wavenumber k of the sound, in radians per meter.
k = ____

Continued on next page

Problem

Continued from previous page

Part c: Calculate the angular frequency of the sound ω, in radians per second.
ω = ____

Part d: Calculate the displacement of the air molecules using an function for the traveling sound wave in terms of time and position at time $t = 0.001$ s and displacement $x = 1.0$ m.
s(1,0.001) = ____

Part e: Write an expression for the maximum pressure exerted by the sound wave ΔP_{max} in terms of the air density Q_a, the sound velocity v, the angular frequency ω, and the maximum displacement s_{max}.
Expression :
ΔP_{max} = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, ω, ρa, θ, d, f, g, h, j, k, m, P, s_{max}, v

Part f: The sound wave is directly incident on a sheet of paper of surface area A = 0.024 m^2. Calculate the maximum force F_{max}, in newtons, exerted on this sheet.
F_{max} = ____

Part g: If the frequency of the sound wave were increased by a factor of 100, how would the force exerted on the sheet in part (f) change?
MultipleChoice :

1) The force would decrease by a factor of 1000.
2) The force would decrease by a factor of 10.
3) The force would increase by a factor of 10.
4) The force would not change.
5) The force would increase by a factor of 100.
6) The force would increase by a factor of 1000.
7) The force would decrease by a factor of 100.

The Second Law of Thermodynamics and Applications

Dr. Teresa Burns currently serves as Associate Dean in the Gupta College of Science at Coastal Carolina University. She earned her Bachelor of Arts in Physics from New York University, and her Doctor of Philosophy in Physics from Utah State University. She completed her teaching postdoc at Oregon State University, before joining the Coastal Carolina University faculty. Dr. Burns has a long-term interest in physics education and outreach. She, along with colleagues, implemented an integrated lecture-laboratory class in the introductory physics sequence at Coastal, has been involved with teacher training courses, and has been actively involved in outreach to teachers in the area through summer workshop programs, and other activities.

"This is a good problem because I think entropy as a concept is underrated. I like to tell my students that entropy is about possibilities, and not disorder, as it is commonly stated. It shows us that the universe is egalitarian. We have to do work to, for example, hoard energy. Tying it to astronomy is a way to draw in students that perhaps are not that interested in heat engines."

Problem

The core of the Sun has a temperature of 1.5×10^7 K, while the surface of the Sun has a temperature of 5540 K (which varies over the surface, with the sunspots being cooler). Treat the core of the Sun and the surface of the Sun as two large reservoirs connected by the solar interior. Nuclear fusion processes in the core produce 3.8×10^{26} J every second. Assume that 100% of this energy is transferred from the core to the surface.

Part a: Calculate the change in the entropy ΔS, in joules per kelvin, of the Sun every second.
ΔS_S = ____

Part b: Rigel is a blue giant star with a core temperature of 5.0×10^7 K and a surface temperature of 10900 K. If the core of Rigel produces 60,000 times as much energy per second as the core of the Sun does, calculate the change in the entropy ΔS_R, in joules per kelvin, of Rigel every second.
ΔS_R = ____

Part c: Barnard's Star is a red dwarf star with a core temperature of 7.0×10^6 K and a surface temperature of 3910 K. If the core of Barnard's Star produces 5% as much energy per second as the core of the Sun does, calculate the change in the entropy ΔS_B, in joules per kelvin, of Barnard's Star every second.
ΔS_B = ____

Gauss's Law

Dr. Kimberly Shaw is a professor and the UTeach Science Co-Director at Columbus State University. She earned a bachelor's degree in physics from Vanderbilt University, then a master's degree in physics and a doctorate in experimental condensed matter physics from Florida State University. She is a member of the American Physical Society, the American Association of Physics Teachers, the National Science Teachers Association and the Association for Women in Science. She was named as the 2015 Georgia Professor of the Year by the Council for Advancement and Support of Education. She was also honored as the 2018-2019 CSU Scholarship of Teaching & Learning Award Winner.

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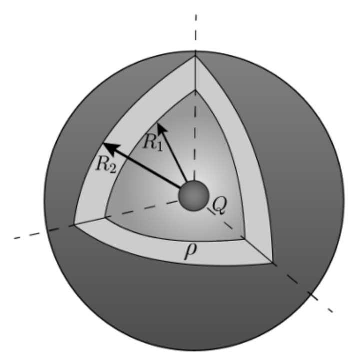
Problem



A hollow non-conducting spherical shell has inner radius R_1=10 cm and outer radius R_2=14 cm. A charge Q=-45 nC lies at the center of the shell. The shell carries a spherically symmetric charge density that increases linearly with radius,

ρ = Ar for R1 ≤ r ≤ R2

where A=15 μC/m4.

Part a: Write an equation for the radial electric field in the region r < R_1 in terms of *Q*, *r*, and Coulomb's constant *k*. You may take the positive direction as outward.
Expression :
E_r<R_1 = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, π, σ, θ, a, A, d, g, k, m, Q, r, R1, R2, t

Part b: What is the radial electric field at the point r=0.5R1? Given your answer in units of kN/C, and take the positive direction outwards.
E(0.5R_1) = ____

Continued on next page

Problem

Continued from previous page

Part c: What is the radial electric field at the point r=0.5(R1+R2)? Give your answer in units of kN/C.
Numeric : A numeric value is expected and not an expression.
$E(0.5(R_1+R_2))$ = ____

Part d: What is the radial electric field at the point r=2R2? Give your answer in units of kN/C.
Numeric : A numeric value is expected and not an expression.
$E(2R_1)$ = ____

Great Problems in Physics

Current and Resistance

Bridget Gormalley is a Physics Instructor at the Massachusetts College of Liberal Arts. After she graduated summa cum laude in physics from MCLA, she headed to Columbia University in New York, N.Y. to earn a master's degree in applied physics. Gormalley previously worked as an adjunct lab instructor at MCLA before joining the school full-time as a physics instructor. In addition to her work at MCLA, she is an Adjunct Mathematics Professor at Berkshire Community College (BCC) in Pittsfield, MA, where she teaches mathematics courses and is also the co-advisor for their VEX U Robotics Club.

> "If a heart defibrillator passes a relatively large current through a torso, why are there no electrical burns? This is the premise of one of my favorite questions. This question highlights relationships between energy, voltage, resistance, current, and charge. It also contains a "blast from the past": energy in the form of heat. Not only is this a good review for any end-of-the-semester exams, but it also demonstrates to students how branches of physics are connected."

Read more about Bridget Gormalley here.

Problem

A heart defibrillator passes 7.5 A through a patient's torso for 4.8 ms in an attempt to restore normal beating.

Part a: How much charge passed, in coulombs?
Q = ____

Part b: What voltage, in kilovolts, is applied if 490 J of energy was dissipated?
Δ*V* = ____

Part c: What is the path's resistance, in ohms?
R = ____

Part d: Find the temperature increase, in degrees Celsius, caused in the 8.5 kg of affected tissue, assuming flesh has a specific heat of 3500 J/kg•°C.
Δ*T* = ____

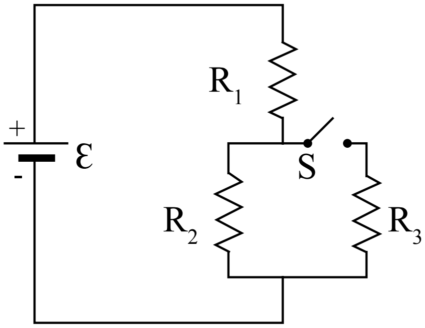
DC Circuits

Anne J. Cox has a B.S. in physics from Rhodes College and a Ph.D. in physics from the University of Virginia. She was awarded Eckerd's Staub Distinguished Teacher of the Year Award in 2004 and named a Fellow of the American Association of Physics Teachers in 2014. Her current research interests are pedagogical strategies to enhance student learning and developing mentoring programs for women physics faculty. She is a contributing author of Physlet Physics: Interactive Illustrations, Explorations, and Problems for Introductory Physics and co-author of Physlet Quantum Physics. She has served as a co-PI on NSF grants to support women in physics, provide scholarships for science students, and to develop simulations for teaching introductory and upper-level physics.

> “This problem challenges you to have a good conceptual model of current flow and resistance. You can solve it, of course, by using equations (which is useful for checking your answers), but a robust conceptual model can allow you to skip such calculations.”

Read more about Dr. Cox and her research here.

Problem



@theexpertta.com

Consider the circuit shown in the picture. It consists of three identical resistors, an ideal battery, and a switch S. Answer the following questions about what happens after you close the switch.

Part a: After closing switch S, the total resistance of the circuit:
MultipleChoice :
1) increases
2) stays the same
3) decreases

Part b: After closing switch S, the voltage drop of resistor 2:
MultipleChoice :
1) increases
2) stays the same
3) decreases

Continued on next page

Problem

Continued from previous page

Part c: After closing switch S, current through resistor 2:
MultipleChoice :
1) increases
2) stays the same
3) decreases

Part d: After closing the switch S, current through resistor 1:
MultipleChoice :
1) stays the same
2) decreases
3) increases

Part e: After closing the switch S, voltage drop on resistor 1:
MultipleChoice :
1) decreases
2) stays the same
3) increases

Part f: After closing the switch S, current through the battery:
MultipleChoice :
1) decreases
2) stays the same
3) increases

Part g: After closing the switch S, the total power dissipated in the circuit:
MultipleChoice :
1) decreases
2) stays the same
3) increases

Part h: After closing the switch S, the power dissipated in resistor 1:
MultipleChoice :
1) stays the same
2) decreases
3) increases

Continued on next page

Problem

Continued from previous page

Part i: After closing the switch S, the power dissipated in resistor 2:

MultipleChoice :

1) increases
2) stays the same
3) decreases

Great Problems in Physics

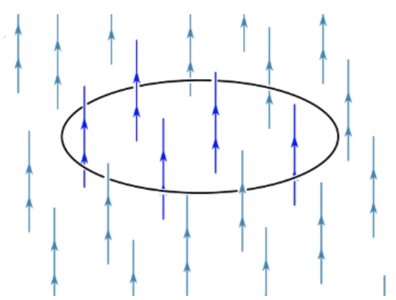
Faraday's Law

Dr. Paige Ouzts is a Professor of Physics at the Department of Physical Sciences at Lander University. She earned her Bachelor of Science degree from Furman University. She was awarded a Masters of Science and a PhD from the University of Alabama.

> "I like this problem as it walks the students through the steps of a topic they typically struggle with, Faraday's and Lenz's Laws. Generally the variable we are interested in knowing is the current induced as well as the direction of this current. By asking the intermediate questions, it reminds the students that it isn't the flux that governs the induced emf and current, it is the change in the flux. I follow similar steps when working problems with the students, so I believe it is helpful for them to have similar practice problems when they begin working problems on their own. I also like this problem as it starts by asking for expressions in terms of the variables and not numerical values. I find my students tend to make calculation errors when they introduce numerical values into the problems during early steps and they then lose sight of the physical nature of the problem."

Read more about Dr. Ouzts and her research here.

Problem



A loop of wire with radius r=0.075m is placed in a region of uniform magnetic field with magnitude B. As shown in the figure, the field direction is perpendicular to the plane of the loop. The magnitude of the magnetic field changes at a constant rate from B_1=0.35 T to B_2=5.5 T in time Δt=3.5 s. The resistance of the wire is R=4Ω.

Part a: Enter an expression for the magnitude of the magnetic flux through the loop using the symbols in the palette below. Your expression must be valid at all times described in the problem statement.
Expression :
Φ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
Δt, ε0, μ0, π, B, B1, B2, r, R

Continued on next page

Problem

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Part b: Enter an expression for the change in the magnitude of the magnetic flux through the loop using the symbols in the palette below.

Expression :

ΔΦ = ____

Select from the variables below to write your expression. Note that all variables may not be required.

Δt, ε0, μ0, π, B, B1, B2, r, R

Part c: Calculate the numerical value, in tesla squared meters, of the change in the magnitude of the flux.

ΔΦ = ____

Part d: Enter an expression for the magnitude of the induced emf in the loop using the symbols in the palette.

Expression :

ε = ____

Select from the variables below to write your expression. Note that all variables may not be required.

ΔΦ, Δt, ε0, μ0, π, B, B1, B2, r, R

Part e: Calculate, in volts, the numerical value of the magnitude of the emf.

ε = ____

Part f: Enter an expression for the magnitude of the current induced in the loop using the symbols in the palette.

Expression :

I = ____

Select from the variables below to write your expression. Note that all variables may not be required.

ΔΦ, Δt, ε, μ0, π, B, B1, B2, r, R

Part g: Calculate the numerical value, in amperes, of the magnitude of the induced current.

I = ____

Part h: If you are looking down at the loop from above, so that the magnetic field is directed towards you, what is the direction of the induced current?

MultipleChoice :

1) clockwise
2) counterclockwise

Geometric Optics

Dr. Jenny Magnes has researched various areas involving optics: diatomic spectroscopy of alkalis, quantum optics, molecular optics, opto-mechanical techniques, nano-structures and biophotonics. Jenny Magnes is interested in developing techniques that are beneficial during classroom interactions. She has also successfully involved undergraduates in her research and bringing research topics into the classroom. Jenny Magnes and her research group dove into investigating micro-organisms using optical techniques like scattering and various interference effects involve iridescence.

> "Everyone loves what-if scenarios in science fiction. I love de-bunking science fiction stories using physics. Usually, there are some laws of physics violated. So, this problem is the reverse where you create your own physics and universe. This creates really wonky and funny stories."

Read more about Dr. Magnes and her research here.

Problem

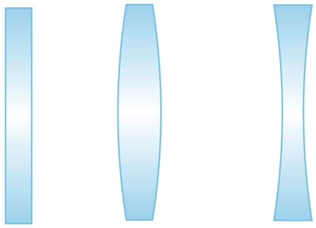
Assume we live in a weird universe where Snell's law reads:

$$n_1 \cos \theta_1 = n_2 \cos \theta_2,$$

where n_1 and n_2 are indices of refraction, and θ_1 and θ_2 are the angle of incidence and the angle of refraction respectively.

Part a: What is the angle of refraction in degrees if the light beam is incident on a piece of glass at an angle of 12° with respect to the normal, and the index of refraction, n_2, is 1.5?
θ_2 = ____

Part b: What would be the shape of a magnifying glass in this weird universe?
ScheaticChoice :



None of the Choices

Part c: In this weird universe, we would have (check all that apply)
MultipleSelect :
1) Total internal reflection
2) Neither of the choices
3) Total external reflection

Great Problems in Physics

Spacial Relativity

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Problem

Assume a weird universe where the speed of light is c=100km/hr.

Part a: A bus travels from New York City to Washington D.C. at a speed of 0.9*c* relative to the White House in D.C. How long in hours does the journey take relative to an observer in the White House? Assume that the distance between New York City and Washington D.C. is 240 miles.
Δt = ____

Part b: How long in hours does the journey take as measured by the bus driver?
Δt = ____