Collection of High School Physics Problems and Solutions

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Contents

1 1D Motion

1.1 Formulas

For a vector $\vec{r} = (x, y)$, $x = r\cos\theta$ and $y = r\sin\theta$

Radians versus degrees: $\theta_{\text{radians}} = \theta_{\text{degrees}}\pi/180$

Arc Length: $s = r\Delta\theta$, $r = \sqrt{r_x^2 + r_y^2}$

$\theta = a\tan(r_y/r_x) = \tan^{-1}(r_y/r_x)$.

Area of circle: πr^2

Volume of sphere: $\frac{4}{3}\pi r^3$

Surface area of sphere: $4\pi r^2$

$\log(AB) = \log A + \log B$; $\log(A/B) = \log A - \log B$

$ax^2 + bx + c = 0 \implies x = (-b \pm \sqrt{b^2 - 4ac})/2a$

Quantity and Units:

- Position, m
- Time, s
- Mass, kg
- Velocity, m/s
- Acceleration, m/s^2
- Energy, Joules = kg m^2/s^2
- Force, Newtons = kg m/s^2

Velocity: $\overline{v} = \frac{\Delta x}{\Delta t}$ $\quad v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$

Acceleration: $a = \lim \Delta t \to 0 \frac{\Delta v}{\Delta t}$

Speed: Absolute value (one dimension) of velocity.

Uniform acceleration: $x = x_0 + v_0 t + \frac{1}{2}at^2$

Velocity: $v = v_0 + at$

Velocity and distance: $v^2 = v_0^2 + 2a(x - x_0)$

1.2 Bird and Runner Problem

A runner is jogging in a straight line at a steady $v_r = 5$ km/hr. When the runner is $L = 5$ km from the finish line, a bird begins flying straight from the runner to the finish line at $v_b = 10$ km/hr (2 times as fast as the runner). When the bird reaches the finish line, it turns around and flies directly back to the runner.

What cumulative distance does the bird travel? Even though the bird is a dodo, assume that it occupies only one point in space (a "zero" length bird), travels in a straight line, and that it can turn without loss of speed. Answer in units of km.

1.3 Dropped Tennis Ball Problem

A tennis ball is dropped from 1.2 m above the ground. It rebounds to a height of 1 m.

(a) With what velocity does it hit the ground?

The acceleration of gravity is 9.8 m/s^2. (Let down be negative.) Answer in units of m/s.

(b) With what velocity does it leave the ground? Answer in units of m/s.

(c) If the tennis ball were in contact with the ground for 0.01 s, find the acceleration given to the tennis ball by the ground. Answer in units of m/s^2.

1.4 Reconnaissance Plane Problem

A reconnaissance plane flies 600 km away from its base at 400 m/s, then flies back to its base at 600 m/s.

What is its average speed? Answer in units of m/s.

2 2D Motion and Newton's Laws

2.1 Formulas

Speed: Magnitude of velocity (2 dimensions)

Two-dimensional uniformly accelerated motion: In the absence of air resistance, for uniformly accelerated motion in two dimensions, the x and y directions can be treated independently.

Free fall: $y = y_0 + v_0 t - \frac{1}{2}gt^2$

$v_x = v_{0x} \qquad \Delta x = v_{0x}t$

$\Delta x = v_0 \cos\theta_0 t \qquad v_y = v_{0y} - gt$

$\Delta y = v_{0y}t - \frac{1}{2}gt^2$

$\Delta y = v_0 \sin\theta_0 t - \frac{1}{2}gt^2$

$v_y^2 = v_0^2 \sin^2\theta_0 - 2g\Delta y$

Range: $\Delta x = \frac{v_0^2 \sin 2\theta_0}{g}$

Newton's second law: $\vec{F} = m\vec{a}$

Newton's third law: $\vec{F}_{12} + \vec{F}_{21} = 0$

Force due to static friction is less than or equal to $\mu_s N$.

Force due to kinetic friction is $\mu_k N$.

2.2 Two Planes Problem

Two airplanes leave an aiport at the same time. The velocity of the first plane is 700 m/h at a heading of 23.4°. The velocity of the second is 620 m/h at a heading of 116°.

How far apart are they after 2.9 h? Answer in units of m.

2.3 Projectile Final Velocity Problem

A ball is thrown horizontally from the top of a building 140 m high. The ball strikes the ground 68 m horizontally from the point of release.

What is the speed of the ball just before it strikes the ground?

2.4 Two Snowballs Problem

One strategy in a snowball fight is to throw a snowball at a high angle over level ground. While your opponent is watching this first snowball, you throw a second snowball at a low angle and time it to arrive at the same time as the first.

Assume both snowballs are thrown with the same initial speed 24 m/s. The first snowball is thrown at an angle of 59° above the horizontal. At what angle should you throw the second snowball to make it hit the same point as the first? Note that starting and ending heights are the same. The acceleration of gravity is 9.8 m/s^2.

How many seconds after the first snowball should you throw the second so that they arrive on target at the same time? Answer in units of s.

2.5 Cheetah and Gazelle Problem

A cheetah can run at a maximum speed 109 km/h and a gazelle can run at a maximum speed of 73.8 km/h.

(a) If both animals are running at full speed, with the gazelle 90.2 m ahead, how long before the cheetah catches its prey? Answer in units of s.

The cheetah can maintain its maximum speed for only 7.5 s.

(b) What is the minimum distance the gazelle must be ahead of the cheetah to have a chance of escape? (After 7.5 s the speed of cheetah is less than that of the gazelle.) Answer in units of m.

2.6 Salmon Problem

Salmon often jump waterfalls to reach their breeding grounds.

Starting downstream, 1.99 m away from a waterfall 0.354 m in height, at what minimum speed must a salmon jumping at an angle of 38.4° leave the water to continue upstream? The acceleration due to gravity is 9.81 m/s^2. Answer in units of m/s.

2.7 Block at Rest on Plane Problem

A block is at rest on an incline where the mass of the block is 10 kg and the angle of the incline is 28°. The coefficients of static and kinetic friction are $\mu_s = 0.62$ and $\mu_k = 0.53$, respectively. The acceleration of gravity is 9.8 m/s^2.

(a) What is the frictional force acting on the 10 kg mass? Answer in units of N.

(b) What is the largest angle which the incline can have so that the mass does not slide down the incline? Answer in units of °.

(c) What is the acceleration of the block down the incline if the angle of the incline is 39°? Answer in units of m/s^2.

2.8 Atwood Machine Problem

A light, inextensible cord passes over a light, frictionless pulley with a radius of 14 cm. It has a(n) 1.5 kg mass on the left and a(n) 1 kg mass on the right, both hanging freely. Initially their center of masses are a vertical distance 3.3 m apart. The acceleration of gravity is 9.8 m/s^2.

(a) At what rate are the two masses accelerating when they pass each other? Answer in units of m/s^2.

(b) What is the tension in the cord when they pass each other? Answer in units of N.

2.9 Force Between Two Blocks Problem

Consider the following system, where there is a force $F = 40$N right on a block of $M = 9$ kg and a smaller block $m = 1$ kg that is touching block with mass M.

What is the magnitude of the force with which one block acts on the other?

2.10 Two Cars Braking Problem

You are driving at the speed of 30 m/s (67.1224 mph) when suddenly the car in front of you (previously traveling at the same speed) brakes and begins to slow down with the largest deceleration possible without skidding. Considering an average human reaction, you press your brakes 0.5 s later. You also brake and decelerate as rapidly as possible without skidding. Assume that the coefficient of static friction is 0.8 between both cars' wheels and the road. The acceleration of gravity is 9.8 m/s^2.

(a) Calculate the acceleration of the car in front of you when it brakes. Answer in units of m/s^2.

(b) Calculate the braking distance for the car in front of you. Answer in units of m.

(c) Find the minimum safe distance at which you can follow the car in front of you and avoid hitting it (in the case of emergency braking described here). Answer in units of m.

3 Energy

3.1 Formulas

Work is force times distance. $W = Fd\cos\theta$. Power P is work per time; also $P = Fv$. Mechanical energy is conserved for systems without external forces, and which do not generate heat through friction, and do not create or consume chemical energy.

Kinetic Energy: KE $= \frac{1}{2}mv^2$

$W_{\text{net}} = \Delta KE$

$U_{\text{gravity}} = mgh$; $\qquad U_{\text{spring}} = \frac{1}{2}kx^2$

3.2 Crate Pulled up Ramp Problem

A crate with mass 15 kg is pulled by a force (parallel to the incline) up a rough incline. The crate has a initial speed is 1.5 m/s. The crate is pulled a distance of 7.5 m on the incline by a 150 N force. The angle of the incline is 30° and the coefficient of friction is 0.3. The acceleration due to gravity is 9.8 m/s^2.

(a) What is the change in kinetic energy of the crate? Answer in units of J.

(b) What is the speed of the crate after it is pulled the 7.5 m? Answer in units of m/s.

3.3 Work Done from Two Vectors Problem

A force $\vec{F} = F_x\hat{\imath} + F_y\hat{\jmath}$ acts on a particle that undergoes a displacement of $\vec{s} = s_x\hat{\imath} + s_y\hat{\jmath}$ where $F_x = 6$N, $F_y = -2$N, $s_x = 3$ m, and $s_y = 1$ m.

(a) Find the work done by the force on the particle. Answer in units of J.

(b) Find the angle between $\vec{F}$ and $\vec{s}$. Answer in units of °.

3.4 Block on a Wall Problem

A 5.0 kg block is pushed 3.0 m at a constant velocity up a vertical wall by a constant force applied at an angle of $30.0°$ with the horizontal. The acceleration of gravity is 9.81 m/s^2.

If the coefficient of kinetic friction between the block and the wall is 0.30, find

(a) the work done by the force on the block. Answer in units of J.

(b) the work done by gravity on the block. Answer in units of J.

(c) the magnitude of the normal force between the block and the wall. Answer in units of N.

3.5 Car Driving Up Pike's Peak Problem

The engine of a 2000 kg Mercedes going up Pike's Peak delivers energy to its drive wheel at the rate 100 kW.

Neglecting air resistance, what is the largest speed the car can sustain on the steep Pike's Peak mountain highway, where the road is $30°$ to the horizontal? The acceleration due to gravity is 10 m/s^2.

3.6 Block Dragged on Rough Surface Problem

A 15 kg block is dragged over a rough, horizontal surface by a constant force of 70 N acting at an angle of 30° above the horizontal. The block is displaced 5 m, and the coefficient of kinetic friction is 0.1.

(a) Find the work done by the 70 N force. The acceleration of gravity is 9.8 m/s^2. Answer in units of J.

(b) Find the magnitude of the work done by the force of friction. Answer in units of J.

4 Momentum

4.1 Formulas

Momentum: $\vec{p} = m\vec{v}$

Momentum is conserved for any system for which total external force vanishes.

$$\Delta p = I = F\Delta t$$

$m_1 v_{1\text{before}} + m_2 v_{2\text{before}} = m_1 v_{1\text{after}} + m_2 v_{2\text{after}}$

Elastic: $v_{1\text{before}} - v_{2\text{before}} = v_{2\text{after}} - v_{1\text{after}}$

Inelastic: $v_{2\text{after}} = v_{1\text{after}}$

Rocket Thrust: $(\Delta m/\Delta t)v_{\text{ejected gas}}$

Rocket Speed: $v = v_{\text{ejected gas}} \ln(m_0/m_f)$

4.2 Two Blocks and a Spring Problem

A massless spring with force constant 433 N/m is fastened at its left end to a vertical wall. The acceleration of gravity is 9.8 m/s^2.

Initially there is a 6 kg and a 5 kg block at rest on a horizontal surface with the 6 kg block in contact with the spring (but not compressing it) and with the 5 kg block in contact with the 6 kg block. The 6 kg block is then moved to the left, compressing the spring a distance of 0.6 m, and held in place while the 5 kg block remains at rest.

Determine the elastic energy U stored in the compressed spring. Answer in units of J.

4.3 Neutron Collision Problem

A neutron in a reactor makes an elastic head-on collision with the nucleus of an atom initially at rest.

Assume the mass of the atomic nucleus is about 13.8 the mass of the neutron.

(a) What fraction of the neutron's kinetic energy is transferred to the atomic nucleus?

(b) If the initial kinetic energy of the neutron is 3.38×10^{-13} J, find its final kinetic energy. Answer in units of J.

4.4 Aircraft Thrust Problem

A jet aircraft is traveling at 208 m/s in horizontal flight. The engine takes in air at a rate of 100 kg/s and burns fuel at a rate of 2.7 kg/s. The exhaust gases are ejected at 472 m/s relative to the aircraft.

(a) Find the thrust of the jet engine. Answer in units of N.

(b) Find the delivered power. Answer in units of W.

5 Rotational Motion and Gravity

5.1 Formulas

$\Delta\theta = \theta_f - \theta_i$

Angular velocity: $\omega = \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t}$

Tangential velocity: $v = r\omega$

Angular acceleration: $\alpha = \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t}$

Tangential acceleration: $a = r\alpha$

Const. angular accel: $\omega = \omega_0 + \alpha t$

$\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

Centripetal accel: $a_c = \frac{v^2}{r}$

Gravitation: $F = G\frac{m_1 m_2}{r^2}$

Torque: $\tau = rF\sin\theta$

Center of Gravity: $x_{\mathsf{cg}} = \frac{\sum_i m_i x_i}{\sum_i m_1}$

Moment of Intertia: $I = \sum_i m_i r_i^2$

Hoop: $I = MR^2$

Solid Sphere: $I = \frac{2}{5}MR^2$

Thin Spherical Shell: $I = \frac{2}{3}MR^2$

Solid Cylinder: $I = \frac{1}{2}MR^2$

Thin Rod (Center): $I = \frac{1}{12}MR^2$

Thin Rod (End): $I = \frac{1}{3}MR^2$

For statics problems, sum of torques vanishes and vector sum of forces vanishes. Angular momentum is conserved for any system where the total torque vanishes. Results can depend on origin of choice.

Torque: $\tau = I\alpha$

Angular Kinetic Energy: $\mathsf{KE}_{\mathsf{rot}} = \frac{1}{2}I\omega^2$

Angular Momentum: $L = I\omega$

5.2 Rotating Disks Problem

The speed of a moving bullet can be determined by allowing the bullet to pass through two rotating paper disks mounted a distance 72 cm apart on the same axle. From the angular displacement $20.9°$ of the two bullet holes in the disks and the rotational speed 509 rev/min of the disks, we can determine the speed of the bullet.

What is the speed of the bullet? Answer in units of m/s.

5.3 Car Decelerating Problem

The driver of a car traveling at 31.3 m/s applies the brakes and undergoes a constant deceleration of 1.6 m/s^2.

How many revolutions does each tire make before the car comes to a stop, assuming that the car does not skid and that the tires have radii of 0.31 m? Answer in units of rev.

5.4 Testing Car Tires Problem

To test the performance of its tires, a car travels along a perfectly flat (no banking) circular track of radius 190 m. The car increases its speed at a uniform rate of

$$a_t \equiv \frac{\mathrm{d}|v|}{\mathrm{d}t} = 4.94 \text{m/s}^2$$

until the tires start to skid.

If the tires start to skid when the car reaches a speed of 29.7 m/s, what is the coefficient of static friction between the tires and the road? The acceleration of gravity is 9.8 m/s^2.

5.5 Coin on Turntable Problem

A coin is placed 33 cm from the center of a horizontal turntable, initially at rest. The turntable then begins to rotate. When the speed of the coin is 120 cm/s (rotating at a constant rate), the coin just begins to slip. The acceleration due to gravity is 980 cm/s^2.

What is the coefficient of static friction between the coin and the turntable?

5.6 Amusement Park Ride Problem

An amusement park ride consists of a rotating circular platform 7.66 m in diameter from which 10 kg seats are suspended at the end of 3.71 m massless chains. When the system rotates, the chains make an angle of 33.1° with the vertical. The acceleration of gravity is 9.8 m/s^2.

(a) What is the speed of each seat? Answer in units of m/s.

(b) If a child of mass 57.2 kg sits in a seat, what is the tension in the chain (for the same angle)? Answer in units of N.

5.7 VCR Tape Problem

The tape in a videotape cassette has a total length 272 m and can play for 2.4 h. As the tape starts to play, the full reel has an outer radius of 44 mm and an inner radius of 12 mm. At some point during the play, both reels will have the same angular speed.

What is this common angular speed? Answer in units of rad/s.

5.8 Apollo Spacecraft Problem

On the way to the moon, the Apollo astronauts reach a point where the Moon's gravitational pull is stronger than that of Earth's.

(a) Find the distance of this point from the center of the Earth. The masses of the Earth and the Moon are 5.98×10^{24} kg and 7.36×10^{22} kg, respectively, and the distance from the Earth to the Moon is 3.84×10^{8} m. Answer in units of m.

(b) What would the acceleration of the astronaut be due to the Earth's gravity at this point if the moon was not there? The value of the universal gravitational constant is 6.672×10^{-11} N·m^2/kg^2. Answer in units of m/s^2.

5.9 Car on a Curve Problem

A highway curves to the left with radius of curvature of 47 m and is banked at $25°$ so that cars can take this curve at higher speeds. Consider a car of mass 909 kg whose tires have a static friction coefficient 0.64 against the pavement.

How fast can the car take this curve without skidding to the outside of the curve? The acceleration due to gravity is 9.8 m/s^2. Answer in units of m/s.

5.10 Force from Two Large Masses Problem

Objects with masses of 149 kg and 424 kg are separated by 0.413 m. A 75 kg mass is placed midway between them.

(a) Find the magnitude of the net gravitational force exerted by the two larger masses on the 75 kg mass. The value of the universal gravitational constant is 6.672×10^{-11} N·m^2/kg^2. Answer in units of N.

(b) Leaving the distance between the 149 kg and the 424 kg masses fixed, at what distance from the 424 kg mass (other than infinitely remote ones) does the 75 kg mass experience a net force of zero? Answer in units of m.

5.11 Man on a Ladder Problem

A 17.7 kg person climbs up a uniform ladder with negligible mass. The upper end of the ladder rests on a frictionless wall. The bottom of the ladder rests on a floor with a rough surface where the coefficient of static friction is 0.22. The angle between the horizontal and the ladder is θ. The person wants to climb up the ladder at a distance of 0.91 m along the ladder from the ladder's foot. The length of the ladder is 2.1 m.

What is the minimum angle θ_{min} (between the horizontal and the ladder) so that the person can reach a distance of 0.91 m without having the ladder slip? The acceleration of gravity is 9.8 m/s^2. Answer in units of °.

5.12 Ladder on a Wall Problem

A ladder rests against a vertical wall. There is no friction between the wall and the ladder. The coefficient of static friction between the ladder and the ground is $\mu = 0.547$.

Determine the smallest angle θ for which the ladder remains stationary. Answer in units of °.

5.13 Hammer and Nail Problem

A hammer of length 28 cm pulls a nail at an angle $33°$ 3.63 cm left from the point of contact of the hammer on a horizontal board.

(a) If a force of magnitude 211 N is exerted horizontally 28 cm from the board on the hammer, find the force exerted by the hammer on the nail. (Assume that the force the hammer exerts on the nail is parallel to the nail). Answer in units of N.

(b) Find the force exerted by the surface on the point of contact with the hammer. Assume that the force the hammer exerts on the nail is parallel ot the nail. Answer in units of N.

5.14 4 Plates Center of Mass Problem

A square plate is produced by welding together four smaller square plates, each of side a. The weight of each of the four places are 30 N on the bottom left, 60 N on bottom right, 80 N on top left, and 80 N on top right.

(a) Find the x-coordinate of the center of gravity (as a multiple of a). Answer in units of a.

(b) Find the y-coordinate of the center of gravity (as a multiple of a). Answer in units of a.

5.15 Blocks and Pulley Problem

An Atwood machine is constructed using two wheels (with the masses concentrated at the rims). The left wheel has a mass of 2.4 kg and radius 22.24 cm. The right whell has a mass of 2.2 kg and radius 32.91 cm. The hanging mass on the left is 1.91 kg and on the right 1.68 kg.

What is the acceleration of the system? The acceleration of gravity is 9.8 m/s^2. Answer in units of m/s^2.

5.16 Energy of Merry-Go-Round Problem

A horizontal 846 N merry-go-round of radius 1.95 m is started from rest by a constant horizontal force of 77.8 N applied tangentially to the merry-go-round.

Find the kinetic energy of the merry-go-round after 3.62 s. The acceleration of gravity is 9.8 m/s^2. Assume the merry-go-round is a solid cylinder. Answer in units of J.

5.17 Rolling Basketball Problem

A regulation basketball has a 29 cm diameter and may be approximated as a thin spherical shell.

How long will it take a basketball starting from rest to roll without slipping 2.9 m down an incline that makes an angle of 51.9° with the horizontal? The acceleration of gravity is 9.81 m/s^2.

5.18 Dishonest Pan Balance Problem

Two pans of a balance are 72.6 cm apart. The fulcrum of the balance has been shifted 1.01 cm away from the center by a dishonest shopkeeper.

By what percentage is the true weight of the goods being marked up by the shopkeeper? Assume the balance has negligible mass. Answer in units of %.

5.19 Pitched Baseball Problem

The center of mass of a pitched baseball of radius 2.57 cm moves at 50.2 m/s. The ball spins about an axis through its center of mass with an angular speed of 198 rad/s.

Calculate the ratio of the rotational energy to the translational kinetic energy. Treat the ball as a uniform sphere.

5.20 Rotating Stool Problem

A student sits on a rotating stool holding two 4 kg objects. When his arms are extended horizontally, the objects are 1.1 m from the axis of rotation, and he rotates with angular speed of 0.62 rad/sec. The moment of inertia of the student plus the stool is 7 kg m^2 and is assumed to be constant. The student then pulls the objects horizontally to a radius 0.27 m from the rotation axis.

Calculate the final angular speed of the student. Answer in units of rad/s.

5.21 Merry-Go-Round Conservation of Angular Momentum Problem

A merry-go-round rotates at the rate of 0.12 rev/s with an 83 kg man standing at a point 1.5 m from the axis of rotation.

(a) What is the new angular speed when the man walks to a point 0 m from the center? Consider the merry-go-round is a solid 63 kg cylinder of radius of 1.5 m. Answer in units of rad/s.

(b) What is the change in kinetic energy due to this movement? Answer in units of J.

5.22 Man Walking in Boat Problem

A 70.8 kg man sits on the stern of a 4.1 m long boat. The prow of the boat touches the pier, but the boat isn't tied. The man notices his mistake, stands up and walks to the boat's prow, but by the time he reaches the prow, it's moved 1.75 m away from the pier.

Assuming no water resistance to the boat's motion, calculate the boat's mass (not counting the man). Answer in units of kg.

6 Solids and Fluids

6.1 Formulas

Stress is Force/Area, F/A. Strain is $\Delta L/L_0$

Young's Modulus: $\frac{F}{A} = Y\frac{\Delta L}{L}$

Density: $\rho = M/V$; Pressure: $P = F/A$.

$$P_2 = P_1 + \rho g(y_1 - y_2)$$

Water has density of 1000 kg/m^3. 1 liter (L) is 1 m^3/1000 = 1000 cm^3. Atmospheric pressure is 1.013×10^5 Pa.

Pa = N/m^2.

Archimedes' Principle: The upward force on any stationary object partially or completely submerged in non-moving water is equal to the weight of the displaced water.

Continuity: $v_1 A_1 = v_2 A_2$

Bernoulli's Law: $P + \frac{1}{2}\rho v^2 + \rho g h =$ const

6.2 Bulk Modulus Problem

Find the density of seawater at a depth where the pressure is 160 atm if the density at the surface is 1025 kg/m^3. Seawater has a bulk modulus of 2.3×10^9 N/m^2. Bulk modulus is defined to be

$$B \equiv \frac{\rho_0 \Delta P}{\Delta \rho}$$

Answer in units of kg/m^3.

6.3 Block in Oil and Water Problem

Oil having a density of 930 kg/m^3 floats on water. A rectangular block of wood 4 cm high and with a density of 960 kg/m^3 floats partly in the oil and partly in the water. The oil completely covers the block.

How far below the interface between the two liquids is the bottom of the block? Answer in units of m.

6.4 Block on Spring Underwater Problem

A light spring of constant 160 N/m rests vertically on the bottom of a large beaker of water. A 5 kg block of wood of density 650 kg/m^3 is connected to the top of the spring and the block-spring system is allowed to come to static equilibrium.

What is the elongation ΔL of the spring? The acceleration of gravity is 9.8 m/s^2. Answer in units of cm.

6.5 Basic Pressure Problems

(a) How much pressure is applied to the ground by a 104 kg man who is standing on square stilts that measure 0.05 m on each edge? Answer in units of Pa.

(b) What is this pressure in pounds per square inch? Answer in units of lb/in^2.

6.6 Pressure Under the Ocean Problem

Calculate the depth in the ocean at which the pressure is three times atmospheric pressure. Atmospheric pressure is 1.013×10^5 Pa. The acceleration of gravity is 9.81 m/s^2 and the density of sea water is 1025 kg/m^3. Answer in units of m.

6.7 Object Immersed in Water and Oil Problem

An object weighing 300 N in air is immersed in water after being tied to a string connected to a balance. The scale now reads 265 N. Immersed in oil, the object appears to weigh 275 N.

(a) Find the density of the object. Answer in units of kg/m^3.

(b) Find the density of the oil. Answer in units of kg/m^3.

6.8 Hailstones on Windshield Problem

In a 30 s interval, 500 hailstones strike a glass window of area 0.6 m^2 at an angle $45°$ to the window surface. Each hailstone has a mass of 5 g and speed of 8 m/s.

(a) If the collisions are elastic, find the average force on the window. Answer in units of N.

(b) Find the pressure on the window. Answer in units of N/m^2.

6.9 Two Scales Buoyancy Problem

A beaker of mass 1 kg containing 2 kg of water rests on a scale. A 3 kg block of a metallic alloy of density 2700 kg/m^3 is suspended from a spring scale and is submerged in the water of density 1000 kg/m^3.

(a) What does the hanging scale read? The acceleration of gravity is 9.8 m/s^2. Answer in units of N.

(b) What does the lower scale read? Answer in units of N.

6.10 Water Squirting from Tank Problem

A jet of water squirts out horizontally from a hole 1 m from the bottom of the tank and to a point 0.6 m right from the tank.

If the hole has a diameter of 3.5 mm, what is the height of the water above the hole in the tank? Answer in units of cm.

6.11 Oil in Horizontal Pipe Problem

A horizontal pipe of diameter 1 m has a smooth constriction to a section of diameter 0.6 m. The density of oil flowing in the pipe is 821 kg/m^3.

If the pressure in the pipe is 8000 N/m^2 and in the constricted section is 6000 N/m^2, what is the rate at which oil is flowing? Answer in units of m^3/s

6.12 Fireman Hose Problem

A fireman standing on a 10 m high ladder operates a water hose with a round nozzle of diameter 2 inch. The lower end of the hose (10 m below the nozzle) is connected to the pump outlet of diameter 3 inch. The gauge pressure of the water at the pump is

$$\begin{aligned} P^{\text{(gauge)}}_{\text{pump}} &= P^{\text{(abs)}}_{\text{pump}} - P_{\text{atm}} \\ &= 43.2\text{PSI} = 297.854\text{kPa} \end{aligned}$$

Calculate the speed of the water jet emerging from the nozzle. Assume that water is an incompressible liquid of density 1000 kg/m^3 and negligible velocity. The acceleration of gravity is 9.8 m/s^2. Answer in units of m/s.

6.13 U Tube Problem

A heavy liquid with a density 13.6 g/cm^3 is poured into a U-tube. The left-hand arm of the tube has a cross-sectional area of 10 cm^2, and the right-hand arm has a cross-sectional area of 5 cm^2. A quantity of 100 g of a light liquid with a density 1 g/cm^3 is then poured into the right-hand arm.

(a) Determine the height L of the light liquid in the column in the right arm of the U-tube. Answer in units of cm.

(b) If the density of the heavy liquid is 13.6 g/cm^3, by what height h_1 does the heavy liquid rise in the left arm? Answer in units of cm.

7 Waves and Sound

7.1 Formulas

Simple Harmonic Motion: $F(x) = ma = -kx$

$x(t)$ and $v(t)$ are the same as if the mass is traveling around a circle of radius A with velocity $v_{\mathsf{max}} = 2\pi A/T = \omega A$, but one keeps track of only motion in the x direction.

$$x = A\cos(2\pi t/T) \qquad v = v_{\mathsf{max}}\sin(2\pi t/T)$$

$$\omega = 2\pi f = 2\pi/T = \sqrt{k/m}$$

Pendulum: $F = -mgs/L \implies \omega = \sqrt{g/L}$

$$T = 2\pi\sqrt{L/g}$$

Waves: $v = \frac{\lambda}{T} = f\lambda$

Transverse wave on a string: $v = \sqrt{F/\mu}$; $\mu = m/L$

- Superposition: Two waves traveling through each other simply add point by point
- Waves reflecting off fixed ends reverse direction and amplitude
- Waves reflecting off free ends reverse direction but not amplitude

Longitudinal waves:

Bulk modulus: $B = -\frac{\Delta P}{\Delta V/V}$

$$v = \sqrt{B/\rho} \qquad v = \sqrt{Y/\rho}$$

For sound in air: $v \approx 331$ m/s $\sqrt{\frac{T}{273K}}$

For a string fixed at both ends.

$$f_1 = v\lambda_1 = v/(2L) = \frac{1}{2L}\sqrt{F/\mu}$$

$$f_n = nf_1 = \frac{n}{2L}\sqrt{F/\mu}, \text{ where } n = 1, 2, 3, \ldots$$

Here n describes the n'th harmonic. For a standing wave in an air column closed at one end and open at the other,

$$f_n = nf_1 = \frac{nv}{4L}, \text{ where } n = 1, 3, 5, \ldots$$

Sound: $I = \frac{P}{A}, I_0 = 10^{-12}$ W/m^2; Threshold of pain: 1 W/m^2.

$$\beta = 10\log_{10}(I/I_0)$$

Spherical waves:

$$I = P_{\mathsf{ave}}/4\pi r^2$$

7.2 Temperature of Air Problem

A sound wave has a frequency of 700 Hz in air and a wavelength of 0.5 m.

What is the temperature of the air? Relate the speed of sound in air to temperature in units of Kelvin, but answer in units of Celsius. Assume the velocity of sound at 0°C is 331 m/s. Answer in units of $\deg$ C.

7.3 Rock Band Music Problem

A rock group is playing in a bar. Sound emerging from the door spreads uniformly in all directions. The intensity level of the music is 80 dB at a distance of 5 m from the door.

At what distance is the music just barely audible to a person with a normal threshold of hearing? Disregard absorption. Answer in units of m.

7.4 Intensity of Chorus Problem

The sound level produced by one singer is 80 dB.

What would the sound level produced by a chorus of 29 such singers (all singing at the same intensity at approximately the same distance as the original singer)? Answer in units of dB.

7.5 String Harmonics Problem

A cello string vibrates in its fundamental mode with a frequency of 220 1/s. The vibrating segment is 70 cm long and has a mass of 1.2 g.

(a) Find the tension in the string. Answer in units of N.

(b) Find the frequency of the string when it vibrates in three segments. Answer in units of 1/s.

7.6 Spring Constant Problem

A common technique used to measure toe force constant k of a spring is the following:

Hang the spring vertically, then allow a mass m to stretch if a distance d from the equilibrium position under the action of the "load" mg.

Find the spring constant k if the spring is stretched a distance 55 m by a suspended weight of 39 N. The acceleration of gravity is 9.8 m/s^2. Answer in units of N/m.

7.7 String Stretched Twice Problem

A load of 50 N attached to a spring hanging vertically stretches the spring 5 cm. The spring is now placed horizontally on a table and stretched 11 cm.

What force is required to stretch it by this amount? Answer in units of N.

7.8 Half of Max Speed SHM Problem

A particle executes simple harmonic motion with an amplitude of 3 cm.

At what positive displacement from the midpoint of its motion does its speed equal one half of its maximum speed? Answer in units of cm.

7.9 Tension in Phone Cord Problem

A phone cord is 4 m long. The cord has a mass of 0.2 kg. A transverse wave pulse is produced by plucking one end of the taut cord. The pulse makes four trips down and back along the cord in 0.8 s.

What is the tension in the cord? Answer in units of N.

8 Thermal Energy and the Laws of Thermodynamics

8.1 Formulas

Zeroth Law of Thermodynamics: Objects in equilibrium are at same temperature

$$T_F = \frac{9}{5}T_C + 32; T = T_C + 273.15$$
$$\Delta L = \alpha L_0 \Delta T \text{(Thermal Expasion)}$$
$$N_A = 6.02 \times 10^{23} \text{particles/mole}$$
$$k_B = 1.3806 \times 10^{23} J/K \qquad R = 8.314\text{J/mole/K}$$
$$PV = Nk_BT; \qquad PV = nRT \text{(Ideal Gas, } T \text{in Kelvin)}$$
$$P = \frac{2}{3}\left(\frac{N}{V}\right)\frac{1}{2}m\overline{v^2}$$
$$\frac{1}{2}m\overline{v^2} = \frac{3}{2}k_BT$$
$$U = \frac{3}{2}nRT$$

$mc\Delta T = Q = nC\Delta T$ (Specific Heat)

$mL = Q$ (Latent Heat)

Second Law of Thermodynamics: Heat always flows spontaneously from hot to cold:

Thermal Conductivity:
$$\frac{Q}{t} = \frac{\kappa A(T_h - T_c)}{L} = \frac{A(T_h - T_c)}{\sum_i R_i}, R = \frac{L}{\kappa}$$

First Law of Thermodynamics: Energy is conserved. W is $-PV$(area)

$$\Delta U = U_f - U_i = Q + W$$

Efficiency; $e = \frac{|W|}{|Q_h|} = \frac{|Q_h| - |Q_c|}{|Q_h|} = 1 - \frac{|Q_c|}{|Q_h|}$

$$e_C = 1 - \frac{T_c}{T_h}$$

$$\text{COP} = \frac{|Q_c|}{|W|} = \frac{|Q_c|}{|Q_h| - |Q_c|} \leq \frac{T_c}{T_h - T_c}$$

For a general process, $\Delta U = nC_V\Delta T$, $Q = \Delta U - W$, $W = PV$Area, $P - V = P(V)$.

For an isobaric process, $\Delta U = nC_V\Delta T$, $Q = nC_P\Delta T$, $W = -P\Delta V$, $P - V$ has $P =$ const

For an adiabatic process, $\Delta U = nC_V\Delta T$, $Q = 0$, $W = \Delta U$, $P - V$ has $PV^\gamma =$ const, where $\gamma = C_P/C_V$

For an isovolumetric process, $\Delta U = nC_V\Delta T$, $Q = \Delta U$, $W = 0$, and $P - V$ has $V =$ const

For an isothermal process, $\Delta U = 0$, $Q = -W$, $W = -nRT\ln\left(\frac{V_f}{V_i}\right)$, $P - V$ has $PV =$ const

8.2 Steel Track Expansion Problem

A steel railroad track has a length of 30 m when the temperature is 0° C.

(a) What is the increase in the length of the rail on a hot day when the temperature is 40° C? The linear expansion coefficient of steel is $11 \times 10^{-6}(^\circ$ C$)^{-1}$. Answer in units of m.

(b) Suppose the ends of the rail are rigidly clamped at 0° C to prevent expansion. Calculate the thermal stress in the rail if its temperature is raised to 40° C. Young's modulus for steel is 20×10^{10} N/m^2. Answer in units of N/m^2.

8.3 Mercury Thermometer Problem

A mercury thermometer is has a capillary tube with a diameter of 0.004 cm and a bulb with diameter of 0.25 cm.

Neglecting the expansion of the glass, find the change in height of the mercury column for a temperature change of 30° C. The volume expansion coefficient of mercury is $0.000182(^\circ$C$)^{-1}$. Answer in units of cm.

8.4 Concrete Expansion Problem

Two concrete spans of a 250 m long bridge are placed end to end so that no room is allowed for expansion.

If the temperature increases by 20° C, what is the height to which the spans rise when they buckle? Assume the thermal coefficient of expansion is $1.2 \times 10^{-5}(^\circ$ C$)^{-1}$. Answer in units of m.

8.5 Molecule escaping Earth Problem

If it has enough kinetic energy, a molecule at the surface of the Earth can escape the Earth's gravitation. The acceleration of gravity is 9.8 m/s^2 and the Boltzmanns' constant is 1.38066×10^{-23} J/K.

(a) Using energy conservation, determine the minimum kinetic energy needed to escape in terms of the mass of the molecule, m, the free-fall acceleration at the surface, g, and the radius of the Earth R.

(b) Calculate the temperature for which the minimum escape energy is 10 times the average kinetic energy of an oxygen molecule. Answer in units of K.

8.6 Railroad Spike Problem

A 0.75 kg spike is hammered into a railroad tie. The initial speed of the spike is equal to 3.0 m/s.

If the tie and spike together absorb 85 percent of the spike's initial kinetic energy as internal energy, calculate the increase in internal energy of the tie and spike. Answer in units of J.

8.7 Translational KE of Oxygen Problem

Find the total translational kinetic energy of 1 L of oxygen gas held at a temperature of 0° C and a pressure of 1 atm. Answer in units of J.

8.8 Pressure in a Tire Problem

An automobile tire having a temperature of -5° C (a cold tire on a cold day) is filled to a gauge pressure of 20 lb/in^2.

What would be the gauge pressure in the tire when its temperature rises to 20° C? For simplicity, assume that the volume of the tire remains constant, that the air does not leak out and that the atmospheric pressure remains constant at 14.7 lb/in^2. Answer in units of lb/in^2.

8.9 Average KE of a Gas Molecule Problem

Boltzmann's constant is 1.38066×10^{-23} J/K and the universal gas constant is 8.31451 J/K· mol.

If 2 mol of a gas is confined to a 5 L vessel at a pressure of 8 atm, what is the average kinetic energy of a gas molecule? Answer in units of J.

8.10 Climbing to Work Off Cake Problem

A 75 kg weight-watcher wishes to climb a mountain to work off the equivalent of a large piece of chocolate cake rated at 500 (food) calories.

How high must the person climb? The acceleration due to gravity is 9.8 m/s^2 and 1 food Calorie is 10^3 calories. Answer in units of km.

8.11 Bullet Fired into Steel Problem

A 4.2 g lead bullet moving at 275 m/s strikes a steel plate and stops.

If all its kinetic energy is converted to thermal energy and none leaves the bullet, what is its temperature change? Assume the specific heat of lead is 128 J/kg·° C. Answer in units of ° C.

8.12 Glass Thermometer in Hot Water Problem

A 300 g glass thermometer initially at 25° C is put into 200 cm^3 of hot water at 95° C.

Find the final temperature of the thermometer, assuming no heat flows to the surroundings. The specific heat of glass if 0.2 cal/g·° C and of water 1 cal/g·° C.

8.13 Water Freezing onto Ice Cube Problem

A 50 g ice cube at -20° C is dropped into a container of water at 0° C.

How much water freezes onto the ice? The specific heat of ice is 0.5 cal/g·° C and its heat of fusion is 80 cal/g. Answer in units of g.

8.14 Hot Ingot in Water Problem

A 0.05 kg ingot of metal is heated to 200° C and then is dropped into a beaker containing 0.4 kg of water initially at 20° C.

If the final equilibrium state of the mixed system is 22.4° C, find the specific heat of the metal. The specific heat of water is 4186 J/kg ·° C. Answer in units of J/kg·° C.

8.15 Brick Wall Conductivity Problem

The brick wall (of thermal conductivity 0.8 W/m·° C) of a building has dimensions of 4 m by 10 m and is 15 cm thick.

How much heat flows through the wall in a 12 h period when the average inside and outside temperatures are, respectively, 20° C and 5° C? Answer in units of MJ.

8.16 Ice added to Tea Problem

One liter of water at 30° C is used to make iced tea.

How much ice at 0° C must be added to lower the temperature of the tea to 10° C? The specific heat of water is 1 cal/g·° C and latent heat of ice is 79.7 cal/g. Answer in units of g.

8.17 Conductivity of Insulator Problem

A box with a total surface area os 1.2 m^2 and a wall thickness of 4 cm is made of an insulating material. A 10 W electric heater inside the box maintains the inside temperature at 15° C above the outside temperature.

Find the thermal conductivity of the insulating material. Answer in units of W/m·° C.

8.18 Tea in the Sun Problem

A jar of tea is placed in sunlight until it reaches an equilibrium temperature of 32° C. In an attempt to cool the liquid, which has a mass of 180 g, 112 g of ice at 0.0° C is added.

At the time at which the temperature of the tea is 31.7° C, find the mass of the remaining ice in the jar. The specific heat of water is 4186 J/kg·° C. Assume the specific heat capacity of the tea to be that of pure liquid water. Answer in units of g.

8.19 Three Liquids Problem

Three liquids are at temperatures of 10° C, 20° C, and 30° C, respectively. Equal masses of the first two liquids are mixed, and the equilibrium temperature is 17° C. Equal masses of the second and third are then mixed and the equilibrium temperature is 28° C.

Find the equilibrium temperature when equal masses of the first and third are mixed. Answer in units of ° C.

8.20 Ice in a Copper Cup Problem

A 40 g block of ice is cooled to -78° C. It is added to 560 g of water in an 80 g copper calorimeter at a temperature of 25° C.

Find the final temperature. The specific heat of copper is 387 J/kg·° C and of ice is 2090 J/kg·° C. The latent heat of fusion of water is 3.33×10^5 J/kg and its specific heat is 4186 J/kg·° C. Answer in units of ° C.

8.21 Refrigerator Power Problem

The interior of a refrigerator has a surface area of 4 m^2. It is insulated by a 3 cm thick material that has a thermal conductivity of 0.021 J/m· s · ° C. The ratio of the heat extracted from the interior to the work done by the motor is 7.5% of the theoretical maximum. The temperature of the room is 24° C, and the temperature inside the refrigerator is 0° C.

Determine the power required to run the compressor.

9 Electrostatics

9.1 Constants and units for chapter 9 through 16

Permittivity of free space: $\epsilon_0 = 8.85 \times 10^{-12}$ C^2/(N·m^2)

Coulomb constant: $k_e = \frac{1}{4\pi\epsilon_0} = 8.987 \times 10^9$ N·m^2/C^2

Permeability of free space: $\mu_0 = 4\pi \times 10^{-7}$ T·m/A

Speed of light in vacuum: $c = 3.00 \times 10^8$ m/s

Electron charge: $e = 1.604 \times 10^{-19}$ C

Electron mass: $m_e = 9.11 \times 10^{-31}$ kg

Proton mass: $m_p = 1.67 \times 10^{-27}$ kg

Unified atomic mass unit: $1u$ = 931.5 MeV/c^2

Planck's constant: $h = 6.63 \times 10^{-34}$ J·s

Electron Volt: 1 eV = 1.60×10^{-19} J

curie: 1 Ci = 3.70×10^{10} Bq

becquerel: 1 Bq = 1 decay/second

Radiation dose unit: 1 rad = 0.01 J/kg

9.2 Formulas

Coulomb's Law: $F = \frac{k_e |q_1||q_2|}{r^2}$

Definition of electric field: $\vec{E} = \vec{F}/q$

Position in a uniform E field:

$$x = x_0 + v_0 \Delta t + \frac{1}{2}\frac{qE}{m}\Delta t^2$$

Velocity (Δt) in a uniform E field:

$$v = v_0 + \frac{qE}{m}\Delta t$$

Velocity (Δx) in a uniform E field:

$$v_2 - v_0^2 = \frac{2qE}{m}\Delta x$$

Surface charge density: $\sigma = Q/A$

Electric field of a point charge: $\vec{E} = \left(\frac{k_e q}{r^2}\right)\hat{r}$

Gauss' law: $\varphi_E \equiv EA = Q_{\mathsf{inside}}/\epsilon_0$, where $\epsilon_0 = \frac{1}{4\pi k_e}$

Spherical symmetry: $\varphi_E = E 4\pi r^2$

Planar symmetry: $\varphi_E = E2A$ (two sides) or $\varphi_E = EA$ (one side)

Electric field due to an infinite sheet of charge: $E = \frac{\sigma}{2\epsilon_0}$

Relation between electric potential and potential energy: $\Delta V = \frac{\Delta PE}{q}$

Electric potential due to a point charge: $V = \frac{k_e q}{r}$

Relation between electric potential and potential energy: $\Delta V = Ed$

9.3 Three Point Charges Problem

Three point charges are located at the vertices of an equilateral triangle. The charge at the top vertex of the triangle is -6.3μC. The two charge q at the bottom vertices of the triangle are equal. A fourth charge -7μC is placed below the triangle 0.85 m on its symmetry-axis, and experiences a zero net force from the other three charges. The distance from the top vertex to either of the bottom vertices is 3.7 m.

Find q. The value of the Coulomb constant is 8.98755×10^9 N·m^2/C^2. Answer in units of μC.

9.4 Two Hanging Spheres Problem

Two identical small charged spheres of mass 0.03 kg hang in equilibrium with equal masses. The length of the strings are 0.15 m at an angle of 5° with the vertical.

Find the magnitude of the charge on each sphere. The acceleration of gravity is 9.8 m/s^2 and the value of Coulomb's constant is 8.98755×10^9 N·m^2/C^2. Answer in units of C.

9.5 Two Spheres Problem

Two identical small metal spheres with $q_1 > 0$ and $|q_1| > |q_2$ attract each other with a force of magnitude 85.3 mN when separated by a distance of 1.19 m/ The radius of each sphere is 25μm. The spheres are then brough together until they are touching, enabling the spheres to attain the same final charge q. After the charges on the spheres have come to equilibrium, they spheres are separated so that they are again 1.19 m apart. Now the spheres repel each other with a force of magnitude 17.06 mN.

(a) What is the final charge on the sphere on the right? The value of the Coulomb constant is 8.98755×10^9 N·m^2/C^2. Answer in units of μC.

(b) What is the initial charge q_1 on the first sphere? Answer in units of μC.

9.6 4 Charges in a Square Problem

Four point charges, each of magnitude 2 μC, are placed at the corners of a square 10 cm on a side.

If three of the charges are positive and one is negative, find the magnitude of the force experienced by the negative charge. The value of Coulomb's constant is 8.98755×10^9 N·m^2/C^2. Answer in units of N.

9.7 Three Charges in a Plane Problem

Three charges are arranged in the (x, y) plane where there is a 4 nC charge at the point $(0, 6)$, there is a -2 nC charge at $(0, 0)$ and a -3 nC charge at $(8, 0)$.

What is the magnitude of the resulting force (in nano-Newtons) on the -2 nC charge at the origin? The value of the Coulomb constant is 8.98755×10^9 N·m^2/C^2. Answer in units of nN.

9.8 Electrons in a Nickel Problem

We want to find how much charge is on the electrons in a nickel coin. Follow this method. A nickel coin has a mass of about 5 g.

(a) Find the number of atoms in a nickel coin. Each mole (6.02×10^{23} atoms) has a mass of about 58 g. Answer in units of atoms.

(b) Find the number of electrons in the coin. Each nickel atom has 28 electrons/atom. Answer in units of electrons.

(c) Find the magnitude of the charge of all these electrons. Answer in units of C.

9.9 Alpha Particle Fired at Nucleus Problem

In Rutherford's famous scattering experiments (which led to the planetary model of the atom), alpha particles (having charges of $+2\ e$ and masses of 6.64×10^{-27} kg) were fired toward a gold nucleus with charge $+79$ e. An alpha particle, initially very far from the gold nucleus, is fired at 2×10^{7} m/s directly toward the gold nucleus.

How close the alpha particle get to the gold nucleus before turning around? Assume the gold nucleus remains stationary. The fundamental charge is 1.602×10^{-19} C and the Coulomb constant is 8.98755×10^{9} N·m^2/C^2. Answer in units of m.

9.10 Four Charges in a Square Problem

Four charges are fixed at the corners of a square centered at the origin as follows: q at $(-a, +a)$; $2q$ at $(+a, +a)$; $-3q$ at $(+a, -a)$; and $6q$ at $(-a, -a)$. A fifth charge $+q$ with mass m is placed at the origin and released from rest.

Find the speed when it is a great distance from the origin, where the potential energy of the fifth charge due to the four point charges is negligible.

9.11 Electron Through Electric Field Problem

An electron traveling at 3×10^{6} m/s enters a 0.1 m region with a uniform electric field of 200 N/C.

(a) Find the magnitude of the acceleration of the electron while in the electric field. The mass of an electron is 9.109×10^{-31} kg and the fundamental charge is 1.602×10^{-19} C. Answer in units of m/s^2.

(b) Find the time it takes the electron to travel through the region of the electric field, assuming it doesn't hit the side walls. Answer in units of s.

(c) What is the magnitude of the vertical displacement Δy of the electron while it is in the electric field? Answer in units of m.

10 Capacitors and DC Circuits

10.1 Formulas

Definition of capacitance: $C = Q/V$

Energy stored in a capacitor:

$$U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

Parallel plate capacitance w/o dielectric: $C = \epsilon_0 A/d$

Parallel plate capacitance w/ dielectric: $C = \kappa\epsilon_0 A/d$

Capacitors in series: $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$

Capacitors in parallel: $C = C_1 + C_2 + \cdots + C_n$

Definition of current: $i = \Delta Q/\Delta t$

Current and drift velocity: $I = nqv_d A$

Definition of resistance: $R = \Delta V/I$

Resistance of a wire: $R = \rho l/A$

Temperature variation of resistivity:

$$\rho = \rho_0[1 + \alpha(T - T_0)]$$

Power dissipation in a resistor:

$$P = I\Delta V = I^2 R = \frac{\Delta V^2}{R}$$

Steps: in application of Kirchhoff's Rules

- Label current: $i_1, i_2, i_3, \ldots$
- Node equation: $\sum i_{\text{in}} = \sum i_{\text{out}}$
- Loop equation: $\sum(\pm V) + \sum \mp iR = 0$

Resistors in series: $R = R_1 + R_2 + \cdots + R_n$

Resistors in parallel: $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$

Charging in an RC circuit: $q(t) = Q(1 - e^{-t/RC})$

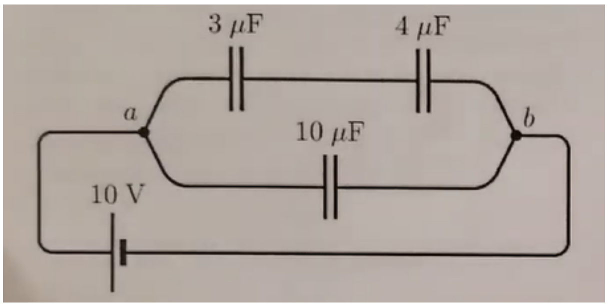
Discharging in an RC circuit: $q(t) = Qe^{-t/RC}$, where RC = τ is the time constant.

10.2 Electrons Through a Resistor Problem

If 5×10^{21} electrons pass through a 20Ω resistor in 10 min, what is the potential difference across the resistor? The fundamental charge is 1.602×10^{-19} C. Answer in units of V.

10.3 Voltage across a capacitor problem

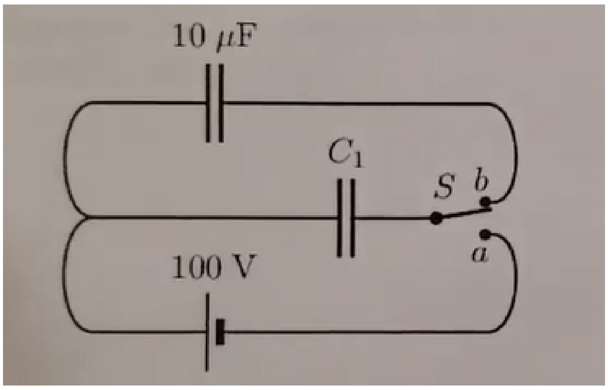
Consider the capacitor network



What is the voltage across the 4 μF (upper right hand) capacitor? Answer in units of V.

10.4 Unknown Capacitance Problem

When the switch is in position a, an isolated capacitor of unknown capacitance has been charged to a potential difference of 100 V. When the switch is moved to position b, this charged capacitor is then connected parallel to the uncharged 10 μF capacitor. The voltage across the combination becomes 30 V.



Calculate the unknown capacitance. Answer in units of μF.

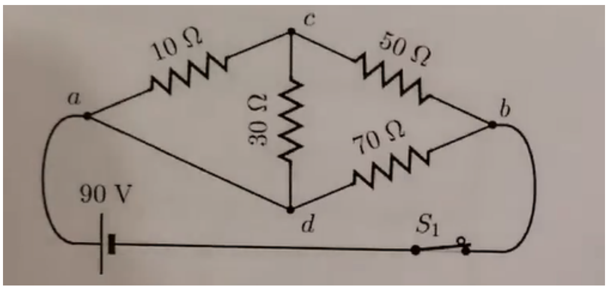
10.5 Drift Velocity Problem

An aluminum wire with a cross-sectional area of 4×10^{-6} m^2 carries a current of 5 A.

Find the drift speed of the electrons in the wire. Assume that each atom supplies one electron. Aluminum has a molecular weight of 26.98 g/mol and a density of 2.7 g/cm^3. Avogadro's number is 6.022×10^{23} and the fundamental charge is 1.602×10^{-19} C. Answer in units of m/s.

10.6 Equivalent Resistance Problem

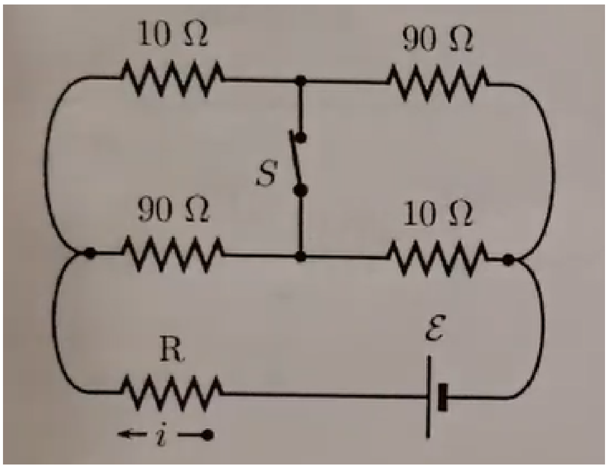
Four resistors are connected as shown in the figure.



Find the resistance between points a and b. Answer in units of Ω.

10.7 Find R in Circuit with Switch Problem

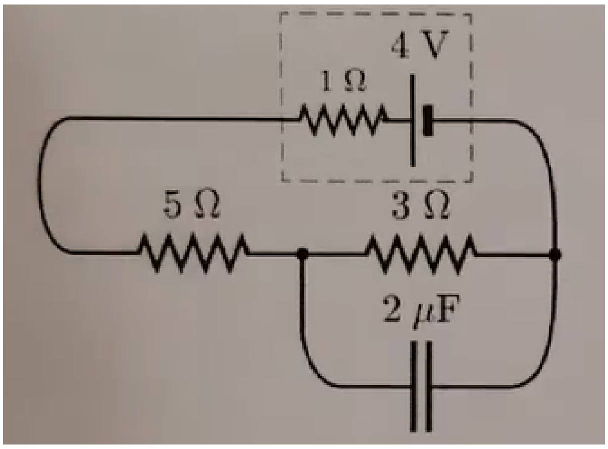
In the circuit shown below, the current i in the resistor R doubles its original value when the switch S is closed.



Find the value of R. Answer in units of Ω.

10.8 Charge on Capacitor Problem

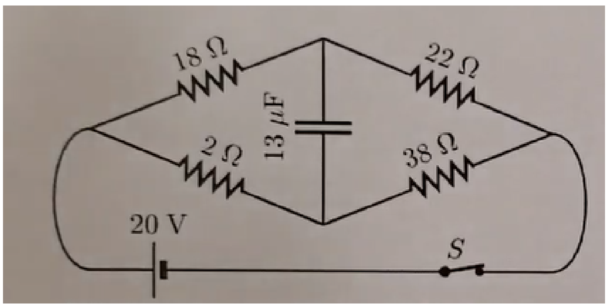
In the figure below the battery has an emf of 4 V and an internal resistance of 1Ω. Assume there is a steady current flowing in the circuit.



Find the charge on the 2 μF capacitor. Answer in units of μC.

10.9 Voltage across Capacitor Problem

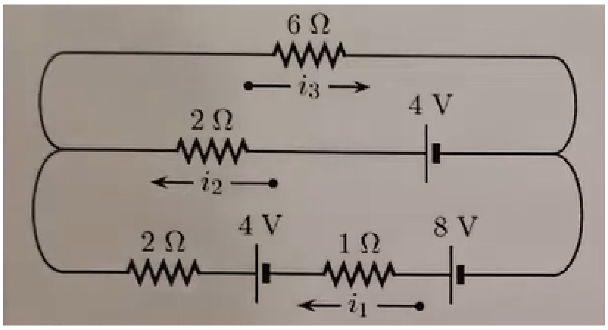
The circuit has been connected as shown in the figure for a "long" time.



What is the magnitude of the electric potential across the capacitor? Answer in units of V.

10.10 Two Loop Circuit Problem

Consider the circuit



Find i_1. Answer in units of A.

11 Magnetism

11.1 Formulas

Magnetic force on a moving charge: $F = qvB\sin\theta$

Magnetic force on a current carrying wire: $F = BIl\sin\theta$

Magnetic moment of a current carrying coil of N turns: $\mu = NIA$

Torque on a current carrying coil: $\tau = \mu B\sin\theta$

Radius of uniform circular motion of a charged particle in a magnetic field: $r = \frac{mv}{qB}$

Magnetic field of a long straight wire: $B = \frac{\mu_0 I}{2\pi r}$

Ampere's Law: $\sum B_{\|}\Delta l = \mu_0 I$

Magnetic force between two parallel wires: $\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$

Magnetic field at the center of a circular coil: $B = \frac{\mu_0 I}{2r}$

Magnetic field inside a solenoid: $B = \mu_0 nI = \mu_0 NI/l$

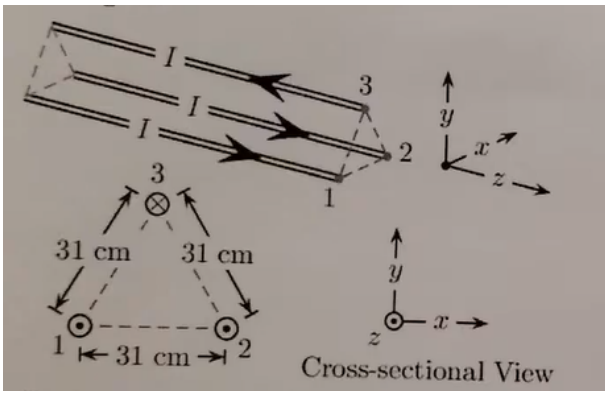
11.2 Electron Orbiting Hydrogen Atom Problem

In Niels Bohr's 1913 model of the hydrogen atom, and electron circles the proton at a distance of 8.24×10^{-11} m with a speed of 9.16×10^{5} m/s. The permeability of free space is 1.25664×10^{-6} T· m/A.

Compute the magnetic field strength that this motion produces at the location of the proton. Answer in units of T.

11.3 Three Parallel Wires Problem

Three very long wires are strung parallel to each other as shown in the figure below. Each wire is at a distance 31 cm from the other two, and each wire carries a current of magnitude $I = 3.3$ A in the directions shown in the figure.



Find the magnitude of the net force per unit length exerted on the upper wire (wire 3) by the other two wires. Answer in units of N/m.

11.4 Energy of Undeflected Electron Problem

The charge on an electron is 1.60218×10^{-19} C and its mass is 9.10939×10^{-31} kg.

What is the kinetic energy of an electron that passes undeviated through perpendicular electric and magnetic fields if $E = 0.23$ kV/m and $B = 1.5$ mT? Answer in units of eV.

11.5 Torque on Circular Loop Problem

A circular loop of radius 3.82 cm contains 64 turns of tightly wound wire.

If the current in the windings is 0.328 A and a constant magnetic field of 0.384 T makes an angle of $66°$ with a vector perpendicular with the loop, what torque acts on the loop? Answer in units of N·m.

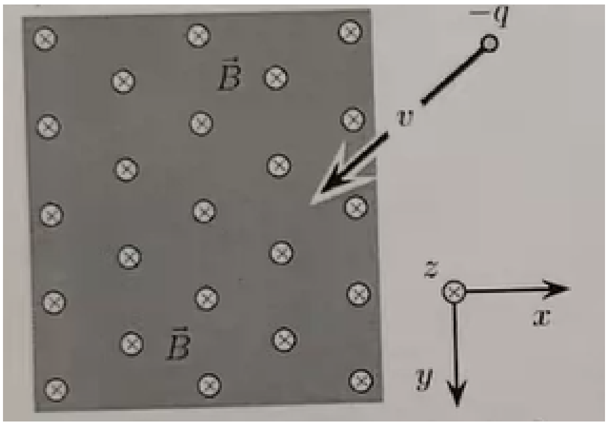
11.6 Dropped Steel Beam Problem

A 8.97 m long steel beam is accidentally dropped by a construction crane from a height of 12.3 m. The horizontal component of the Earth's magnetic field over the region is 23.3 μT. The acceleration of gravity is 9.8 m/s^2.

What is the induced emf in the beam just before impact with the Earth, assuming its long dimension remains in a horizontal plane, oriented perpendicularly to the horizontal component of the Earth's magnetic field? Answer in units of mV.

11.7 Right Hand Rule Problems

A negatively charged particle moving at $45°$ angles to both the x-axis and y-axis enters a magnetic field (pointing into of the page), as shown. $\hat{\imath}$ is in the x-direction, $\hat{\jmath}$ is in the y-direction, and $\hat{k}$ is in the z-direction.



What is the initial direction of deflection?

12 Induction and AC Circuits

12.1 Formulas

Faraday's law of induction: $\Delta V = -N\Delta\varphi_B/\Delta t$ where the magnetic flux $\varphi_B = BA\cos\theta$

Induced emf in a wire moving $\perp$ to a magnetic field (Hall Effect): $\Delta V = \epsilon = Blv$

Induced emf in a wire moving in a magnetic field: $\Delta V = Blv\sin\theta$

Maximum emf in a generator: $\Delta V = NBA\omega$

Definition of self inductance L: $\Delta V = -L\Delta I/\Delta t$

Energy stored in an inductor: $U = LI^2/2$

RL circuit with $I_0 = 0$: $I(t) = I_{\mathsf{max}}(1 - e^{-Rt/L})$

AC current RMS value: $I_{\mathsf{rms}} = I_{\mathsf{max}}/\sqrt{2}$

AC voltage RMS value: $\Delta V_{\mathsf{rms}} = \Delta V_{\mathsf{max}}/\sqrt{2}$

Reactance of a capacitor: $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$

Reactance of an inductor: $X_L = \omega L = 2\pi fL$

Impedance of a series RLC circuit: $Z = \sqrt{R^2 + (X_L - X_C)^2}$

Amplitudes: $V_R = IR, VL = IX_L, V_C = IX_C$, and $\epsilon = IZ$

Angular frequency at resonance: $\omega_0 = 2\pi f = \frac{1}{\sqrt{LC}}$

AC transformer: $I_1/I_2 = \Delta V_2/\Delta V_1 = N_2/N_1$

12.2 Dropped Steel Beam Problem

A 11.5 m long steel beam is accidentally dropped by a construction crane from a height of 5.41 m. The horizontal component of the Earth's magnetic field over the region is 12.9 μT. The acceleration of gravity is 9.8 m/s^2.

What is the induced emf in the beam just before impact with the Earth, assuming its long dimension remains in a horizontal plane, oriented perpendicularly to the horizontal component of the Earth's magnetic field? Answer in units of mV.

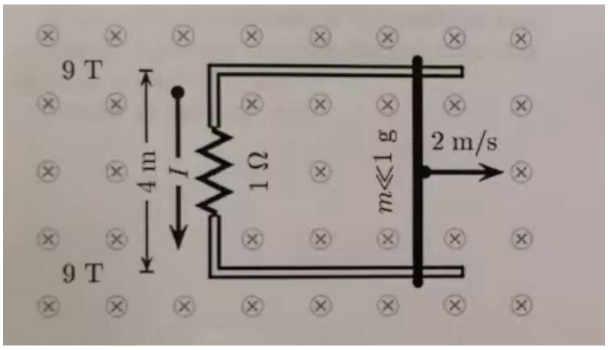
12.3 Energy Stored in Inductor Problem

An inductor of 140 turns has a radius of 5 cm and a length of 28 cm. The permeability of free space is 1.25664×10^{-6} N/A^2.

Find the energy stored in it when the current is 0.4 A. Answer in units of J.

12.4 Force on a Bar Problem

In the arrangement shown in the figure, the resistor is 1Ω and a 9 T magnetic field is directed into the paper. The separation between the rails is 4 m. An applied force moves the bar to the right at a constant speed of 2 m/s.



Calculate the applied force required to move the bar to the right at a constant speed of 2 m/s. Assume the bar and rails have negligible resistance and friction. Neglect the mass of the bar. Answer in units of N.

12.5 Rate of Change of Current in Inductor Problem

An inductor in the form of an air-core solenoid contains 183 turns, is of length 22.7 cm, and has a cross-sectional area of 1.2 cm^2. The permeability of free space is 1.25664×10^{-6} N/A^2.

What is the magnitude of the uniform rate of change in current through the inductor that induces an emf of 275 μV? Answer in units of A/s.

12.6 Change in Field of Rectangular Coil Problem

The plane of a rectangular coil, 6.9 cm by 3.6 cm, is perpendicular to the direction of a uniform magnetic field B.

If the coil has 75 turns and a total resistance of 8.9Ω, at what rate must the magnitude of B change to induce a current of 0.04 A in the windings of the coil? Answer in units of T/s.

12.7 Inductor with Series in Lamp Problem

A 0.834 H inductor is connected in series with a fluorescent lamp to limit the current drawn by the lamp.

If the combination is connected to a 67 Hz, 125 V line, and if the voltage across the lamp is to be 46.2 V, what is the current in the circuit? (The lamp is a pure resistive load.) Answer in units of A.

13 Electromagnetic Waves and Wave Optics

13.1 Formulas for Chapter 13 and Chapter 14

Note these are for this chapter and the next chapter.

EM waves in vacuum: $E/B = c = 1/\sqrt{\mu_0 \epsilon_0}$

Relationship between wavelength and frequency: $c = \lambda f$

Intensity of EM wave: $I = \text{Power/Area} = \frac{E_{\text{max}} B_{\text{max}}}{2\mu_0}$

Intensity of point source at distance, r: $I = \frac{\text{Power}}{4\pi r^2}$

Power: $P = \Delta E/\Delta t$

Index of refraction: $n = c/v = \lambda_0/\lambda_n$

Regular reflection: $\theta_{\text{incident}} = \theta_{\text{reflected}}$

Snell's law of refraction: $n_1 \sin\theta_1 = n_2 \sin\theta_2$

Critical angle for total internal reflection: $\sin\theta_c = n_2/n_1$

Ray tracing rules:

Mirror: Ray arriving at center of sphere (axis) reflects symmetrically. Ray parallel to axis, converges towards F (or diverges away from F), $f = R/2$

Lens: Ray through center of lens, undeflected. Ray parallel to axis, converges toward F (or diverges away from F).

Image: $d_i > 0$ (real), $d_i < 0$ (virtual)

Focal point f: at $d_0 = \infty$, $d_i = f$

$$f = \pm|f|, \text{ "+" convergent, "-" divergent}$$

Magnification: $M = h_i/h_0 = -d_i/d_0$

Power of a lens: $P = 1/f$

Two-lens magnification: $M = M_1 M_2$

Telescope angular magnification: $M = \theta'/\theta = -f_0/f_e$

Double slit interference: $d\sin\theta_{\text{bright}} = m\lambda$, $d\sin\theta_{\text{dark}} = (m + 1/2)\lambda$

Single slit diffraction minima: $a\sin\theta_{\text{dark}} = m\lambda$

Small angle approximation: $\sin\theta \approx \tan\theta = y/L$

Grating maxima: $d\sin\theta_{\text{bright}} = m\lambda$

Reflection phase change: 180° from denser medium (larger n) and 0° from lighter medium (smaller n)

Malaus' law for polarized EM wave or light: $I = I_0 \cos^2\theta$

Polarization by reflection: Brewster's angle: $\tan\theta_b = n_2/n_1$

Unpolarized EM wave or light through a polarizer: $I = I_0/2$

Rayleigh's criterion for a circular aperture: $\theta_{\text{min}} = 1.22\lambda/D$

13.2 Power from a Radio Transmitter Problem

The amplitude of the electric field is 0.7 V/m 10 km from a radio transmitter.

What is the total power emitted by the transmitter, if one assumes that the radiation is emitted isotropically (uniformly in all directions)? The impedence of free space is 377 Ω. Answer in units of W.

13.3 Energy from the Sun through a Window Problem

The average energy per unit time per unit area that reaches the upper atmosphere of the Earth from the Sun, called the solar constant, is 1.35 kW/m^2. Because of absorption and reflection by the atmosphere, about 0.2 kW/m^2 reaches the surface of the earth on a clear day.

How much energy is collected during 2 h of daylight by a window that measures 1.2 m by 1.4 m? The window is on a mount that rotates, keeping the window facing the sun so the sun's rays remain perpendicular to the window. Answer in units of MJ.

13.4 High Power Laser Problem

High power lasers in factories are used to cut through cloth and metal. One such laser has a beam diameter of 0.825 mm and generates an electric field at the target having an amplitude of 1.02 MV/m. The speed of light is 2.99792×10^8 m/s the permeability of free space is $4\pi \times 10^{-7}$ T·N/A.

(a) What is the amplitude of the magnetic field produced? Answer in units of T.

(b) What is the intensity of the laser? Answer in units of W/m^2.

(c) What is the power dissipated? Answer in units of W.

13.5 EMF in Receiving Antenna Problem

An AM radio station broadcasts with an average power of 3.6 kW. A dipole receiving antenna 62.5 cm long is located 1.7 km from the transmitter. Assume the transmitter is a point source, the waves are traveling perpendicular to the axis of the receiving antenna, and that the source is far enough away that the wave amplitude is constant along the receiving antenna.

Compute the amplitude of the induced emf by this signal between the ends of the receiving antenna. $\mu_0 c = 377\Omega$ and 1.609 km = 1 mi. Answer in units of V.

13.6 Microwave Transmitter Problem

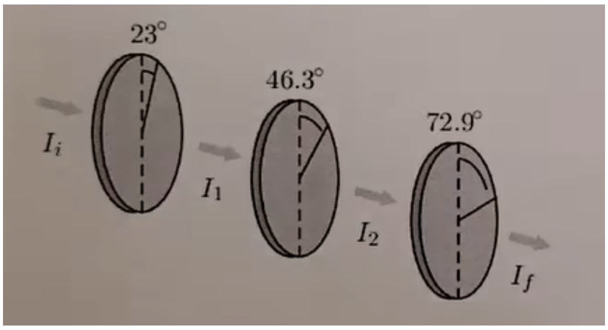
A microwave transmitter emits electromagnetic waves of a single wavelength. The maximum electric field 1.44 km from the transmitter is 8.39 V/m. The speed of light is 2.99792×10^8 m/s and the permeability of free space is $4\pi \times 10^{-7}$ N/A^2.

(a) Assuming that the transmitter is a point source and neglecting waves reflected from the Earth, calculate the maximum magnetic field at this distance. Answer in units of T.

(b) Calculate the total power emitted by the transmitter. Answer in units of W.

13.7 Three Polarizers Problem

Three polarizing disks whose planes are parallel are centered on a common axis. The directions of the transmission axes relative to the common vertical direction are shown. A linearly polarized beam of light with the plane of polarization parallel to the vertical reference direction is incident from the left on the first disk with intensity $I_i = 7.62$ units (arbitrary).



Calculate the transmitted intensity I_f when $\theta_1 = 23^{\circ}$, $\theta_2 = 46.3^{\circ}$, and $\theta_3 = 72.9^{\circ}$.

13.8 Two Glass Plates Problem

A hair is placed at one edge between two flat glass plates 10.3 cm long. When this arrangement is illuminated with 541 nm light, 120 bands are counted, starting at the point of contact of the two plates.

How thick is the hair? Answer in units of m.

13.9 Satellite Problem

A converging lens with a diameter of 41.5 cm forms an image of a satellite passing overhead. The satellite has two green lights (wavelength 492 nm) spaces 0.9 m apart.

If the lights can just be resolved according to the Rayleigh criterion, what is the altitude of the satellite? Answer in units of km.

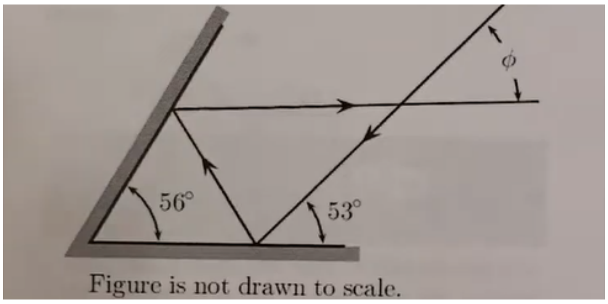
14 Geometric Optics

14.1 Formulas

Check chapter 13 formulas.

14.2 Two Mirrors Problem

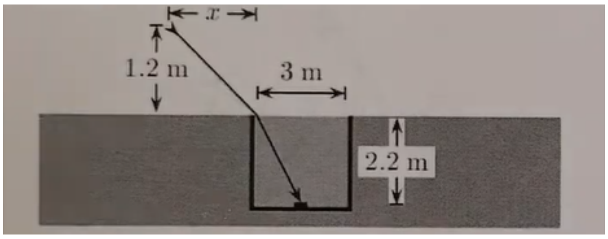
The reflecting surfaces of two intersecting flat mirrors are at an angle of 56°. A light ray strikes the horizontal mirror at an angle of 53° with respect to the mirror's surface.



Calculate the angle of φ. Answer in units of $^{\circ}$.

14.3 Liquid in a Cistern Problem

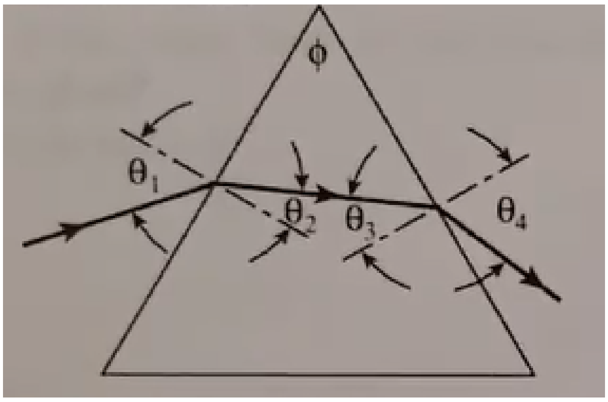
A cylindrical cistern, constructed below ground level, is 3 m in diameter and 2.2 m deep and is filled to the brim with a liquid whose index of refraction is 1.52. A small object rests on the bottom of the cistern at its center.



How far x from the edge of the cistern can a girl whose eyes 1.2 m from the ground stand and still see from the object? Answer in units of m.

14.4 Silica Prism Problem

Light of wavelength 700 nm is incident on the face of a silica prism at an angle of $\theta_1 = 75^{\circ}$ (with respect to the normal to the surface). The apex angle of the prism is $\varphi = 60^{\circ}$. The value of the index of refraction for silica is $n = 1.455$.



(a) Find the angle of refraction at this first surface. Answer in units of degrees.

(b) Find the angle of incidence at the second surface. Answer in units of degrees.

(c) Find the angle of refraction at the second surface. Answer in units of degrees.

(d) Find the angle between the incident and emerging rays. Answer in units of degrees.

14.5 Two Beams in Glass Problem

A certain kind of glass has an index of refraction of 1.65 for blue light of wavelength 430 nm and an index of 1.615 for red light of wavelength 680 nm. A beam containing these two colors is incident at an angle of 30° on a piece of this glass.

What is the angle between the two beams inside the glass? Answer in units of $^\circ$.

15 Quantum Physics

15.1 Formulas for Chapters 15 and 16

Mass-energy equivalence: $E = \gamma mc^2 = \sqrt{p^2c^2 + m^2c^4}$

Lorentz factor: $\gamma = \sqrt{1 - v^2/c^2}$

Photon energy: $E = hf - hc\lambda$

Photon momentum: $p = E/c$

Photoelectric effect: $KE_{\text{max}} = hf - \phi$

de Broglie wavelength: $\lambda = h/p$

Heisenberg's uncertainty principle: $\Delta x \Delta p_x \geq \frac{h}{4\pi}, \Delta E \Delta t \geq \frac{h}{4\pi}$

Bohr angular momentum quantization:

$$L = mvr_n = n\frac{h}{2\pi}(n = 0, 1, 2, 3, \dots)$$

Energy levels in hydrogen: $E_n = -13.6$ eV/n^2

Hydrogen spectrum wavelengths: $\frac{1}{\lambda} = R\{\frac{1}{n_f^2} - \frac{1}{n_i^2}\}$

Quantum numbers in atoms:

Principal quantum number: $n = 1, 2, 3, \dots$

Orbital angular momentum:

mag: $L = \sqrt{l(l+1)} \cdot \frac{h}{2\pi}(l = 0, 1, \dots, n-1)$

z component: $L_z = \frac{m_l h}{2\pi}(m_l = -l, \dots, 0, \dots l)$

Spin angular momentum:

mag: $S = \sqrt{s(s+1)} \cdot \frac{h}{2\pi}(s = \frac{1}{2}$ for electrons)

z component: $S_z = \frac{m_s h}{2\pi}(m_s = \pm\frac{1}{2})$

Mass number A, atomic number Z, and number of neutrons N: A = N + Z

Size of nucleus: $r = r_0 A^{1/3}$, where $r_0 = 1.2$ fm

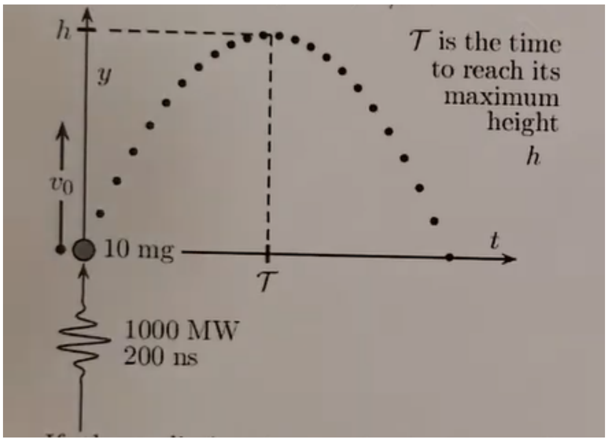
Radioactive decay: $N = N_0 e^{-\lambda t} = N_0 2^{-t/t_{1/2}}$ where $t_{1/2} = \ln 2/\lambda$

Decay rate: $R = \Delta N/\Delta t = 0.0693N/t_{1/2}$

Binding energy: BE = $\{[Zm(^1H) + Nm_n] - m(^AX)\}c^2$

15.2 Pulsed Laser Problem

A vertical pulsed laster fires a 1000 MW pulse of 200 ns duration at a small 10 mg pellet at rest. The pulse hits the mass squarely in the center of its bottom side. The speed of light is 3×10^8 m/s and the acceleration of gravity is 9.8 m/s^2.



If the radiation is completely absorbed without other effects, what is the maximum height the mass reaches? Answer in units of μm.

15.3 Solar Radiation Problem

Solar radiation falls on Earth's surface at a rate of 1400 W/m^2.

ASsuming that the radiation has an average wavelength of 550 nm, how many photons per square meter per second fall on the surfaces? The speed of light is 3×10^8 m/s and Planck's constant is 6.62607×10^{-34} J·s. Answer in units of photons/m^2·s.

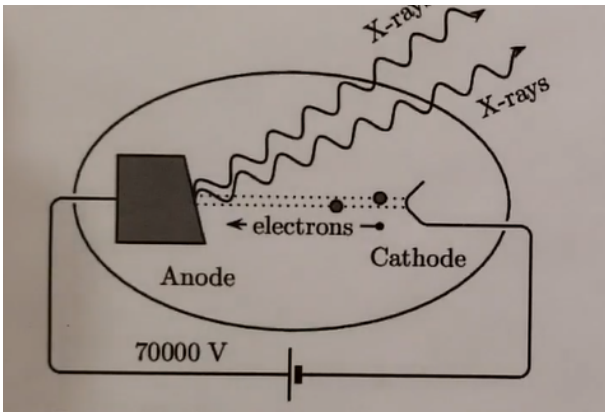
15.4 Electron Beam Diffraction Problem

A beam of electrons, each with the same kinetic energy, illuminates a pair of slits separated by a distance of 54 nm. The beam forms bright and dark fringes on a screen located a distance 1.5 m beyond the two slits. The arrangement is otherwise identical to that used in the optical two-slit interference experiment. The bright fringes are found to be separated by a distance of 0.68 mm.

What is the kinetic energy of the electrons in the beam? Planck's constant is 6.63×10^{-34} J·s. Answer in units of keV.

15.5 X-ray Tube Problem

In the X-ray tube shown, a potential difference of 70000 V is applied across the two electrodes. Electrons emitted from the cathode are accelerated to the anode, where X-rays are produced.



(a) Determine the maximum frequency of the X-rays produced by the tube. Answer in units of kHz.

(b) Find the maximum momentum of the X-ray photons produced by the tube. Answer in units of kg m/s.

15.6 Alpha Particle and Gold Nucleus Problem

(a) Find the speed of an alpha particle requires to come within 3.2×10^{-14} m of a gold nucleus. Coulomb's constant is 8.99×10^{9} N·m^2/C^2, the charge on an electron is 1.6×10^{-19}C, and the mass of the alpha particle is 6.64×10^{-27} kg. Answer in units of m/s.

(b) Find the energy of the alpha particle. Answer in units of MeV.

15.7 Lyman Series Problem

If, in

$$\frac{1}{\lambda} = R_y \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

you set $n_1 = 1$ and take n_2 greater than 1, you generate what is known as the Lyman series.

(a) Find the wavelength of the first member of this series. The value of $\hbar$ is 1.05457×10^{-34} J·s; the Rydberg constant for hydrogen is 1.09735×10^{7} m^{-1}; the Bohr radius is 5.29177×10^{-11} m; and the ground state energy for hydrogen is 13.6057 eV. Answer in units of nm.

(b) Consider the next three members of this series. The wavelengths of successive members of the Lyman series approach a common limit as $n_2 \to \infty$. What is this limit? Answer in units of nm.

15.8 Bohr Model Problem

Using the Bohr model, find the ionization energy of the ground He$^+$ ion. Answer in units of eV.

15.9 Energy of Magnetic Moment Problem

The potential energy of a magnetic moment in an external magnetic field is given by $U = -\mu \cdot \vec{B}$. The magnetic moment associated with the spin of an electron is 5.79×10^{-5} eV/T.

(a) Calculate the difference in energy between the two possible orientations of an electron in energy in a magnetic field $\vec{B} = (0.6\text{T})\hat{k}$. Answer in units of eV.

(b) If these electrons are bombarded with photos of energy equal to this energy difference, "spin flip" transitions can be induced. Find the wavelength of thie photons needed for such transitions. (This phenomenon is called electron spin resistance). Answer in units of cm.

16 Nuclear Physics

16.1 Formulas

Check chapter 15 formulas

16.2 Half-Life of Radioactive Substance Problem

Suppose that you start with 1.23 g of a pure radioactive substance and determine 4 h later that only 0.076875 g of the substance is left undecayed.

What is the half-life of this substance? Answer in units of h.

16.3 Radioactive Sample Activity Problem

A sample of radioactive isotope is found to have an activity of 115 Bq immediately after it is pulled from the reactor that formed the isotope. Its activity 2 h, 15 min later is measured to be 85.2 Bq.

(a) Find the decay constant of the sample. Answer in units of h^{-1}.

(b) Find the half-life of the sample. Answer in units of h.

(c) How many radioactive nuclei were there in the sample initially?

16.4 Rubidium Isotope Problem

The rubidium isotope ^{87}Rb is a β emitter with a half life of 4.9×10^{10} y that decays into ^{87}Sr. It is used to determine the age of rocks and fossils. Rocks containing the fossils of early animals contain a ratio of ^{87}Sr to ^{87}Rb of 0.01.

Assuming that there was no ^{87}Sr present when the rocks were formed, calculate the age of these fossils. Answer in units of y.

16.5 Reduced Activity of Sample Problem

A 200 mCi sample of a radioactive isotope is purchased by a medical supply house.

If the sample has a half-life of 14 d, how long will it keep before its activity is reduced to 20 mCi?

Answer in units of d.

16.6 Carbon Dating Charcoal Problem

A piece of charcoal used for cooking is found at the remains of an ancient campsite. A 1 kg sample of carbon from the wood has an activity of 2000 decays per minute.

Find the age of the charcoal. Living material has an activity of 15 decays/minute per gram of carbon present and the half-life of ^{14}C is 5730 y.

Answer in units of y.

17 Solutions

Solutions can be found via: