PHY231 Review

- Lecturer is Prof. J. Huston

- Final Exam, Thursday May 3, 8:00 – 10:00PM ANH 1281 (Anthony Hall)
- RCPD students: Thursday May 3, 5:00 – 9:00PM, BPS 3239
- Alternate Final Exam, Tuesday May 1, 10:00 – 12:00 PM, BPS 3239; BY APPOINTMENT ONLY, and deadline has past.

Kinematics Review

1D motion equations for constant acceleration

Velocity, Acceleration, Displacement, initial values at $t = 0$

$$v = v_o + at$$

$$x = \tfrac{1}{2}(v_o + v)t$$

$$v^2 = v_o^2 + 2ax$$

$$x = v_o t + \tfrac{1}{2}at^2$$

t = time relative to the start of the clock ($t = 0$)

x = displacement over the time t

v_0 = velocity at time $t = 0$

v = final velocity after time t or displacement x

a = constant acceleration (typical units: $\mathrm{m/s^2}$)

Kinematics Review

2D motion equations for constant acceleration

Velocities, Accelerations, Displacements, initial values at *t* = 0

x-direction

$$v_x = v_{ox} + a_x t$$

$$x = \tfrac{1}{2}\left(v_{ox} + v_x\right) t$$

$$v_x^2 = v_{ox}^2 + 2a_x x$$

$$x = v_{ox} t + \tfrac{1}{2} a_x t^2$$

y-direction

$$v_y = v_{oy} + a_y t$$

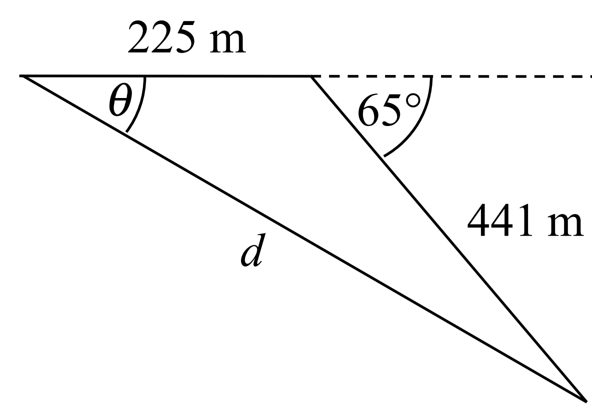
$$y = \tfrac{1}{2}\left(v_{oy} + v_y\right) t$$

$$v_y^2 = v_{oy}^2 + 2a_y y$$

$$y = v_{oy} t + \tfrac{1}{2} a_y t^2$$

FE-1. An eagle takes off from a tree branch on the side of a mountain and flies due west for 225 m in 19 s. Spying a mouse on the ground to the west, the eagle dives 441 m at an angle of 65° relative to the horizontal direction for 11 s to catch the mouse. Determine the eagle's average velocity for the thirty second interval.

a) 19 m/s at 44° below the horizontal direction
b) 22 m/s at 65° below the horizontal direction
c) 19 m/s at 65° below the horizontal direction
d) 22 m/s at 44° below the horizontal direction
e) 25 m/s at 27° below the horizontal direction



FE-1. An eagle takes off from a tree branch on the side of a mountain and flies due west for 225 m in 19 s. Spying a mouse on the ground to the west, the eagle dives 441 m at an angle of 65° relative to the horizontal direction for 11 s to catch the mouse. Determine the eagle's average velocity for the thirty second interval.

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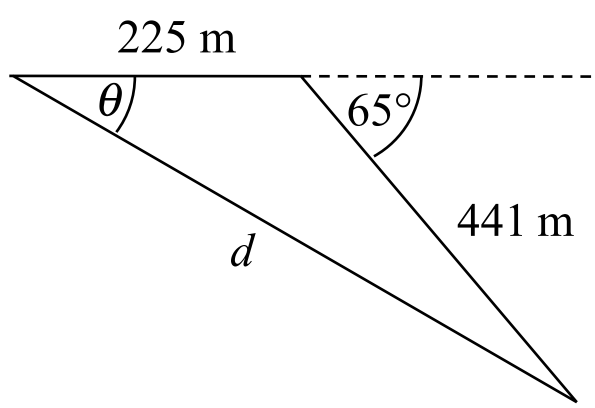
$$x = x_1 + x_2 = \left(225 + 441\cos 65°\right)\text{m} = 411\text{ m}$$

$$y = y_1 + y_2 = \left(0 + 441\sin 65°\right)\text{m} = 400\text{ m}$$

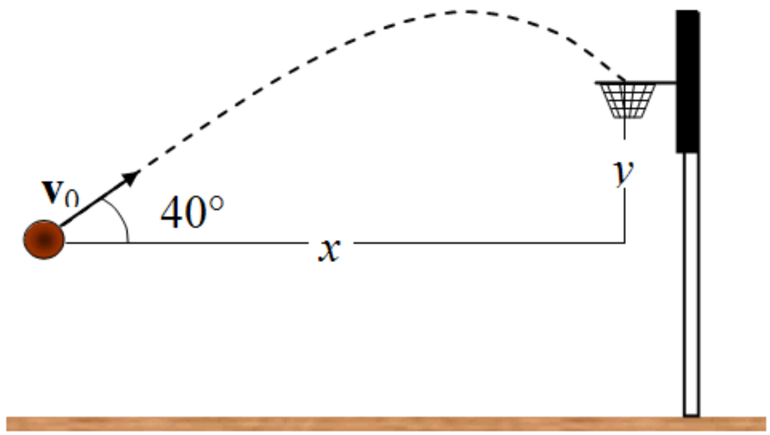
$$\bar{v} = \frac{d}{t} = \frac{\sqrt{x^2 + y^2}}{t} = \frac{574\text{ m}}{30\text{ s}} = \underline{19.1\text{ m/s}}$$

$$\theta = \tan^{-1}(y/x) = \tan^{-1}\left(0.973\right) = \underline{44.2°}$$



FE-2. A basketball is launched with an initial speed of 8.5 m/s and follows the trajectory shown. The ball enters the basket 0.92 s after it is launched. What are the distances x and y? **Note: The drawing is not to scale.**

a) $x = 6.3$ m, $y = 0.96$ m
b) $x = 5.4$ m, $y = 0.73$ m
c) $x = 5.7$ m, $y = 0.91$ m
d) $x = 7.6$ m, $y = 1.1$ m
e) $x = 6.0$ m, $y = 0.88$ m



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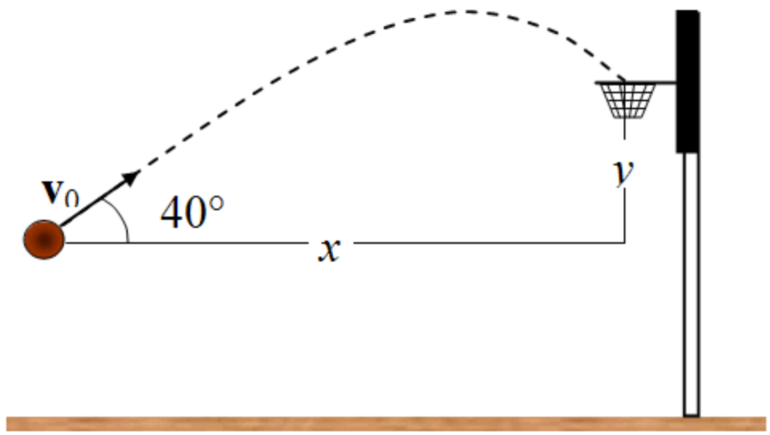

$$x = v_{0x} t = v_0 t \cos 40°$$
$$= (8.5\text{m/s})(0.92\text{ s})(0.77) = \underline{6.0\,\text{m}}$$
$$y = v_{0y} t - \tfrac{1}{2} g t^2$$
$$= (8.5\text{m/s})(0.92\text{s})\sin 40° - (0.5)(9.8\text{m/s}^2)(0.92\text{s})^2 = \underline{0.88\,\text{m}}$$

Dynamics Review

linear	rotational
x	θ
v	ω
a	α
m	$I = mr^2$ (point m)
F	$\tau = Fr\sin\theta$
p	$L = I\omega$

linear	rotational
$\vec{\mathbf{F}} = m\vec{\mathbf{a}}$	$\vec{\tau} = I\vec{\alpha}$
$\vec{\mathbf{p}} = m\vec{\mathbf{v}}$	$\vec{L} = I\vec{\omega}$
$W = Fs\cos\theta$	$W_{rot} = \tau\theta$
$KE = \frac{1}{2}mv^2$	$KE_{rot} = \frac{1}{2}I\omega^2$
$W \Rightarrow \Delta\text{KE}$	$W_{rot} \Rightarrow \Delta\text{KE}_{rot}$
$\vec{\mathbf{F}}\Delta t \Rightarrow \Delta\vec{\mathbf{p}}$	$\vec{\tau}\Delta t \Rightarrow \Delta\vec{L}$

Gravitational force: $F_G = Gm_1m_2 / r^2$

Gravitational PE

$PE_G = mgh$

Conservation laws

If $W_{\text{NC}} = 0$,
Conserved: $KE + PE$

If $\mathbf{F}_{ext} = 0$,
$\mathbf{P} = \sum \mathbf{p}$

If $\tau_{ext} = 0$,
$L = I\omega$

FE-3. If an object is moving can you conclude there are forces acting on it? If an object is at rest, can you conclude there are no forces acting on it? Consider each of the following situations. In which one of the following cases, if any, are there no forces acting on the object?

a) A bolt that came loose from a satellite in a circular orbit around the earth.
b) After a gust of wind has blown through a tree, an apple falls to the ground.
c) A man rests by leaning against a tall building in downtown Dallas.
d) Sometime after her parachute opened, the sky diver fell toward the ground at a constant velocity.
e) Forces are acting on all of the objects in choices a, b, c, and d.

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FE-4. On a rainy evening, a truck is driving along a straight, level road at 25 m/s. The driver panics when a deer runs onto the road and locks the wheels while braking. If the coefficient of friction for the wheel/road interface is 0.68, how far does the truck slide before it stops?

a) 55 m
b) 47 m
c) 41 m
d) 36 m
e) 32 m

FE-4. On a rainy evening, a truck is driving along a straight, level road at 25 m/s. The driver panics when a deer runs onto the road and locks the wheels while braking. If the coefficient of friction for the wheel/road interface is 0.68, how far does the truck slide before it stops?

a) 55 m
b) 47 m
c) 41 m
d) 36 m
e) 32 m

$$v_0 = +25 \text{ m/s}, \mu = 0.68, f = -\mu mg$$

$$v^2 = v_0^2 + 2ax; \quad \frac{f}{m} = a = -\mu g, v = 0$$

$$-v_0^2 = -2\mu gx$$

$$x = \frac{v_0^2}{2\mu g} = \frac{25^2}{2(0.68)(9.8)} = \underline{47\text{m}}$$

FE-5. A truck is traveling with a constant speed of 15 m/s. When the truck follows a curve in the road, its centripetal acceleration is 4.0 m/s^2. What is the radius of the curve?

a) 3.8 m
b) 14 m
c) 56 m
c) 120 m
e) 210 m

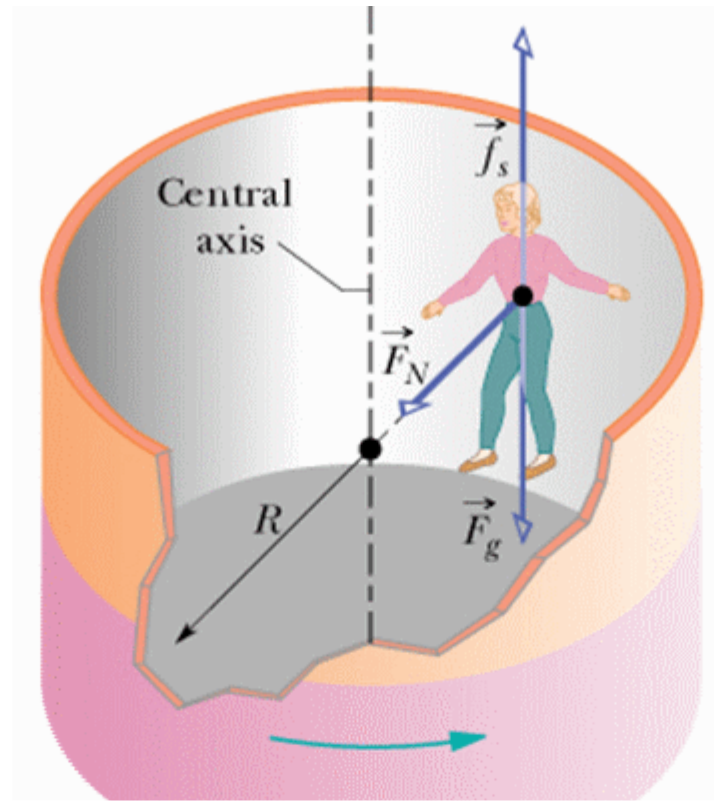
FE-5. A truck is traveling with a constant speed of 15 m/s. When the truck follows a curve in the road, its centripetal acceleration is 4.0 m/s². What is the radius of the curve?

a) 3.8 m
b) 14 m
c) 56 m
d) 120 m
e) 210 m

$$r = \frac{v^2}{a_c} = \frac{225\ \text{m}^2/\text{s}^2}{4.0\ \text{m/s}^2}$$

56 m

FE-6. The Rapid Rotor amusement ride is spinning fast enough that the floor beneath the rider drops away and the rider remains in place. If the Rotor speeds up until it is going twice as fast as it was previously, what is the effect on the frictional force on the rider?



a) The frictional force is reduced to one-fourth of its previous value.
b) The frictional force is the same as its previous value.
c) The frictional force is reduced to one-half of its previous value.
d) The frictional force is increased to twice its previous value.
e) The frictional force is increased to four times its previous value.

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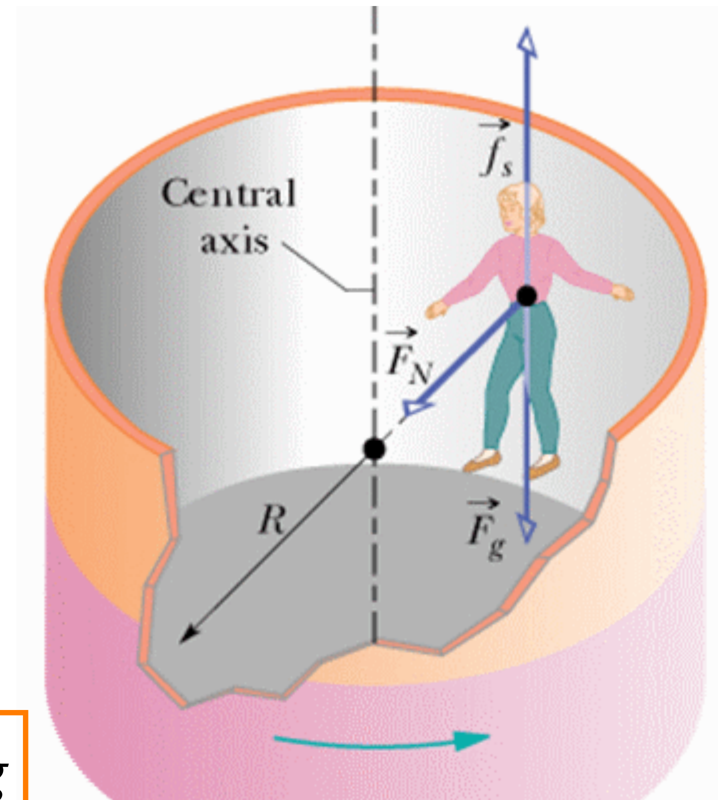

$$f^{MAX} = \mu F_{\perp},\ F'_{\perp} = 4F_{\perp}, \quad \text{but } f = F_G = mg$$

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FE-7. Determine the amount of work done in firing a 2.0-kg projectile with an initial speed of 50 m/s. Neglect any effects due to air resistance

a) 900 J
b) 1600 J
c) 2500 J
d) 4900 J
e) Need to know the launch angle

FE-7. Determine the amount of work done in firing a 2.0-kg projectile with an initial speed of 50 m/s. Neglect any effects due to air resistance

a) 900 J
b) 1600 J
c) 2500 J
d) 4900 J
e) Need to know the launch angle

$$W = \Delta KE \quad m = 2.0\text{kg}, v_0 = 0, v = 50 \text{ m/s}$$

$$= \tfrac{1}{2} m v^2 = 1\text{kg}(50 \text{ m/s})^2 = \underline{2500 \text{ J}}$$

FE-8. A roller coaster car travels down a hill and is moving at 18 m/s as it passes through a section of straight, horizontal track. The car then travels up another hill that has a maximum height of 15 m. If frictional effects are ignored, what is the speed of the car at the top of the hill?

a) Can’t make it up the hill.
b) 0 m/s
c) 5.5 m/s
d) 9.0 m/s
e) 18 m/s

FE-8. A roller coaster car travels down a hill and is moving at 18 m/s as it passes through a section of straight, horizontal track. The car then travels up another hill that has a maximum height of 15 m. If frictional effects are ignored, what is the speed of the car at the top of the hill?

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d) 9.0 m/s
e) 18 m/s

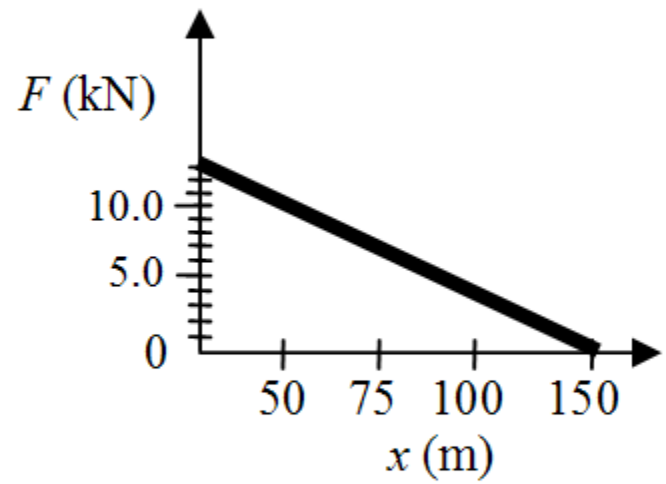
$$\tfrac{1}{2}mv_0^2 = \tfrac{1}{2}mv_f^2 + mgh$$

$$v_f = \sqrt{v_0^2 - 2gh} = \sqrt{(18)^2 - 2(9.8)(15)}$$

$$= 5.5 \text{ m/s}$$

FE-9. A 12 500-kg truck is accelerated from rest by a net force that decreases linearly with distance traveled. The graph shows this force. Using the information provided and work-energy methods, determine the approximate speed of the truck when the force is removed.

(NOTE: kN)



a) 8.41 m/s
b) 12.5 m/s
c) 17.7 m/s
d) 25.0 m/s
e) 35.4 m/s

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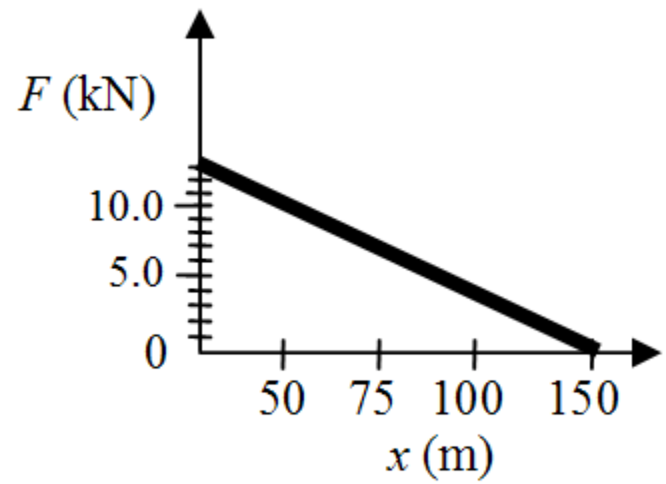

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b) 12.5 m/s
c) 17.7 m/s
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$$W_{net} \approx \bar{F}s = \left(6.5\times10^3\,\text{N}\right)(150\text{ m}) = 975\times10^3\,\text{J}$$

$$W_{net} = \Delta KE = \tfrac{1}{2}mv^2$$

$$v = \sqrt{\frac{2W_{net}}{m}} = \sqrt{\frac{1950\times10^3\text{ J}}{12{,}500\text{ kg}}} = \underline{12.5\text{m/s}}$$

FE-10 A small asteroid collides with a planet. Which one of the following statements concerning what happens during the collision is correct?

a) The asteroid exerts a smaller force on the planet than the planet exerts on the asteroid.
b) The planet exerts a force on the asteroid, but the asteroid does not exert a force on the planet.
c) The asteroid exerts the same amount of force on the planet as the planet exerts on the asteroid.
d) The asteroid exerts a force on the planet, but the planet does not exert a force on the asteroid.
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Newton's 3rd Law

d) The asteroid exerts a force on the planet, but the planet does not exert a force on the asteroid.

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FE-11 Ryan, m = 45 kg, runs and jumps off a stationary, 168-kg floating platform on a lake. Ryan's horizontal velocity as he leaps is +2.7 m/s. Ignoring any frictional effects, what is the recoil velocity of the platform?

a) –2.7 m/s
b) +0.72 m/s
c) 1.4 m/s
d) –0.72 m/s
e) +2.7 m/s

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d) –0.72 m/s
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No external forces ⇒ momentum is conserved.

$$P_i = P_f$$

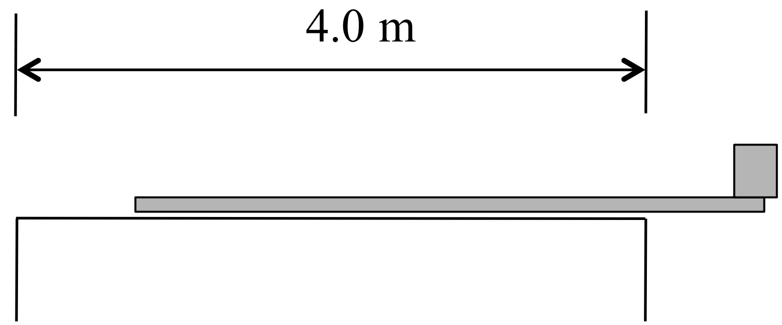
$$0 = p_{Ryan} + p_{plat}$$

$$m_{plat} v_{plat} = -m_{Ryan} v_{Ryan}$$

$$v_{plat} = -\frac{m_{Ryan}}{m_{plat}} v_{Ryan} = -\frac{45}{168}(+2.7\,\text{m/s})$$

$$= \underline{-0.72\,\text{m/s}}$$

FE-12 A 4.0-m board is resting directly on top of a 4.0-m long table. The weight of the board is 340 N. An object with a weight of 170 N is placed at the right end of the board. What is the maximum horizontal distance that the board can be moved toward the right such that the board remains in equilibrium?



a) 0.75 m
b) 1.0 m
c) 1.3 m
d) 1.5 m
e) 2.0 m

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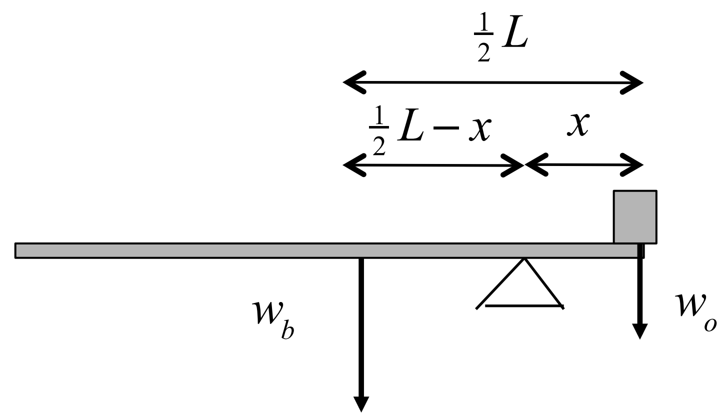
c) 1.3 m
d) 1.5 m
e) 2.0 m



x : amount that sticks out over the table

for equilibrium: $\tau_b + \tau_o = 0 = w_b(\frac{1}{2}L - x) - w_o x$

$$x = \frac{w_b}{w_b + w_o}\frac{1}{2}L = \frac{340}{340+170}(2\text{m}) = \underline{1.3\text{m}}$$

FE-13 A solid sphere of radius R rotates about an axis that is tangent to the sphere with an angular speed ω . Under the action of internal forces, the radius of the sphere increases to 2R. What is the final angular speed of the sphere?

a) $\omega_0 / 4$

b) $\omega_0 / 2$

c) ω_0

d) $2\omega_0$

e) $4\omega_0$

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a) $\omega_0 / 4$

b) $\omega_0 / 2$

c) ω_0

d) $2\omega_0$

e) $4\omega_0$

Only internal forces,

angular momentum conserved.

$$I_0\omega_0 = I_f\omega_f; \qquad I_0 \propto mR^2; \quad I_f \propto m(2R)^2 = 4mR^2$$

$$\omega_f = \frac{I_0}{I_f}\omega_0 = \frac{mR^2}{4mR^2}\omega_0$$

$$= \omega_0 / 4$$

Springs & Oscillations

Hooke's Law $F_A = kx$ Restoring Force $F_R = -kx$

Oscillations $\omega = \sqrt{k/m}$ Angular frequency $(\omega = 2\pi f = 2\pi/T)$

position $x = A\cos(\omega t)$

velocity $v_x = -A\omega\sin(\omega t)$

acceleration $a_x = -A\omega^2\cos\omega t$

Elastic PE $PE_S = \frac{1}{2}kx^2$

Pendulum $\omega_{\text{pendulum}} = 2\pi/T = \sqrt{g/L}$

Elastic Materials $F = Y\left(\frac{\Delta L}{L_o}\right)A$ Y is Young's modulus

FE-14 A steel ball is hung from a vertical ideal spring where it oscillates in simple harmonic motion with an amplitude of 0.157 m and an angular frequency of π rad/s. With time, $t = 0$, at the maximum vertical position, which one of the following expressions represents the acceleration, in m/s^2, of the ball as a function of time?

a) $-1.55 \cos \omega t$

b) $+1.55 \cos^2 \omega t$

c) $-0.157 \cos \omega t$

d) $-0.493 \cos^2 \omega t$

e) $-0.493 \cos \omega t$

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c) $-0.157\cos\omega t$

d) $-0.493\cos^2\omega t$

e) $-0.493\cos\omega t$

$$x = A\cos\omega t; \quad v = -A\omega\sin\omega t$$

$$a = -A\omega^2\cos\omega t; \quad A = 0.157\text{ m}, \quad \omega = \pi\text{ rad/s}$$

$$A\omega^2 = (0.157\text{ m})(\pi\text{ rad/s})^2 = 1.55\text{ m/s}^2$$

$$a = -1.55\cos\omega t;$$

FE-15 In designing a spring loaded cannon, determine the spring constant required to launch a 2.0-kg ball with an initial speed of 1.2 m/s from a position where the spring is displaced 0.15 m from its equilibrium position.

a) 16 N/m
b) 32 N/m
c) 64 N/m
d) 130 N/m
e) 180 N/m

FE-15 In designing a spring loaded cannon, determine the spring constant required to launch a 2.0-kg ball with an initial speed of 1.2 m/s from a position where the spring is displaced 0.15 m from its equilibrium position.

a) 16 N/m

b) 32 N/m

c) 64 N/m

d) 130 N/m

e) 180 N/m

$E_{total} = KE + PE$ is conserved

$E_f = KE = \frac{1}{2}mv^2; \quad E_i = PE_S = \frac{1}{2}kx^2;$

$\frac{1}{2}mv^2 = \frac{1}{2}kx^2$

$$k = \frac{mv^2}{x^2} = \frac{(2\text{kg})(1.2 \text{ m/s})^2}{(0.15\text{m})^2} = \underline{130 \text{ N/m}}$$

Fluids

Force derived from pressure on an area

$$F = PA$$

Pressure grows linearly with depth (h)

$$P_2 = P_1 + \rho g h$$

Buoyant force = Weight of displaced fluid

$F_B = \rho V g$, where ρV is the mass of displaced fluid

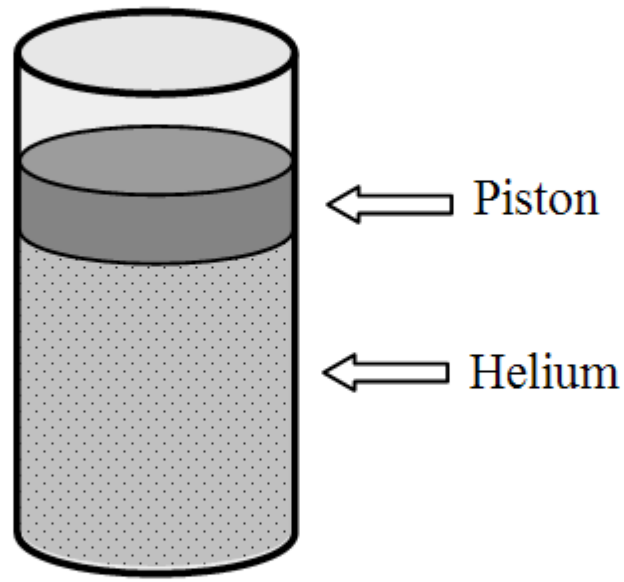
Bernoulli's equation for a nonviscous, incompressible fluid

$$P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g y_2$$

Poiseuille's Law (flow of viscous fluid)

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

FE-16 Helium gas is confined within a chamber that has a moveable piston. The mass of the piston is 8.7 kg; and its radius is 0.013 m. If the system is in equilibrium, what is the pressure exerted on the piston by the gas?



a) 1.639×10^4 Pa

b) 8.491×10^4 Pa

c) 1.013×10^5 Pa

d) 1.606×10^5 Pa

e) 2.619×10^5 Pa

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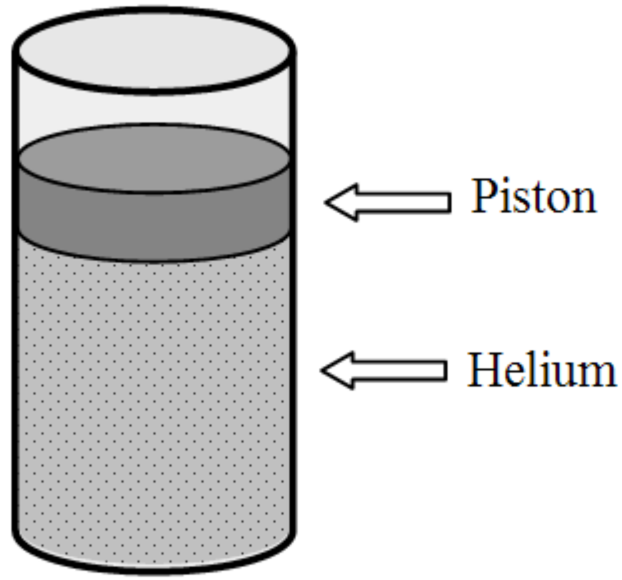

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b) 8.491×10^4 Pa

c) 1.013×10^5 Pa

d) 1.606×10^5 Pa

e) 2.619×10^5 Pa

$$P = \frac{F}{A} = \frac{mg}{\pi r^2} = \frac{8.7\text{kg}(9.8\text{ N/kg})}{3.14(.013\text{m})} = 1.606 \times 10^5 \text{ Pa}$$

FE-17 An above ground water pump is used to extract water from a well. A pipe extends from the pump to the bottom of the well. What is the maximum depth from which water can be pumped?

a) 19.6 m
b) 39.2 m
c) 10.3 m
d) 101 m
e) A big pump can lift an arbitrarily large column of water

FE-17 An above ground water pump is used to extract water from a well. A pipe extends from the pump to the bottom of the well. What is the maximum depth from which water can be pumped? (water density: $1x10^3$ kg/m^3) (atmospheric pressure: $1.01x10^5$ N/m^2)

a) 19.6 m

b) 39.2 m

c) 10.3 m

d) 101 m

e) A big pump can lift an arbitrarily large column of water

$$P = \frac{\rho V g}{A} = \rho g L$$

$$L = \frac{P}{\rho g} = \frac{1.01 \times 10^5 \text{ N/m}^2}{\left(1 \times 10^3 \text{kg/m}^3\right)\left(9.8 \text{N/kg}\right)}$$

$$= 10.3 \text{ m}$$

Temperature and Heat

Kelvin temperature scale

$$T_K = T_C + 273.15$$

Thermal Expansion

$$\Delta L = \alpha L_0 \Delta T$$

$$\Delta V = \beta V_0 \Delta T$$

Heat needed to make a temperature change to a solid or liquid

$$Q = mc\Delta T$$

$$\Delta T = \left(T_f - T_i\right)$$

Heat needed to make a phase change

$$Q = mL$$

Mixing heat sources with no loss of heat

$$\sum Q = \sum \left(mc\Delta T\right) + \sum \left(mL\right) = 0$$

FE-18 Elena's normal body temperature is 36.5 °C. When she recently became ill, her body temperature increased to 38.0 °C. What was the minimum amount of heat required for this increase in body temperature if her weight is 561 N? (specific heat 3500 J/kg•C)

a) 3.0×10^6 J

b) 3.5×10^3 J

c) 5.0×10^4 J

d) 3.1×10^5 J

e) 7.6×10^5 J

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e) 7.6×10^{5} J

$$\Delta T = (38 - 36.5)\ ^{\circ}\mathrm{C} = 1.5\ ^{\circ}\mathrm{C}$$

$$m = W / g = 561\mathrm{N} / (9.8\ \mathrm{N/kg}) = 60.2\ \mathrm{kg}$$

$$Q = mc\Delta T = (60.2\ \mathrm{kg})(3500\ \mathrm{J/kg \cdot C})(1.5\ ^{\circ}\mathrm{C})$$

$$= 3.1 \times 10^{5}\ \mathrm{J}$$

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$$= 3.1\times10^{5}\text{ J}$$

Ideal Gas Law & Thermodynamics

Ideal Gas Law

$PV = nRT \quad (\text{or } PV = NkT)$

$R = 8.31\ \text{J}/\left(\text{mole}\cdot\text{K}\right)$

$k = 1.38\times10^{-23}\ \text{J/K}$

Average Kinetic Energy
is proportional to Temperature

$\overline{KE} = \tfrac{1}{2}mv_{rms}^2 = \tfrac{3}{2}kT \quad (T \text{ in Kelvin})$

Internal Energy
monoatomic Ideal Gas

$U = \tfrac{3}{2}nRT$

1st Law: $\Delta U = Q - W$

$W = P\Delta V$ (isobaric)

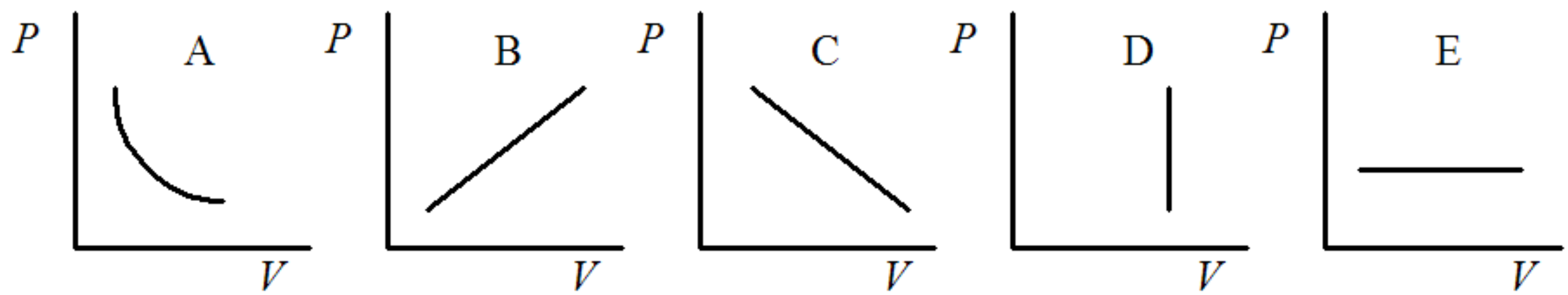
$W = \tfrac{3}{2}nR(T_i - T_f)$ (adiabatic)

$W = nRT\ln(V_f/V_i)$ (isothermal)

$e_{Carnot} = 1 - T_C/T_H$

$\Delta S = \left(Q/T\right)_R$ reversible

FE-19 An isobaric process is represented by which one of the following graphs?



a) A

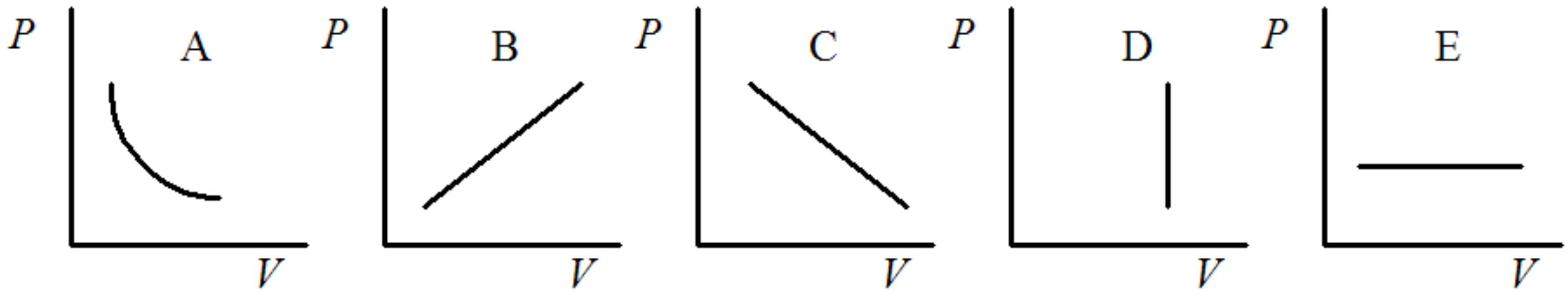
b) B

c) C

d) D

e) E

FE-19 An isobaric process is represented by which one of the following graphs?



a) A

b) B

c) C

d) D

e) E

FE-20 An ideal gas undergoes an isothermal expansion. Determine which of the following expressions is true.

a) ΔU is positive

b) ΔU is negative

c) Q is positive

d) Q is negative

e) $Q = -W$

FE-20 An ideal gas undergoes an isothermal expansion. Determine which of the following statements is true.

a) ΔU is positive

b) ΔU is negative

c) Q is positive

d) Q is negative

e) $Q = -W$

1st Law: $\Delta U = Q - W$

$U = \frac{3}{2} nRT$

$\Delta U = \frac{3}{2} nR\Delta T = 0$ (isothermal)

$Q = W$

Expansion $\Rightarrow W$ is positive

$\Rightarrow Q$ is positive.