### Uniform Circular Motion
- \( a_c \) – centripetal acceleration
- \( v \) – speed
- \( \rho \) – radius of curvature
- \( \omega \) – rotational speed
- \( T \) – period
- \( f \) – frequency

### Universal Law of Gravitation
\[
F = G \frac{m_1 m_2}{r^2}
\]
\( G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2 \)

### Kepler’s Third Law
\[
\frac{T^2}{r^3} = C
\]

### Satellites
\[
\begin{align*}
\rho &= \left(\frac{GM_\text{Earth}}{r^2}\right)^{\frac{1}{3}} \\
\varepsilon &= \frac{1}{\sqrt{\frac{r}{M_\text{Earth}}}} \\
\tau &= \sqrt{\frac{GM_\text{Earth}}{r}} \\
T &= \frac{2\pi}{\sqrt{\frac{GM_\text{Earth}}{r}}} \\
f &= \frac{1}{T} \\
\Delta t &= \varepsilon^2 \Delta \phi \\
\delta &= 2\varepsilon^2 \phi
\end{align*}
\]

### Density of Water
- 62.4 lb/ft\(^3\)
- 1000 kg/m\(^3\)

### Atmospheric Pressure
- 101.3 kPa
- 14.7 psi

### Conversions
- 1 ft\(^3\) = 7.48 gal
- 1 m\(^3\) = 1000 L

### Stokes’ Law
Sphere through fluid for laminar flow
\[
F_\text{drag} = 6\eta v L
\]

### Poiseuille’s Equation
\[
Q = \frac{8\eta L}{\pi R^4}
\]
\( \eta \) – viscosity
\( L \) – characteristic length
\( v \) – velocity
\( \rho \) – mass density
\( R \) – sphere radius

### Strain and Stress
- \( \sigma = \frac{P}{A} \)
- \( \epsilon = \frac{\Delta L}{L} \)
- \( \sigma = \frac{\Delta F}{A} \)
- \( \epsilon = \frac{\Delta L}{L} \)

### Fluids
- \( p \) – pressure
- \( h \) – height
- \( \rho \) – mass density
- \( v \) – velocity
- \( K \) – empirical constant
- \( A \) – area
- \( d \) – depth
- \( p_0 \) – pressure on top of fluid

### Conservation of Mass (Continuity)
- \( \dot{A}_1 = \dot{A}_2 \)

### Bernoulli’s Equation
\[
P_1 + \frac{1}{2} \rho v_1^2 + \rho gh_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho gh_2
\]

### Lift
\[
L = \rho \frac{1}{2} c v^2 A
\]

### Pressure in a fluid
\( p = p_0 + \rho gh \)

### Harmonic Motion
\[
\begin{align*}
\omega &= \text{angular frequency} \\
A &= \text{amplitude} \\
A &= \text{amplitude} \\
\delta &= \text{phase angle} \\
v_0 &= \text{initial displacement} \\
v_0 &= \text{initial velocity} \\
T &= \text{period} \\
f &= \text{frequency}
\end{align*}
\]

### Parallel Axis Theorem
\[
I = I_a + M d^2
\]

### Sound Level
\[
I = I_0 \times 10^{(f_f f_0)^2} \\
I_0 = 1 \times 10^{-12} \text{ W/m}^2
\]

### Doppler Shift
\[
\begin{align*}
\Delta f &= f - f_0 \\
f_0 &= \text{frequency} \\
f &= \text{shifted frequency} \\
v &= \text{velocity of medium} \\
v_s &= \text{velocity of source} \\
v_l &= \text{velocity of listener}
\end{align*}
\]
Positive is from listener to source.

### Stokes’ Law
Sphere through fluid for laminar flow
\[
F = 6\eta v L
\]
\( \eta \) – viscosity
\( L \) – characteristic length
\( v \) – velocity

### Poiseuille’s Equation
\[
Q = \frac{8\eta L}{\pi R^4}
\]
\( \eta \) – viscosity
\( L \) – characteristic length
\( v \) – velocity
\( \rho \) – mass density
\( R \) – sphere radius

### Wave Equation
\[
\begin{align*}
v &= \text{wave velocity} \\
A &= \text{amplitude} \\
\omega &= \text{angular frequency} \\
\lambda &= \text{wavelength} \\
T &= \text{period} \\
f &= \text{frequency}
\end{align*}
\]

### Wave Speed
\[
\begin{align*}
\lambda &= \text{wavelength} \\
T &= \text{period} \\
\mu &= \text{mass per unit length} \\
p &= \text{mass density} \\
E &= \text{modulus of elasticity}
\end{align*}
\]

### Beat Frequency
\[
|f_2 - f_1|
\]

### Sound Level
\[
I = I_0 \times 10^{(f_f f_0)^2}
\]
\( I_0 = 1 \times 10^{-12} \text{ W/m}^2\)

### Parallel Axis Theorem
\[
I = I_a + M d^2
\]

### Index of Refraction
\[
\eta = \frac{c}{v}
\]

### Law of Reflection
\[
\theta_1 = \theta_2
\]

### Light Waves
\[
\begin{align*}
\lambda &= \text{wavelength} \\
\eta &= \text{mass density} \\
\mu &= \text{mass per unit length} \\
E &= \text{modulus of elasticity}
\end{align*}
\]

### Total Internal Reflection
\[
\sin \theta_i = \frac{\eta_2}{\eta_1}
\]

### Wave Energy, Power, Intensity
\[
\begin{align*}
I &= \frac{P}{A} \\
P &= \text{average power} \\
E &= \text{intensity} \\
F &= \text{power} \\
\lambda &= \text{wave number} \\
\lambda &= \text{wavelength} \\
T &= \text{tension} \\
\mu &= \text{mass per unit length} \\
\rho &= \text{mass density}
\end{align*}
\]

### Air Columns
\[
\begin{align*}
\lambda &= \frac{4\pi L}{2n - 1} \\
\text{both ends open}
\end{align*}
\]

### Beats
\[
|f_2 - f_1|
\]

### Wave Speed
Cables, Ropes, etc.
\[
\begin{align*}
\lambda &= \text{wavelength} \\
T &= \text{period} \\
\mu &= \text{mass per unit length} \\
E &= \text{modulus of elasticity}
\end{align*}
\]

### Transverse:
\[
\begin{align*}
\lambda &= \frac{2\pi L}{n} \\
T &= \text{tension} \\
\mu &= \text{mass per unit length} \\
E &= \text{modulus of elasticity}
\end{align*}
\]

### Longitudinal:
\[
\begin{align*}
\lambda &= \frac{4\pi L}{2n - 1} \\
\text{both ends open}
\end{align*}
\]

### Sound Level
\[
I = I_0 \times 10^{(f_f f_0)^2}
\]
\( I_0 = 1 \times 10^{-12} \text{ W/m}^2\)

### Parallel Axis Theorem
\[
I = I_a + M d^2
\]

### Index of Refraction
\[
\eta = \frac{c}{v}
\]

### Law of Reflection
\[
\theta_1 = \theta_2
\]

### Light Wavelength
\[
\lambda = \frac{c}{v}
\]

### Total Internal Reflection
\[
\sin \theta_i = \frac{\eta_2}{\eta_1}
\]
**EF 152 Final Exam, Fall, 2011**

### Work of Thermal Systems

- **Isobaric (constant pressure)**: $W = -p \Delta V$
- **Isochoric (constant volume)**: $W = -nRT \Delta T$
- **Isothermal (constant temperature)**: $W = -nRT \ln \left( \frac{T_2}{T_1} \right)$

### Heat

- $Q$ - heat
- $c$ - specific heat
- $k$ - thermal conductivity
- $R$ - thermal resistance

### Heat Capacity

- $C_p$ - heat capacity at constant pressure
- $C_v$ - heat capacity at constant volume

### Thermal Conductivity

- $k = \frac{Q}{A \Delta T}$

### Thermal Resistance

- $R = \frac{L}{kA}$

### Efficiency

- General: $\eta = 1 - \frac{W}{Q}$
- Otto Cycle: $\eta = 1 - \frac{1}{r}$
- Carnot Cycle: $\eta = 1 - \frac{T_2}{T_1}$

### Refrigerators

- **General**: $\eta = 1 - \frac{W}{Q}$
- **Carnot**: $\eta = 1 - \frac{T_2}{T_1}$

### Molecular Thermal Physics

- $m$ - mass of a molecule
- $M$ - molecular mass
- $n$ - number of moles
- $N$ - number of molecules
- $k$ - Boltzmann constant

### Water Properties

- $c = 1 \text{ cal/(g-°C)} = 4.186 \text{ J/(g-°C)}$
- $L_v = 79.6 \text{ cal/g}$
- $L_f = 3400 \text{ cal/g}$
- $L_v = 1 \text{ kcal/kg}$
- $L_f = 0.5 \text{ kg}/\text{ m}^3$
- $L_f = 1 \text{ kcal}/\text{ L}$
- $L_v = 0.5 \text{ kg}/\text{ m}^3$
- $L_f = 0.5 \text{ kcal}/\text{ L}$

### Conversions

- 1 cal = 4.186 J
- 1 L = 1000 cm$^3$
- 1 m$^3$ = 1000 L

---

### Capacitance

- $C = \frac{Q}{V}$

### Kirchhoff’s Rules

- $\sum I = 0$ for a closed loop
- $\sum V = 0$ for a junction

---

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### Capacitance – parallel plates

- $C = \frac{4\pi \varepsilon_0 A}{d}$

### Capacitance – energy storage

- $U = \frac{1}{2} C V^2 = \frac{1}{2} Q^2$

### Capacitors in series

- $C_{eq} = \frac{1}{C_1 + C_2 + C_3 + \ldots}$

### Capacitors in parallel

- $C_{eq} = C_1 + C_2 + C_3 + \ldots$

### Resistors in series

- $R_{eq} = R_1 + R_2 + R_3 + \ldots$

### Resistors in parallel

- $R_{eq} = \frac{1}{R_1 + \frac{1}{R_2} + \frac{1}{R_3} + \ldots}$

### Current

- $I = \frac{Q}{t}$
- $I = \frac{V}{R}$

### Voltage, Resistance, Current, Power

- $P = I V$
- $P = V I$

---

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### Ideal Gas

- $W = \frac{1}{2} m v^2$
- $T = \frac{m v^2}{2k_B}$
- $P = \frac{k_B T}{V}$

### Electric Field – point charge

- $E = \frac{1}{4 \pi \varepsilon_0} \frac{Q}{r^2}$

### Potential energy - point charges

- $U = \frac{1}{2} \sum_{i<j} q_i q_j r_{ij}$

### Potential

- $U = \frac{1}{q}$

### Potential of a set of point charges

- $V = \frac{1}{4 \pi \varepsilon_0} \sum q_i r_i$

### Potential difference between two parallel plates

- $V_f - V_i = \frac{q}{C}$

---

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### Constants

- $m_a = 9.109 \times 10^{-31}$ kg
- $m_i = 1.673 \times 10^{-27}$ kg
- $m_r = 1.675 \times 10^{-27}$ kg

- $k = 9 \times 10^9 \text{ Nm}^2\text{/C}^2$
- $\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2\text{Nm}^{-1}\text{F}^{-1}$

- $e = 1.602 \times 10^{-19}$ C (electron charge)
- $eV = 1.602 \times 10^{-19}$ J (electron volt)

### Molecular Thermal Physics

- $N = 1.38 \times 10^{-23} \text{ J/K}$

### Kirchhoff’s Rules

- $P = \text{power}$
- $V = \text{voltage}$

---

**EF 152 Final Exam, Fall, 2011**

### Capacitance

- $C = \frac{Q}{V}$
- $1 \text{ F} = 1 \text{ C} \text{ V}^{-1}$

---

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### Kirchhoff’s Rules

- $\sum I = 0$ for a closed loop
- $\sum V = 0$ for a junction

---
1. (1 pt) Consider two identical pails of water filled to the brim. One pail contains only water, the other has a piece of wood floating in it. Which pail has the greater weight?
   a. pail with water only
   b. pail with wood
   c. they both weigh the same

2. (1 pt) Consider a wave on a string moving to the right. What is the direction of the velocity of a particle at the point labeled A?
   a. b. c. d. e. zero

3. (1 pt) A gas is maintained at a constant temperature while the pressure is doubled. The internal energy:
   a. is reduced by a factor of 2
   b. does not change
   c. is increased by a factor of 2
   d. is increased by a factor of 4

4. (1 pt) Two charged particles are 3 m apart and the force between them is \(-4 \times 10^{-6}\) N. Determine the factor by which the force between the charged particles changes if they are 1 m apart.
   a. 1/9
   b. 1/3
   c. 3
   d. 9

5. (6 pts) Isaac, 220 lb, is painting a barn for his camel. The ladder, 20 lb, is 6.0 ft from the base of the barn and hits the side of the barn at a height of 8.0 ft. What is the normal force from the wall onto the ladder when Isaac is \(\frac{1}{3}\) of the way up the ladder? Assume negligible friction on the side of the barn. A separate, complete FBD is required for full credit.

6. (6 pts) A copper weight is placed on top of a 0.5 kg block of wood floating in water. What is the mass of the copper if the top of the wood block is exactly at the water’s surface?
   \(\rho_{\text{water}} = 0.6 \times 10^3 \text{ kg/m}^3, \rho_{\text{copper}} = 8.9 \times 10^3 \text{ kg/m}^3\)
9. (6 pts) A police car (Smokey) traveling at 70 mph is chasing the Bandit, whose speedometer is broken. The frequency of Smokey’s siren is 912 Hz. The apparent frequency heard by the Bandit is 860 Hz. How fast is he going? Assume the speed of sound in air is 767 mph.

10. (6 pts) Two springs of equal length are suspended in parallel. A 2.5 kg weight is added and the system oscillates in simple harmonic motion. If the stiffness of the springs are 12.0 N/m and 7.0 N/m, what is the period of the system?

11. (6 pts) Larry the Cable Guy is replacing a coaxial cable (copper wire). To determine the length, he sends a longitudinal pulse down the cable and measures the time for it to return. If it takes 0.15 sec for the pulse to return, how long is the cable? \( E_{\text{copper}} = 110 \text{ GPa}, \rho_{\text{copper}} = 8.9 \times 10^3 \text{ kg/m}^3 \)

12. (6 pts) A ray of light passes from air \( (n = 1) \) into a glass prism at an angle of incidence of 35°. If the angle of refraction in the glass is 23.7°, what is the speed of the light in the glass?

13. (6 pts) 3 kg of lemonade is initially at 35°C. Determine the amount of ice at 0°C needed to cool the lemonade down to 0°C while melting half the ice.

14. (6 pts) The humble Morrison abode (1200 ft² wall area) has insulation with an R value of 2 ft²·hr·°F/BTU. Determine the R-value of insulation that Shane would need to install in series so that the heat loss is limited to 14000 BTU in 3 hours for a 23°F temperature difference.
15. (6 pts) The $p$-$v$ diagram for the Schleter engine is shown. Determine the amount of work done in one cycle of the Schleter engine.

![p-v diagram]

16. (6 pts) Isaac's 400 kg pet camel is at a temperature of 34°C. The specific heat of a camel is 3480 J/kg·K. The camel has an entropy change of 25000 J/K. What is the final temperature of the camel?

17. (6 pts) An electron starts from rest at point A where the potential is 12kV. The electron travels 0.76 m to point B where the potential is 18kV. Determine the speed of the electron at point B.

18. (6 pts) A 12 V potential is applied across a circuit that has 20μF capacitors. Determine the number of capacitors needed if it is desired to store $8.64\times10^{-3}$ J of energy in the circuit.

![Circuit diagram]

19. (6 pts) Determine the current in the circuit.

![Circuit diagram]

20. (6 pts) A particle with a charge of 8 nC is moving with a velocity of $(6\hat{i} + 4\hat{j})m/s$ is moving through a magnetic field of $(-3\hat{j} + 5\hat{k})\times10^{-7}T$. What is the force on the particle?

![Force diagram]