No time limit. No notes. No books. Testing Center calculators only.

Constants:

- $g = 9.8 \text{ m/s}^2 \rightarrow \text{but you may use 10 m/s}^2 \text{ in nearly all cases}$
- $G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$
- $k_B = 1.381 \times 10^{-23} \text{ J/K}$
- $N_A = 6.022 \times 10^{23}$
- $\sigma = 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4$
- Mass of Sun = $1.991 \times 10^{30} \text{ kg}$
- Mass of Earth = $5.98 \times 10^{24} \text{ kg}$
- Radius of Earth = $6.38 \times 10^6 \text{ m}$
- Radius of Earth’s orbit = $1.496 \times 10^{11} \text{ m}$
- Density of water: $1000 \text{ kg/m}^3$
- Density of air: $1.29 \text{ kg/m}^3$
- Linear exp. coeff. of copper: $17 \times 10^{-6} \degree \text{C}$
- Linear exp. coeff. of steel: $11 \times 10^{-6} \degree \text{C}$
- Specific heat of water: $4186 \text{ J/kg} \cdot \degree \text{C}$
- Specific heat of ice: $2090 \text{ J/kg} \cdot \degree \text{C}$
- Specific heat of steam: $2010 \text{ J/kg} \cdot \degree \text{C}$
- Specific heat of aluminum: $900 \text{ J/kg} \cdot \degree \text{C}$
- Latent heat of melting (water): $3.3 \times 10^5 \text{ J/kg}$
- Latent heat of boiling (water): $2.26 \times 10^6 \text{ J/kg}$
- Thermal conduct. of aluminum: $238 \text{ J/s} \cdot \text{m} \cdot \degree \text{C}$
- $v_{air} = 343 \text{ m/s}$ at $20 \degree \text{C}$
- $\sin(30 \degree) = 0.5$
- $\cos(30 \degree) \approx 0.866$
- $\tan(30 \degree) \approx 0.577$
- $\pi \approx 3.14$

Conversion factors

- $1 \text{ inch} = 2.54 \text{ cm}$
- $1 \text{ m}^3 = 1000 \text{ L}$
- $1 \text{ atm} = 1.013 \times 10^5 \text{ Pa} = 14.7 \text{ psi}$

Other equations

- $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
- $\text{Surface area of sphere} = 4\pi r^2$
- $\text{Volume of sphere} = \left(\frac{4}{3}\right) \pi r^3$
- $v_{ave} = \frac{v_i + v_f}{2}$
- $v = v_i + at$
- $x = x_i + v_i t + \frac{1}{2}at^2$
- $v_f = v_i + 2a \Delta x$
- $w = mg, \ P_E = mgv$
- $F = -kx, P_{E_{vis}} = \frac{1}{2}kx^2$
- $f = \mu_x N$ (or $f \leq \mu_x N$ )
- $P = F_i/v = Fv\cos\theta$
- $\Delta P = \Delta \tilde{P}$
- Elastic: $(v_i - v_f)_{after} = (v_f - v_i)_{after}$
- arc length: $s = r\theta$
- $v = r\omega$
- $a_{tan} = r\alpha$
- $a_r = v^2/r$
- $F_g = \frac{GMm}{r^2}, \ P_{E_{g}} = \frac{-GMm}{r}$
- $I_{pt mass} = mR^2$
- $I_{sphere} = \frac{(2/5)mR^2}$
- $I_{hoop} = mR^2$

Did you write down your CID at the top of the page? _______  If not, you may not get this test booklet back.
Instructions:

- Record your answers on the bubble sheet.
- The Testing Center no longer allows students to see which problems they got right & wrong, so I strongly encourage you to mark your answers in this test booklet. You will get this test booklet back (but only if you write your CID at the top of the first page).
- You may write on this exam booklet, and are strongly encouraged to do so.
- In all problems, ignore friction, air resistance, and the mass of all springs, pulleys, ropes, cables, strings etc., unless specifically stated otherwise.
- Use $g = 9.8 \text{ m/s}^2$ only if there are “9.8” numbers in the answer choices; otherwise use $g = 10 \text{ m/s}^2$. 