

On my honor as a Texas A&M University student, I will neither give nor receive unauthorized help on this exam.

Name (signed) _____

The multiple-choice problems carry no partial credit.

Circle the correct answer or answers. An answer is approximately correct if it is correct to 2 significant figures.

In the work-out problems, you are graded on your work, with partial credit.

(The answer by itself is not enough, and you receive credit only for your work.)

Be sure to include the correct units in the answers, and give your work in the space provided.

Note that the score in points here – maximum of 140 – will be divided by 1.4 to get the score based on a maximum of 100.

For a diatomic ideal gas, $C_V = \frac{5}{2}R$ and $C_P = \frac{7}{2}R$, so $\gamma \equiv \frac{C_P}{C_V} = \frac{7}{5} = 1.4$.

For a solid disc or cylinder: moment of inertia $= \frac{1}{2}MR^2$.

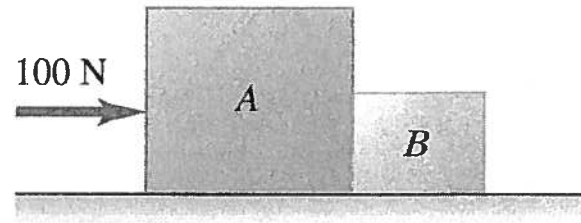
heat of fusion for water $= 334 \times 10^3$ J/kg

mass density of water $= 1000$ kg/m³

1. (5) In an ideal gas, which of the following quantities can be determined by measuring *only* the temperature of the gas?

- (a) the pressure of the gas
- (b) the pressure times the volume
- (c) the average kinetic energy of the molecules**
- (d) the total kinetic energy of the molecules

2. (5) A person pushes two boxes with a 100 N force across a frictionless floor, as shown in the figure. Box A is heavier than box B. Which of the following statements is correct?



- (a) Box A pushes on box B harder than box B pushes on box A.
- (b) Boxes A and B push on each other with equal forces of less than 100 N.**
- (c) The boxes will not begin to move unless the total weight of the two boxes is less than 100 N.
- (d) Box A pushes on box B with a force of 100 N, and box B pushes on box A with a force of 100 N.

3. (5) A flat (unbanked) curve on a highway has a radius of 200 m. A car rounds the curve at a speed of 30 m/s. What is the minimum coefficient of friction that will prevent sliding?

- (a) 0.23
- (b) 0.46**
- (c) 0.34
- (d) 0.68
- (e) 0.17

$$\mu_s g = \gamma \frac{v^2}{r}$$

$$\Rightarrow \mu_s = \frac{(30)^2}{(200)(9.8)} = 0.459$$

4. (5) Blood stored at 5°C lasts safely for about 3 weeks. Express this temperature in $^{\circ}\text{F}$.

(a) 41°F

(b) 9°F

(c) 37°F

(d) approximately 32.6°F

(e) approximately 34.8°F

5. (5) The graph in the figure shows the temperature as a function of time for a substance being heated at a constant rate. Which statements are true?

(a) There are two phases of the substance coexisting along OA .

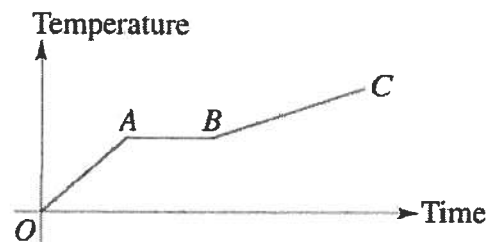
(b) There are two phases of the substance coexisting along AB .

(c) There are two phases of the substance coexisting along BC .

(d) The heat capacity is higher for BC than for OA .

(e) The heat capacity is higher for OA than for BC .

(f) This is a single-phase temperature-time diagram.



6. (5) If you throw a ball straight up in the air with an initial velocity of 20 m/s , approximately how high does the ball rise?

(a) 2 m

(b) 4 m

(c) 20 m

(d) 40 m

(e) 200 m

(f) 400 m

$$v^2 = v_0^2 + 2(-g)(h)$$
$$\Rightarrow h = \frac{v_0^2}{2g} = \frac{(20)^2}{(2)(9.8)} = 20.4\text{ m}$$

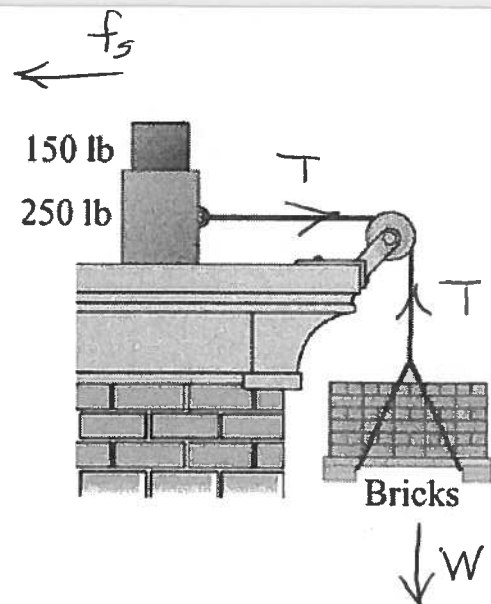
7. (12) At a construction site, a pallet of bricks is to be suspended by attaching a rope to it and connecting the other end to a couple of heavy crates on the roof of a building, as shown in the figure.

The rope pulls horizontally on the lower crate, and the coefficient of static friction between the lower crate and the roof is 0.60.

Neglect friction in the pulley.

What is the weight of the heaviest pallet of bricks that can be supported this way?

Maximum weight = 240 lb



$$T = W \Rightarrow f_s = T = W \Rightarrow W_{\max} = f_{s, \max}$$

$$f_s \leq \mu_s n = \mu_s (150 \text{ lb} + 250 \text{ lb}) \quad \text{with } \mu_s = 0.60$$

$$\therefore \boxed{W_{\max} =} f_{s, \max} = (0.60)(150 \text{ lb} + 250 \text{ lb}) = \boxed{240 \text{ lb}}$$

[other version: 160 lb]

8. A thin, light wire 50 cm long has a circular cross-section 0.8 mm in diameter. A 10 kg weight is attached to it, causing it to stretch by 2 mm. Calculate the following.

(Here and everywhere, show all the relevant steps in your work.)

(a) (4) stress in the wire = $1.95 \times 10^8 \frac{N}{m^2}$

$$A = \pi r^2 = \pi \left(\frac{0.8 \times 10^{-3} m}{2} \right)^2 = 5.03 \times 10^{-7} m^2$$

$$F = mg = (10 \text{ kg})(9.8 \frac{m}{s^2}) = 98 \text{ N}$$

$$\boxed{\frac{F}{A} = 1.95 \times 10^8 \frac{N}{m^2}} \quad [\text{or Pa}] \quad \left[\text{other version: } 3.9 \times 10^8 \frac{N}{m^2} \right]$$

(b) (4) strain of the wire = 0.004

$$\boxed{\frac{\Delta l}{l_0} = \frac{2 \times 10^{-3} m}{0.50 m} = 0.004} \quad \text{or } 4 \times 10^{-3}$$

(c) (4) Young's modulus for the material in the wire = $4.9 \times 10^{10} \frac{N}{m^2}$

$$\boxed{Y = \frac{F/A}{\Delta l/l_0} = 4.9 \times 10^{10} \frac{N}{m^2}} \quad [\text{or Pa}]$$

$$[\text{other version: } 9.8 \times 10^{10} \frac{N}{m^2}]$$

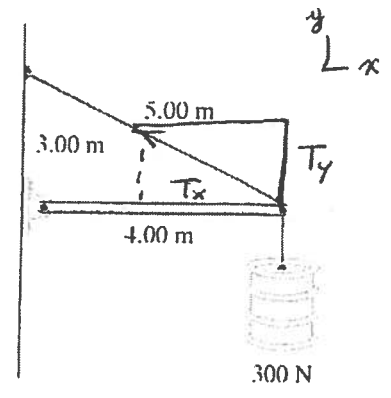
9. The horizontal beam to the right weighs 300 N, and it is uniform (with center of gravity at its center).

(a) (5) Calculate T_y , the vertical component of the tension in the cable.

Answer 450 N

$$(4\text{ m}) T_y + (4\text{ m})(-300\text{ N}) + (2\text{ m})(300\text{ N}) = 0$$

$$\Rightarrow \boxed{T_y = \frac{1800}{4} = 450\text{ N}}$$



[500 N in other version - the white version]

(b) (5) Calculate T_x , the horizontal component of the tension in the cable.

$$\frac{T_x}{T_y} = \frac{4\text{ m}}{3\text{ m}} \Rightarrow \boxed{T_x = \frac{4}{3} T_y = 600\text{ N}} \quad [\text{or } -600\text{ N more precisely}]$$

[667 N in other version]

(c) (2) Calculate H_x , the horizontal force exerted on the beam by the hinge at the wall.

$$\boxed{H_x = T_x = 600\text{ N}} \quad [\text{or } H_x = |T_x|]$$

[667 N in other version]

(d) (2) Calculate H_y , the vertical force exerted on the beam by the hinge at the wall.

$$H_y + T_y = 300\text{ N} + 300\text{ N}$$

$$\Rightarrow \boxed{H_y = 600\text{ N} - 450\text{ N} = 150\text{ N}}$$

[200 N in other version]

10. (12) The emissivity of tungsten is 0.35. A tungsten sphere with a radius of 2.0 cm is suspended within a large evacuated enclosure whose walls are at 300 K. What power input is required to maintain the sphere at a temperature of 3000 K if heat conduction along the supports is negligible?

(Here and everywhere, show all the relevant steps in your work.)

required power input = _____

$$\begin{aligned} H_{\text{net}} &= A e \sigma (T^4 - T_s^4) \\ &= 4\pi (0.02 \text{ m})^2 (0.35) (5.67 \times 10^{-8} \frac{\text{W}}{\text{m}^2 \text{K}^4}) \\ &\quad \times [(3000 \text{ K})^4 - (300 \text{ K})^4] \\ &= (9.98 \times 10^{-11} \frac{\text{W}}{\text{m}^2 \text{K}^4}) (8.1 \times 10^{13} \text{ K}^4 - 8.1 \times 10^9 \text{ K}^4) \\ &= \boxed{8080 \frac{\text{W}}{\text{m}^2}} \end{aligned}$$

$$\text{[other version: } 32,300 \frac{\text{W}}{\text{m}^2} \text{]}$$

11. A hollow metal sphere is held below the surface of a freshwater lake by a cord anchored to the bottom of the lake. The sphere has a volume of 0.2 m^3 and the tension in the cord is 500 N .

(a) (4) Calculate the buoyant force exerted by the water on the sphere.

Answer 1960 N

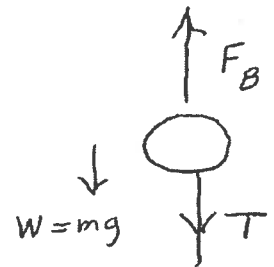
$$\begin{aligned} \boxed{F_B} &= \text{weight of water displaced} \\ &= (\rho_{\text{water}})(0.2 \text{ m}^3)(9.8 \text{ m/s}^2) \\ &= (1000)(0.2)(9.8) \\ &= \boxed{1960 \text{ N}} \end{aligned}$$

(b) (4) What is the mass of the sphere?

Answer 149 kg

[other version: 98 kg]
(white)

$$\begin{aligned} mg + T &= F_B \\ \Rightarrow \boxed{m} &= \frac{F_B - T}{g} \\ &= \frac{1960 - 500}{9.8} \\ &= \boxed{149 \text{ kg}} \end{aligned}$$



(c) (4) The cord breaks and the sphere rises to the surface. When the sphere comes to rest, what fraction of its volume will be submerged?

Answer 0.745 [or 74.5%]

[other version: 0.49, or 49%]
(white)

$$F'_B = (\rho_{\text{water}})(V_{\text{displaced}})(9.8 \frac{\text{m}}{\text{s}^2})$$

$$F'_B = mg$$

$$= (149)(9.8)$$

$$= 1460 \text{ N}$$

$$\therefore V_{\text{displaced}} = \frac{1460 \text{ N}}{(1000 \frac{\text{kg}}{\text{m}^3})(9.8 \frac{\text{m}}{\text{s}^2})}$$

$$\boxed{\frac{V_{\text{displaced}}}{0.2 \text{ m}^3}} = \frac{0.149}{0.2} = \boxed{0.745} = 0.149 \text{ m}^3$$

12. A bucket of mass $m = 3$ kg falls into a well. It is attached by a cord to a winch cylinder of mass $M = 1$ kg, which has a radius $R = 0.1$ meter. (See the drawing, which is not to scale.)

(a) (1) Calculate the moment of inertia I of the cylinder.

moment of inertia I of the cylinder = $5 \times 10^{-3} \text{ kg} \cdot \text{m}^2$

$$\boxed{I = \frac{1}{2} MR^2 = \frac{1}{2} (1)(0.1)^2 = 0.005 \text{ kg} \cdot \text{m}^2}$$

(b) (1) Calculate the weight W of the bucket.

weight W of the bucket = 29.4 N

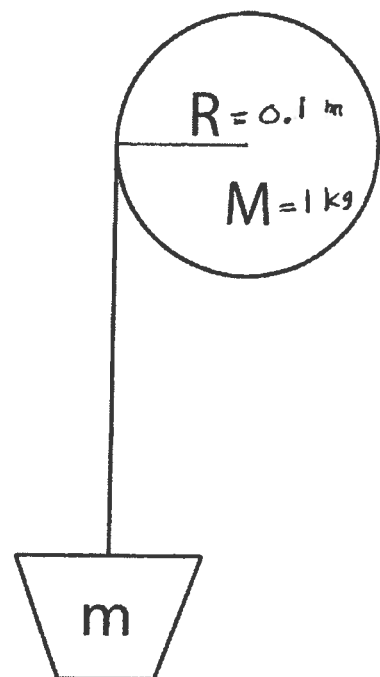
$$\boxed{W = mg = (3)(9.8) = 29.4 \text{ N}}$$

[other version: 19.6 N]

(c) (3) Obtain an expression for the downward acceleration a of the bucket in terms of the weight W of the bucket, the tension T in the cord, and the mass m of the bucket.

$$ma = W - T \Rightarrow \boxed{a = \frac{W - T}{m}}$$

$$[F = ma]$$



(d) (3) Obtain an expression for the angular acceleration α of the cylinder in terms of the tension T in the cord, the radius R of the cylinder, and the moment of inertia I of the cylinder.

$$I\alpha = RT \Rightarrow \boxed{\alpha = \frac{RT}{I}}$$

$$[\tau = \text{moment arm} \times \text{force}, \tau = I\alpha]$$

(e) (3) Use the result of part (d) to obtain an expression for the acceleration a of the bucket in terms of the tension T in the cord, the radius R of the cylinder, and the moment of inertia I of the cylinder.

$$\begin{aligned} \boxed{a} &= a_{\text{tan}} \text{ for point on circumference of cylinder} \\ &= R\alpha \\ &= R \cdot \frac{RT}{I} \\ &= \boxed{\frac{R^2 T}{I}} \end{aligned}$$

(f) (3) Set your result from part (c) for a equal to your result from part (e) for a , and then calculate the tension T in the cord.

tension $T = \underline{4.2 \text{ N}}$

$$\frac{R^2 T}{I} = \frac{W - T}{m} \Rightarrow T = \frac{I}{R^2} \frac{W - T}{m} = \frac{I}{mR^2} W - \frac{I}{mR^2} T$$

Can be solved numerically or algebraically. [Numerically, just put in I, W, m, R & solve.]
Algebraically, since $\frac{I}{mR^2} = \frac{\frac{1}{2}MR^2}{mR^2} = \frac{M}{2m}$, and $W = mg$,

$$T = \frac{M}{2m} mg - \frac{M}{2m} T \Rightarrow T \left(1 + \frac{M}{2m}\right) = \frac{Mg}{2}$$

$$\Rightarrow \boxed{T = \frac{Mg/2}{1 + M/2m}} = \frac{Mg/2}{M/2m + 1} \cdot \frac{2m/M}{2m/M} = \boxed{\frac{mg}{1 + 2m/M}}$$

(g) (3) Now use your result from Part (c) to calculate the acceleration of the bucket.

acceleration = $\underline{8.4 \text{ m/s}^2}$

$$\boxed{a = \frac{29.4 \text{ N} - 4.2 \text{ N}}{3 \text{ kg}}} = \boxed{8.4 \text{ m/s}^2}$$

[other version: 7.85 m/s^2]

$$= \frac{(3)(9.8)}{1 + (2)(3)/1}$$

$$\boxed{= 4.2 \text{ N}}$$

[other version: 3.92 N]

(h) (3) If the bucket starts from rest, what is its velocity after it has fallen 6 meters?

velocity = $\underline{10 \text{ m/s}}$

$$v^2 = v_0^2 + 2a(y - y_0) = 0^2 + 2 \left(8.4 \frac{\text{m}}{\text{s}^2}\right)(6 \text{ m}) = 100.8 \frac{\text{m}^2}{\text{s}^2}$$

$$\Rightarrow \boxed{v = 10 \text{ m/s}}$$

[other version: 9.7 m/s]

13. The figure is a pV diagram for 5 moles of air, which is to be treated as an ideal diatomic gas. Segment ca is an isothermal process.

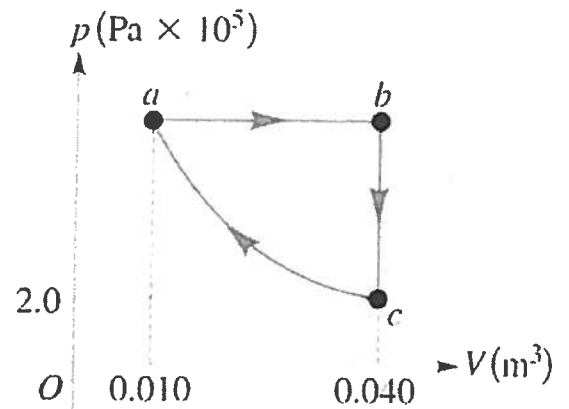
(a) (2) Calculate the temperature at point c .

Answer: 192 K

$$p_c V_c = n R T_c$$

$$\Rightarrow \boxed{T_c = \frac{(2 \times 10^5)(0.04)}{(5)(8.314)}} = \boxed{192.4 \text{ K}}$$

[other version: 96 K]
(white)



(b) (2) Calculate the pressure at point a .

Answer: $8 \times 10^5 \text{ Pa}$

$$p_a V_a = n R T_a \quad \text{with } T_a = T_c = 192.4 \text{ K}$$

$$\Rightarrow \boxed{p_a = \frac{(5)(8.314)(192.4)}{0.01}} = \boxed{8.00 \times 10^5 \text{ Pa}}$$

$$\text{or better, } \frac{p_a V_a}{T_a} = \frac{p_c V_c}{T_c} \Rightarrow p_a = p_c \frac{V_c}{V_a} = (2 \times 10^5) \frac{0.04}{0.01} = 8 \times 10^5 \text{ Pa}$$

(c) (2) Calculate the temperature at point b .

Answer: 770 K

$$p_b V_b = n R T_b \quad \text{with } p_b = p_a \text{ [and } T_a = T_c \text{ again]}$$

$$\Rightarrow \frac{p_b V_b}{T_b} = \frac{p_a V_a}{T_a} \Rightarrow \boxed{T_b = T_a \frac{V_b}{V_a}} = (192.4 \text{ K}) \frac{0.04}{0.01} = \boxed{769.6 \text{ K}}$$

[other version: 385 K]

(d) (2) How much heat entered the gas during process ab ?
[A minus sign means heat left, of course.]

Answer: 84000 J

$$\begin{aligned} \boxed{Q_{ab}} &= n C_p \Delta T, \quad C_p = \frac{7}{2} R, \quad \Delta T = T_b - T_a \\ &= (5) \left(\frac{7}{2}\right) (8.314) (769.6 - 192.4) \\ &= \boxed{84000 \text{ J}} \end{aligned}$$

(e) (2) How much work was done by the gas during process ab ?
[A minus sign means work was done on the gas, of course.]

Answer: 24000 J

$$\begin{aligned} \boxed{W_{ab}} &= \text{area under } ab \text{ curve (actually horizontal line)} \\ &= \int_a^b (V_B - V_a) \\ &= (8 \times 10^5) (0.04 - 0.01) \\ &= \boxed{24000 \text{ J}} \end{aligned}$$

(f) (2) What was the change in the internal energy of the gas during process ab ?

Answer: 60000 J

$$\begin{aligned} \boxed{\Delta U} &= Q - W \\ &= 84000 - 24000 \\ &= \boxed{60000 \text{ J}} \end{aligned}$$

(g) (2) How much heat entered the gas during process bc ?

Answer: -60000 J

$$\begin{aligned} \boxed{Q_{bc}} &= n C_v \Delta T, \quad C_v = \frac{5}{2} R, \quad \Delta T = T_c - T_b \\ &= (5) \left(\frac{5}{2}\right) (8.314) (192.4 - 769.6) \\ &= \boxed{-60000 \text{ J}} \end{aligned}$$

(h) (2) How much work was done by the gas during process *bc*?

Answer: 0

$$\boxed{W = 0} \text{ since } \Delta V = 0$$

(i) (2) What was the change in the internal energy of the gas during process *bc*?

Answer: -60 000 J

$$\boxed{\Delta U = Q - W = -60 000 \text{ J}}$$

(j) (2) What was the change in the internal energy of the gas during process *ca*?

Answer: 0

$U = U(T)$ for ideal gas and $\Delta T = 0$

$$\Rightarrow \boxed{\Delta U = 0}$$

(k) (2) How much work was done by the gas during process *ca*?

Answer: -11 090 J

From (Ford) formula sheet (and from class),

$$\boxed{W_{ca} = nRT_c \ln \left(\frac{V_a}{V_c} \right)} \text{ for isothermal process}$$

$$= (5)(8.314)(192.4) \ln \left(\frac{0.01}{0.04} \right)$$

$$= \boxed{-11 090 \text{ J}} \quad \underbrace{\ln \left(\frac{0.01}{0.04} \right)}_{= -1.386}$$

(l) (2) How much heat entered the gas during process *ca*?

Answer: -11 090 J

$$\Delta U = Q - W \Rightarrow \boxed{Q = \Delta U + W = 0 - 11 090 \text{ J} = -11 090 \text{ J}}$$

14. (extra credit)

(a) (3) There is a lot of ice floating on the oceans near the North Pole. If this ice were to melt due to global warming, what would happen to the level of the oceans? Would the ocean level fall, rise, or stay the same? Explain.

If only this, would stay the same, because the floating ice and the liquid water that the ice becomes (after melting) displace the same volume of other water. If the mass of the ice is M , static equilibrium requires that the weight of the other water displaced is Mg in both cases.

(b) (2) Then answer a further question: Why is the answer to (a) not completely relevant if all the ice in Alaska, Greenland, Antarctica, etc. also continue to melt?

But ice on land (and Antarctica, for example, is a continent with a land surface, whereas there is no land around the North Pole) is not initially displacing any water. So when this ice melts, it just flows into the oceans and raises their level.

So good investments (in the long term) are (i) ice-locked regions that will eventually become viable ports and (ii) land-locked regions that will eventually become ocean-front property.

Please have a pleasant summer!