

Version I

Final Exam

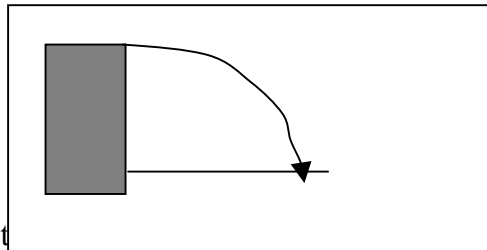
May 4, 1999

Name:

Useful constants: For water: $\rho=1000 \text{ kg/m}^3$, $c = 1 \text{ kcal/kg/}^\circ\text{C}$, latent heat of fusion = 80 kcal/kg, latent heat of vaporization = 540 kcal/kg. $G=6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$, $R=8.31 \text{ J/(mol K)}$, $k = 1.38 \times 10^{-23} \text{ J/K}$, $g=9.8 \text{ m/s}^2$.

1. A ball is thrown horizontally from the top of a 100 m tall building with initial horizontal velocity of 5 m/s. How far from the base of the building does it land?

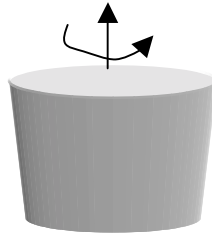
- A) 4.5 m
- B) 9.0 m
- C) 20.4 m
- D) **22.6 m**
- E) 45.1 m



$$t = (2s/g)^{1/2} = (2 \cdot 100/9.8)^{1/2} = 4.5 \text{ s}; x = v_0 t = 4.5 \times 5 = 22.6 \text{ m}$$

2. A carnival ride in the shape of a barrel rotates about a vertical axis. People on the inside are pressed against the barrel with a force equal to 6 times their weight. If the barrel makes one revolution a second, what is its minimum radius?

- A) 59 m
- B) 14.7 m
- C) 4.7 m
- D) 5.9 m
- E) **1.5 m**



$$M v^2/r = M \omega^2 R = 6 Mg \\ R = 6 g / \omega^2 = 6 g (2 \pi f)^2 = 6 \cdot 9.8 / (2 \pi \cdot 1)^2 = 1.5 \text{ m}$$

3. A spring with spring constant $k = 15 \text{ N/m}$ is compressed 1.5 m from its equilibrium value. How much energy in Joules is stored in the spring?

- A) 22.5 J
- B) 11.2 J
- C) 33.8 J
- D) 112 J
- E) **16.9 J**

$$U = 1/2 k x^2 = 1/2 \cdot 15 \cdot 1.5^2 = 16.9 \text{ J}$$

Version I

4. A 64 kg baseball player running at 6 m/s slides into second base. If the coefficient of friction between him and the ground is 0.8, how far will he slide before he stops?

- A) 0.38 m
 B) 1.2 m
 C) 1.8 m
 D) **2.3 m**
 E) 3.6 m

$$KE = W = F x; F = \mu F_N = \mu m g; KE = 1/2 m v^2$$

$$X = v^2 / (2 \mu g) = 6^2 / (2 \cdot 0.8 \cdot 9.8) = 2.3 \text{ m}$$

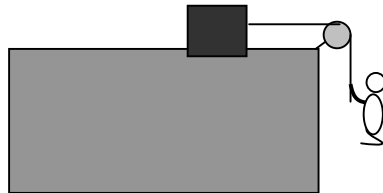
5. An object with rotational inertia $I = 15 \text{ kg m}^2$ has a torque of 3 N m applied to it, what will be the magnitude of its angular acceleration?

- A) **0.2 rad/s²**
 B) 5 rad/s²
 C) 12 rad/s²
 D) 18 rad/s²
 E) 45.5 rad/s²

$$\alpha = \tau / I = 3 / 15 = 0.2 \text{ rad/s}^2$$

6. A rope is passed over a massless pulley and attached to a weight resting on a horizontal surface. If the coefficient of static friction between the weight and the surface is 0.3, what is the minimum mass the weight must have to permit a 60 kg woman to hang from the rope?

- A) 180 kg
 B) **200 kg**
 C) 60 kg
 D) 400 kg
 E) 588 kg



$$\mu_s M g \geq M_w g$$

$$M \geq M_w / g = 60 / 0.3 = 200 \text{ kg}$$

7. At what depth will seawater (density $\rho = 1.03 \times 10^3 \text{ kg/m}^3$) exert a pressure of 45 MPa ($45 \times 10^6 \text{ Pa}$)?

- A) **4.45 km**
 B) 43.6 km
 C) 8.9 km
 D) 13.2 km
 E) 15.8 km

$$P = \rho g h; h = P / (\rho g)$$

$$= 45 \times 10^6 / (1.03 \times 10^3 \cdot 9.8)$$

$$= 4,450 \text{ m} = 4.45 \text{ km}$$

Version I

8. Two identical pieces of metal, "A" at -20°C and "B" at $+20^{\circ}\text{C}$, are brought together so that they arrive at the same temperature. Choose the most nearly correct answer below.

- A) The total entropy stays constant since the process is reversible
- B) The total entropy decreases because the process is reversible
- C) The concept of entropy cannot be applied here
- D) The total entropy increases because the entropy increase of "B" exceeds the entropy decrease of "A"
- E) **The total entropy increases because the entropy increase of "A" exceeds the entropy decrease of "B"**

$$\Delta Q/253 > \Delta Q/293$$

9. A piano tuner uses a tuning fork of 440 Hz to tune a string on a piano. When both are struck a beat frequency of 2 Hz is heard. Choose the most nearly correct response below.

- A) The vibrational frequency of the piano string is 438 Hz
- B) The vibrational frequency of the piano string is 442 Hz
- C) The vibrational frequency of the piano string is 436 Hz
- D) **The vibrational frequency of the piano string is either 438 or 442 Hz**
- E) The vibrational frequency of the piano string is either 436 or 444 Hz

$$\text{Beats} = |f_1 - f_2|$$

10. A train at rest emits a fixed frequency sound of 7200 Hz. If it moves away from the station at a speed equal to 33% of the speed of sound, what is the frequency of the sound heard by a person at the station?

- A) **5400 Hz**
- B) 4800 Hz
- C) 9600 Hz
- D) 10800 Hz
- E) 2400 Hz

$$f' = f/(1 + v/v_s) = 7200/(1 + 0.33) = 5400 \text{ Hz}$$

11. What is the amount of heat (in kcal) needed to convert 2.5 kg of ice at 0°C to water at 65°C ?

- A) 162.5 kcal
- B) **362.5 kcal**
- C) 242.5 kcal
- D) 605 kcal
- E) 1512.5 kcal

$$Q = M H_F + M c \Delta T = 2.5 \cdot 80 + 2.5 \cdot 1 \cdot 65 = 362.5 \text{ kcal}$$

Version I

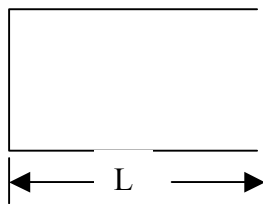
12. What is the frequency of a wave that has a velocity $v = 1 \text{ km/s}$ and a wavelength of 5m ?

- A) 0.2 Hz
 B) 5.0 Hz
 C) 5×10^{-3} Hz
 D) 5000 Hz
 E) **200 Hz**

$$f = v/\lambda = 1000 / 5 = 200 \text{ Hz}$$

13. What is the frequency of the 3rd harmonic in a pipe closed at one end if the primary frequency is 600 Hz ?

- A) 1200 Hz
 B) 1800 Hz
 C) 900 Hz cm
 D) **3000 Hz**
 E) 1500 Hz



Open pipe: $L = \lambda/4, 3/4 \lambda/4, 5/4 \lambda/4 \dots$
 $f_n = v_s/\lambda = 1 v_s/(4L), 3 v_s/(4L), 5 v_s/(4L)$
 3rd harmonic = $5 v_s/(4L) = 5$ primary
 frequency = $5 \times 600 = 3000 \text{ Hz}$

14. A heat engine operates between temperatures of 400 Kelvin and 300 Kelvin . Its maximum efficiency is:

- A) 10%
 B) **25%**
 C) 30%
 D) 40%
 E) 75%

Most efficient engine is Carnot engine
 $\epsilon = 1 - T_L/T_H = 1 - 300/400 = 0.25 = 25\%$

15. How much volume is occupied by 10 moles of oxygen at 0.5 atmospheres pressure and a temperature 333 Kelvin ? (The universal gas constant $R = 0.0821 \text{ L atm / mol K}$)

- A) 22.4 L
 B) 127.5 L
 C) 372.8 L
 D) **546.8 L**
 E) 626.4 L

$$V = n R T/P = 10 \times 0.0821 \times 333/0.5 = 546.8 \text{ L}$$

Version I

16. A bicyclist (total mass=68kg) is traveling at a speed of 1 m/s. How much work (in Joules) must he do if he wants to accelerate uniformly from this speed to a new speed of 3 m/s?

- A) 340 J
 B) 306 J
 C) **272 J**
 D) 68 J
 E) 34 J

$$\begin{aligned}
 W &= \Delta KE = \frac{1}{2} m v_2^2 - \frac{1}{2} m v_1^2 \\
 &= \frac{1}{2} m (v_2^2 - v_1^2) = \frac{68}{2} (3^2 - 1^2) \\
 &= 68/2 (9 - 1) = 272 \text{ J}
 \end{aligned}$$

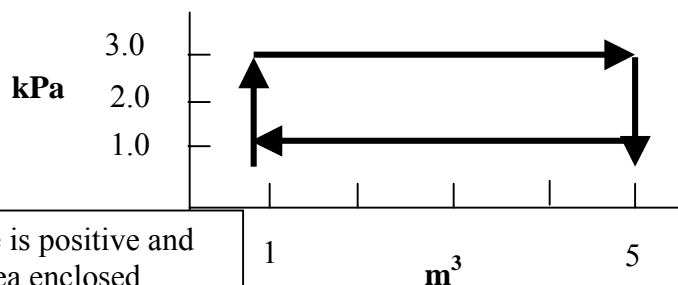
17. A block of mass m and a cylinder of mass m are released from the top of a ramp making an angle Θ with the horizontal while at the same time a cylinder also with mass m rolls without slipping down the same ramp. Pick out the correct answer below.

- A) At the bottom of the ramp both object will have the same speed.
 B) **The block will arrive at the bottom of the ramp before the cylinder.**
 C) The cylinder will arrive at the bottom of the ramp before the block.
 D) The cylinder will have greater speed at the bottom of the ramp than the block.
 E) The change in potential energy on arriving at the bottom of the ramp is greater for the block than the cylinder.

$$\begin{aligned}
 a_{\text{block}} &= g \sin \Theta \\
 a_{\text{cyl}} &= \frac{1}{2} g \sin \Theta \\
 \text{Thus block will arrive} \\
 &\text{at bottom before} \\
 &\text{cylinder}
 \end{aligned}$$

18. The diagram on the right shows a pressure-volume plot for a heat engine. The pressure is given in kilo Pascals and the volume in m^3 . About how much work (in Joules) is done by the engine per revolution?

- A) **$8 \times 10^3 \text{ J}$**
 B) $4 \times 10^3 \text{ J}$
 C) $1 \times 10^4 \text{ J}$
 D) $-8 \times 10^3 \text{ J}$
 E) $-1 \times 10^4 \text{ J}$



$$\begin{aligned}
 \text{Work done is positive and} \\
 \text{equal to area enclosed} \\
 &= 2 \times 10^3 (5 - 1) = 8 \times 10^3 \text{ J}
 \end{aligned}$$

19. A grandfather clock uses a simple pendulum for its timing mechanism. Pick the correct answer below.

- A) The period depends only on the length of the pendulum.
 B) The period depends on the mass and the length of the pendulum.
 C) The period would be the same on the moon as on the earth.
 D) The period is doubled if the length of the pendulum is doubled.
 E) **The period is doubled if the length is multiplied by four.**

$$T = (2\pi) (L/g)^{1/2}$$

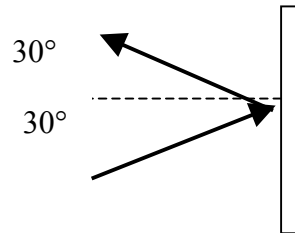
Version I

20. A tennis ball with mass 0.1 kg moving in the + x direction with a speed of 20 m/s has an elastic collision with a 3 kg bowling ball moving with the same speed in the - x direction. Assume that this is a one dimensional collision and choose the best answer below.
- A) After the collision both balls have the same speed.
 - B) **After the collision the bowling ball continues in the - x direction with nearly the same speed.**
 - C) After the collision the tennis ball continues in the + x direction with nearly the same speed.
 - D) After the collision the tennis ball goes in the -x direction at approximately 20 m/s.
 - E) After the collision both balls have zero speed.

Bowling ball is not much affected because of its weight

21. A billiard ball with mass 0.2 kg moving at 5 m/s strikes one of the table cushions at an angle of 30° with the perpendicular, rebounding elastically. What is the magnitude of the change of momentum of the ball?

- A) **1.7 kg m/s**
- B) 1.0 kg m/s
- C) 0.5 kg m/s
- D) 0.86 kg m/s
- E) 2.0 kg m/s



$$\begin{aligned}
 |\Delta p| &= 2 p \cos\theta \\
 &= 2 (0.2 \text{ kg}) (5 \text{ m/s}) \cos(30^\circ) \\
 &= 1.7 \text{ kg m/s}
 \end{aligned}$$

22. A circular tube of radius 0.5 m and mass 1.2 kg is mounted horizontally. A string is wound around it and a mass of 0.3 kg is attached to the string. Recalling that $I_{\text{cyl}} = m R^2$, what is the acceleration of the mass?

- A) 9.8 m/s²
- B) 4.9 m/s²
- C) 7.8 m/s²
- D) 2.45 m/s²
- E) **2.0 m/s²**



Hanging mass: $ma = mg - T$
 Tube: $T R = I \alpha = I a/R = MR^2 a/R$
 $T = Ma$ and $ma = mg - Ma$ or
 $a = mg/(m + M) = 0.3 \cdot 9.8 / (0.3 + 1.2)$
 $= 2.0 \text{ m/s}^2$

Version I

23. The Goodyear airship contains about $5.4 \times 10^3 \text{ m}^3$ of helium whose density is 0.18 kg/m^3 . What is the load the airship can carry at an altitude where the air density is 1.20 kg/m^3 ? (The load includes everything except for the He gas.)

- A) **5500 kg**
 B) 6480 kg
 C) 54000 kg
 D) 648 kg
 E) 972 kg

Archimedes Principle: $F_B = V \rho_{\text{Air}} g$;
 Weight carried = $F_B - \text{Weight of He} = V \rho_{\text{Air}} g - V \rho_{\text{He}} g$
 Load in kg = $\text{Weight}/g = V (\rho_{\text{Air}} - \rho_{\text{He}})$
 $= 5.4 \times 10^3 \text{ m}^3 (1.20 - 0.18) \text{ kg/m}^3 = 5500 \text{ kg}$

24. A patient with atherosclerosis has a partially blocked part of the artery blood flows three times faster than in a normal artery. Assuming both regions are circular, by what factor is the radius of the blocked region reduced relative to the normal?

- A) 3
 B) 1/2
 C) 0.9
 D) **1.7**
 E) 9

$V/t = \text{constant} \rightarrow A_1 x_1/t = A_2 x_2/t$ or
 $A_1 v_1 = A_2 v_2$ or $\pi R_1^2 v_1 = \pi R_2^2 v_2 \rightarrow$
 $R_2/R_1 = (v_1/v_2)^{1/2} = (1/3)^{1/2} = 1/1.7$

25. At what temperature do the Fahrenheit and Celsius scales have the same value?

- A) There is no such temperature
 B) **-40°C**
 C) -273 °C
 D) 32° F
 E) 40 °F

$^{\circ}\text{F} = 32 + 9/5 ^{\circ}\text{C}$;
 $^{\circ}\text{C} = 32 + 9/5 ^{\circ}\text{C}$ when $4/5 ^{\circ}\text{C} = -32$ or
 $^{\circ}\text{C} = -40$