Possibly useful facts:

**Ideal Gas:** $PV = nk_BT$  \hspace{1cm} (P=pressure, \hspace{1mm} V=volume, \hspace{1mm} n=number, \hspace{1mm} T=temperature)

**Kepler’s Third Law:** $T^2 = K_sa^3$, $T=$period, $a=$semimajor axis (Solar System)

Gravitational acceleration near earth’s surface $g = 9.8$ m/s$^2 \approx 10$ m/s$^2$.

1-dim. pos. as func. of time $t$ with init. vel. $v_0$ & const. accel. $a$ is $x(t) = (1/2)at^2 + v_0t + x_0$.

In same circumstance, velocity is $v(t) = at + v_0$.

Acceleration needed to keep a body moving in a circle of radius $r$ at speed $v$ is $v^2/r$.

A mass $m$ moving with velocity $v$ has **kinetic energy** $mv^2/2$ and **momentum** $mv$.

Hooke’s-law spring force $F = -kx$, where $x$ is displacement and $k$ the spring constant. Such a spring stores potential energy $U = (1/2)kx^2$.

**Moment of inertia** about its center of a uniform sphere of mass $M$ and radius $R$ is $I = (2/5)MR^2$. **Rotational kinetic energy** at angular frequency $\omega$ is $(1/2)I\omega^2$. The torque exerted by a force $F$ through a moment arm $R$ about an axis is $F_R = FR \sin \theta$.

**Bernoulli’s equation:** on a given streamline in an incompressible liquid, $P + (1/2)\rho v^2 + \rho sy$ is a constant, where $P$ is pressure, $\rho$ density, and $y$ the height above some reference point.

$\sin 60^\circ = \cos 30^\circ = \sqrt{3}/2$

ANSWER ONLY EIGHT OF THE TEN PROBLEMS. To indicate the problems you prefer not to answer, leave them blank or cross out the answer areas. If you answer nine or ten problems, the last one or two will not be marked. YOU MUST SHOW ALL WORK, EVEN ON MULTIPLE-CHOICE PROBLEMS.

The quiz is graded out of 80 (but will be normalized to 100 when final grades are calculated). Each question is worth 10 points. Grade cutoffs (see syllabus): A−=69, B−=50, C−=31. Partial credit is possible (but not guaranteed) on the short-answer questions. A homework bonus of up to 8 points (10%) will be added to your score.
1. A mass, hanging from a spring suspended from the ceiling, oscillates up and down. For which position does the velocity point **upward** while the acceleration points **downward**?

(a) at the bottom of the mass’s trajectory
(b) on the way up, while the mass is still below its equilibrium point
(c) on the way up, while the mass is exactly at its equilibrium point
(d) on the way up, while the mass is above its equilibrium point
(e) at the top of the mass’s trajectory
(f) more than one of the above choices
(g) none of the above

2. Which single statement among the following is true?

(a) In a large isolated system, it is highly unlikely but still possible that entropy could decrease in time.
(b) The entropy of a finite system can never decrease.
(c) If two systems, A and B, are in thermal contact, the sum of their entropies, \( S_A + S_B \), is conserved.
(d) Entropy is defined as the natural logarithm of the number of particles in a system, multiplied by Boltzmann’s constant.
(e) Entropy has the same units as energy (work).
(f) Entropy has the same units as temperature.
ANSWER ONLY EIGHT OF THE TEN PROBLEMS.

3. The c.g.s. (centimeter-gram-second) unit of energy is called the erg. An erg is equal to which of the following?

(a) g cm/sec
(b) g cm/sec^2
(c) g cm^2/sec
(d) g cm^2/sec^2
(e) cm/sec
(f) cm/sec^2
(g) cm^2/sec
(h) cm^2/sec^2

4. A wimpy 3-kg bomb flying horizontally through the air with an instantaneous velocity of 10 m/s to the left explodes into three pieces of equal mass. One piece flies straight up at an initial speed of 5 m/s; this is the only fragment whose final speed is measured. One piece flies straight down, and one piece continues in the original direction (all instantaneously, so that gravity plays no role in this problem). How much energy was converted in the explosion from chemical form to kinetic?

(a) none
(b) 150 J
(c) 325 J
(d) 475 J
(e) 625 J
(f) 950 J
(g) We cannot answer without knowing how much chemical energy was converted into heat.
5. A cylinder with a piston contains an ideal gas, which is allowed to expand isothermally for a time after which the pressure is increased isovolumetrically (at a constant volume).

(a) Sketch the two stages in a P-V plot (pressure on the vertical axis, volume on the horizontal).

(b) Does the gas do a net amount of mechanical work on the piston, does the piston do a net amount of work on the gas, or is the net mechanical work done zero?

(c) After both stages, is the final temperature of the gas lower than the initial temperature, higher than the initial temperature, or equal to the initial temperature?
6. A puck of mass 100 g is tied to a string and allowed to revolve in a circle of radius 1.0 m on a frictionless horizontal table. The other end of the string passes through a hole in the center of the table, and a mass of 1.0 kg is tied to it. The suspended mass remains in equilibrium while the puck on the tabletop revolves. What is the speed of the puck?

7. Starting at rest, a solid 10-kg sphere of radius 10 cm rolls down a 30° incline of length 14 m without slipping. What is its linear speed at the bottom of the incline? (Hint: use conservation of energy. You may set $g = 10 \text{ m/s}^2$.)
8. A spring-loaded toy cannon works when a 100-g steel ball compresses a spring a distance 10 cm and is then released from rest. When shot at an angle of 30° from the horizontal, the ball lands 10 m away (on flat ground). Neglect air resistance; what is the spring constant?

(a) $\frac{2}{\sqrt{3}}$ Nt/m  
(b) $\frac{10}{\sqrt{3}}$ Nt/m  
(c) $\frac{50}{\sqrt{3}}$ Nt/m  
(d) $\frac{100}{\sqrt{3}}$ Nt/m  
(e) $\frac{200}{\sqrt{3}}$ Nt/m  
(f) $\frac{500}{\sqrt{3}}$ Nt/m  
(g) $\frac{900}{\sqrt{3}}$ Nt/m  
(h) $\frac{2000}{\sqrt{3}}$ Nt/m

9. Rabson’s comet comes within 1.000 A.U. of the Sun at perihelion (closest approach), and its orbital period is 1000 years. (A.U. = astronomical unit is the semimajor axis of the Earth’s orbit around the Sun.) How far from the Sun is the comet at aphelion (furthest distance)? *Hint: it is not necessary to look up any numerical constants.*

(a) 1 A.U.  
(b) 9 A.U.  
(c) 15 A.U.  
(d) 99 A.U.  
(e) 199 A.U.  
(f) 499 A.U.  
(g) 1999 A.U.  
(h) $10^6$ A.U.
10. A pair of eyeglass frames is made of epoxy plastic with a coefficient of linear expansion $10^{-4}/^\circ C$. At room temperature ($20^\circ C$), the frames have circular lens holes 2.00 cm in radius. To what temperature must the frames be heated in order to insert lenses 2.02 cm in radius?

(a) 21$^\circ$C
(b) 23$^\circ$C
(c) 30$^\circ$C
(d) 50$^\circ$C
(e) 80$^\circ$C
(f) 90$^\circ$C
(g) 100$^\circ$C
(h) 120$^\circ$C

answer here