Massachusetts Institute of Technology
Department of Aeronautics and Astronautics
Cambridge, MA 02139

16.01/16.02 Unified Engineering I, II
Fall 2006

Problem Set 2

Name: ________________________

Due Date: 9/19/2006

	Time Spent (min)
F1	
F2	
F3	
F4	
M2.1	
M2.2	
M2.3	
Study Time	

Announcements:

Unified Engineering Fall 2006
Fluids Problem 1

Part A. (70%) An Ultimate Frisbee has a diameter of 27 cm, and a mass of 175 g.

a) In level flight, the net upward pressure force on the frisbee is equal to its weight. Determine the average pressure difference $\Delta p = p_{\mathrm{l}} - p_{\mathrm{u}}$ between the lower and upper surfaces of the frisbee.

b) When a frisbee slows down too much, the airflow around it can no longer generate the Δp needed for level flight, and the frisbee will then start to descend steeply, more like a parachute than a wing. It is reasonable to assume that the maximum level-flight Δp is comparable to the dynamic pressure $\frac{1}{2}\rho V_\infty^2$ of the oncoming flow that the frisbee sees. Estimate the frisbee's minimum level-flight speed in meters per second, and also in miles per hour.

Part B. (30% freebie if completed)

Math skills self-assessment

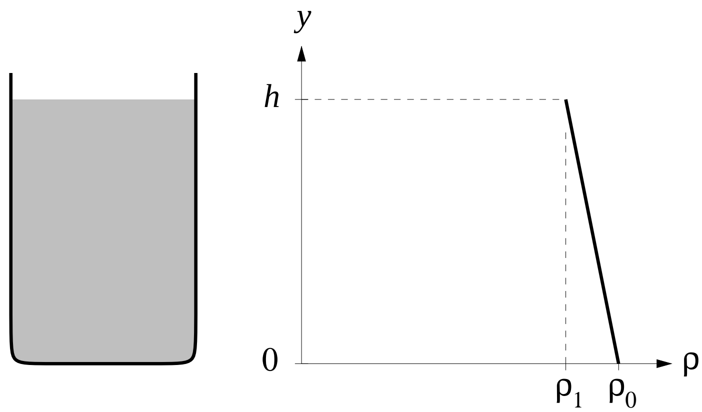
The objective is to establish the average UE student's understanding of material taught in the prerequisite math subjects, particularly in 18.02 or equivalent.

For each line in the table below, circle one of the 1-5 numbers using the following scale:

1 Poor understanding, or never heard of the concept
2 Weak understanding, probably couldn't apply it properly
3 OK understanding, could apply it with considerable effort
4 Good undertanding, could apply it with little or no trouble
5 Excellent understanding, almost second nature

	TOPIC OR CONCEPT	UNDERSTANDING
1	Vector addition and subtraction $\vec{u} + \vec{v}$	1 2 3 4 5
2	Scalar (Dot) product of two vectors $\vec{u} \cdot \vec{v}$	1 2 3 4 5
3	Vector (Cross) product of two vectors $\vec{u} \times \vec{v}$	1 2 3 4 5
4	Vector operations in polar coordinates r, θ	1 2 3 4 5
5	Conversion of a vector into a new coord. system $(x, y) \rightarrow (x', y')$	1 2 3 4 5
6	Normal and tangential vectors on a surface $\hat{n}$, $\hat{t}$	1 2 3 4 5
7	Gradient of a scalar field ∇p	1 2 3 4 5
8	Divergence of a vector field $\nabla \cdot \vec{v}$	1 2 3 4 5
9	Curl of a vector field $\nabla \times \vec{v}$	1 2 3 4 5
10	Line, Surface, Volume integrals $\int \vec{v} \cdot d\vec{s}$, $\iint \vec{v} \cdot \hat{n}\, dA$, $\iiint \vec{v}\, d\mathcal{V}$	1 2 3 4 5
11	Stokes Theorem $\iint (\nabla \times \vec{v}) \cdot \hat{n}\, dA = \oint \vec{v} \cdot d\vec{s}$	1 2 3 4 5
12	Gauss (Divergence) Theorem $\iiint \nabla \cdot \vec{v}\, d\mathcal{V} = \oiint \vec{v} \cdot \hat{n}\, dA$	1 2 3 4 5
13	Gradient Theorem $\iiint \nabla p\, d\mathcal{V} = \oiint p\hat{n}\, dA$	1 2 3 4 5
14	Conservation of mass	1 2 3 4 5
15	Conservation of linear momentum	1 2 3 4 5
16	Conservation of angular momentum	1 2 3 4 5
17	Conservation of energy	1 2 3 4 5

A glass is filled with water to a depth of $h = 10\,\text{cm}$.



The glass also has sugar on the bottom which causes the following density variation over the water depth:

$$\begin{aligned} \rho(y) &= \rho_0 + (\rho_1 - \rho_0)\frac{y}{h} \\ \rho_0 &= 1.2\,\text{g/cm}^3 \\ \rho_1 &= 1.0\,\text{g/cm}^3 \end{aligned}$$

a) The pressure on the surface is some known p_1. Determine the pressure variation versus depth, $p(y)$.

b) A $1 \times 1 \times 1\,\text{cm}$ cube of mass $1.15\,\text{g}$ is now submerged in the glass, and held centered on $y = h/2 = 5\,\text{cm}$. Determine the buoyancy force on the cube.

c) If the cube is released, at what y position will it come to rest?

a) Anderson problem 1.5 (p 93).

b) Anderson problem 1.6 (p 93).

A rectangular wing of chord c and span b is operating in high-speed flow in air. Its drag is known to depend on the following parameters:

$$D = f(\alpha, \rho_\infty, V_\infty, a_\infty, \mu_\infty, b, c)$$

and a_∞ is the speed of sound in air. Determine the dimensionless parameters (Pi products) which determine the drag coefficient C_D, defined as follows.

$$C_D = \frac{D}{\frac{1}{2}\rho_\infty V_\infty^2 \, b \, c}$$

Unified Engineering Problem Set **Lectures: M1, M2, M3**
Week 2 Fall, 2006 **Units: M1.1, U-B, M1.2 (part)**

M2.1 ***(10 points)*** For the following structures, list key design considerations and discuss the relative importance of these considerations.

(a) space station

(b) commercial transport aircraft

(c) glider

(d) automobile

(e) bridge

(f) step ladder

M2.2 ***(10 points)*** A 10 m by 10 m grid is situated in the (x-y) plane. The grid is made up of rigid rods connected at 1 m increments. The following set of forces act on this grid:

Force 1 acts at point (-2,-1) at an angle of 73.5° with a magnitude of 4 N
Force 2 acts at point (5,-5) at an angle of 135° with a magnitude of 5 N
Force 3 acts at point (-3,-4) at an angle of -315° with a magnitude of 2 N
Force 4 acts at point (1,1) at an angle of -106.5° with a magnitude of 4 N
Force 5 acts at point (3,2) at an angle of 0° with a magnitude of 3 N
Force 6 acts at point (-4,3) at an angle of -25° with a magnitude of 3 N

(**Note:** Angles are measured positive counterclockwise relative to a line drawn parallel to the x-axis and through the acting point of the force.)

For this configuration:

(**NOTE:** Express the answer as a vector as appropriate.)

(a) Describe each force as a vector and neatly draw out the described configuration.

(b) Determine the total (resultant) force acting on the grid and its magnitude.

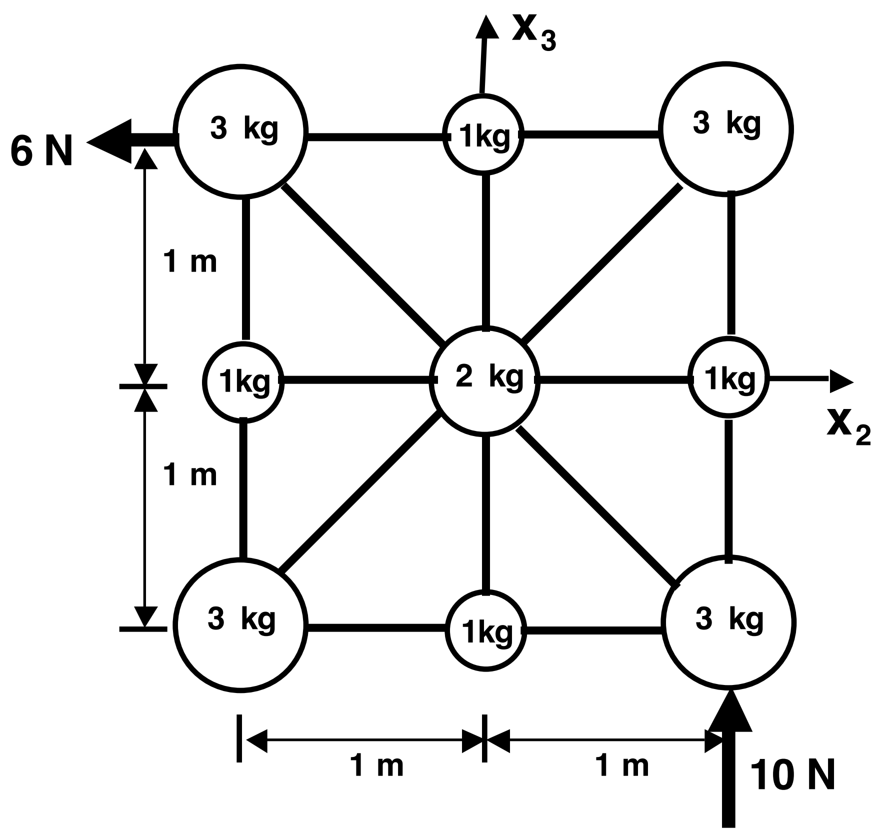
(c) Can any of the forces be expressed as a couple? If so, do so?

(d) Determine the moment acting about the origin (center) of the grid.

(e) Determine the moment acting about the lower left-hand corner of the grid.

(f) Determine the components of the moment acting about the y-axis and about the x-axis.

M2.3 *(10 points)* Consider a system of eight masses located in the x_2- x_3 plane as shown with one mass located at the origin of the plane. The masses are connected by rigid, massless rods. One force of 10 N acts parallel to the $+x_3$ direction on the mass at the lower right-hand corner, as shown. A second force of 6 N acts parallel to the $-x_2$ direction on the mass at the upper left-hand corner, as shown.



(a) This system is not in equilibrium, describe its initial motion.

For the following cases, carefully give your reasoning and express any forces and moments as vectors, as appropriate.

(b) Can equilibrium be achieved via the application of a force on the mass at the origin? If so, what is the force?

(c) Can equilibrium be achieved via the application of a moment at the origin? If so, what is the moment?

(d) Can equilibrium be achieved via the application of a force and moment at the origin? If so, what are the force and moment?

(e) Can equilibrium be achieved via the application of a couple anywhere (including along the rods)? If so, what is the force and where must it be applied?

(f) Can equilibrium be achieved via the application of a force anywhere (including along the rods)? If so, what is the force and where must it be applied?