Space Hardware Experiment Design

ASEN5519-002 FALL 2003

Final Exam DUE NOT LATER THAN 12/15/03 EOB

Name: ______________________ *Date:* __________

Unique Identifier ______________________ *(due 12/15/03)*

1. Space Cabin Pressure:

Assuming a cylindrical shell (diameter D, length L), the required wall thickness of a space habitat (ISS, Mars habitat, rover) can be estimated based only on the material property and the differential pressure (internal pressure, assuming vacuum on outside): $\sigma = \Delta P*D/(2t) \leq \sigma max.y$*. Reducing the internal pressure would provide substantial mass savings. To counteract potential difficulties in oxygen supply for humans, the partial pressure of oxygen is kept constant when reducing the absolute cabin pressure, but raising the O2 content above 30% changes the flammability characteristics of many materials (almost anything burns above 30% O2) and should be avoided.*

1.1 Compare required wall thickness, t, for ISS (14.7 psi) with an option of 10.2 psi (Leadville, Colorado), or 4.3 psia (US spacesuit), built from Aluminum ($\sigma max.y = 39$ *kpsi).*

Absolute Pressure	*Required wall thickness for D= 4m (ISS-type)*	*Potential mass saving (cylinder)*
14.7 psia	*t=*	*0% (reference)*
10.2 psia	*t=*	*=*
4.3 psia	*T=*	*=*

1.2 At 14.7 psia, the oxygen concentration on ISS/STS is 21%. For constant partial pressure, what would the required partial pressure be at the suggested lower pressures below:

Absolute Pressure	*Partial pressure O2*	*Volumetric O2 concentration*
14.7 psia	*=*	*21% v/v*
10.2 psia	*= Same as above =*	*=*
4.3 psia	*= Same as above =*	*=*

1.3 Despite the potential mass savings (good) and the increased fire hazard with higher oxygen concentration (bad), what is the most important rationale to NOT reduce the pressure (i.e., leave at 14.7 psia) in order to avoid problems during operations of powered equipment ? What other reasons to leave pressure high ?

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2. Inflatable Structures:

2.1 *Transhab (ISS habitation module) and AG-Pod (plant growth green house) are suggested examples of inflatable space structures. Why Inflatables ? What do they promise ? What key problems remain to be solved for inflatable structures ?*

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3. Phase Change Materials:

3.1 *During ascent and descent, there is very little electric power available. Even for the entire transportation process for ISS payloads, there is little if any power between handover (loading into Shuttle) and arrival at ISS. Phase change materials have been suggested to control the temperature of sensitive samples. What are phase change materials ? What is the advantage of using a phase change material for temperature control ?*

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3.2 *Water as an example: Cp = 4183 Joule / (kg K). Latent heat of fusion (solid to liquid) L = 333 kJoule/ Kg). You have a thermos container that 'leaks' 1 Watt when the inside temperature is 0°C, and the outside is 30°C. How long can you keep your samples at 0°C±1°C, if you use a) 1 kg liquid water at 0°C and let it warm up to 1°C, or b) if you use 1 kg of water ice (solid) at 0°C and let it melt.*

t_{liquid} = ______________________ = __________ *sec* = __________ *days*

t_{ice} = ______________________ = __________ *sec* = __________ *days*

4. Pumps:

Pumps are often characterized by the 'pressure head' they can deliver.

4.1 *what is the definition or equation for 'pressure head' or 'dead head pressure'?*

H = ____

4.2. *What's the flow rate V_{dot} at the max. pressure head (dead head pressure) H_{max} for a pump.*

V_{dot} *at* $p = H_{max}$ = _______ *liter / min* = _________ *GPM* = ________

4.3 *What is priming ? What is a self-priming pump ? If you have the choice between a centrifugal pump (low pressure head, not self-priming) and a positive displacement gear pump (high pressure head, self-priming), which one are you selecting for spaceflight (microgravity) application with respect to priming and vapor lock ?*

Priming: ____

____

Self-Priming: ____

____

Gear Pump vs. Centrifugal Pump in μg: ______________________________

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4.4 *A pump transfers energy / power to the fluid stream. What is the energy (power - watt) transferred to the fluid flow by the pump in a circulating flow? Calculate the energy efficiency of the following pump system. Where is the rest of the energy / power going to ?*

Gear pump: ΔP = 3 psi, V = 300 ml/min, U=24 VDC, I=0.125 A

P_{el} = ____________, P_{flow} = ______________, $\eta = P_{flow}/P_{el}$=________

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4.5 *You are using a positive displacement pump. You have to ensure, in dual-redundant fashion (3 independent controls), that your pump will not exceed the maximum allowable design pressure (MDP) of the circulation system (tubing, sensors, heat exchanger). What 'control features' could you design into your system to control (limit) the maximum pressure the pump can create, where:*

a) *the max. pump pressure (pump deadhead pressure) is lower than MDP of system,*

b) *the max. possible pump pressure is higher than the allowable MDP of the circulation system. How do you ensure that the max. pump pressure does not exceed the MDP value ?:*

a) Pmax < MDP:

1. ____

b) Pmax > MDP:

1. ____

2. ____

3. ____

5. Space Experimentation – Automated vs. Human-Tended:

5.1 *List some of the key arguments for and against the use of humans in support of space experimentation.*

a) *Pro: Humans should be employed in support of space experimentation (space biology, materials sciences, space physics, observation) because: .....*

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

b) *Contra: Instruments / experiments could be conducted better without the presence of astronauts because: .....*

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

c) *Without the presence of astronauts, the following technologies would need further development to enable autonomous science experimentation: .....*

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

6. Porous Tube Plant Nutrient Delivery System:

6.1 The forces affecting water transport and water availability to the plant roots in the porous tube nutrient delivery system (NASA KSC) are governed by:

a) hydrostatic pressure: P_{hs} = ____________________ (add equation)

b) dynamic pressure: $P_{dyn} = 0.5 * \rho * V^2$ V = flow velocity

c) capillary pressure: $P_c = 2 * \sigma / r$ (r = pore diameter)

For a porous tube of 12 mm diameter, a pore size r of 2 μm, Earth gravity g_o for ground testing and microgravity ($1*10^{-5}$ g_o) for flight, and surface tension σ of the water / air / ceramic 3-phase system, calculate the three different pressures controlling the water availability (expressed as pressure in Pa and mm H_2O) across the tube cross-section.

	Earth: $1*g_o$	*Microgravity: $1*10^{-5}$ g_o*
P_{hs}	________ *Pa* = ________ *mmH2O*	_______ *Pa* = ________ *mmH2O*
P_{dyn}	________ *Pa* = ________ *mmH2O*	_______ *Pa* = ________ *mmH2O*
P_c	________ *Pa* = ________ *mmH2O*	_______ *Pa* = ________ *mmH2O*

$G=9.81\ m/s^2$, r (pore size) = $2*10^{-6}$m, σ = 72 dyne/cm = 0.072 N/m. ρ = 998 kg/m^3. tube surface area: 0.1 m long, 12 mm diameter (neglect wall thickness). flow rate through the single tube of 1 liter / day.

7. *Plant Growth (all data provided is typical conservative plant performance data)*

Your plants convert 44 gram of CO2 per square meter of growth area per day, and produce 32 gram of O2 per square meter. In the process, they evaporate 1.1 kg/(m^2 growth area) of water per day into the air as humidity. Water has a latent heat of vaporization of L=2.26 Mjoule/kg. One human produces typically 1 kg CO2, uses 0.9 kg of O2.

7.1 *How much growth area do you need to support one human being with O2 / absorb the CO2 produced by that human ?*

based on CO2: ____ m^2

based on O2: ____ m^2

7.2 *how much water vapor (kg) would be produced per day by a plant-based atmosphere regeneration system that can convert all CO2 into the required O2 ?*

____ *kg*

7.3 *how much energy (joule) is needed to condense that amount of water per day ? What heat exchange rate (watt) is needed continuously to condense that amount of water per day ?*
E = ______________________________ = ______________ Joule

Q = ______________________________ = ______________ watt

7.4 *What volumetric flow rate does your atmosphere treatment system need to transport the CO2 and O2 gases for one person ? (Avogadro: 22.4136 l / mol. 1 mol CO_2 = 44 gram. 1 mol O_2 = 32 gram at standard atmosphere.)*
CO_2: __________ gram / day = _________ liter CO_2/ day @ 100% CO_2

O_2: : __________ gram / day = _________ liter O_2/ day @ 100% O_2

7.5 *What is the minimum airflow necessary at actual atmospheric concentrations (21% O_2, 78% N_2, <1% CO_2) to transport / mix the O2 and CO2 gases for one human being.*

need _______liter air / day = ______liter / minute = _______cfm to transport the CO2 in air stream at < 1% CO2.

7.6 *How much water is evaporated by a plant system capable of providing all atmospheric needs (CO2, O2) of one human being (assume no soil evaporation, only plant evapo-transpiration.*
Where does that energy come from to evaporate the water from the plants ? How much heat has to be removed from PGBA to condense the water again (consider only latent heat of condensation).

M_{h2o} = ____________ kg / day

E = ______________joule – energy comes from: ______________________

Q = ______________ watt – heat transfer from condenser to remove latent heat of condensation (dehumidifier).

8. *RoboArm (assume constant deceleration in all calculations).*

Your satellite moves at 0.25 miles per hour towards you. The satellite has a mass of 85 kg. You are leaning against the space station hull, and since you just worked out in the rec.center, you feel strong and adventurous and decide to stop the satellite with your bare hands (push-up style). What force do you need to stop the thing at 1 meter travel distance (length of your arm from time you touch satellite to stop to the distance your nose gets crushed) ? Now assume you are traveling at 25 miles per hour, hitting a wall. You want to catch yourself, doing a pushup against the dash board of your car. What

force do you need to stop yourself (85 kg) with 1 meter long arms, assuming constant deceleration.
Don't try this with your car or bike !!!! Do not drive into a wall ! Calculations will suffice !!!!

8.1 *Time to stop (V=0 m/s): _______ seconds. Deceleration: _____ m / s*^{2}

8.2 *Force (m=85 kg): _______ N = ________ lbf at 0.25*miles / hr*

8.3 *Force (m=85 kg): _______ N = ________ lbf at 25*miles / hr*

Merry Christmas and a happy new year. This exam is due NOT LATER THAN 12/15/03 EOB. I will email you once the grades have been posted on the web. Please do not forget to provide a softcopy of your presentation (slides + reference / documents if/as necessary and applicable.) by 1215/03 at the latest. Any excuses have to be co-signed by Santa !!!.
Thanks for your attention and I hope you learned something in the class. Any constructive feedback would be greatly appreciated. Thanks and good luck, Alex Hoehn

Grades:
http://www.colorado.edu/ASEN/asen5519/shw-fall-2003-grades.pdf