The University of British Columbia

Supplemental Examination – Spring session 2004

BIO/P 438

Time 2 1/2 hrs

Candidates Name:...

Registration #:.......................................

Candidates Signature ....

This is an open book /lecture -notes exam

The exam has four parts.

Part A: Attempt 1 out of 6 questions
Part B: Attempt this question
Part C Poster questions (or another question from Part A)
Part D: Write an essay on one of the topics

show all your rough work

	A: select 1 out of 6						Part B	Part C	Part D	
Question	1	2	3	4	5	6	Whale		essay	total
max. mark	25	25	25	25	25	25	30	20	25	100
mark										

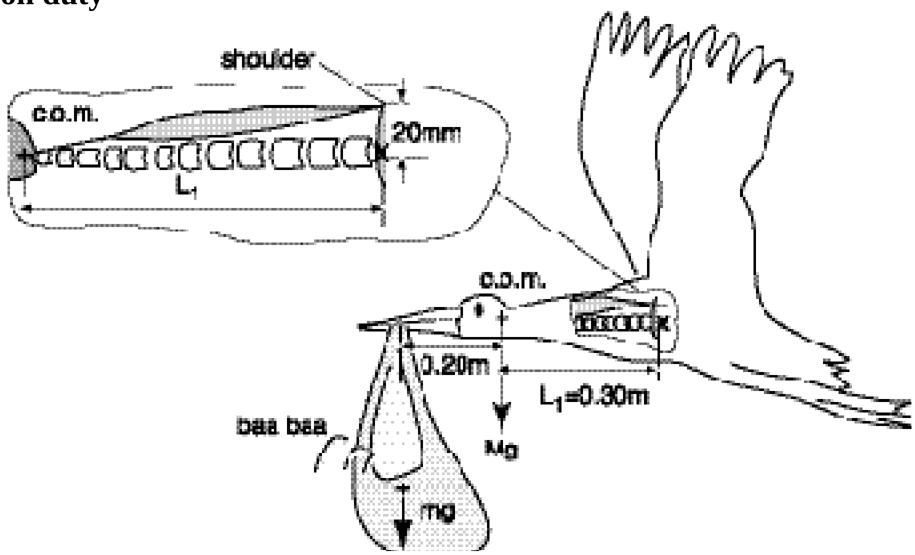
If you think some necessary information is missing from the exam or from the green lecture notes make an "educated guess" namely quote a number and write down why this number would make sense.

When you use a number from the lecture notes please quote the page number.

Lecture Notes Index appended

Part A: (max: 25 marks) ***Solve 1 out of the following 6 questions.***

Statics **1 Stork on duty**



A stork is battling the laws of physics to deliver baby Liam. The combined mass of the stork's head and neck is M=1.1 kg with its center of mass (c.o.m.) located just behind its head. Added to this is the m=2.5 kg mass of the baby, held in the beak 200 mm in front of the c.o.m. The stork has to hold its payload using a muscle that runs just above the spine the length of its neck, L_1=300 mm. The muscle attaches to the head at the same spot that the spine attaches, but at the "shoulders" it attaches to a bone 20 mm above the spine.

(a)Calculate the torques acting at the point "x" by the "shoulders".

(b)What is the tensile force on the neck muscle?

(c)Assuming the muscle holds a static stress of $f=2\cdot10^5$N/m^2, what is the muscle diameter?

(d)What is the compressive force on the vertebrae and discs? (e)If the disc is loaded to 90% of its maximum compressive stress $Y=10^7$N/m^2, what is the disc diameter?

(f) Briefly identify any other physics problems particular to stork couriers.

Motion **2 Extinct flying machine**

The partial skeleton of a now extinct dinosaurs *Pterodactyls phantasiensis elegans* has been excavated The body had a length of L=2m, and an estimated body mass M=12.0kg. The one recovered wing has a wing span of L_{wing}=2.4m with an average wing width of W=1.1m. Assume $(1/2)C_L\rho=0.3$.

(a) Determine the flight velocity.

(b) Compare this speed to the velocity that the animal would have according to the great flight diagram $v_{fl}=17M^{1/6}$,

(c) Infer all you can on the dinosaur from your results from (a) and (b). (You may go beyond the physics of motion).

Optics **3 Young and old eyes**

An image of low quality (like a blown up square newspaper photo of height h and width $w=h$) contains typically 10,000 image points (pixels).

(a) What physical principle sets the size of the smallest image point on the retina?

What is the smallest size of a pixel in the retina of the human eye?

(b) How large (height h_i, and width w_i) is the low quality image on the retina?

(c) If the image was produced by an object located at the distance o=30 cm what would be the height h of the object? **(d)** A filament light bulb of $P_{electric}$=1.5W power input is observed by a really old man (of 80 years) from a distance of 100m. How many photon enter one of his eyes in 5 seconds. Average wavelength λ 600nm. Typical efficiency η_{light}=3%. How many photon would the eye of a 20year old collect in 5 seconds? **(e)** Describe the image of the light bulb on the old man's retina, qualitatively and quantitatively.

Thermodynamics and energy ; **4) A Horse and buggy story**

A farmer (M=90kg when fully dressed) owns a horse of M_h=300kg.

(a)What is the metabolic rate of the horse on a day when it is just standing in the stable, not doing any work? And how much energy does it require per day?

(b) The farmer feeds the horse 1.2 kg of oats (Δh_{oats}=14MJ/kg) and hay (Δh_{hay} = 300kJ/kg) per day. How much hay does the farmer have to give the horse to support it's basic metabolic rate?

(c) When the horse is working it operates with an activity factor b=5.5 and an efficiency η=24%. What is it's mechanical power output P[Watt] Express your result in watt and horsepower (1HP=750watt); and how much heat [Watt]does the horse generate per second.

(d) The farmer uses the horse to draw a cart M_c=80kg, loaded with 2 bags of grain M_g=60kg each, up to a cattle feedlot, which is located on a little hill, h=75m high. Of course he sits on the cart as well.
How much mechanical (potential) energy does the horse have to generate on this trip?

(e) How much heat does the horse generate on this trip, and how much sweat (water) would the horse evaporate if it kept its temperature constant sweating.

(f) How long does it take the horse to make the trip?

(g) If the road to the feedlot has a gentle constant slope of 5%, how long this the road?

(h) At what speed does the cart travel?

(i)Considering your result from (c). Can you think of a reason why engineers often use the unit 1Horse Power (1HP=750W)?

Fluids**: 5) Is the lung ideal?**

The lung of a typical person of M=75kg has a volume of V=5liter, and during maximum exhaling it is reduced in volume by up to 13%. The air is admitted through the windpipe, a tube of $L\approx$20 cm length and $R\approx$0.8cm radius. The O_2 and the CO_2 molecules are exchanged in a huge number of alveoli, tiny bubbles of $r\approx$100µm radius. Assume allometric scaling according to Table 11.21, page 1-5.

$\nu_{blood}=4\cdot 10^{-6}$m^2/s

(a) What is the allometric breathing frequency. What is the exhaling time interval?
(b) What is maximum exchanged volume ΔV_{ex}, and how large is the volume flow φ. [m^3/s]?
(c) What is the flow velocity, and what is the Reynolds number Re at the maximum flow rate? Is this flow in the windpipe laminar or turbulent?
(d) How large a pressure drop Δp is needed to drive the volume flow through the windpipe?
(e) How many molecules of oxygen are in 1m^3 of freshly inhaled air, and how many oxygen molecules are in a single alveola ?
(f) Explain qualitatively why the lung has so many alveoli. Give some reasons why the radius r of the alveolae is $r\approx$100µm, and not much smaller and not much larger.

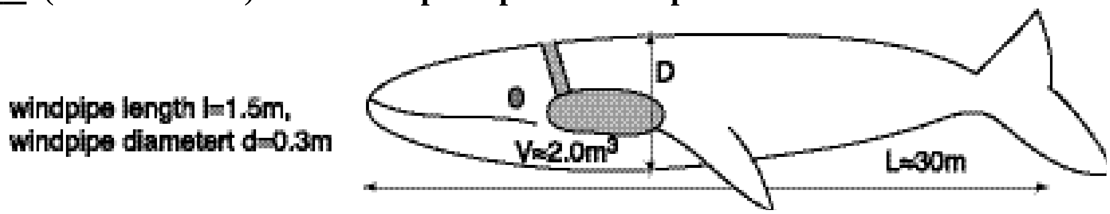
Motion 6) How does the flea get you?

A flea can be modeled as a sphere of diameter 1mm with as density close to ρ_{water}. The flea accelerates at an average rate of 200g (2000 m/s2), achieving a takeoff velocity that allows it to reach a potential host at a height of 0.35m

a) What is the takeoff velocity. b) How long is the acceleration phase? What force is required obtain this acceleration, and what is the power (force x velocity) at takeoff?

c) Make a reasonable assumption about the muscle mass involved in a jump and calculate the power requirements per kg muscle. Given that the typical muscle output is roughly 100 W/kg, comment on your answer. d) Before a jump, fleas store energy in a pad of resilin, a rubber-like protein, associated with each hind leg. Given that the energy storage capacity of resilin is 1.5×10^6 J/m^3, and that a pad is a cylinder 30 µm thick and diameter 80 µm, how much energy can the flea store in the resilin? e) How long would it take the flea to put the energy into the resilin?

<u>Part B</u> (max: 30 marks) **attempt all parts of this problem**



Giants of the deep

Blue Whales, typically have a body mass M=100,000 kg, and cruise at the velocity v=2m/s.
(a)Treat this mammal like any other from the mouse to elephant curve and determine its resting metabolic rate Γ_o.
(b) Its favorite food, krill has an energy content of typically Δh_c=5MJ/kg. How much krill does the whale have to ingest daily in order to supply its basic metabolic need?
(c) Assume that the whale, when active, generates a metabolic power that is a factor b=3 above its resting rate Γ_o, and that it operates at a mechanical efficiency of η=25%. How much mechanical power does the whale generate?
(d)If the whale swims straight up at a speed of v=2.8m/s how high can it propel its center of mass over the water surface?
(e)Assume that its streamlined shape gives the whale a drag coefficient C_D=0.12. What is the fluid resistance (drag force F_D) of the whale at its cruising speed?
(f) Why is seeing under water different from seeing in air?
(g) Whales can generate 1.2W of acoustic power. If this power spreads spherically what is the intensity [Watt/m^2] at a distance of 500 m?
h) Blue whales are known to produce sounds of 5-20 Hz. Why do these animals use such low frequencies? (i)
(i)These sounds are generated inside the animal. The sound could be produced in a cavity filled with air, or it could be produced by some vocal cords. (Speed of sound in air 340m/s) The figure shows the body cavities, and some body dimensions.
Consider the various resonators, (chapters 84.2,3,4) What mechanism do you think is used by the animal to make this low frequency sound?

****

<u>Part C</u> (20 marks)

Describe the results of one of the term projects (as shown on the poster) **not your own**, and explain what physical principles have been used, and what expected and unexpected results have been obtained.

Alternately you can select <u>another question from part A</u> (for 20 marks)

****

<u>Part D</u> (25 marks) ***Write an Essay*** *(typically 200- 300 words) on one of the topics*

Essay must include relevant equations

(a) Describe some physical principles which animals in hot climates have adopted to control overheating and describe physical principles which animals living in cold climates utilize to avoid the loss of body heat.

(b)Define efficiency, and briefly discuss it with respect to human locomotion.

(c) What is the benefit of being small or large and what limits body size?

(d) Is there a best sense for an animal? (Why do some animals mainly rely on their ears, other on their eyes, or detect electric and magnetic fields, and others on their sense of smell?)

(e) Describe some examples of resonance used by animals to save energy in locomotion and sound production.

(f) Describe some of the physical principles which one of the animals below uses to survive in its niche: alligator, bat, crow, dolphin, honey bee, monkey, octopus, pit snake, shark, wolf