The University of British Columbia

Sessional Examination - April / 17/ 2002

PHYSICS 438

Time 2 1/2 hrs

Candidates Name:...

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

Candidates Signature ....

This is an open -lecture -notes exam

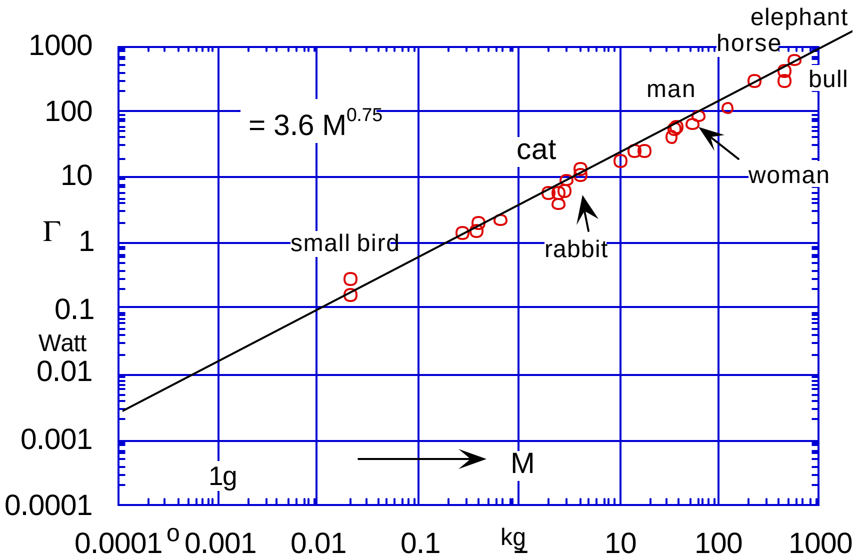
The exam consists of 5 pages. It has four parts:

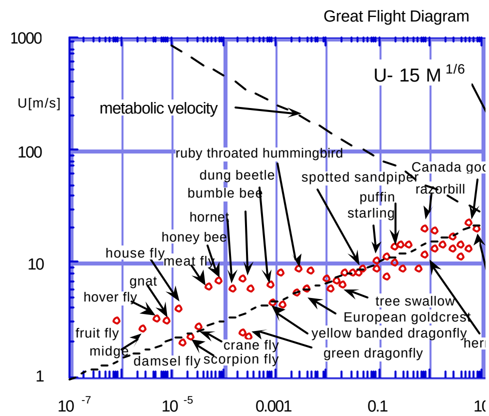
Part A: Select 1 out of 6 questions
Part B: Do this question
Part C: Select 1 out of 2 poster questions
Part D: Write an essay on one of the topics

Please hand in this cover sheet, and show all your rough work,

If you think some necessary information is missing make an "educated guess" namely quote a number and write down why this number would makes sense. Explain all your assumptions, and approximations.

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





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Part A: ♦ Solve 1 out of the following 6 questions.

Always indicate what assumptions you make if you think that some vital information is not given.

Thermodynamics

1) The hippopotamus…..latin name?

A hippo of M=900 kg has been sleeping in a thicket and it waddles into the open late in the morning. It stands in the bright light of the sun overhead for 20 minutes before it starts its active day.

a) How much radiation energy does it absorb in the 20 minutes? Model the hippo body as a cylinder of radius R and length L=4R supported by 4 chubby legs each having the mass of M_{leg}=50 kg. The solar constant is S=1.37kW/m^2. Assume an absorption factor α=0.65. Hint the average density of the animal is like that of water.

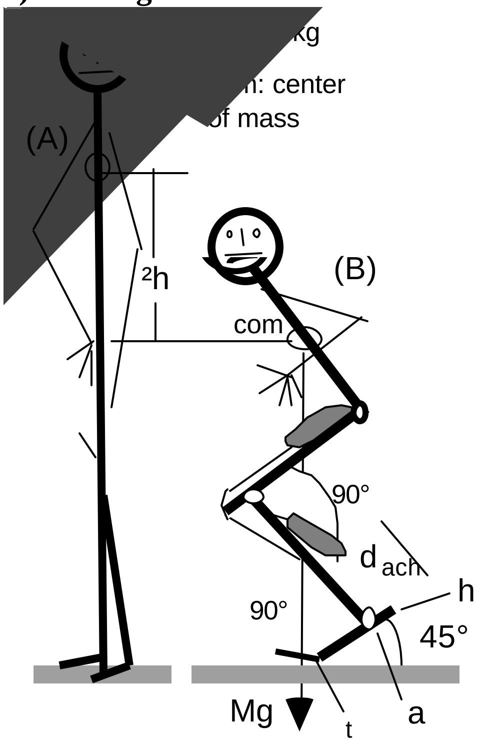
b) It is getting very hot and the hippo decides to take a bath in a pool of T= 22 °C. How much heat does it lose in the pool by thermal conduction through its bum (area A_b=0.4m^2, thickness of bum fat insulation ?s=0.08cm, thermal conductivity 4=0.11W/mK)?

c) Thereafter the hippo rolls in the mud, accumulating a healthy layer of wet dirt all over its body. Then standing in a gentle afternoon breeze it cools off by evaporating some water from the mud. How much water must be evaporated to lower its average body temperature by 2.5 °?

d) Can you think of some body features of the hippo that makes it well suited to prosper in its niche in the biosphere?

Statics

2) Strong Tendons



A person of M=65kg, height H= 1.74m crouches on a single foot in the position (B) having lowered his center of mass by ?h=35 cm. The body dimensions are as follows ;
Distance from toe (t) to ankle joint (a): d_{t-a}= 14.0cm, distance from ankle to heel(h) : d_{a-h}= 3 cm,
tendon length: d_{ach} = 12.0 cm.

a) Calculate the tensile force T in the Achilles tendon.
b) Determine the stretch ?L of the tendon, assuming a tendon diameter of D= 8.0 mm, Young's modulus Y= 1.5 10^9 N/m^2.
c) How much elastic strain energy is stored in the tendon in this crouching position?

d) Describe qualitatively the difference of the forces that act on the knee joint if the person jumps down from a table top onto the ground landing either in position (A),
or in position (B)

Fluids

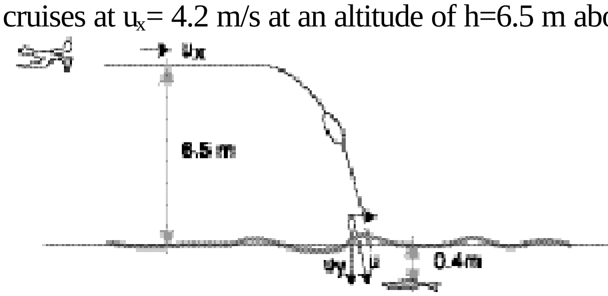
3) Careless Operation.

In an open chest operation the aorta of patient has been accidentally punctured by a round hole of 2.0 mm diameter.
a) What is the average pressure inside the artery close to the heart?
b) Why does blood escape out of the hole?
c) What is the average velocity of the blood flowing out of the hole ?
d) How much blood will escape within the first 5 sec?
e) Could you use the same calculation method to accurately predict the blood loss in the first minute? Explain.
(e) If a bypass of L= 0.30 m length and radius R= 0.002 m was inserted across the heart, and the pressure in the heart did not change during this procedure, how much blood would flow through the bypass in 5 seconds?

Dynamics

4) Pelican Dive bomber

A pelican of mass M= 3.6kg cruises at u_x= 4.2 m/s at an altitude of h=6.5 m above the sea looking for a meal.



Suddenly the bird spots a mackerel just d = 0.4 m below the surface. To catch it the bird pulls in its wings (without changing its horizontal velocity component) and drops down in free fall like a stone.

(a) How long does it take the bird to fall down to the water surface.

(b) What is the vertical component of the bird's velocity on impact, and what is the total speed u on impact.

(c) What is the initial drag force when the bird is fully submerged (assume C_d=0.03, and model the bird as a sphere), and what is its initial deceleration du to this drag?

(d) Calculate approximately how much time it takes the bird to reach the depth d=0.4m of the fish? (If you made a simplifying assumption in your calculation indicate if the numerical answer you got is larger or smaller than what one would get with a more accurate model).

Optics

5) Eagel Eyes

An eagle circles at a height of 500m above a field.

a) What is the size of the smallest detail ?x that its eye could resolve, (diffraction limit) given that its pupil has a diameter of 8.0 mm and the eagle is using blue light of the wavelength λ = 0.4µm. Assume that the eagle's eye has a focal length of 12.0 mm. The eagle's retina has typically $2.5*10^5$ cones/mm^2?

b) Determine the amount of light (power in Watt) which this eye would collect when looking from a distance of 50 m at a point source (say a glow worm) emitting 6 µWatt of light at λ=500nm, in a perfectly dark night (no moon, dark overhead clouds to obscure the stars).

c) How many photons would this eye collect from the glow worm in one "blink" (1 blink = 1/15 sec, Planck's constant h= $6.6\cdot10^{-34}$Joule).

d) Why was a "perfectly dark night" specified in part d?

Sound

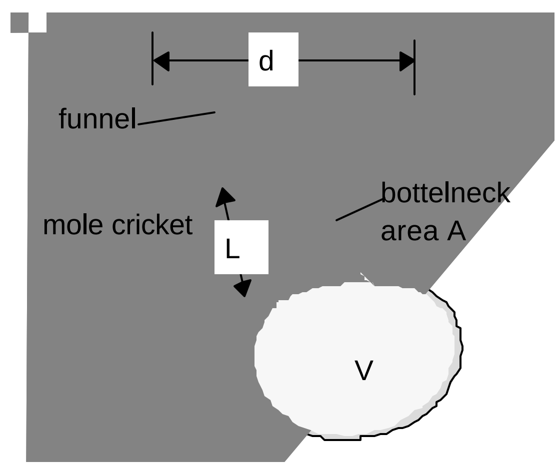
4) The mole cricket

Waldo, the mole cricket, believes that he amplifies his sound with a Helmholtz resonator. Waldo's sound producing instruments are tuned to a frequency f_o=2500 Hz. He has dug a hole in the ground of volume V= 4cm^3 and sits in a narrow passage of L= 3.0 cm length .

a) If he wants to tune the resonant frequency of his Helmholtz burrow to his instrument frequency, f_o, how large should he make the bottleneck area A?

b) If the cricket increases the area A making it larger than needed in (a) by 10 %, by what % would the frequency change? Would the Helmholtz frequency go up or down?

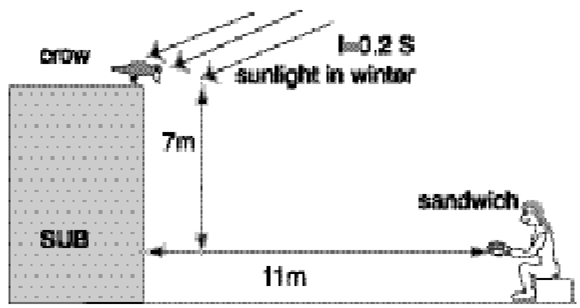
c) If the cricket sound spreads out uniformly into the hemisphere above his burrow, and this sound has a sound level of 40 dB at a distance of 60 m what is the displacement amplitude, s_o, of the air molecules at the distance r=60m ?



Part B ♦♦ **attempt all parts of this problem** ♦♦♦

Shared Meal

On a frosty winter day a crow ($M=\rho V= 0.40$kg) on the SUB roof watches a student, M= 63 kg sitting on the bench above the Pendulum Restaurant eating his SUB-standard 6" turkey sandwich ($5.99, rated as ?H=1100kJ). Solar constant S= 1.37 kW/m^2.



After 5 minutes the student has eaten 1/2 of his meal, while the crow just absorbed the mild winter sun (intensity only 20% of its full power).

a) How much energy has the student ingested, and how long could he survive from this alone if his metabolic activity rate is a factor b= 3.5 above his basic metabolic rate Γ_o

b) How much sun energy has the bird absorbed during this time? (Assume she is huddled into a sphere with feathers ruffled. Assume an absorption coefficient α~ 0.8)

c) Suddenly the student becomes aware of a pretty girl nearby, and does not watch his sandwich. The crow sees her chance, and swoops down to steal the last half of the sandwich. How long was the student's attention sidetracked? (Calculate the time it took the bird to get from A to B. Find the crow's flight speed. from the great flight diagram)

d) The crow flies back to her initial perch, and shows off her catch. How high is the image of the d=6" sandwich on the retina of the student?

e) Being University bread the crow croakes a polite "craw crow" (meaning "thank you, Sir" in Crowcanese) which the student (who unfortunately did not take Crowcanese 100) perceives only as a noise of ß=55dB. How large is the intensity I of this sound at the location of the student, and what it the acoustic power P emitted by the crow.

f) What did the student say when losing sight of the girl and the last half of his meal?

Part C ¨ ¨ ¨ **Chose one of the two poster questions** ¨ ¨ ¨

C1 Near surface of swimmers (Natasha Szucs)
(Sorry Natasha this one is not for you.)
Natasha swims the width of the UBC Aquatic center pool at various depths using the dolphin kick. She determined that her pulse rate stayed the same at remains the same at all depths. Therefore she assumes that she always applies the same force to overcome the drag.
At the depth of 3.O m where the pool width is $W_{3.0}$= 22.86m she needs in 21.2 seconds to traverse the pool.
a) What is her speed $u_{3.0}$ at d= 3m?
She has determined that the drag coefficient $C_{D0.5}$ at a depth of 0.5 m is 1.3 times larger than at the depth of 3.0 m. How much time does she need to swim across the pool at a depth of 0.5 m, where the width of the pool is $W_{0.5}$=25 m? (Hint: First write down how drag force and speed are related. Then work out the speed $u_{0.5}$ at the depth d=0.5m)

C2 Cormorant preparing for a long dive.
(sorry Corey, this one is not for you.)
Cormorants have a high body of T˜40°C. During a dive at their favorite depth of 33m they lose a significant amount of heat by conduction, since their feather insulation is compressed to a thin layer of ?R ˜ 1.2mm. The metabolic heat production Γ can not keep up with heat loss, so that the bird cools down during the dive. The bird therefore has a total net heat loss $Q' = \Gamma - Q_{conduction}$.
(a) Suppose a bird of M=2kg loses heat at the average rate of Q'=59watt, Assuming that the bird has a specific heat like water (C=4.18kJ/kg) by how much would its temperature drop in 2 minutes.
(b) How long can the bird stay under water if it allows its body temperature to drop from 40° to 36.8°C?
(c) How much longer can it stay under water if it heats up to a body temperature of 41.8° prior to the dive?

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Part D **short Essay** ...Chose on one of the topics.

A. Describe some Physics tricks that could help athletes achieve higher performance.
B. Describe the physical origins of "occupational" hazards of free style skiers, divers, figure skaters or mountain bikers.
C. Describe some physics principles that enable animals to enter new niches in the biosphere .
D. Describe some examples where one organ serves different purposes that impose different limitations
E. What is more important for animals, energy or information? Explain using physical concepts.
F. Describe some physical principles that animals in hot climates use to control overheating, and some physical principles that animals living in cold climates use to minimize loss of body heat.
G. Compare sight and hearing, and describe what information each of these senses yields. Explain why some animals rely more on their eyes and others more on their ears.

Part of 2) From the definition of Young's modulus Y in the equation $\frac{F}{A} = Y \cdot \frac{\Delta L}{L}$ which can be written as $F = \frac{Y \cdot A}{L} \cdot \Delta L$?L one can obtain a "spring constant" $k = \frac{Y \cdot A}{L}$ of the tendon. In order to do this problem you must estimate (i) the length of the levers that the muscles employ (e.g.length 6-7 on your heel or 2-3 on the knee), (ii) the length L of the tendons (e.g. 5-6), (iii) the diameter A of the tendons. Assume a Young's modulus for the tendons of $Y_t = 1.6\ 10^9$ N/m^2

Part of 3)

a) Using Fig 3-3.03 we determine the pressure of the blood in the aorta as $p_o = 10^5$ (˜1 atm)+1.3 10^4 N/m^2= 1.1310^5 N/m^2. b) The blood squirts oput because of the overpressure ?p= 1.3*10^4 N/m^2. The outside pressure is p= 10^5 [N/m^2]. c) The blood escapes in radial direction at some velocity v_r. Within the vessel there is no radial velocity. v_o˜0. The density of the blood ρ˜ 1000 is approximately like the water density. Then by Bernoulli's equation we have $p_o + 1/2\ \rho v_o^2 = p_o = p + 1/2\ \rho v_r^2$, $v_r^2 = 2(p_o - p)\ \rho = 2 \cdot 1.3 \cdot 10^4 / 10^3 = 26$ [m^2] or v_r = v26 = 5.1 m/s

d) The mass flow rate through the hole of 2mm diameter (area p $10^{-3})^2$ is m' = ρ A v_r = 0.016 kg/s. equivalent to 16 ml of blood. In the first 5 seconds the patient would loose ?m = 5 sec* 16 ml/s = 80 mL of blood.

e) At this mass loss rate the patient would loose 60 * 0.016 l= 0.96 l of blood. Such a loss of blood woiuld no doubt lead to a collapse of the circulation system and the heart would not be able to maintain the excess pressure ?p.

f) The flow in the bypass can be described by Hagen Poiseulle

$$m' = \frac{\pi \cdot r^4}{8 \cdot n} \cdot \frac{\Delta p}{L} = \frac{\pi \cdot \left(5 \cdot 10^{-3}\right)^4 \cdot 1.3 \cdot 10^4}{8 \cdot 4 \cdot 10^{-6} \cdot 0.3} = 2.66\ {kg}/{s}\ .$$

In 5 minutes the amount ?m = m' * 5.0 s= 13.29 l would flow through the bypass.