6.055J/2.038J (Spring 2010)

Homework 4

*Do the following problems. Submit your answers and explanations online by **10pm on Wednesday, 10 Mar 2010**.*

***Open universe:** Collaboration, notes, and other sources of information are **encouraged.** However, avoid looking up answers to the problem, or to subproblems, until you solve the problem or have tried hard. This policy helps you learn the most from the problems.*

Homework is graded with a light touch: P (made a decent effort), D (made an indecent effort), or F (did not make an effort).

Problem 1 Bandwidth

To keep your divide-and-conquer muscles strong, here is an exercise from lecture: Estimate the bandwidth of a 747 crossing the Atlantic filled with CDROMs.

$10^{\square} \pm \square$ bits/s ***or*** $10^{\square} \ldots \square$ bits/s

Problem 2 Gravity versus radius

Assume that planets are uniform spheres. How does g, the gravitational acceleration at the surface, depend on the planet's radius R? In other words, what is the exponent n in

$$g \propto R^n? \qquad (1)$$

$\square \pm \square$ ***or*** $\square \ldots \square$

Problem 3 Gravity on the moon

The radius of the moon is one-fourth the radius of the earth. Use the result of **Problem 2** to predict the ratio g_{moon}/g_{earth}. In reality, g_{moon}/g_{earth} is roughly one-sixth. How might you explain any discrepancy between the predicted and actual ratio?

Problem 4 Minimum power

In the readings we estimated the flight speed that minimizes energy consumption. Call that speed v_E. We could also have estimated v_P, the speed that minimizes power consumption. What is the ratio v_P/v_E?

$\square \pm \square$ ***or*** $\square \ldots \square$

Here is homework 4 on NB in case you would like to collaborate. It has more problems than the previous homeworks, but they are a lot shorter (and not divided into warmup versus problems). Have fun!

With or without a case? This will be much smaller if each CD is in a CD case.

I'm assuming he wants the same calculations as class...so no case!

It's a weight issue anyway, not volume

what stays constant? the planet's mass or its density? (or something else?)

Uniform spheres= constant density

A uniform sphere does have constant density (i.e. density at each point is not a function of its coordinates) but I don't think that it necessarily mean that each sphere has the same density as each other sphere. Doing Problem 3, however, suggests that we are in fact assuming the same density across all planets vs. same mass.

The first statement in this question sounds very factual, making the second one sound very contradictory. Maybe you could start off with saying "Imagine the radius of the moon is..."

Could someone give me a hint how to set this up? I think I'm still generally confused by proportional reasoning... I know how to relate P to E in terms of v, but I'm not sure where to go from there.

Which day's notes discuss this. I don't recall.

Problem 5 Highway vs city driving

Here is a measure of the importance of drag for a car moving at speed v for a distance d:

$$\frac{E_{\text{drag}}}{E_{\text{kinetic}}} \sim \frac{\rho v^2 A d}{m_{\text{car}} v^2}.$$

This ratio is equivalent to the ratio

$$\frac{\text{mass of the air displaced}}{\text{mass of the car}}$$

and to the ratio

$$\frac{\rho_{\text{air}}}{\rho_{\text{car}}} \times \frac{d}{l_{\text{car}}},$$

where ρ_{car} is the density of the car (its mass divided by its volume) and l_{car} is the length of the car.

Make estimates for a typical car and find the distance d at which the ratio becomes significant (say, roughly 1).

$$10^{\boxed{}} \pm \boxed{}\ \text{m} \quad \textit{or} \quad 10^{\boxed{} \ldots \boxed{}}\ \text{m}$$

To include in the explanation box: How does the distance compare with the distance between exits on the highway and between stop signs or stoplights on city streets? What therefore are the main mechanisms of energy loss in city and in highway driving?

Problem 6 Mountains

Here are the heights of the tallest mountains on Mars and Earth.

Mars	27 km	(Mount Olympus)
Earth	9 km	(Mount Everest)

Predict the height of the tallest mountain on Venus.

$$10^{\boxed{}} \pm \boxed{}\ \text{km} \quad \textit{or} \quad 10^{\boxed{} \ldots \boxed{}}\ \text{km}$$

To include in the explanation box: Then check your prediction in a table of astronomical data (or online).

Problem 7 Raindrop speed

Use the drag-force results from the readings to estimate the terminal speed of a typical raindrop (diameter of about 0.5 cm).

$$10^{\boxed{}} \pm \boxed{}\ \text{m}\,\text{s}^{-1} \quad \textit{or} \quad 10^{\boxed{} \ldots \boxed{}}\ \text{m}\,\text{s}^{-1}$$

To include in the explanation box: How could you check this result?

Comments on page 2

Is there anything we're allowed to assume about Venus?

it's 6.055. assume away.

Problem 8 Cruising speed versus air density

For geometrically similar animals (same shape and composition but different size), how does the minimum-energy speed v depend on air density ρ? In other words, what is the exponent α in $v \propto \rho^{\alpha}$?

$\boxed{} \pm \boxed{}$ ***or*** $\boxed{} \ldots \boxed{}$

Problem 9 Cruising speed versus mass

For geometrically similar animals (same shape and composition but different size), how does the minimum-energy speed v depend on mass M? In other words, what is the exponent α in $v \propto M^{\alpha}$?

$\boxed{} \pm \boxed{}$ ***or*** $\boxed{} \ldots \boxed{}$

Problem 10 Speed of a bar-tailed godwit

Use the results of **Problem 8** and **Problem 9** to write the ratio $v_{747}/v_{\text{godwit}}$ as a product of dimensionless factors, where v_{747} is the minimum-energy speed of a 747, and v_{godwit} is the minimum-energy speed of a bar-tailed godwit (i.e. its cruising speed). By estimating the dimensionless factors and their product, estimate the cruising speed of a bar-tailed godwit. [Useful information: $m_{\text{godwit}} \sim 0.4\,\text{kg}$; $v_{747} \sim 600\,\text{mph}$.]

$10^{\boxed{} \pm \boxed{}}\ \text{m}\,\text{s}^{-1}$ ***or*** $10^{\boxed{} \ldots \boxed{}}\ \text{m}\,\text{s}^{-1}$

To include in the explanation box: Compare your result with the speed of the record-setting bar-tailed godwit, which made its 11,570 km journey in 8.5 days.

Comments on page 3

Can I possibly get a hint on these? I'm not good at physics.

This problem was especially confusing to me, although I had the same sort of difficulty with the examples of these in the readings.