Physics 123 section 2
Winter 2010
Instructor: Dallin S. Durfee
Final Exam

Don't forget to fill in your CID number!

CID ________

Problems		
1.	________	/ 10
2.	________	/ 8
3.	________	/ 8
4.	________	/ 16
5.	________	/ 8
Ex.	________	/ 3
Total:	________	/ 50

Allowed: Textbook, class handouts, graded exams, homework, labs, etc., any notes you have written yourself, and an un-programmed calculator.

Your exam must be turned in by 10:00 a.m.!

To receive full credit, please show *all* work clearly and write neatly. If you wish to get partial credit on problems with incorrect answers, be sure to solve all questions algebraically first, then plug in numbers (with units) to get the final answer. Unless otherwise instructed, give all numerical answers in SI units. Give all numerical answers to *3 significant digits*.

For answers that rely on intermediate results, remember to keep extra digits in the intermediate results, otherwise your final 3 significant digits may be off - be especially careful when subtracting two similar numbers!

You may use the front and back of the test pages to do your work, but do not do work for one problem in space allotted for another problem. Be sure to work all of the problems. The point breakdown for all of the problems is listed in the column to the right.

To remind you, standard units in the SI (mks) system include the meter, the kilogram, the second, the Newton, and the Pascal.

HINTS: Work carefully and don't make mistakes! Try to *understand* each problem before you begin to *solve* the problem, and remember that drawing pictures and diagrams can be a big help. Remember to work all of your problems algebraically first, then put in numbers when necessary. Check your units when you are done, and make sure that your answers make sense. It also helps if you let some quantity in your problem go to infinity or zero to check that the equations you solve have the appropriate behavior in those limits.

1. Jimmy Neutron is flying through deep space in pursuit of Finbar Calamitous.

(a) At one point Jimmy does a long burn on his rocket thruster, raising the temperature of the thruster to 965°C at the end of the burn. The rest of the space ship is at a temperature of 20°C. The thruster is mostly made of 2,500 kg of iron, and the rest of the space ship is mostly made of 1,150 kg of aluminum. Assuming that Jimmy didn't devise a way to radiate a significant amount of heat into space, what will the temperature of the ship and the thruster be after they come into thermal equilibrium. Assume that the specific heat of aluminum is 900 J/kg $\cdot^\circ$ C and the specific heat of iron is 448 J/kg $\cdot^\circ$ C over the entire temperature range involved in this problem.

(b) Jimmy has a bucket of water on-board. The bucket is oriented such that as the ship accelerates, the "effective gravity" due to the acceleration keeps the water in the bucket. If the ship is accelerating at a rate of 7 m/s^2, and the water is 0.2 meters deep, what is the difference in the pressure at the top of the water and the bottom of the water?

(c) When Jimmy reaches Finbar, he launches a water balloon at him. The balloon is gray in color, such that it absorbs 50% of all of the light that hits it, and is spherical with a 20 cm diameter. The balloon misses, and flies off into deep space. Assuming that the water balloon was initially at 0°C, and assuming that the blackbody temperature of deep space is essentially absolute zero, how long will it take for all of the water in the balloon to freeze solid? Remember that the area of a sphere is $4\pi r^2$, and the volume of a sphere is $(4/3)\pi r^3$. The latent heat of fusion for water is 3.34×10^5 J/kg and the Stefan-Boltzmann constant is 5.67×10^{-8} W/m^{2}K^4.

Problem 1 continued...

2. Carl's incessant singing of the "folding and hanging" song is driving Jimmy crazy.

(a) Jimmy decides to use his jet-pack to fly so fast that Carl's voice is Doppler shifted to a frequency that he can't hear. If Carl's singing contains tones from 100 Hz to 2,400 Hz, and if Jimmy can hear sounds from 20 Hz to 20,000 Hz, how fast would Jimmy need to fly away from Carl in order for this scheme to work? Take the speed of sound to be 343 meters per second.

(b) A simpler thing for Jimmy to do would be to just move away from Carl. Lets assume that intensity of Carl's voice drops off like a spherical wave. If Jimmy is initially 10 meters from Carl, how far must he move away from Carl in order for the sound level to drop by 40 dB?

3. Evil Finbar Calamitous is watching Jimmy prepare for the first test of his new rocket. Finbar is on a space ship hovering 4.5 km directly above the place where Jimmy is assembling his rocket. The rocket is lying down on the ground.

(a) Jimmy presses a button and activates the laser on a robotic submarine which is floating just below the surface of a lake which is 0.4 km to the north of Jimmy. At what angle from the vertical should the submarine aim its laser in order to hit Finbar?

(b) The lake is a popular swimming spot for engineers, and as a result it has a 0.218 micron thick oily film covering it. To reduce reflections of the laser beam as it comes out of the water, Jimmy has chosen a wavelength for his laser which will result in maximum transmission through the oil. What wavelengths in the range from 400 nm to 800 nm (in air) will result in maximum transmission through the film? For simplicity, assume that the laser is exiting the water at normal incidence for this part of the problem.

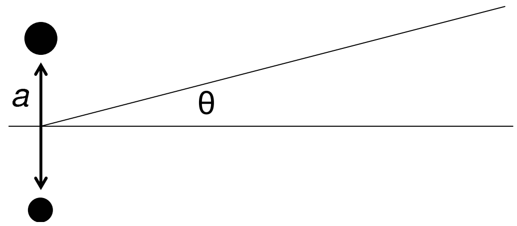
Assume that the index of refraction for water is 1.333 and for engineer grime is 1.47.

4. Jimmy Neutron is using his friend Carl as a guinea pig to test his rocket ship. Jimmy watches from his playhouse on the moon as the ship accelerates from its launch pad on the earth. The ship accelerates at a rate of 8.79×10^7 m/s^2, reaching its final velocity of 0.867 c just before it passes Jimmy. Precisely 25.2 minutes after passing Jimmy (as measured by Carl) Carl remembers that he forgot his lunch, and sends an urgent radio signal to Jimmy.

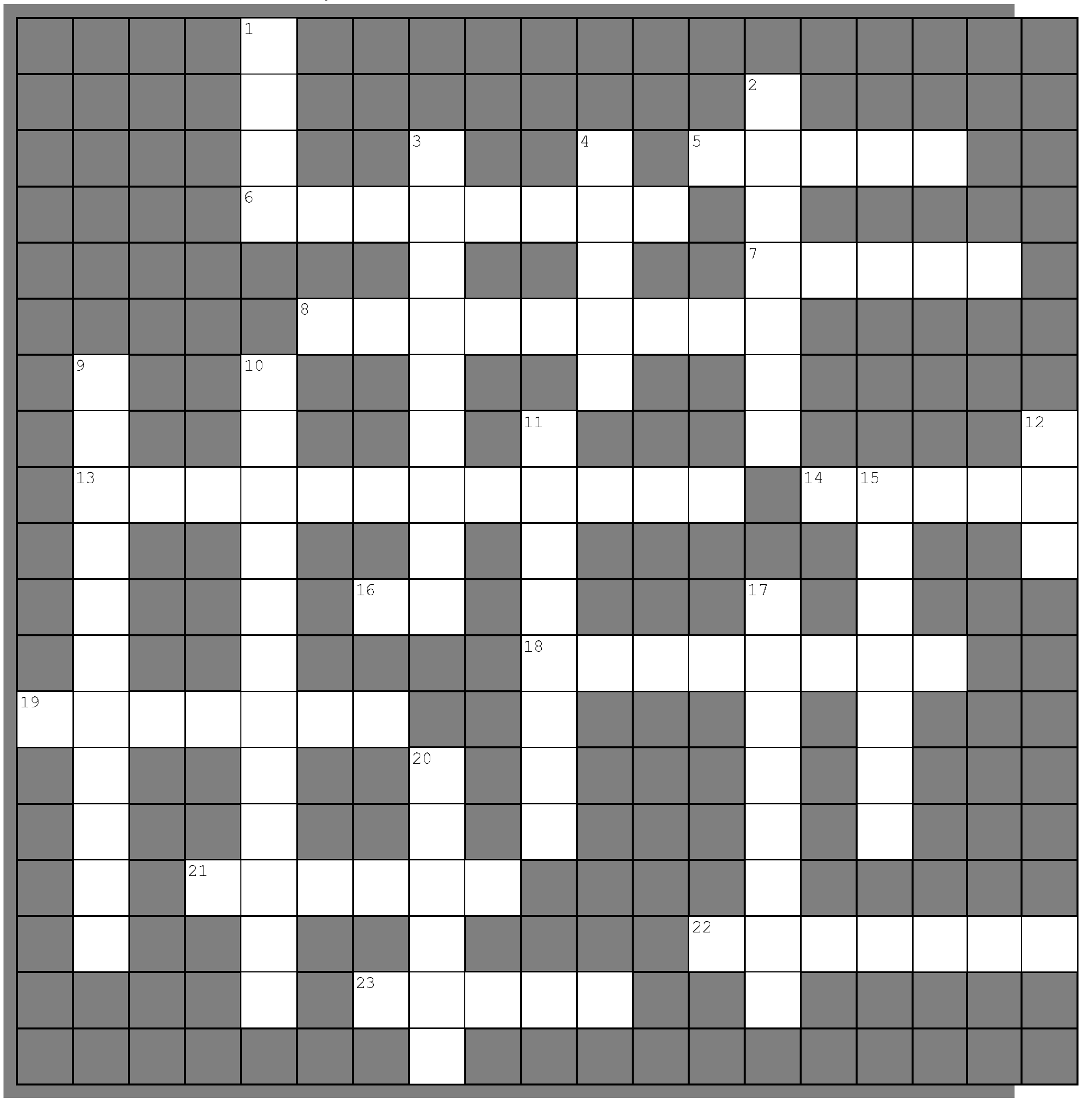
- **(a)** As Carl is accelerating, he notices that an atomic clock attached to the ship 10 meters below him is running slower than an atomic clock attached to the ship right next to him. If the atomic clocks are perfect, how many nanoseconds will the clock below him fall behind each second?
- **(b)** Before the test, when the rocket is at rest on the Earth, the rocket is 20 meters long. When the ship is at its final velocity, how long does the "20 meter long" rocket ship appear to be in Carl's reference frame?
- **(c)** How long does it appear to be in Jimmy's reference frame?
- **(d)** In Jimmy's reference frame, how much time elapses between Carl passing him and Carl *sending* the message?
- **(e)** In Jimmy's reference frame, how much time elapses between Carl passing him and the time Jimmy *receives* the message?

Problem 4 continued...

5. Jimmy is communicating with Carl using a pair of radio antennas, separated by distance a as shown in the figure below. Both antennas emit a sine wave with a wavenumber k and are exactly in phase with each other. The upper antenna emits a signal that is 9 times the power of the wave emitted by the lower antenna. A long distance from the antennas, what is the intensity of the interference pattern? Give your answer in terms of k, θ, a, and I_{max} (the intensity at $\theta = 0$).



Extra Credit. Remember that this is only worth 3 points. Be sure to work all of the other problems first.



Across

5. The guy who figured out that $e^{i\phi} = \cos(\phi) + i\sin(\phi)$

6. What physics majors do on a Friday night

7. Inventor of Holography

8. What you get when you change i to $-i$

13. Clocks run slow in moving frames due to this effect

14. The kind of 3D wave whose amplitude is the same everywhere

16. 180 degrees in radians

18. The best teacher you've ever had

19. Man who said that all functions are really sums of sine waves

21. Principle that light travels path that takes least time

22. A lens which is made lighter by removing material from the middle

23. Did the first double-slit experiment

Down

1. Invented the Equal Temperament Scale

2. Principle that says you can treat each point on a wave front as a point emitter

3. Equation that relates P, v, and y named after him

4. Diffracted x-rays off of crystals

9. An early musical scale using just intonation

10. Heat capacity per unit mass

11. A type of wave in which certain points in space don't oscillate

12. The color of light with a wavelength of 650 nm

15. The name of the relativistic transformations

17. Force per unit area

20. A vector in the complex plane

Extra Extra Credit This is a "make up" question to atone for my lousy extra credit question on exam 3. It is worth one point.

A solid sphere of glass with a radius of 10 cm and an index of refraction of 1.45 is held such that it is half submerged in a lake of water (with an index of refraction of 1.33). The sun is directly overhead. Light from the sun is focused by this set up a distance d under water. What is d?

Unused. Foil with three tiny slits spaced a, 2a.

– If the contribution from the middle slit is $E_0\sin(\omega t+\phi_m)$, then the phase of the lower slit will be $\phi_l=\phi_m-ka\sin(\theta)$, and the phase of the contribution from the upper slit will be $\phi_u=\phi_m+2ka\sin(\theta)$. If I define $Q=ka\sin(\theta)$ then the total, in complex expo form, will be

$$\tilde{E}=E_0e^{i(\omega t+\phi_m)}+E_0e^{i(\omega t+\phi_m-Q)}+E_0e^{i(\omega t+\phi_m+2Q)}=E_0\left[1+e^{-iQ}+e^{i2Q}\right].$$

To get the time averaged intensity, we just evaluate the amplitude squared $=|\tilde{E}|^2=\tilde{E}^*\tilde{E}$ and change E_0^2 to I_0:

$$I=I_0[1+e^{+iQ}+e^{-i2Q}][1+e^{-iQ}+e^{i2Q}]=I_0[1+e^{-iQ}+e^{i2Q}+e^{iQ}+1+e^{i3Q}+e^{-i2Q}+e^{-i3Q}+1]=$$

$$I_0[3+(e^{iQ}+e^{-iQ})+(e^{i2Q}+e^{-i2Q})+(e^{i3Q}+e^{-i3Q})]=I_0[3+2\cos(Q)+2\cos(2Q)+2\cos(3Q)].$$

Now we just plug in $Q=a\sin(\theta)$ and normalize so that we get I_{max} at $\theta=0$:

$$I=\frac{I_0}{9}[3+2\cos(ka\sin(\theta))+2\cos(2ka\sin(\theta))+2\cos(3ka\sin(\theta))].$$

- You could also do this with a phasor diagram. In this case I'm going to let $\phi_l=0$ at some time t. At this time, $\phi_m=-Q$, and $\theta_u=-3Q$. Then, when I add the phasors together, the real part of the total will be

$$E_{real}=E_0+E_0\cos(Q)+E_0\cos(3Q),$$

and the imaginary part will be

$$E_{imag}=0+E_0\sin(-Q)+E_0\sin(-3Q).$$

So the total magnitude is

$$E=E_0\sqrt{(1+\cos(Q)+\cos(3Q))^2+(-\sin(Q)-\sin(3Q))^2},$$

and

$$I=I_0[(1+\cos(Q)+\cos(3Q))^2+(\sin(Q)+\sin(3Q))^2]=I_0[1+\cos(Q)+\cos(3Q)$$