Physics 101 Exam 3

November 15, 2002

YELLOW VERSION

Select the single best answer for each question, unless otherwise instructed. No notes are permitted. Calculators are allowed.

Density of water = 1000 kg/m^3 Density of air = 1.25 kg/m^3
Air viscosity = 0.0000183 Pa s Water viscosity = 0.00100 Pa s
1 Atmosphere = 10^5 Pa Absolute zero = 0 K= -273 ^{0} C
Stefan-Boltzmann Constant s = 5.67 x 10^{-8} W/(m^2 K^4)

1. A curve ball in baseball curves because of

(a) lift forces. (b) drag forces. (c) turbulent flow. (d) laminar flow.

Lift forces include any aerodynamic forces perpendicular to the direction of motion.

2. Which of the following quantities is not conserved?

(a) Energy (b) Angular momentum (c) Entropy (d) Momentum

Entropy normally increases.

3. Why does an ice cube feel cold?

(a) Heat from your hand enters the cube by convection.

(b) Cold from the cube enters your hand by convection.

(c) Heat from your hand enters the cube by conduction.

(d) Cold from the cube enters your hand by conduction.

Heat is energy, and can be transferred. Cold cannot be transferred.

4. You have three incandescent light bulbs that are each consuming 50 W (50 watts) of power. Bulb #1 is a 50W halogen bulb operating at its designed power level. Bulb #2 is a three-way bulb, with 50W, 100W, and 150W settings, which is presently operating at its 50W setting. Bulb #3 is an ordinary 100W light bulb that is connected to a dimmer system so that it is only consuming 50 W. Rank these three bulbs from brightest to dimmest (i.e. put the bulb that that emits the most visible light first).

(a) #2 (brightest), #3 (middle), #1 (dimmest).

(b) #2 (brightest), #1 (middle), #3 (dimmest).

(c) #3 (brightest), #1 (middle), #2 (dimmest).

(d) #1 (brightest), #2 (middle), #3 (dimmest).

The halogen bulb is hottest, so it produces the most visible light. The light on the dimmer will be cooler than it is designed to operate, and will produce less visible light.

5. You construct a water-powered go-cart by attaching a large tank of water to a cart. The water can be forced out a nozzle by connecting a tank of high-pressure air to the water tank. In preparation for your first ride, you position this contraption facing away from a brick wall. You climb on and start spraying the water against the wall. To your delight you accelerate away from the wall and begin to move. When you have moved far enough away from the wall that the stream of water can no longer hit it, you

(a) continue to accelerate as the water sprays out the back of the cart.

(b) continue to move, but stop accelerating since the water can no longer push against the wall.

(c) feel lighter than normal since the water hitting the ground will produce an upward force.

(d) continue to accelerate, but less since it takes more force to accelerate a moving object than a stationary one.

The cart accelerates because it is continually throwing mass out the back, like a rocket engine. The recoil force propels the cart forward.

6. You are in a dark 20°C room, looking at a shiny metal ball that has a temperature of 1000°C. The ball doesn't emit any visible light because the shiny ball

(a) isn't hot enough to emit visible light.

(b) neither emits nor absorbs any thermal radiation.

(c) would need some white in it in order to produce visible light.

(d) has none of the flat surfaces needed to emit light.

An object at this temperature only emits infrared light. This is less than half the temperature of a light bulb. Although shiny objects are poor emitters, the ball would emit visible light at a higher temperature.

7. As air flows through the horizontal ductwork in a warehouse, that air passes through a fan inside the duct and the air's total energy increases. Since the air's speed doesn't change as the result of going through the fan, you know that the air's

(a) kinetic energy has decreased but its pressure has remained the same.

(b) kinetic energy has increased but its pressure has remained the same.

(c) pressure has decreased but its kinetic energy has remained the same.

(d) pressure has increased but its kinetic energy has remained the same.

The fan does work on the air, increasing its pressure. The work could have increased the kinetic energy, but we are told the velocity is the same, so that did not happen.

8. You are holding two identical-looking balloons, one filled with air and one filled with water. You drop these two balloons from a very tall bridge and notice that the water-filled balloon hits the ground first because its terminal velocity is larger. The terminal velocity of the water balloon is larger than that of air balloon because

(a) conservation of momentum requires the lighter air-filled balloon to travel more slowly.

(b) although the drag forces on the two equally shaped balloons are the same, the buoyant force on the air balloon is larger so the net force on that balloon is smaller and it falls more slowly.

(c) the larger force of gravity on the water balloon must be balanced by a larger drag force, which occurs at a higher speed.

(d) although the force of gravity on the two balloons is the same, the water balloon has more inertia and travels downward more quickly.

The heavier water balloon feels a stronger gravitational force. At a constant velocity, the drag force must balance this. Larger drag forces occur at larger velocities.

9. If a normal bulb 1 and bulb 2 have identical filaments, except that bulb 1 operates at 3000^{o} C and bulb 2 operates at 2500^{o} C, what is the ratio of the power radiated by bulb 1 to the power radiated by bulb 2? Choose the closest answer.

(a) 1.2 (b) 1.5 (c) 2.0 (d) 2.5

The power radiated is proportional to T^4 by the Stefan-Boltzmann law, where T is the absolute temperature. The absolute temperatures of the bulbs are 3273 K and 2773 K, respectively, so the ratio of power emitted is $(3273K / 2773K)^4 = \mathbf{1.94}$.

10. Which statement about emitting and absorbing radiation is true?

(a) A dark object is a more efficient emitter but a light one is a more efficient absorber of radiation.

(b) A dark object is a more efficient absorber but a light one is a more efficient emitter of radiation.

(c) A light object emits and absorbs radiated energy more efficiently.

(d) A dark object emits and absorbs radiated energy more efficiently.

Emission and absorption occur through the same physical process, only in reverse. When emitting, vibrating electrons produce electromagnetic waves, and when absorbing, electromagnetic waves make the electrons vibrate. Materials where this effect is the strongest are the best emitters and absorbers. Good absorbers appear dark.

11. The air in this room consists of countless tiny, independent molecules. You can be sure that these air molecules will not all shift spontaneously to the other side of the room (leaving you in a vacuum) because that would

(a) violate Newton's laws of motion.

(b) be extremely unlikely and therefore violate the 2nd law of thermodynamics.

(c) violate Bernoulli's equation.

(d) not conserve energy and therefore violate the 1st law of thermodynamics.

This actually wouldn't violate any physical laws of motion, but is statistically improbable. The 2nd law of thermodynamics is a statistical law about the behavior of materials on the average. This law would be violated by the spontaneous decrease in entropy caused by all of the atoms moving into a much less probable configuration.

12. Some satellites orbit the earth at such large distances that they are never in the earth's shadow. These satellites are constantly exposed to full sunlight. With no air around them to take away heat, why don't these satellites continue to grow hotter forever?

(a) They have solar panels that convert the sun's thermal radiation completely into electricity and avoid any need to eliminate heat.

(b) Their temperatures rise until they are able to radiate heat away into space as fast as it arrives from the sun.

(c) They use air conditioners (which NASA calls "thermal stabilization units") to eliminate the excess thermal energy as rapidly as it arrives.

(d) Because they are isolated from the sun by empty space, the sun's heat can't reach them and they don't experience any changes in temperature.

The Stefan-Boltzmann law shows that the amount of energy radiated is proportional to the fourth power of the temperature. The temperature will increase until the amount of energy emitted by electromagnetic radiation matches the amount of energy received from the sun.

13. A thermoelectric cooler is a type of heat pump that uses electric power to move heat against its natural direction of flow. In such a heat pump electrical power must be converted to thermal energy because

(a) the entropy of the system must be conserved.

(b) Newton's laws of motion prevent heat from moving from a cool region to a warm region.

(c) the flow of heat from a cool region to a warm region alone would decrease the entropy (disorder) of the system.

(d) the flow of heat from a cool region to a warm region alone would violate the conservation of energy.

Entropy normally increases, but moving heat from a cool place to a warm place causes a net decrease in entropy, which is forbidden by the second law of thermodynamics, unless some more entropy can be added from outside the system. The laws of motion and energy conservation say nothing about this.

14. The glass envelope of an ordinary incandescent light bulb is filled with a low-pressure mixture of nitrogen and argon gases. If there were no gas at all inside a bulb's envelope, this special bulb would be

(a) more energy efficient but would have a shorter operating life than an ordinary bulb.

(b) less energy efficient and would have a shorter operating life than an ordinary bulb.

(c) less energy efficient but would have a longer operating life than an ordinary bulb.

(d) more energy efficient and would have a longer operating life than an ordinary bulb.

The bulb would be more energy efficient because there would be no air to carry thermal energy away from the filament. The bulb would not last as long, because the inert gasses inside a normal light bulb help to keep the tungsten from subliming away.

15. You place three nonflammable objects in a fire. They are identical in shape and size, but one object is black, the second is white, and the third is shiny silver. After a few minutes, all three objects are at the same temperature: 1800° C. They remain solid and are now glowing with thermal radiation. Which one is glowing most brightly?

(a) The first object (black). (b) They are all glowing with equal brightness.

(c) The third object (silver). (d) The second object (white).

Since black objects are the best emitters as well as the best absorbers of electromagnetic radiation, the black object will glow the brightest in the fire.

16. The circulation of air to heat a room is an example of

(a) conduction. (b) convection. (c) transmission. (d) radiation.

17. The maximum speed a rocket can achieve is

(a) equal to the speed of its exhaust plume.

(b) less than the speed of its exhaust plume.

(c) greater than the speed of its exhaust plume but less than the speed of light.

(d) the speed of light.

The speed can increase until the rocket is moving faster than its exhaust, but is limited by the amount of fuel it can carry. The bigger the fraction of its mass is made of fuel, the faster the rocket can go. Nothing that has mass can reach the speed of light.

18. You are on an airplane trip to the islands for vacation. Your first flight is on a propeller driven airplane. The air flowing toward the spinning propeller blades doesn't slow down before it encounters those blades. Your second flight is on a turbofan-driven jet airplane. The air flowing toward the spinning fan blades slows down significantly before it encounters those blades. The air's pressure just before it encounters the turbofan's fan blades is

(a) much higher than the air's pressure just before it encounters the propeller's blades.

(b) much lower than the air's pressure just before it encounters the propeller's blades.

(c) equal to atmospheric pressure at the plane's altitude.

(d) the same as the air's pressure just before it encounters the propeller's blades.

The air pressure encountering a propeller would be at atmospheric pressure. In a turbofan jet engine, the air is slowed down upon entering the engine, and pressurized at the same time (by Bernoulli's relation).

19. If a car is traveling at 55 mph (25 m/s), and the car is about 3 m across, what would the Reynolds number be?

(a) about 500 (b) about 2000 (c) about 20,000 (d) about 5 million

The Reynolds number, which determines the onset of turbulence, is the dimensionless quantity

$$R = v\, L\, \rho\, /\, \eta = (25\ \text{m/s})(3\ \text{m})(1.25\ \text{kg/m}^3)\ /\ 0.0000183\ \text{Pa s} = \mathbf{5.1 \times 10^6}\ .$$

Here, v is the velocity of air past the car of size L, and ρ and η are the density and viscosity of the air. A Reynolds number of 5 million corresponds to very turbulent flow.

20. When a 1 cm diameter pipe was new, it would carry 0.50 liters per second, but when it got old, it would carry only only 0.20 liters per second. If this is due to mineral deposits inside the pipe, what is the remaining pipe diameter available for water flow?

(a) 4 mm (b) 6 mm (c) 8 mm (d) 2 mm

Poiseuille's equation shows that the ratio of the flow rates is proportional to the fourth power of the ratio of the pipe diameters, so (0.2 L/s) / (0.5 L/s) = $(d_2/d_1)^4$. Therefore,

$$d_2 = d_1 \times (0.2 / 0.5)^{1/4} = (1\ \text{cm})(0.4)^{1/4} = 0.8\ \text{cm} = \mathbf{8\ mm}.$$