1. Energy Coupling, MMD 3.4
This problem can be solved simply as long as we apply the law of conservation of energy. We have two objects, the mass and the spring.

Initially, the only energy present in the system comes from potential energy (PE) from the mass. There might be some amount of PE in the spring, say X joules. As the mass falls, PE is converted into kinetic energy (KE) in the mass. The spring is compressed by the mass, so KE from the mass is converted into PE in the spring. We are told that energy is lost as the spring compresses. When the spring decompresses, we add supplemental energy to the system. The PE in the spring is converted to KE in the mass. Finally, KE is converted to PE in the mass as the mass returns to its original height. In this final state, we once again have X joules of potential energy in the spring.

Since $PE_{initial} = PE_{final}$ in both the mass and spring, the amount of energy in the system at intial state is the same as the amount in the final state. **Thus, the amount of supplemental energy we add equals whatever energy we lost from compression.** So,

$PE_{mass,initial}$ = mass*gravity*height = (1 kg) * (9.8 m/s^2) * (1 m) = 9.8 Joules

10% of this energy, or 0.98 J, is lost due compression. Thus, **we must add 0.98 Joules** for the mass to return to its original height.

2. Energy Balancing, MMD 3.6
a) For this problem use the information of p. 53 of MMD that the energy stored in each phosphate-phosphate bond (P-P) in ATP is about 7000 cal/mol. There are two P-P bonds in ATP. So assuming that we are creating ATP from AMP (adenosine monophosphate) by adding two P-P bonds, we get:

$$\frac{10^{-2}\,mol}{h*g\,cell}*\frac{5\,kcal}{mol}=\frac{50^{-2}\,kcal}{h*g\,cell}$$ = energy produced in one gram of cells in one hour

$$\frac{50^{-2}\,kcal}{h*g\,cell}*\frac{mol\ ATP}{2*7\,kcal}*\frac{6.02*10^{23}\,ATP}{mol\ ATP}=\frac{2.15*10^{21}\,ATP}{h*g\,cell}$$

With significant figures, the answer is

$$\frac{2*10^{21}\,ATP}{h*g\,cell}$$

Had we assumed that we are creating ATP from ADP instead of AMP, we would only need one P-P bond. We would bind that we could generate

$$\frac{4*10^{21}\,ATP}{h*g\,cell}$$

In both cases, quite a bit of ATP is generated in a gram of cells in one hour! This makes sense because ATP has a high rate of turnover.

b) Assuming that the heat capacity of the cell equals the heat capacity of water, 1 cal / (g ºC), and having already calculated the energy produced in one gram of cell in one hour, we can solve the problem as follows:

$$1\,g\,cell * 50\,min * \frac{.05\,cal}{h * g\,cell} * \frac{1\,h}{60\,min} = 41.6\,cal$$
$$41.6\,cal * \frac{g\,^{\circ}C}{1\,cal} * \frac{1}{100\,g\,water + 1\,g\,cell} = .41254\,^{\circ}C$$

Thus, one gram of cells causes 100 grams of water to heat up by **0.4 ºC** (notice from part a that we have only one significant figure).

3. Information Flow and Control, MMD 3.8
(a), (b), and (c) are discrete, continuous, and fairly discrete or mixed, respectively.

In (a), once the air conditioner is ON, the fan speed and compressor circulation are constant and uninformed about the deviation from the set point. Thus, the response does not increase in proportion to the deviation. The only way to increase the response is for someone to manually alter the fan setting from, for example, low to high. Thus, additional control logic (i.e. a person-based sensor and actuator) is required.

In (b), the colder you are (i.e., further the body temperature drops), the more you shiver.

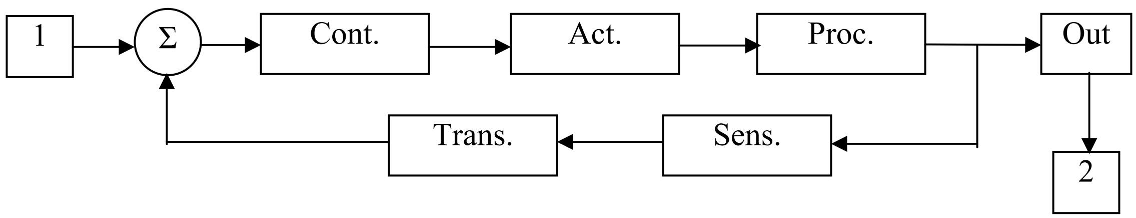
Concerning an automobile, here is a deeper explanation and depending on how much you know about cars, the more you can say. The way the problem is worded, the thermostat is closed when T < 220 and open when T > 220. So based on the given info, the only conclusion is discrete. In reality, a thermostat opens at around 180 degree F. The mechanism is a wax melts and its density decreases. The increased volume of the wax pushes up a control rod, which opens a path for water to be pumped from the engine ports to the radiator. A thermostat opens continuously over a 10-15 degree F span. Thus, to be exact one can say for T < 180, the radiator cooling system is OFF. Over around 180 –200, the system is variably ON and possibly emulating continuous control. Emulation is the caveat because the partial opening may reflect the wax melting dynamics and a distributed melting temperature if the wax is a blend of different materials. Thereafter, for T > ca 200 degrees F, the system is ON. For more information on car parts, consult: http://auto.howstuffworks.com/cooling-system8.htm.

4. Information Flow and Control, MMD 3.9
a) ATP hydrolysis to ADP will exceed rate of ADP to ATP, so ADP/ATP will be higher than when the rates are balanced.

b) High ADP will stimulate rate 3 via positive feedback. Because ATP is lower, there will be lessened negative feedback on rates 3 and 10. The stimulatory and lessened restricting effects will combine to increase the rate of glucose use until ATP concentration increases relative to ADP concentration.

c) Lower ADP stimulates rate 3 less via positive feedback. Initially, because ATP is higher, there is increased negative feedback on rates 3 and 10. These effects combine to decrease the rate of glucose use until ATP production decreases. This in turn causes less ATP-mediated negative feedback on steps 3 and 10, and allows the rate of glucose use to increase slightly. The net effect is that rate glucose use- initially less because of the high value of ATP- will eventually creep back up to a more normal rate.

5. Information Flow and Control



Manipulated variable: flow of gasoline into tank
Output variable: level of gasoline in tank
Sensor: vision (inputs information about level)
Transmitter: nervous system (transmits control signals to actuator)
Controller: Iggy’s brain (processes input information)
Actuator: hand & arm muscles (manipulates gas pump)

This is a negative feedback control loop. Once the gasoline reaches the desired level, Iggy stops pumping gas. We can assume that transport of gasoline to the tank is instantaneous.

In order for Iggy's to tell when he has reached the limit, he must pull the pump out of the tank and visually check the level. If the level has not been reached, he puts the pump back into the tank and fills a little more. Thus, this is a discrete control problem.