University of Maryland
Department of Physics

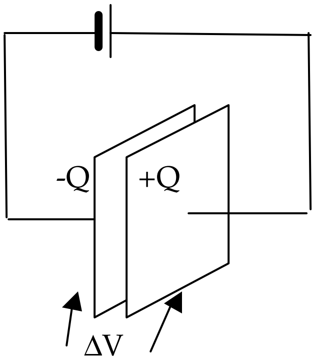
Spring 2002 **Laura Lising**
Physics 122 **April 24, 2003**

Exam #2 Solutions

Multiple choice questions.

Just the answer counts for these. (8 points each)

1) Suppose you have two parallel plates hooked up to opposite sides of a battery as shown. Opposite charges (+Q and -Q) have built up on the two plates and there is a voltage difference (ΔV) between them. You then move the two plates farther apart from each other. What happens?



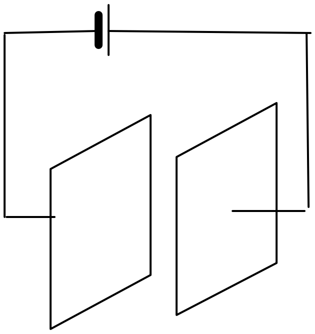
a) The amount of charge on the two plates increases and the voltage difference decreases.

[✓ b)] The amount of charge decreases and the voltage difference stays the same.

c) The amount of charge and the voltage difference both stay the same.

d) The amount of charge decreases and the voltage difference increases.

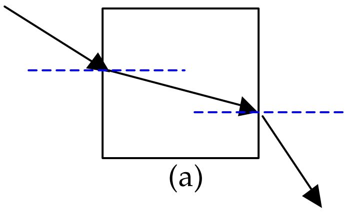
e) The amount of charge increases and the voltage difference stays the same.

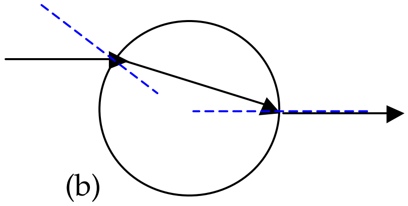


One way to think about this is that the capacitance decreases as you move the plates apart. But the voltage difference can't change because the capacitor is stuck to a battery, which is trying it's darndest to keep the potential difference it's made for. So, for a given potential difference, lower capacitance means lower charge.

Another way to think about it is by thinking about the charges and the pressure. The battery is pushing with a certain pressure difference on both sides. This allow charge to pile up on the capacitor even though the charges on each plate are repelling each other. The fact that the plates are close helps more charge go on since the charges on one plate repel each other but are attracted the oppositely charged plate nearby. When the plates are pulled apart, there is still the repelling forces from the like charges, but the attractive forces from the opposite plate are now weaker because it's farther away. So the same pressure is unable to keep the same amount of charge squeezed onto the plates.

2) Which of these is a possible picture of light passing through plastic?


(a)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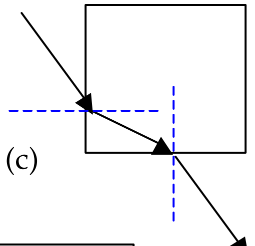
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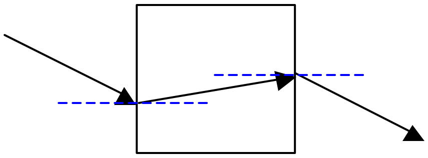
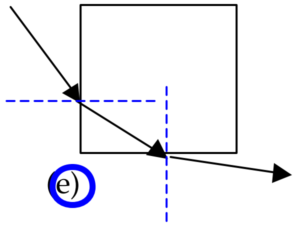

(d)

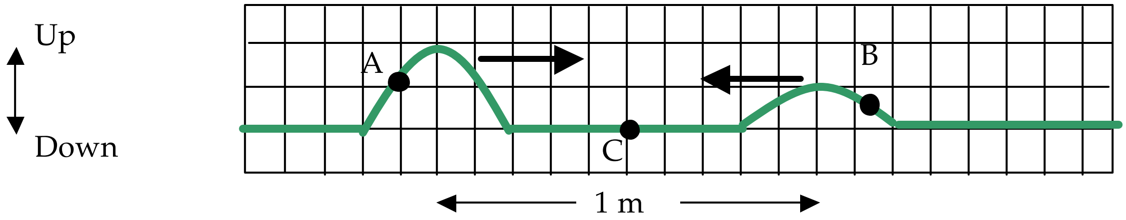

[✓ (e)]

One thing we know about refraction is that from air to plastic (higher index of refraction) light will bend towards the normal, whereas from plastic to air it will bend away from the normal line. We decided that this bend was a bend such that it bent towards or away from the normal with respect to it's original direction: that is, the light won't pass over the normal to bounce like a reflection. So let's look at the choices from that point of view. In (a) the light bends towards and then away. Good. In (b) it's towards but then towards again coming out. So (b) must be wrong. Same with (c), towards and towards. (d) has this problem that it's bending way too much, bending past the normal completely. And (e) is towards and then away.

Now we have to choose between (a) and (e). With (a) you notice that the second bend is much bigger than the first. We decided in class that the light would have the same relative bends coming in and going out. So (a) must be wrong. In (e) the relative bends are about the same. It bends some toward going in and then some away going out. It's a pretty sharp angle going out, but that's because the angle with the surface inside is steeper, too.

Note how if you remembered a rule about same angle in and out you'd have chosen b,c, or d.

3) Two pulses on a stretched spring are moving toward each other. Three beads are glued to the spring and labeled points A, B, and C. Which of the following statements is true at this instant in time?



a) Bead A is moving up and B is moving down and A is moving faster than B.

b) Bead A is moving up and B is moving down and A is moving slower than B.

c) Bead A is moving down and B is moving up and A is moving faster than B.

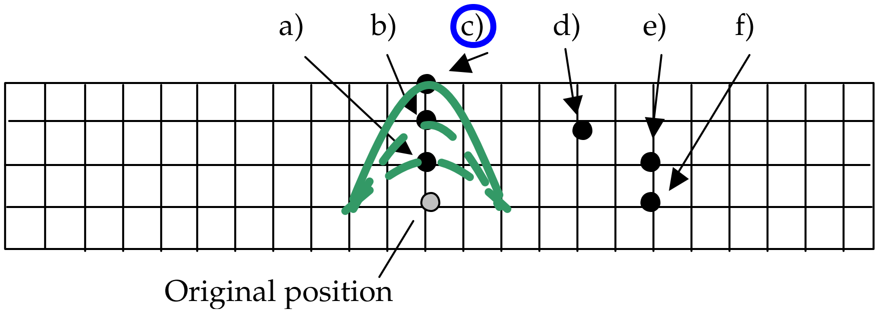
d) Bead A is moving down and B is moving up and A is moving slower than B.

e) Both A and B are moving up and A is moving slower than B

[✓ f)] Both A and B are moving down and A is moving faster than B

Both A and B are points on the rope where the pulses are almost past, so they are moving down. It's like if you were sitting on a raft on the ocean. If you're at point A, you've just gone up and now you are headed down as the wave passes you by. Same with B, since the wave passing it is going the other direction. A is going faster than B, though, because the pulse it's on is narrower. It had to go up twice as far in the same time, so it has to move faster on the up and down parts to do that. Of course, if A and B were on different springs you wouldn't be able to answer this. Even if A and B were on pulses shaped like they are here, if B's wave pulse was traveling much faster it could make B travel much faster. But since they are on the same spring we know their wave pulse travel speeds are the same since that only depends on the medium, not the pulse.

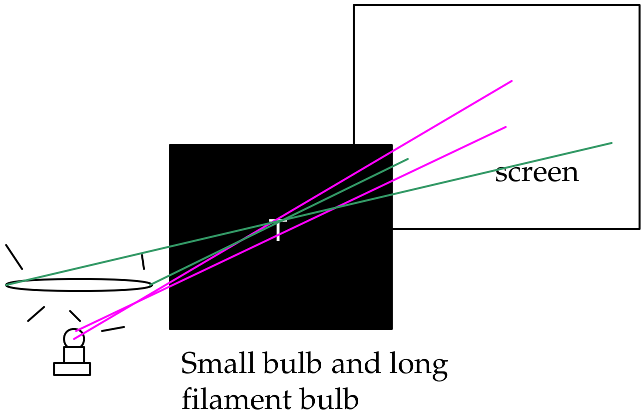
4) Same pulses as question above. If the pulses are moving at 1 m per second, in ½ second, where is bead C?

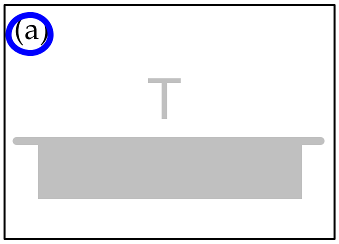


At 1 m/s in ½ second the pulses have gone ½ meter or 5 squares and are now completely on top of each other. Thus the pulses add up in the middle to be 2 squares plus 1 square = 3 squares high. Note that the pulses move right and left but the bits of spring only move up and down. So C is still in the middle and is at the top of this summed pulse at position (c).

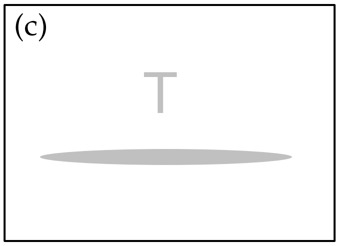
Name______________________
Section____________________

5) A small bulb and a long filament bulb are placed in front of a board with a T-shaped aperture. What will we see on the screen?




[✓ (a)]


(b)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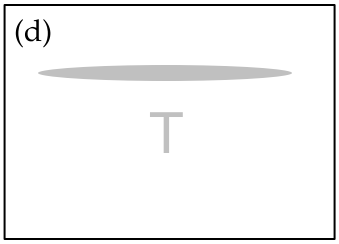
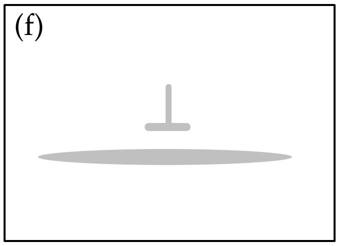

(d)

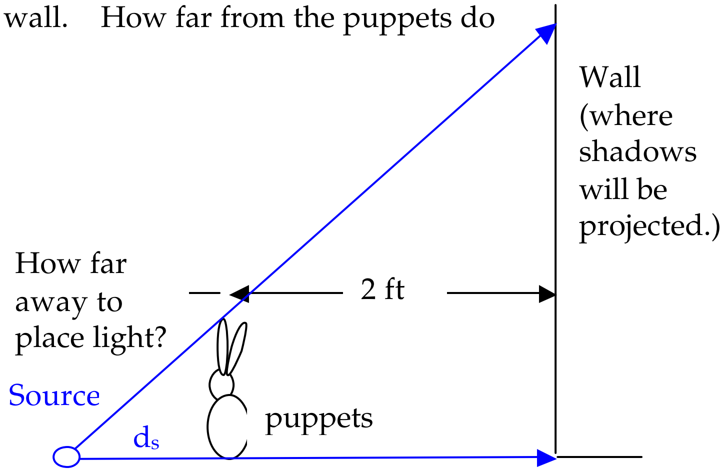

(e)

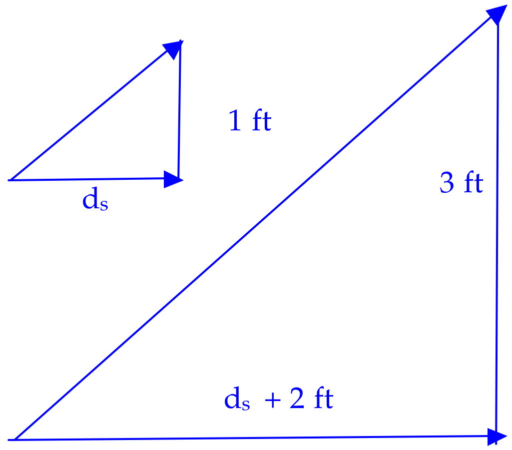

(f)

Following the rays of light from the point source to the screen (pink lines) gives us an idea of the size and position of the bright spot the point source makes. Also, we can see, as usual, that the light from a single point that goes through the top of the aperture appears on the top of the bright spot and the light that goes through the bottom appears on the bottom. Thus, the point source will make a T-shaped bright spot that is right-side up. The long filament bulb is like a whole bunch of point sources in a row. Looking at light from the right side of the filament, we can see that it ends up below the bright spot from the point source and on the left side of the screen. Light from the left side goes down and to the right. Each of these points on the long filament does the same as the point source and makes a T-shaped spot. There are lots of these T-shaped spots all overlapping each other left-to-right, as if you took a T-shaped magic marker and smeared it from right to left. Thus we'll end up with picture (a).

6) Suppose you want to put on a shadow puppet show for the neighborhood kids. Your puppets are each about a foot high. You want the shadows to be 3 feet high and you want to sit with the puppets 2 feet from the wall. How far from the puppets do you need to put your light source?

a) 1/2 foot from puppets (to the left).
b) 2/3 foot from puppets.
c) 1 foot from puppets.
d) 1 1/2 feet from puppets.
e) 2 feet from puppets.





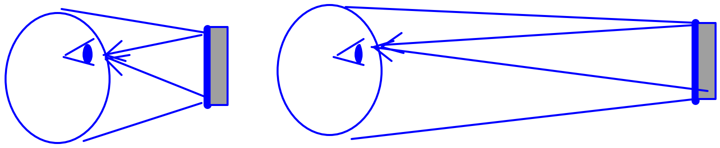
If we want the bottom of the shadows to be at the bottom of the wall, we should put the light source on the floor. Then the light ray that defines the bottom of the shadow just goes straight along the floor. Next we draw the light ray that defines the top of the shadow, the one that goes from the source to the top of the puppet and past it to the wall. Now we have two similar triangles, both with the source and the light rays above and below, but one with the puppet as the vertical side and one with the wall as the vertical side. Looking at these triangles we see $(1\text{ ft})/(d_s) = (3\text{ ft})/(d_s + 2\text{ ft})$. This gives 1 foot for the source distance.

Short answer questions, with explanations. For these, you do need to explain.

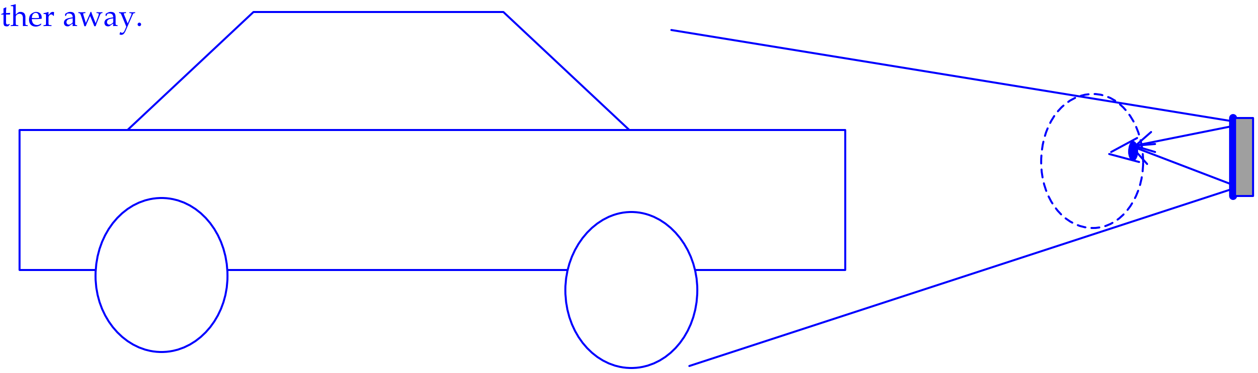
7) (10 pts.) In class and homework we found that, to see your whole face in the mirror required a portion of the mirror that was half as tall as your face, no matter how far away you stood from the mirror. However, when you are driving, you can see whole cars in the rearview mirror even though it is much smaller than half the size of the cars. How can you explain this? Is it consistent with what our model for light says? (Draw diagrams to illustrate your point.

Quite a few people solved this problem by saying that the mirror was convex. If you did so and were clear about why this would make a difference, you got most of the credit. However, all of you have experience that could have told you that the rearview mirror is flat or at least almost perfectly flat. For instance, on occasions when you look at yourself in the rearview mirror, you look much like you do in a regular mirror. You're not smaller or distorted. Same for looking at passengers. They are not much smaller and distorted like they would be in a curved mirror. They look smaller than you look in the mirror but that's because they are farther away; you are looking at them (their images) from a distance. Also, when you look at the cars, if the mirror was more than slightly convex they'd be really teeny tiny and distorted. [The passenger side mirror is slightly curved, I think, though. That's why it has that warning on it "Objects in mirror are closer than they appear." But even that is only a slight curvature."] [If any of you have no experience looking in rearview mirrors and got points off for not using your experience to figure it out as flat, see me, make your case, and I can give those (about 2) points back.]

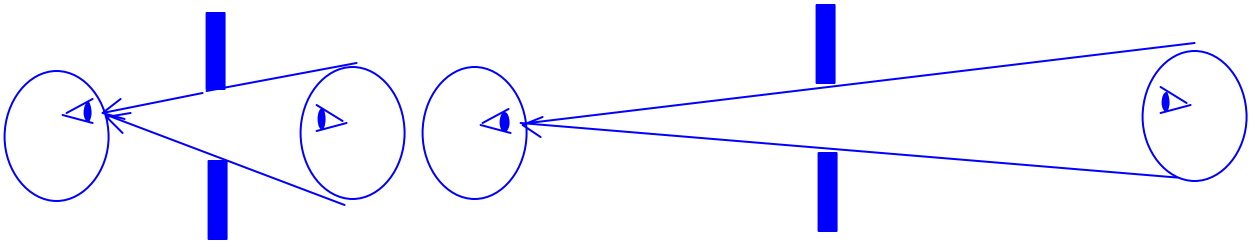
Okay, so let's talk about why this works for a flat mirror. When you are looking at your own face, the light comes from the parts of your face, bounces off the mirror and hits you in the eye. When you move back, you are getting farther from the mirror, so the angles the light makes from your face to the mirror are smaller angles (more parallel) and your image looks smaller because it's farther away, but you are also moving your eye, which perceives the light, farther away.



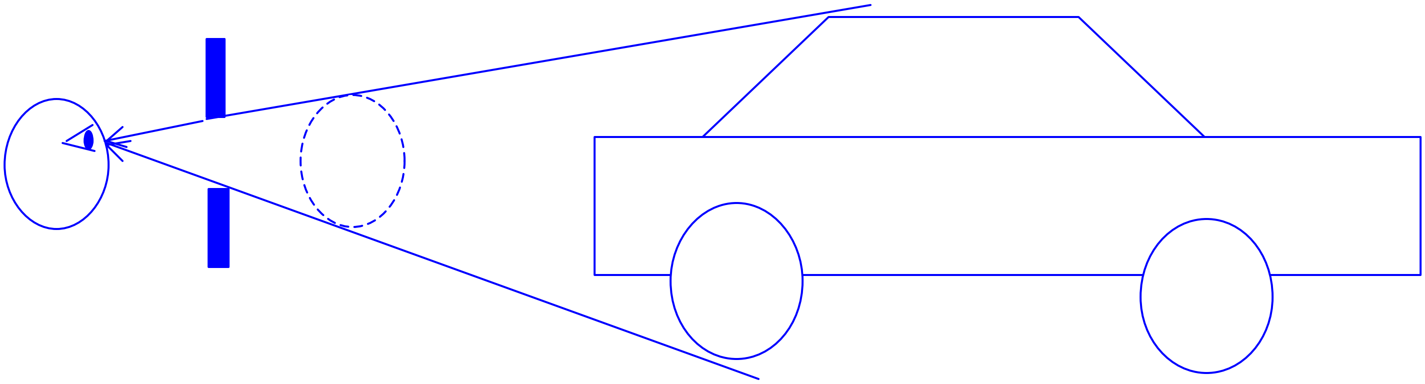
When you look at the car, however, you are not looking at an object at the same distance as the object. Looking at the angles the light can come in to hit your eye (which is close to the mirror), you can see that the angles that would have worked for your face (close to the mirror) are the same angles that work for a much larger object farther away.



Another way to think about it is using a few facts we discovered applying our model of light to find mirror images. We found that, for a flat mirror, the image is always the same size as the object and the same distance from the mirror as the object. When you are looking at yourself in the mirror, it's like looking through a window the size of the mirror at yourself. You need a window have the size of your face to see your whole image behind. If you walk away from the mirror, your image also walks backwards, so you'll still need the same size window to see it.



For the car situation, the car's image is very far back from the mirror while you are closer. You only need a small window to see a large object if you are close the window and it is far.



8) (15 pts.) In class and tutorial and in your everyday life, you've seen things that may have seemed different than what you expected, but were explained when we used our model of light. Give an example of such an observation, explain what you or someone else might have predicted, and explain how the model accounts for what you see. Include a diagram.
Lots of good answers were given for this. For right now I won't give a sample solution, but I may later, especially if folks tell me they'd like that.

9) (25 pts.)

a) In class we came up with the formula $\tau=RC$. Explain what that means and why it makes sense.

This formula tells us the time it takes for a capacitor to charge or discharge through a resistor.

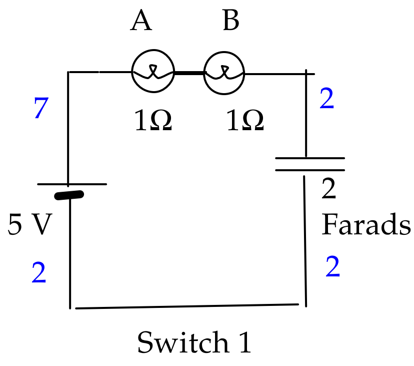
As either the resistance or the capacitance increase, the time it takes for the charge or discharge increases.

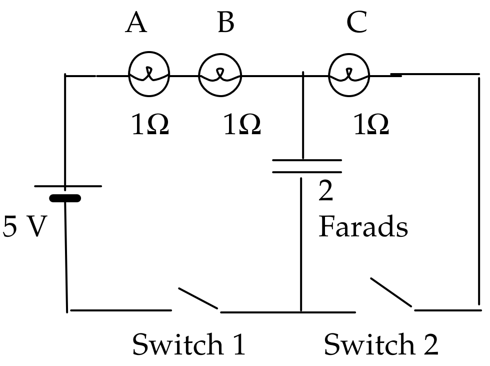
This makes sense for the resistance because the capacitor discharges or charges when a current flows through the resistor. More resistance makes it harder for current to flow, less current flows, and the discharge or charge proceeds more slowly.

The capacitance tells us how hard or easy it is to pile charges onto a capacitor (determined by the capacitor shape.) Thus if it is harder to put charges onto a capacitor, the process will proceed more slowly and vice versa.

The time constant does not, however, depend on how much charge is ON the capacitor. How much charge goes on depends on both the capacitance and the charging voltage. For a very low voltage, even a big capacitor won't charge up much. But, even though there's not much charge there, it will take a long time for it to discharge because the large capacitance means it's easy for the charge to stay on the capacitor and the charges feel not too much pressure (yes, voltage) to leave the capacitor. Some of you used an analogy of a swimming pool to explain this capacitance issue. But a swimming pool is not a good analogy for a capacitor. A pool fills up and then you can't put any more water in. When we say a capacitor is "full" we don't actually mean it has all the charge it can possibly hold, like the pool. Rather we mean it has all the charge it will accept for the voltage pushing the charges on. But you can always put more charge on it (until the thing sparks and breaks down, at least) by putting a higher and higher voltage across it. A somewhat better analogy is like an incompressible box as in our electricity examples. The amount of air that goes in depends on how big the box is (the capacitance) and the pressure you're using to push the air in. You can use a higher pressure to get more air in. How fast the box fills (meaning won't let any more air in) or how fast it lets the air out depends on both how big the opening is that the air goes in and out through (the resistance) and how big the box is. If you have two boxes with the same amount of air, the smaller one will have a higher pressure and will try to leak out faster.

b) Suppose you have the circuit as shown below, with the capacitor initially uncharged and the switches open as shown. If you close switch 1 and leave it closed for a long time, what will happen? If you think a current will flow, state what you think the initial value of the current will be.





Initially a current will flow and the capacitor will start to charge. We know that from experience, but we can also look at the voltages to tell us. If we call the voltage at the bottom of the battery 2 Volts, we see that the bottom of the capacitor, connected by a wire, is also at 2 now. So is the top of the capacitor since there is no voltage drop across the capacitor unless there is charge there ($\Delta V = Q/C$.) The top of the battery is at 7 Volts. Thus there is a voltage drop of 5 Volts across the two resistors so I(1 Ω) + I(1 Ω)= 5 V and I = 2.5 Amperes.

Then after a while, the capacitor will start to reach it's final charge and voltage difference of 5 volts. Now the voltage on the top of the capacitor is 7 Volts and there is no voltage difference across the resistors, consistent with no current flowing through them. The charging process has a time constant of τ=RC = (2 Ω)(2 F)= 4 seconds.

c) Now suppose that you open switch 1 and then close switch 2. What will happen? If the bulbs A and B lit up earlier, does bulb C now light up brighter or dimmer and for a longer or shorter time? Why?

Now there is no battery in the system, but the capacitor is charged up, so current will flow while it discharges. The voltage difference across the bulb is 5 Volts, because by Kirchoff's rules it's the same as the difference across the capacitor. So the current is now I= (5 V)/(1 W) = 5 Amps, brighter than A and B. This bulb lights up for only half the time, though, because there is twice the current (twice the rate of discharge.)