Quick Note:

I have used equations which use ln and not Log. So, you might not see the correction factors and such. It just makes things seem more "natural" (pun intended). In the coding section I would stick with whatever log form is used. And do not worry unlike some Physicist I have not written ln as log.

1. Assuming we are considering only one channel for Cl and Ca respectively we can use the Nernst equation to calculate the Voltage

E_{ion} represents Voltage as seen in class. I will try to stick to this equation and multiply the results by 1000 to get results in mV.

$$E_{ion} = \frac{RT}{zF} \ln Q$$

$$E_{ion} = \frac{RT}{zF} \ln \frac{[ion]_O}{[ion]_I}$$

$$E_{Cl} = \frac{RT}{zF} \ln \frac{[Cl^-]_O}{[Cl^-]_I}$$

R = 8.3145 J·K^{-1}·mol^{-1} , T = 310K , F = 96458 C·mol^{-1}, z = -1

Below I have taken the negative sign inside the ln and z is therefore 1.

$$1000 \cdot \frac{RT}{(1)F} \ln\left(\frac{1}{11.5}\right) = -65.2447 mV \quad \checkmark$$

For Ca^{2+} we can use the same equation with most constants same except for z = +2

$$1000 \cdot \frac{RT}{(+2)F} \ln\left(\frac{10000}{1}\right) = 123.02 mV \quad \checkmark$$

2. There's a couple of different ways to look at this. The physicist in me would go directly to the Goldman equation, which can be written as follows:

$$V_{Resting} = \frac{RT}{F} \ln\left(\frac{p_K[K^+]_{out} + p_{Na}[Na^+]_{out} + p_{Cl}[Cl^-]_{in}}{p_K[K^+]_{in} + p_{Na}[Na^+]_{in} + p_{Cl}[Cl^-]_{out}}\right)$$

Since the equation is very similar to Nernst equation but with the added permeability we can compare the equilibrium potentials to the resting membrane potentials.

We know that for K+ the Nernst equation gave us -80mV, for Na 62mV and from previous question Cl is -65mV.

By simple analysis, we can see that initially Na makes the potential more positive but not by a lot, since the permeability of K+ is 40 times that of Na. In a similar fashion, Cl would have an effect where by the potential would become more negative, but since it doesn't we can assume that the permeability factor is also very low. A wild guess looking at the table, I would assume

that the permeability of Chloride is much lower than Na. This is however not true. [sidenote: Chloride is more permeable to membranes generally since it has other important functions].

Looking at the hint, resting membrane potential is roughly around -70mV or -65mV, if a cell was impermeable to Chloride, the potential would then be determined by other ions, mainly Na+ and K+. By making it also permeable to Chloride we would expect the potential to become more negative, but the Equilibrium potential for Cl- from previous question is -65mV which is around the same as the resting membrane potential therefore it would not really change anything on its own.

3. $V_{Resting} = \frac{RT}{F} \ln \left(\frac{p_K[K^+]_{out} + p_{Na}[Na^+]_{out} + p_{Cl}[Cl^-]_{in}}{p_K[K^+]_{in} + p_{Na}[Na^+]_{in} + p_{Cl}[Cl^-]_{out}} \right)$ ✓

I think I answered it above.

In brief once again, the Chloride would make the membrane potential much more negative, but as we see it does not have a major effect, which would imply that the permeability is much lower than K+. In class we saw that technically even Na+ can be ignored since K+ is 40:1 for Na. Permeability of K+: Na+: Cl- is 1:0.05:0.45 ; this would suggest that Cl- may have some importance, but majority of it can be governed by Na+ and K+ since they give around the same membrane potential as the equilibrium potential of Chloride. ✗ 💬

4. There's a couple of things that can happen physiologically. If sufficient ATP is not available then the Sodium-Potassium pump will not work effectively. Meaning there will be a disrupted membrane potential. Moreover, the breakdown of pyruvate (byproduct of anaerobic respiration via mitochondria) can produce lactic acid, which could make the membrane potential more negative/depolarize. The effect of this could be inability to fire action potentials, since a very large stimulus might be required, depending on polarity.

5.

```
function a= ah(v) %Alpha value for variable h
a= 0.07*exp(-0.05*(v+60));
end
```

```
function a=am(v) %Alpha for Variable m
 a= (0.1*(v+35))/(1-exp(-(v+35)/10));
end
```

```
function a=an(v)%Alpha for variable n
a= (0.01*(v+50))/(1-exp(-(v+50)/10));
end
```

```
function b= bh(v) %beta value for variable h
b= 1/(1+exp(-0.1*(v+30)));
end
```

```
function b=bm_(v) %Beta for variable m
b= 4.0*exp(-0.0556*(v+60));
end
```

```
function b=bn(v) %Beta for variable n
b= 0.125*exp(-(v+60)/80);
end
```

6. It will be attached as ZIP

7. Plots are attached below

The time varying conductance essentially show the depolarization and repolarization of the different channels during an action potential. However, for Conductance of Potassium channels we need to consider g_k*ODn^4 from the solution, and for Sodium gNa*ODm^3*ODh (I tried plotting them but not sure what's going wrong, so I have not plotted it). ✓

The variables when combined to get appropriate K and Na channels form the equations above would define the propagation of depolarization and repolarization of the channels. They sort of show zones when the channels are open or closed depending on voltages. They can be used to also understand refractory periods.

✗ 💬

Changes in Membrane Potential with time

8.

Gating Kinetics