1A) What is the difference between permeability and conductance?
Permeability is a measure of how easily ions can move across a membrane, regardless of whether they are moving or not. Conductance is a measure of how much charge actually moves across the membrane.

1B) Are the Na+ and K+ conductances responsible for resting potential constant, or do they ever change? Are they different from each other? In what ways?
The Na+ and K+ conductances responsible for resting potential are constant, but unequal. The sodium-potassium pump creates a chemical gradient for both ions: Na+ is more concentrated outside the cell, K+ more concentrated inside the cell. However, there are more “leak” channels for K+ than for Na+. Therefore, there is more leak of positively charged K+ out of the cell (contributing to a negative membrane potential) than there is leak of Na+ into the cell (which would contribute to a positive membrane potential). The difference in leak conductances of K+ and Na+ is a major contributor to the negative resting potential.

2A) In a simplified neuron but only permeable to potassium (with a typical distribution of K+, Na+, Ca2+, Cl−, and anions) and in the absence of any active transport, what two forces are used in creating the equilibrium potential for potassium, Ek and how do they interact?
The equilibrium potential is created by the balance of the chemical driving force and the electrical driving force. The chemical driving force results from a concentration gradient across the cell membrane, with a high concentration of K+ ions inside the cell and a low concentration outside. From the chemical driving force, the K+ ions have the tendency to follow in the direction of the concentration gradient out of the cell. This the asymmetric distribution of ions gives rise to the electrical potential difference across the cell membrane. This creates positive charge build up on the extracellular side and negative charge build up on the cytoplasmic side. The electrical potential difference establishes an electrical gradient that opposes the chemical gradient, driving K+ into the cell. The equilibrium potential is defined to be the electrical potential difference when these two forces are balanced.

2B) In the same type of neuron as above, what is the K+ equilibrium potential if the concentration of K+ outside is 20mM and inside the cell is 400 mM?

\[ E_K = \frac{58 \text{ mV}}{1} \log \left( \frac{[X]_o}{[X]_i} \right) = \frac{58 \text{ mV}}{1} \log \left( \frac{20}{400} \right) = -75 \text{ mV} \]

3. How are the Na+ and K+ ion gradients maintained in a normal neuron?
The Na+-K+ pump moves Na+ and K+ against their gradients by transferring Na+ outside the cell and K+ inside the cell. Using ATP the Na+-K+ pump moves 3 Na+ ions out of the cell and 2 K+ ions into the cell against their concentration gradients and away from their equilibrium potentials.

4A) The concentration of Na+ inside a cell is 18mM, and 150mM outside. What is the equilibrium potential of Na+ in this cell?

\[ E_{Na} = \frac{58 \text{ mV}}{1} \log \left( \frac{[X]_o}{[X]_i} \right) = (58/1) \times \log \left( \frac{110}{11} \right) = +53 \text{ mV} \]
4B) If this cell is at a resting membrane potential of -70mV and its membrane suddenly becomes permeable to Na+, what happens to the membrane potential?
The Na+ equilibrium potential is +53mV; that means that if the membrane were permeable to Na+ ions, the membrane potential would have to be +53mV for there to be zero net flow of Na+ ions across the membrane. Since the resting potential is -70mV, when the membrane becomes permeable to Na+ ions they flow in the direction which brings the membrane potential towards +53mV. Since Na+ ions are positively charged, they will flow INTO the cell, depolarizing the membrane potential in the directions of +53mV. The membrane potential will DEPOLARIZE towards the Na+ equilibrium potential.

5A) The concentration of K+ is 135mM inside a cell, and 3mM outside. What is the equilibrium potential of K+ in this cell?

$E_K = \frac{58 \text{ mV}}{1} - \log\left(\frac{[X]_o}{[X]_i}\right) = (58/1) * \log (3 / 135) = -96 \text{ mV}$

5B) All things being equal, if this cell is at a resting membrane potential of -70mV and all of a sudden it becomes permeable to K+, what will happen to the membrane potential?
The K+ equilibrium potential is -96mV. When the membrane becomes permeable to K+, the K+ ions will freely flow until that membrane potential is reached. In this case, the K+ ions will flow OUT of the cell, contributing to the cell's hyperpolarization (from -70mV towards -96mV) in the direction of the K+ equilibrium potential.

6) You discover a new species of sea creature living in a unique saline environment, and you are uncertain what ions are responsible for its neural activity. You place a neuron in a bath of the seawater from its native habitat and—using two electrodes—find that it has a resting potential of -40mV. How would you go about testing which ions are responsible for its resting potential? Describe your experiment and some potential results.

By changing the concentration of extracellular ions in the bath, you can find which ions have a major effect on the resting potential. For example, if you increased the amount of sodium in the bath and found that the resting potential depolarized to -30mV, you could conclude that there is an outward conductance of Na+ ions contributing to the resting potential. When you added extracellular Na+, it appears that you weakened a chemical gradient which generally contributes to a more negative membrane potential. To contribute to a negative membrane potential, a positively charged ion must leave the cell (a positive charge leaving the cell is equivalent to a negative charge entering). Since a weakening of this gradient resulted in a less depolarized membrane potential, you can conclude that the Na+ gradient contributes towards a negative membrane potential AND that the Na+ chemical gradient must generally flow outwards.

If you increased the amount of Potassium in the bath and the resting potential became more depolarized (e.g., -20mV), you could conclude that K+ is contributing to the resting potential AND that it is more concentrated inside the cell. By by adding K+ you have changed the gradient such that fewer K+ ions are flowing out of the cell, and thereby weakening the depolarizing effect of this K+ conductance.