# 2.1.2 Practice quiz for lesson 2.1.2

**TOTAL POINTS 3**

**1.Question 1**

**Which of the following statements regarding coulombic efficiency are true? (Select all that apply.)**



One reason for imperfect coulombic efficiency has to do with unwanted side reactions occurring in the cell.

**Correct**

Yes. When charging a cell, some of the charge that is intended to increase the state-of-charge of the cell instead participates in electrochemical reactions that do not increase the state-of-charge of the cell but still allow current to flow through the cell.



Coulombic efficiency and energy efficiency are two different names for the same basic quantity.



We model coulombic efficiency *η*[*k*]=1 whenever current is being drawn from a cell.

**Correct**

Yes. We model the discharge efficiency as being ideal, but the charge efficiency as possibly being nonideal. Electrochemically speaking, this is not perfectly correct, but it is "correct enough" for the algorithms you will be learning about.



We model coulombic efficiency *η*[*k*]≤1 whenever current is flowing into the cell.

**Correct**

Correct. Efficiency is less than or equal to one whenever we are charging.

**1 / 1 point**

**2.Question 2**

**Consider the following experiment:A lithium-ion cell having total capacity of 10Ah is first fully charged. Then, 2Ah of charge is removed. What is the state of charge of the cell at the conclusion of this experiment (express your answer as a decimal number between 0 and 1).**

0.8

**Correct**

Yes, 20% of the charge was removed, so 80% remains.

**1 / 1 point**

**3.Question 3**

**Which of the following is true about a cell's open-circuit voltage (OCV)?**



OCV as a function of state-of-charge is the same for every type of lithium-ion battery cell.



OCV is a cell's terminal voltage at every point in time that the input current to the cell is zero (i(t) = 0*i*(*t*)=0).



OCV is a cell's terminal voltage when it has been disconnected from its load and has been allowed to rest until the voltage stabilizes to a constant value.



OCV generally increases as the cell's depth-of-discharge increases.

**Correct**

Yes, this is how we have defined it so far. We will refine this definition somewhat when we talk about hysteresis, later.

# 2.1.3 Practice quiz for lesson 2.1.3

**TOTAL POINTS 3**

**1.Question 1**

**Which of the following phenomena (which are actually observed behaviors of lithium-ion cells) does the Rint model describe? (Select all that apply.)**



The fact that a cell's terminal voltage relaxes over time toward open-circuit voltage whenever the cell is allowed to rest (i.e., whenever i(t) = 0*i*(*t*)=0).



The fact that open-circuit voltage changes over time as the cell is charged and/or discharged.

**Correct**

Yes. The Rint model has all the features of the model developed in lesson 2.1.2, plus others.



The fact that a cell's terminal voltage is greater than open-circuit voltage while charging the cell.

**Correct**

Yes. The voltage "drop" over the series resistance R\_0*R*0​ is actually negative when charging the cell, which causes the model to predict a terminal voltage that is higher than open-circuit voltage.



The fact that a cell's terminal voltage is less than open-circuit voltage while discharging the cell.

**Correct**

Yes. The voltage drop over the series resistance R\_0*R*0​ subtracts from open-circuit voltage when computing a prediction of terminal voltage.

**1 / 1 point**

**2.Question 2**

**Which of the following are true regarding diffusion voltages? (Select all that apply.)**



When a cell has recently been **discharging**, and is subsequently allowed to rest (by setting i(t) = 0*i*(*t*)=0), the cell's terminal voltage **decreases** toward a steady-state value as charge re-distributes inside the cell due primarily to diffusion processes.



When a cell has recently been **discharging**, and is subsequently allowed to rest (by setting i(t) = 0*i*(*t*)=0), the cell's terminal voltage **increases** toward a steady-state value as charge re-distributes inside the cell due primarily to diffusion processes.

**Correct**

Yes. While discharging, terminal voltage is less than open-circuit voltage. When allowed to rest, voltage increases toward open-circuit voltage.



When a cell has recently been **charging**, and is subsequently allowed to rest (by setting i(t) = 0*i*(*t*)=0), the cell's terminal voltage **decreases** toward a steady-state value as charge re-distributes inside the cell due primarily to diffusion processes.

**Correct**

Yes. While charging, terminal voltage is greater than open-circuit voltage. When allowed to rest, voltage decreases toward open-circuit voltage.



When a cell has recently been **charging**, and is subsequently allowed to rest (by setting i(t) = 0*i*(*t*)=0), the cell's terminal voltage **increases** toward a steady-state value as charge re-distributes inside the cell due primarily to diffusion processes.

**1 / 1 point**

**3.Question 3**

**What is the difference between the Thévenin equivalent-circuit model versus the Rint equivalent-circuit model?**



The Thévenin model is the same as the Rint model, except that the Thévenin model adds series resistor-capacitor sub-circuit(s) to model diffusion voltage.



The Thévenin model is the same as the Rint model, except that the Thévenin model adds parallel resistor-capacitor sub-circuit(s) to model diffusion voltage.



The Rint model is the same as the Thévenin model, except that the Rint model adds series resistor-capacitor sub-circuit(s) to model diffusion voltage.



The Rint model is the same as the Thévenin model, except that the Rint model adds parallel resistor-capacitor sub-circuit(s) to model diffusion voltage.

**Correct**

Yes, this is the difference between the models.

# 2.1.4 Practice quiz for lesson 2.1.4

**1.Question 1**

**What is the difference between the Randles equivalent-circuit model and the equivalent-circuit models (e.g., the Thévenin model) we studied earlier this week?**



The Randles model is derived based on a physical understanding of the electrochemical processes occurring in the cell whereas the earlier models were derived based on modeling observed phenomena.



The Randles model includes resistors and capacitors to model time constants in cell dynamics whereas earlier models did not.



The Randles model describes the effect of a double-layer capacitance on cell voltage whereas earlier models did not.



The Randles model describes the effect of electrolyte resistance on cell voltage whereas earlier models did not.

**Correct**

Yes. This is the fundamental difference.

**1 / 1 point**

**2.Question 2**

**How many parallel resistor-capacitor sub-circuits must be placed in series to model a Warburg impedance exactly?**



Four.



Three.



An infinite number.



One.

**Correct**

Yes. However, a small finite number is often adequate to approximate the Warburg impedance "well enough" for our modeling purposes.

**1 / 1 point**

**3.Question 3**

**What challenges are introduced by a Warburg impedance when trying to simulate battery dynamics accurately? (Select all that apply.)**



It is necessary to have studied electrochemistry in order to simulate a Warburg impedance.



The Warburg impedance is a "constant phase" element having magnitude response that slopes at -10 dB/decade and constant phase response of -45^\circ∘.

**Correct**

Yes. No standard linear circuit element (source, resistor, capacitor, inductor) has this behavior, and so we cannot implement the Warburg impedance exactly by simulating a finite combination of these elements.



The Warburg impedance cannot be described as a standard ordinary differential equation, so standard calculus tools cannot be used.

**Correct**

Yes. While a field of calculus called "fractional order differential equations" can be applied, this is a very advanced topic and simulations essentially amount to approximating the Warburg impedance with a large number of parallel resistor-capacitor networks wired in series.



It is no more difficult to simulate a Warburg impedance than other linear-circuit elements like sources, resistors, capacitors, or inductors.

# 

# 2.1.7 Practice quiz for lesson 2.1.7

**TOTAL POINTS 3**

**1.Question 1**

**Which of the following statement(s) regarding hysteresis are true? (Select all that apply.)**



During a long interval where a cell is being charged, its hysteresis voltage becomes more and more positive.

**Correct**

Yes. And, during a long interval during which a cell is being discharged, the hysteresis voltage becomes more and more negative.



If a cell is allowed to rest (i(t)=0*i*(*t*)=0) for a long time, the hysteresis voltage will decay toward zero.



Hysteresis voltage and diffusion voltage are basically the same thing, and cannot be distinguished by experiment.



During a long interval where a cell is being charged, its hysteresis voltage becomes more and more negative.

**1 / 1 point**

**2.Question 2**

**In the simple hysteresis model presented in this lesson, what is the function of the gamma (\gamma*γ*) parameter?**



It describes the magnitude of instantaneous hysteresis voltage at the present state-of-charge.



It describes the rate at which the dynamic hysteresis state moves from one side of the major hysteresis branch to the other as state-of-charge changes.



It describes the sign of the most recent non-negligible value of cell electrical current.



It describes the maximum value of dynamic hysteresis voltage at the present state-of-charge.

**Correct**

Yes. If gamma is large, then hysteresis moves quickly from one extreme to the other; if gamma is small, then it moves slowly.

**1 / 1 point**

**3.Question 3**

**What is the difference between dynamic hysteresis and instantaneous hysteresis?**



Instantaneous hysteresis depends on the entire history of cell input current versus time, whereas dynamic hysteresis depends only on the most recent history.



Dynamic hysteresis changes the instant that the sign of cell input current changes, while instantaneous hysteresis changes more slowly as state-of-charge changes.



Dynamic hysteresis is a random phenomenon that varies in unpredictable ways, while instantaneous hysteresis is completely predictable.



Instantaneous hysteresis changes the moment that the sign of cell input current changes, while dynamic hysteresis changes more slowly as state-of-charge changes.

**Correct**

Yes. That is correct.

# 2.1.5 Practice quiz for lesson 2.1.5

**TOTAL POINTS 3**

**1.Question 1**

**Consider the continuous-time state-space system modeled as**

*x*˙(*t*)=−2*x*(*t*)+3*u*(*t*)

**\qquad y(t) = 0.5 x(t) + 0.8 u(t).*y*(*t*)=0.5*x*(*t*)+0.8*u*(*t*).**

**We wish to convert this to a discrete-time state-space model of the form**

**\qquad x[k+1] = a\_d x[k] + b\_d u[k]*x*[*k*+1]=*ad*​*x*[*k*]+*bd*​*u*[*k*]**

**\qquad y[k] = c\_d x[k] + d\_d u[k].*y*[*k*]=*cd*​*x*[*k*]+*dd*​*u*[*k*].**

**Assume that the sample period \Delta t = 1Δ*t*=1s.**

**What is the value of a\_d*ad*​? Round your answer to two digits to the right of the decimal point.**

0.14

**Correct**

Yes. *ad*=exp(*a*Δ*t*), where a=-2*a*=−2 and \Delta t = 1Δ*t*=1.

**1 / 1 point**

**2.Question 2**

**For the same continuous-time system as defined in Question 1, and for the same sampling period, what is the value of b\_d*bd*​? Round your answer to two digits to the right of the decimal point.**

1.30

**Correct**

Yes. *bd*=*b*(exp(*a*Δ*t*)−1)/*a* where a=-2*a*=−2, b=3*b*=3, and \Delta t=1Δ*t*=1.

**1 / 1 point**

**3.Question 3**

**For the same continuous-time system as defined in Question 1, and for the same sampling period, what is the value of d\_d*dd*​? Round your answer to two digits to the right of the decimal point.**

.8

**Correct**

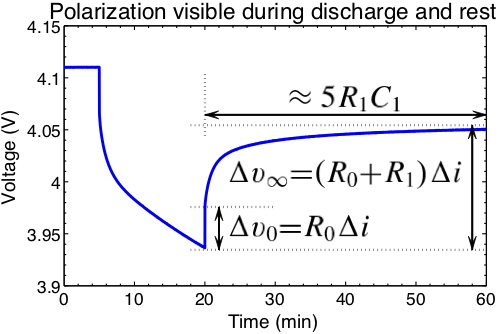
Yes. d\_d = d*dd*​=*d* and d = 0.8*d*=0.8.

# 2.1.6 Practice quiz for lesson 2.1.6

**TOTAL POINTS 3**

**1.Question 1**

**Consider the voltage response of a lithium-ion cell to a discharge-pulse test:**

****

**For the test, | \Delta i | = 10∣Δ*i*∣=10A, | \Delta v\_0 | = 50∣Δ*v*0​∣=50mV, and | \Delta v\_\infty | = 130∣Δ*v*∞​∣=130mV.**

**What is the approximate value of R\_0*R*0​ in a Thévenin equivalent-circuit cell model? Enter your answer in m**Ω**.**

5

**Correct**

Yes. R\_0 = | \Delta v\_0 | / | \Delta i |*R*0​=∣Δ*v*0​∣/∣Δ*i*∣.

**1 / 1 point**

**2.Question 2**

**Consider again the experiment described in Question 1. What is the value of R\_1*R*1​ in a Thévenin equivalent-circuit model? Enter your answer in m**Ω**.**

8

**Correct**

Yes. R\_1 = |\Delta v\_\infty| / |\Delta i| - R\_0*R*1​=∣Δ*v*∞​∣/∣Δ*i*∣−*R*0​.

**1 / 1 point**

**3.Question 3**

**Consider again the experiment described in Question 1. What is the value of C\_1*C*1​ in a Thévenin equivalent-circuit model? Enter your answer in kilo-farads (kF).**

60

**Correct**

Yes. C\_1 = 2400 / (5 R\_1)*C*1​=2400/(5*R*1​).

# 2.1.7 Practice quiz for lesson 2.1.7

**1.Question 1**

**Which of the following statement(s) regarding hysteresis are true? (Select all that apply.)**



During a long interval where a cell is being charged, its hysteresis voltage becomes more and more positive.

**Correct**

Yes. And, during a long interval during which a cell is being discharged, the hysteresis voltage becomes more and more negative.



If a cell is allowed to rest (i(t)=0*i*(*t*)=0) for a long time, the hysteresis voltage will decay toward zero.



Hysteresis voltage and diffusion voltage are basically the same thing, and cannot be distinguished by experiment.



During a long interval where a cell is being charged, its hysteresis voltage becomes more and more negative.

**1 / 1 point**

**2.Question 2**

**In the simple hysteresis model presented in this lesson, what is the function of the gamma (\gamma*γ*) parameter?**



It describes the magnitude of instantaneous hysteresis voltage at the present state-of-charge.



It describes the rate at which the dynamic hysteresis state moves from one side of the major hysteresis branch to the other as state-of-charge changes.



It describes the sign of the most recent non-negligible value of cell electrical current.



It describes the maximum value of dynamic hysteresis voltage at the present state-of-charge.

**Correct**

Yes. If gamma is large, then hysteresis moves quickly from one extreme to the other; if gamma is small, then it moves slowly.

**1 / 1 point**

**3.Question 3**

**What is the difference between dynamic hysteresis and instantaneous hysteresis?**



Instantaneous hysteresis depends on the entire history of cell input current versus time, whereas dynamic hysteresis depends only on the most recent history.



Dynamic hysteresis changes the instant that the sign of cell input current changes, while instantaneous hysteresis changes more slowly as state-of-charge changes.



Dynamic hysteresis is a random phenomenon that varies in unpredictable ways, while instantaneous hysteresis is completely predictable.



Instantaneous hysteresis changes the moment that the sign of cell input current changes, while dynamic hysteresis changes more slowly as state-of-charge changes.

**Correct**

Yes. That is correct.

# 2.1.8 Practice quiz for lesson 2.1.8

**TOTAL POINTS 3**

**1.Question 1**

**Which of the following variables are members of the ESC model "state equation"? (Select all that apply.)**



The cell's open-circuit voltage.

**This should not be selected**

No. The open-circuit voltage appears in the model output equation.



The cell's dynamic hysteresis level.

**Correct**

Yes, h[k]*h*[*k*] is a member of the state variable $$x[k]$, which is updated by the state equation.



The cell's resistor-capacitor voltage(s).

**This should not be selected**

No. The cell's resistor-capacitor currents i\_R[k]*iR*​[*k*] is a member of the state variable x[k]*x*[*k*], but not the voltages.



The cell's state of charge.

**Correct**

Yes, z[k]*z*[*k*] is a member of the state variable x[k]*x*[*k*], which is updated by the state equation.

**0 / 1 point**

**2.Question 2**

**Which of the following variables are members of the ESC model "output equation"? (Select all that apply.)**



The cell's resistor-capacitor voltage(s).

**Correct**

Yes. These are included as the products of the resistor-capacitor currents multiplied by the resistor-capacitor resistances.



The cell's state of charge.

**This should not be selected**

No, not really. It does factor into the open-circuit-voltage calculation, but is not updated in the output equation.



The cell's instantaneous hysteresis voltage.

**Correct**

Yes. This is included as M\_0 s[k]*M*0​*s*[*k*].



The cell's open-circuit voltage.

**Correct**

Yes, this is a major component in the output equation (which computes cell voltage).

**0 / 1 point**

**3.Question 3**

**Which of the following statement(s) is/are true regarding the ESC cell model? (Select all that apply.)**



With appropriate parameter values, it can describe the input/output (current/voltage) dynamics of a lithium-ion cell with arbitrarily small error.

**This should not be selected**

No. By choosing a large number of parallel resistor-capacitor sub-circuits, it can match diffusion voltage arbitrarily well. But, the hysteresis model is too crude to describe hysteresis perfectly. The ESC model is often "good enough" for battery-management application, but it is not perfect.



It describes state-of-charge-dependent open-circuit voltage, ohmic and diffusion voltages, and hysteresis.

**Correct**

Yes! This relatively simple model describes all of these phenomena.



With appropriate parameter values, it can describe the Rint model and the Thévenin model that we studied earlier this week.

**Correct**



It comprises two coupled equations in a (nonlinear) "state-space" form.

**Correct**

## 

## Quiz for week 1

**LATEST SUBMISSION GRADE**

100%

**1.Question 1**

**Consider the following experiment:A lithium-ion cell having total capacity of 5Ah is first fully charged. Then, 2Ah of charge is removed. What is the state of charge of the cell at the conclusion of this experiment (express your answer as a decimal number between 0 and 1).**

**Correct**

**1 / 1 point**

**2.Question 2**

**What is the difference between the Thévenin equivalent-circuit model versus the Rint equivalent-circuit model?**

**Correct**

**1 / 1 point**

**3.Question 3**

**What is the difference between the Randles equivalent-circuit model and the Thévenin equivalent-circuit model?**

**Correct**

**1 / 1 point**

**4.Question 4**

**Consider the continuous-time state-space system modeled as**

*x*˙(*t*)=−3*x*(*t*)+2*u*(*t*)

**\qquad y(t) = 0.8 x(t) + 0.5 u(t).*y*(*t*)=0.8*x*(*t*)+0.5*u*(*t*).**

**We wish to convert this to a discrete-time state-space model of the form**

**\qquad x[k+1] = a\_d x[k] + b\_d u[k]*x*[*k*+1]=*ad*​*x*[*k*]+*bd*​*u*[*k*]**

**\qquad y[k] = c\_d x[k] + d\_d u[k].*y*[*k*]=*cd*​*x*[*k*]+*dd*​*u*[*k*].**

**Assume that the sample period \Delta t = 1Δ*t*=1s.**

**What is the value of b\_d*bd*​? Round your answer to two digits to the right of the decimal point.**

**Correct**

**1 / 1 point**

**5.Question 5**

**Consider the continuous-time state-space system modeled as**

*x*˙(*t*)=−4*x*(*t*)+3*u*(*t*)

**\qquad y(t) = 2 x(t) + 1.5 u(t).*y*(*t*)=2*x*(*t*)+1.5*u*(*t*).**

**We wish to convert this to a discrete-time state-space model of the form**

**\qquad x[k+1] = a\_d x[k] + b\_d u[k]*x*[*k*+1]=*ad*​*x*[*k*]+*bd*​*u*[*k*]**

**\qquad y[k] = c\_d x[k] + d\_d u[k].*y*[*k*]=*cd*​*x*[*k*]+*dd*​*u*[*k*].**

**Assume that the sample period \Delta t = 1Δ*t*=1s.**

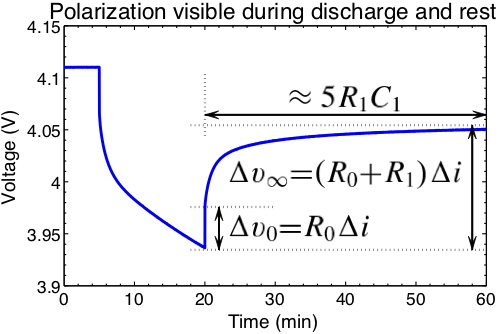
**What is the value of c\_d*cd*​? Round your answer to two digits to the right of the decimal point.**

**Correct**

**1 / 1 point**

**6.Question 6**

**Consider the voltage response of a lithium-ion cell to a discharge-pulse test:**

****

**For the test, | \Delta i | = 20∣Δ*i*∣=20A, | \Delta v\_0 | = 40∣Δ*v*0​∣=40mV, and | \Delta v\_\infty | = 100∣Δ*v*∞​∣=100mV.**

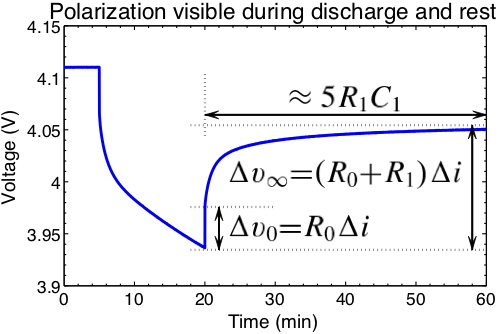
**What is the approximate value of R\_1*R*1​ in a Thévenin equivalent-circuit cell model? Enter your answer in m**Ω**.**

**Correct**

**1 / 1 point**

**7.Question 7**

**Consider the voltage response of a lithium-ion cell to a discharge-pulse test:**

****

**For the test, | \Delta i | = 10∣Δ*i*∣=10A, | \Delta v\_0 | = 40∣Δ*v*0​∣=40mV, and | \Delta v\_\infty | = 130∣Δ*v*∞​∣=130mV.**

**What is the approximate value of C\_1*C*1​ in a Thévenin equivalent-circuit cell model? Enter your answer in kilofarads (kF), with one digit to the right of the decimal point.**

**Correct**

**1 / 1 point**

**8.Question 8**

**In the simple hysteresis model presented this week, what is the function of the gamma (\gamma*γ*) parameter?**

**Correct**

**1 / 1 point**

**9.Question 9**

**Which of the following statement(s) regarding hysteresis are true? (Select all that apply.)**

**Correct**

**1 / 1 point**

**10.Question 10**

**Which of the following statement(s) is/are true regarding the ESC cell model? (Select all that apply.)**

**Correct**