307L Final Quiz. Name (please print clearly): ____________**ANSWER KEY**_________________

Instructions: There are 35 questions below. You only have to answer 20. Clearly indicate the 20 questions you want graded by circling their numbers. Each question is worth 1 point; incorrect answers score 0. If more than 20 questions are circled, each incorrect answer deducts 1 point. Some questions may have multiple correct answers.

1. A fair (non-magician) coin is flipped 100 times and the results recorded in a two column histogram. 67 flips were heads and 33 were tails. What is the *most likely* outcome for flip number 101?

a) Tails. The histogram is skewed toward heads, so over time it must trend back toward the expected 50-50 probability distribution.
b) Heads. The histogram indicates an obvious preference for heads.
c) Heads or tails are equally likely.

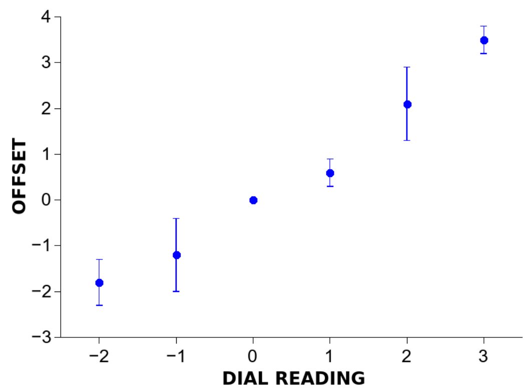
2. The picture at right shows a casino roulette wheel. There are 38 slots: 18 are red, 18 are black, and two are green numbered 0 and 00. If the ball lands in the two green number slots, all bets on numbers 1–36 lose. Observation of casino play over an hour reveals that 75% of the spins have been red. What is the *most likely* outcome for the *next* spin?

a) Black. The histogram is skewed toward black, so over time it must trend back toward an even balance between red and black.
b) Red. The histogram indicates an obvious preference for red.
c) Red or black are equally likely.
d) Can't be determined. The presence of 0 and 00 prevent the use of statistical analysis.

3. The Bitcoin network generates a single block (Bitcoin blocks contain user transaction data) at a rate of approximately once every 10 minutes. This 10 minute period is hard coded into the protocol using Poisson statistics. At t = 0 a block is generated. At t = 5 minutes the next block has not yet appeared. When is the *most likely* time t for the next block to appear?

a) t=5 minutes
b) t=10 minutes
c) t=15 minutes A Poisson process has no memory. The next block is most probable at t+10 minutes
d) t=20 minutes
e) Poisson is completely random; time cannot be determined

4. The user manual for a lab instrument requires that it be periodically calibrated to generate a linear calibration curve for an offset. The manual says to get a few data points on either side of the origin (0,0) and also to include the origin in the calibration. Calibration data is plotted at right with y-error bars. When performing a general least-squares-fit of this data, the graphing software aborts because the point at (0,0) is entered with no error. What is the **best** way to handle this problem?



a) Assign all points an average of the individual error bars.
b) Assign the origin the largest error bar.
c) Assign the origin the smallest error bar.
d) Assign the origin an error that is non-zero, but negligible compared to the other error bars.
e) Ignore the point at the origin.
f) Ignore the error bars.

5. The generalized least-squares-fit is a linear regression for data sets having different sized y-error bars. Which of the following statements is correct?

a) Data with small error bars are weighted more heavily in the fit.
b) Data with large error bars are weighted more heavily in the fit.
c) More data points N produce a higher Coefficient of Determination (R^2).
d) The Goodness of Fit scales as $\sqrt{N}$.

6. The velocity of a moving bicycle is measured with a stopwatch. The bike covers 8 meters in 2 seconds to give a velocity of 4 m/sec. The uncertainty in distance traveled is negligible, but the timing error is $\Delta t = 0.2$ sec. What is the corresponding uncertainty in velocity?

a) 4.0 cm/sec
b) 20 cm/sec
c) 40 cm/sec
d) 80 cm/sec
e) 1.0 m/sec
f) 2.0 m/sec

7. A physics experiment is attempting to deduce the gravitational constant g by measuring the period of a pendulum with a stopwatch. To an excellent approximation, the period is:

$$\tau = 2\pi\sqrt{(L/g)}$$

A single string pendulum of length L = 0.2 m is used. 20 measurements of the period are made, producing a value of $\tau = 1.03 \pm 0.05$ sec. This is larger than the expected period of $\tau = 0.9$ sec using the accepted value of $g = 9.8$ m/s^2. The uncertainty of L is negligible and cannot explain the discrepancy. What is the **best** way to proceed?

a) Accept the result because it is within 2 standard deviations of the expected value.
b) Check for a systematic error. The stopwatch could be slow or the person timing has poor reactions. Perform an independent calibration of the timing system.
c) Make 20 more measurements. The error bar should get bigger and lead to good overlap with the expected result.
d) Not enough statistics. Take more data with different length pendulums.

8. The course lectures described three fundamental probability distributions: Gaussian, Binomial, and Poisson. Which one of the following statements is true?

a) A Gaussian distribution is useful for counting events with few possible outcomes. The Binomial and Poisson distributions are used when there are many possible outcomes.
b) A Binomial distribution is useful for counting events with few possible outcomes. The Gaussian and Poisson distributions are used when there are many possible outcomes.
c) A Poisson distribution is useful for counting events with few possible outcomes. The Gaussian and Binomial distributions are used when there are many possible outcomes.

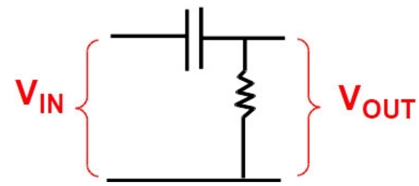
9. Which of the following statements about the Gaussian distribution are true? Select all that apply.

a) It is often called a Bell Curve because of the shape it takes
b) If N is the number of data points in the distribution, the error bar is given by the standard deviation: $\sigma = \sqrt{N}$
c) It is widely used in experimental physics because it accurately describes all distribution sizes
d) The more data that is acquired, the narrower the distribution curve becomes
e) The more data that is acquired, the more accurately the peak of the curve is known

10. An RMS (root-mean-square) measurement may be convenient because a time-varying signal can be characterized by a single number. For example, the RMS voltage of a 60 Hz wall outlet is 115 Volts. Which of the following statements about the RMS measurement is true? (Only one correct answer)

a) It can only be used for 60 Hz signals
b) It can only be used for sine waves
c) It can be applied to any periodic signal
d) It can only be used for voltage measurements

11. The circuit shown at right modifies an input signal V_{IN} to produce an output signal V_{OUT}. How is the function of this circuit described?



a) Differentiation; low-pass filter
b) Differentiation; high-pass filter
c) Integration; low-pass filter
d) Integration; high-pass filter

12. A detector is connected to an oscilloscope; the detector produces voltage pulses of amplitude 50 mV. The AUTO button on the scope is pressed and a constant 2 V signal is displayed, which is the expected DC offset of the detector but no pulses are seen. What can be done to display the pulses?

a) Select DC coupling and reduce the Volts/division
b) Select DC coupling and increase the Volts/division
c) Select AC coupling and reduce the Volts/division
d) Select AC coupling and increase the Volts/division

13. A speed-of-light experiment uses a laser with 10 ns pulses. Assuming the detector is fast enough, what are the *minimum* acceptable specifications for a digital oscilloscope that can resolve the pulses?

a) 10 MHz analog bandwidth; Sampling: 1 GS/sec
b) 100 MHz analog bandwidth; Sampling: 1 GS/sec
c) 1 GHz analog bandwidth; Sampling: 1 GS/sec
d) 10 GHz analog bandwidth; Sampling: 2 GS/sec

14. In the speed of light experiment, the moveable corner cube is displaced a distance $\Delta x = 60$ cm further away from the beamsplitter. What do you expect to see on the oscilloscope? Assume $c = 3 \times 10^{10}$ cm/s.

a) Pulses separate by $\Delta t = 2$ ns
b) Pulses separate by $\Delta t = 4$ ns
c) Pulses separate by $\Delta t = 5$ ns
d) Pulses separate by $\Delta t = 20$ ns
e) Pulses separate by $\Delta t = 40$ ns
f) Pulses separate by $\Delta t = 50$ ns

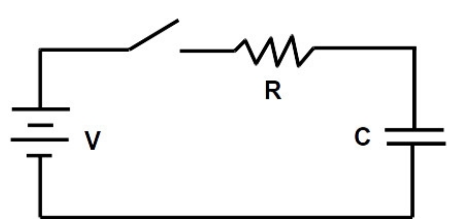
15. Referring to the circuit pictured, the initial potential on the capacitor is zero. At t=0 the switch is closed. What equation describes the voltage on the capacitor? Hint: Do not setup and solve a differential equation. Use the physical boundary conditions.

a) $V_C(t) = V \exp\left(\frac{-t}{RC}\right)$

b) $V_C(t) = -V \exp\left(\frac{-t}{RC}\right)$

c) $V_C(t) = V \left[\exp\left(\frac{-t}{RC}\right) - 1\right]$

d) $V_C(t) = V \left[1 - \exp\left(\frac{-t}{RC}\right)\right]$



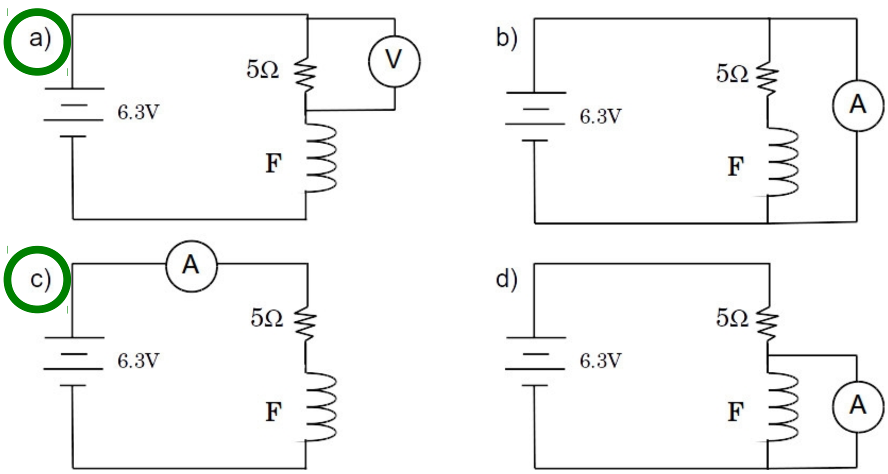
16. Referring to the circuit in Question 15, how much charge is on the capacitor at t = ∞?

a) 0
b) CV
c) V/C
d) C/V
e) 1/CV

17. Referring to the circuit shown in Question 15, how can the charging time of the capacitor be *decreased*? There may be multiple correct answers. Select all that apply.

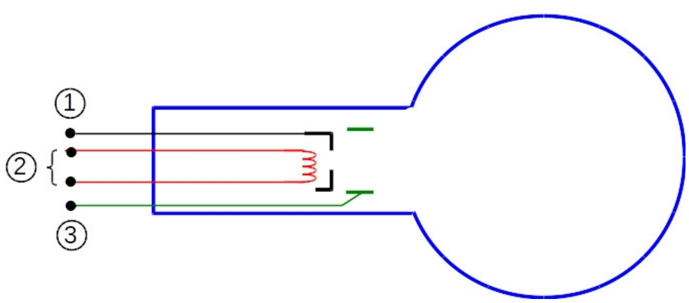
a) Increase R
b) Decrease R
c) Increase C
d) Decrease C
e) Increase V
f) Decrease V

18. A cathode-ray tube has a heated filament F in series with a 5Ω resistor. The heater power supply is set at 6.3 Volts. An ammeter A and voltmeter V are available. What configurations can be used to measure the filament current? Select all that apply.



19. The figure shows an electron gun that was used in several experiments. Match each terminal with the potential/power supply that should be connected to it. Use A for anode, C for cathode, and F for filament.

Terminal 1:_C___
Terminal 2:_F___
Terminal 3:_A___



20. The energy of the electrons injected into the bulb shown in Question 19 is determined by what potential difference?

a) Between 1 and 2
b) Between 2 and 3
c) Between 1 and 3

21. The electron diffraction experiment produces two distinct rings on the phosphorescent screen. Why is this observed?

a) The graphite atoms are arranged in a hexagonal, honeycomb pattern
b) The Lorentz force bends the electrons in a circular trajectory
c) The graphite film is polycrystalline, with randomly oriented domains
d) The rings reveal the presence of quantized energy levels
e) Inelastic scattering of electrons colliding with fixed atoms occurs at predictable angles

22. In the *e/m* experiment used for this course (not the original experiment done by JJ Thomson), what is the purpose of the magnetic field applied with the Helmholtz coils?

a) Balances the Coulomb force (e**E**) with the Lorentz force (e**v** x **B**) to generate a circular electron path
b) Balances the centrifugal force (mv^2/R) **with the Lorentz force** (ev x **B**) **to generate a circular electron path**
c) Induces Zeeman splitting of the helium atoms
d) Cancels the earth's magnetic field vector

23. In the *e/m* experiment used for this course, the electron tube is not at ultrahigh vacuum but has ~ 10 mTorr of helium. Why is this?

a) Helium is essential to keep the filament cool
b) An inert gas inside the bulb prevents it from imploding from atmospheric pressure
c) Photons from excited helium atoms makes the trajectory of electrons visible
d) Helium seals the tube and prevents air from leaking in
e) Helium allows one to observe the excitation of different quantum energy levels

24. The Balmer Series experiment is based on a constant deviation spectrometer. What optics principles are applicable to this experiment? Select all that apply.

a) Dispersion: Refractive index depends on wavelength
b) Refraction (bending) of light at the interface of glass and air
c) Diffraction from a grating to separate wavelengths
d) The ability of a prism to tightly focus light
e) Linear polarization of the **E** and **B** field vectors in the electromagnetic wave

25. How can the resolution of a spectrometer be improved? Select all that apply.

a) Decrease the path that light travels from the grating or prism to detector
b) Increase the path that light travels from the grating or prism to detector
c) Decrease the slit width in front of the detector
d) Increase the slit width in front of the detector

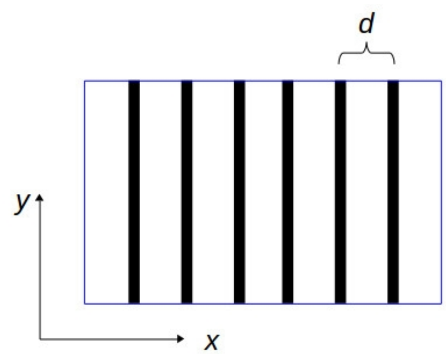
26. In the Franck-Hertz experiment, distinct dips are observed in the collected current as the accelerating voltage is varied. What causes this?

a) Ionization of the quantum states of helium
b) Transfer of electron energy to helium by resonant excitation
c) Inelastic scattering of electrons from helium into the collection electrode
d) Liberation of free electrons from helium at specific quantum energies

27. The Franck-Hertz experiment collects data with an analog-to-digital converter. What is the resolution of an 8-bit analog-to-digital converter?

a) 1 part in 8
b) 1 part in 16
c) 1 part in 64
d) 1 part in 256

28. A transmission grating is formed by opaque vertical lines separated by a distance *d* as shown. The space between the lines is transparent. Light with a single wavelength $\lambda \ll d$ illuminates the grating. What is seen transmitted through the grating?



a) Diffraction orders that are distributed along the x-axis
b) Diffraction orders that are distributed along the y-axis
c) Diffraction orders that are distributed as circular rings
d) Negligible diffraction, just shadows of the vertical lines

29. What statement best describes the function of a scintillator?

a) Generates radioactive decays
b) Counts radioactive decays
c) Converts high energy photons into visible photons
d) Generates gamma rays
e) Converts visible photons into electrons in the photomultiplier tube
f) Converts radioactive decays into Poisson events

30. What produces the backscatter peak in the Compton scattering experiment?

a) Scattered photons with minimum energy resulting from head-on collisions of electrons with gamma-rays
b) Scattered photons with maximum energy resulting from head-on collisions of electrons with gamma-rays
c) Scattered photons that correspond to the energy of incident gamma-rays
d) Photons that are scattered at an angle of ~90° from the direction of the incident gamma-rays

31. In Compton scattering, electrons at rest acquire kinetic energy by scattering with gamma-ray photons. What is the range for this additional *electron* energy?

a) Between 0 and the backscatter energy
b) Between the 0 and the Compton edge energy
c) Between the backscatter energy and the Compton edge energy

32. In the Planck's constant experiment, the intensity of light is changed at a fixed wavelength. The charging time of the phototube is observed to decrease as the light intensity increases. Why?

a) Higher intensity has higher photon flux, which produces more electrons at the cathode
b) Higher intensity has a higher electric field, which is needed to overcome the cathode work function
c) Higher intensity has a higher electric field, which is needed to charge the phototube capacitance
d) Higher intensity has a higher electric field, which causes greater electron generation

33. In the Planck's constant experiment, a known wavelength of incident light produces a stopping potential that is read on the voltmeter. What happens to the stopping potential when the light wavelength decreases?

a) Increases
b) Decreases
c) Unchanged

34. In the electron spin resonance experiment, what is the purpose of the magnetic field that is applied with the Helmholtz coils?

a) Bends the electron trajectory by the Lorentz force
b) Heats the atoms by induction
c) Removes the two-state spin degeneracy
d) Determines sign of the electron charge

35. In the electron spin resonance experiment, how is the resonance of the sample probed?

a) With radio frequency photons
b) With infrared photons
c) With visible photons
d) With ultraviolet photons
e) Absorption of the magnetic field