Every question, except those categorized as "Electrician/Electrical Safety", has a 3-letter code indicating, in order:
- *difficulty at which I would place it as a tossup (B: Regs, C: Regs+, D: Nats, E: CO, F: Nowhere)*
- *by what year I would expect an EE major to learn about the answer (5 being in a graduate program)*
- *where I personally learned about the answer (C: Class, O: Outside of class, T: Tournament, for this).*

Tossups rated "F" have 20-point powers. All others have 15-point powers. All questions are worth 10 points after power.

1. **A "temporal" version of this function is often used as a test case for sequence prediction in recurrent networks. This function was shown to be a connectedness problem that couldn't be solved due to**
3 **the constraints of local processing in a book by Minsky and Papert, which created a notable, though critically misunderstood, controversy surrounding said book. Due to a lack of linear separability, this function is notoriously uncomputable by ADALINE or a single (*)** perceptron, though it's easily solved
6 using a simple multilayer feedforward network with a hidden layer of two units: one of which computes NAND and the other of which computes OR. For 10 points, name this logical function whose output is 1 when its two inputs are different.
ANSWER: **XOR** function [or: **exclusive-OR** function] – D4C

2. **When bandgap engineering, the bandgap is plotted against this quantity for many binary, ternary, and quaternary semiconductors. For a ternary alloy, say, $Ga_{1-x}In_xAs$, this quantity is equal to x times it for**
3 **InAs plus 1 minus x times it for GaAs according to good ol' Vegard's law. Whether a deposited layer is in the compressional or tensile regime depends on its value for this quantity in comparison to its (*)** substrate. Generally, a small mismatch in this quantity is desired for epitaxial layers, to reduce the mechanical
6 stress of a structure. For 10 points, name this "constant" that is the same for all dimensions of a cubic unit cell.
ANSWER: **lattice** constant [or: **lattice** parameter, **cell parameter**; prompt on: **a**] – E3C

3. **In a handbook about technology for this purpose, Werner Kern, a pioneer in this field, describes the period from 1989 to mid-1992 as a period of "literal explosive growth" in technology for it. A good**
3 **process for this purpose uses ultraviolet rays with wavelengths of 184.9 and 253.7 nanometers to generate ozone and cause photolysis. Oxygen plasma ashing, which removes photoresist, was the first dry process applied to this purpose. At intermediate steps in the two most popular processes for**
6 **it, hydrogen-passivation is achieved by using a bath of NH_4F and HF, aka BOE, which is necessary due to said processes making extensive use of H_2O_2. In my experience, the most popular process for this purpose uses two baths that have either NH_4OH or HCl and was developed at (*)** RCA. However,
9 perhaps a more popular low-rent process for it is a mixture of H_2O_2 and H_2SO_4 named "piranha". For 10 points, identify this purpose achieved by removing organic and/or metallic contaminants from the surface of a wafer, in order to reduce defects during processing.
ANSWER: **clean**ing a silicon wafer [until "reduce defects" is read: obvious equivalents involving **reducing** the number of process **defect**s] – F4C

4. **A '90s/'00s book about these systems authored by Joannopoulos, Johnson, Winn, and Meade has a mind-boggling 10,000 citations. Fabricating one variety of these systems is done by the self-assembly of microscopic spheres in a colloid as the colloid is evaporated, forming a synthetic opal whose interstitial space is then filled by a dielectric before dissolving the spheres. These systems are employed in the design of the holey fiber. Fabricating another variety of these systems involves stacking dielectric "logs" in alternating orthogonal directions to form a "woodpile". The hole slab and rod slab example of these systems differ from each other in that the former has TE-like modes while the latter has TM-like modes. The first example of these systems to be fabricated was a dielectric that had been mechanically drilled along the three lattice vectors of an fcc lattice and was named Yablonovite after its discoverer. Their simplest example consists of (*)** alternating layers with different dielectric constants, forming a Bragg mirror. For a specific range of optical frequencies, the local density of states of these systems is zero at their namesake "band gap". For 10 points, name these optical analogs of conductive lattices.
ANSWER: **photonic crystal**s [or: **PC**s] – E5O

5. **Anderson's rule is used when pictorially representing these things. These things occur in one of three configurations: straddling gap, staggered gap, or broken gap. Either the electron affinity or work function must be drawn with respect to the vacuum energy level in order to correctly (*)** align these things when drawing their band diagrams, which always include a cusp or notch, signaling a discontinuity. For 10 points, name this type of interface that exists between two different semiconductors, having different bandgaps, as opposed to a homojunction.
ANSWER: **heterojunction** – E3C

6. **For the 2-color hat game, in which players can see the color of other people's hats but not their own and are required to correctly guess their color, any configuration with a perfect strategy has an example of this code that exists, making it winnable by applying this code. The dual of this code is the simplex code. Building a check matrix for these codes involves taking some r and constructing an $r \times 2^{r-1}$ matrix such that each nonzero binary r-tuple occurs exactly once as a column of the matrix. The (*)** extended form of this code is formed by adding a parity check bit that is the XOR of all bits. Like the Golay code, it's a nontrivial binary perfect code. The $(7,4)$ code in this class was the first error-correcting code to be developed. For 10 points, name this class of linear block codes developed by the Bell Labs scientist who also described the number of positions at which a string is different with his namesake "distance".
ANSWER: **Hamming** codes – E4C

7. **A theorem stating that the support of this operation applied to two functions with some required properties is equal to the sum of the support of each function is due to Edward Titchmarsh. In order to ditch this operation for matrix multiplication, a Toeplitz matrix is constructed. An efficient algorithm for performing this operation is the overlapp-add method. A common way to perform this operation by hand on two discrete time signals, f and g, is to construct an array with f as the first row and g as the second row, then form new rows by multiplying the first row by the first, second, etc. elements of the second row, shifting over one column and down a row every time the index is increased for the second row, and finally summing down the created columns. The (*)** Fourier transform of this operation between functions f and g is equal to the multiplication of the Fourier transform of f and the Fourier transform of g, which is important because this operation applied to the input of an LTI system and the system's impulse response yields the output. For functions $f(t)$ & $g(t)$, this operation is defined as $\int_{-\infty}^{+\infty} f(\tau) \times g(t-\tau)\, \mathrm{d}\tau$. For 10 points, identify this mathematical operation represented by a star.
ANSWER: **convolution** – B2C

8. **A seminal process for fabricating this configuration was published by Tang, Nguyen, and Howe in "Laterally Driven Polysilicon Resonant Microstructures". When perfectly fabricated, these devices** *3* **avoid the pull-in instability by having no transverse motion and allow a large range of longitudinal motion, which is why their super important application is MEMS accelerometers. The capacitance of this configuration is controlled by changing the (*)** overlap and is linear for a large range of displacements. *6* With the parallel-plate configuration, this configuration is the most commonly used electrostatic actuator in MEMS. For 10 points, name this configuration that consists of a fixed and a moving structure that have their teeth interdigitated.
ANSWER: interdigitated **comb**-drive configuration – F5C

9. **Depending on the system, this problem can be an example of a Nevanlinna-Pick interpolation problem or a Nehari interpolation problem. Kwakernaak used J-spectral factorization as a way to obtain a** *3* **polynomial matrix solution to this problem in the frequency domain. Solving this problem in state space can be done by solving two algebraic Riccati equations, with indefinite quadratic terms, that have the same form as those that arise in differential games. The mixed-sensitivity problem is a special** *6* **case of it. A step in solving this problem is determining the Youla parametrization for all stabilizing controllers in a system. Because obtaining an optimal solution for this problem is often too hard, a suboptimal solution is typically sought through gamma iteration. It was formulated by George (*)** *9* Zames in "Feedback and optimal sensitivity: Model reference transformations, multiplicative seminorms, and approximate inverses". This robust control problem involves taking a namesake norm of the transfer matrix that yields the maximum of the transfer matrix's largest singular value over all frequencies. For 10 *12* points, identify this type of problem in control theory named for the space of all complex-valued functions of a complex variable that are analytic and bounded in the open right-half complex plane, which is a Hardy space.
ANSWER: H_∞ control problem [or: H_∞ optimization problem] – F5T

10. **These devices have to meet the requirements of UL 1699. The requirement for this device implicitly requires one not to use a shared neutrals; an often first step in troubleshooting these devices is to** *3* **check for a grounded neutral. As of the 2014 NEC, the "combination" type of them are required in nearly all areas of a dwelling unit (aka house), notably excepting the bathrooms and exterior, for all 120V, 15- and 20-amp branch circuits. It is often confused with a totally different device that protects** *6* **people from being electrocuted because that device has a similar (*)** acronym to this device, which is designed to prevent fires. For 10 points, name this device that trips when it detects an arc and is often confused with a GFCI breaker/receptacle.
ANSWER: **AFCI** breaker [or: **arc-fault circuit interrupter** breaker] – N/A

11. **Kroemer and Chien extended the viability of this technique to heterojunctions by showing that the Debye averaging, or smearing, process preserves the moment of the electron distribution and the** *3* **charge increment. DLCP is a variation of this technique that has the advantage of not being sensitive to interface states and traps. If one is using this method, it's very important to know that its spatial resolution is limited by the Debye length. It is commonly performed in a nondestructive manner with** *6* **a mercury probe or in a destructive manner with an electrochemical cell whose results are computed by the Mott-Schottky relationship. Instead of plotting the y-axis as linear for it, the y-axis is commonly plotted as an inverse square in order to determine the uniformity of (*)** carrier density. As a namesake *9* parameter of this technique is equal to the permittivity times area over junction depth, it's used to determine the doping profile. For 10 points, name this technique used primarily for *pn* junctions and MOSFETs, in which one namesake parameter is measured as the other namesake parameter, aka the bias, is varied.
ANSWER: **C-V** profiling [or: **capacitance-voltage** profiling; in place of "profiling": pretty much anything, including "method", "measurement", "test"] – F4C

12. **This filter's characteristics can be evaluated by utilizing Landen's transformation. The functions used to design these filters are doubly-periodic with periods of $4K$ and $4jK'$, where K and K' are the so-**
3 **called quarter periods. Designing these filters requires calculating the modular constant q, which is also known as the nome q. These filters can be seen as a generalization (*)** of Chebyshev filters because they allow ripples in both the passband and stopband, giving them the best characteristics for a given filter
6 order. For 10 points, name these go-to filters for filter designers that are named for their use of sn and cd, which are Jacobi functions.
ANSWER: **elliptic** filter [or: **Cauer** filter, **Zolotarev** filter]– E4O

13. **Though very hazardous, a solution of ethylene diamine and pyrochatechol, or EDP, is useful as an etch that depends on orientation and these things. The y-axis of an Irvin's curves diagram is for the**
3 **surface concentration of these things. The van der Pauw method is useful for determining the concentration and type of these things. The redistribution of these things during oxidation depends on their segregation coefficient. The solid solubility limit determines the electrically (*)** active concentration of
6 these things. Spin-on glasses are used in low-rent processes for including these things, but the state of the art process is ion implantation. Their addition shifts the Fermi level closer to the conduction or valence band. For 10 points, name these things added to semiconductors to increase the amount of n– or p–type carriers.
ANSWER: **dopant**s [or: **doping agent**s, ionized **impurities**]– C3C

14. **For different devices, this quantity can be evened up by doing a shallow ion implantation as the final implantation step. Fixed and mobile ions in an oxide both decrease this quantity by the magnitude of**
3 **charge over oxide capacitance. Equations for this quantity normally incorporate gamma as a parameter for the body effect. An enhancement-mode MOSFET has a different (*)** sign for this quantity than a depletion-mode MOSFET. A MOSFET is in the saturation region when the condition $v_{DS} \geq v_{GS}-$ {this quantity}
6 is met. For 10 points, what quantity is the voltage between the gate and source when a drain current starts flowing in a MOSFET?
ANSWER: MOSFET **threshold** voltage [or: V_T, V_{th}] – E2C

15. **These devices are certified under UL 2200. EPA's requirement of Tier 4 and Tier 4i ratings for these devices has led to the development of various aftermarket treatments for them. When too lightly**
3 **loaded, these devices can undergo wet stacking. These devices cannot be paralleled if the pitch of their alternators doesn't match. Due to the inrush current determining the size of these devices, a fire pump is usually the first put on them. When designed for bi-fuel, these devices can run on up to 75%**
6 **natural gas. These devices are split into three applications: continuous, prime, and (*)** standby; the latter is required to come online within 10 seconds by the life safety code. Popular manufacturers of these devices include Generac and Caterpillar. For 10 points, name these devices used to provide power in the event
9 of a utility outage.
ANSWER: electric **generator** [or **genset**]– D5O

16. **A method for designing these filters solves the optimum equiripple Chebyshev approximation, which is done using the Remez exchange algorithm. That method is the Parks-McClellan algorithm. The**
3 **signal flow graphs for these filters can only be put in one direct form, since what would normally be direct form I and direct form II are exactly equivalent. These filters require no feedback, so their difference equations are not recursive. Whether the impulse response of these filters is symmetrical**
6 **or anti-symmetrical and (*)** even or odd determines the 4 types of these filters that have linear phase, i.e. constant group delay, a property for which they are often used. The coefficient / delay pairs of these filters are called taps. For 10 points, identify this class of digital filters that is contrasted with IIR filters.
ANSWER: **FIR** filters [or: **finite impulse response** filters] – F4C

17. **When these particles are bound to a neutral donor and undergo photoluminescence spectroscopy, a two-electron satellite feature is observed in the spectrum. These particles are the subject of much study in CuCl quantum dots, including a "bi" version of these particles that's typically abbreviated XX. These particles create a system of energy levels below the conduction band whose mathematical expression includes a term exactly as that of the hydrogen atom's energy levels. Examples of them bound to isoelectronic dopants can be used to efficiently extract (*)** light from indirect semiconductors. These particles can exist as tightly-bound or weakly-bound, in the latter case existing across many unit cells; those two types are respectively named for Frenkel, and Mott and Wannier. They can efficiently couple to photons to form a namesake polariton quasi-particle because these quasi-particles are electric dipoles. For 10 points, name these electron-hole pairs bound by a Coulomb attractive force.
ANSWER: **exciton**s – E4C

18. **Using a disordered polycrystalline form of this material, Cao et al. were the first to demonstrate the existence of coherent random lasing, which is due to photon localization that's analogous to Anderson localization for electrons. In terms of unique 1D nanostructures, and its properties, this material is the #1 most diverse, being capable of forming nanocombs, nanorings, nanohelixes, nanobows, nanobelts, nanowires, and nanocages, among others. A broad peak of unknown origin around 500 to 530 nanometers appears in the luminescence spectra of this semiconductor and is known as its "green band". It's possible to engineer the bandgap of this semiconductor using sufficiently small concentrations of magnesium and cadmium. This semiconductor has a very large excition binding energy, at 60 meV, making it a candidate for exciton-based lasers operated above room temperature. Due to the presence of interstitial hydrogen, which acts as a shallow donor and is ubiquitous, and the fact that only nitrogen is a shallow acceptor in this semiconductor, it's extremely difficult to dope this semiconductor p-type with any sort of quality. It's very easy to grow bulk single crystals of this wurtzite semiconductor with bandgap 3.3 eV, so it may eventually supersede (*)** GaN for many optoelectronic applications, a material for which it's also a great substrate. An aluminum-doped version of this semiconductor has attracted widespread interest as a potential replacement for ITO, which uses a lot of the very-expensive-and-scarce indium. For 10 points, name this piezoelectric transparent conductive oxide.
ANSWER: **ZnO** [or: **zinc** oxide] – F5C

19. **If using immersion lithography, one can realistically have values for this quantity that are greater than 1, in which case you might prefix it with "hyper-". In optical lithography, the resolution is inversely proportional to this quantity while the depth of focus is inversely proportional to its square. The V number can be simplified to this quantity times core diameter times pi over wavelength. For an optical fiber, this quantity is the square root of the difference between the squared (*)** indices of refraction for the core and cladding. In general, it's equal to the index of refraction times the sine of half the cone angle of the lens. For 10 points, name this quantity that measures the ability of a lens to collect light.
ANSWER: **numerical aperture** [or: **NA**] – E4C

20. **The CCNP troubleshooting exam requires one to use this system in a top-down, bottom-up, or divide-and-conquer approach. Switches are often described by one of two places in this system; functionality of one of those switches is akin to a router, with fast forwarding done via hardware. Frames are the protocol data units of a part of it that is subdivided into logical link control and media access control. The Department of Defense, or (*)** TCP/IP, model can be seen as a condensed version of it. Application, presentation, session, transport, network, data-link & physical are the seven layers that constitute this model. For 10 points, name this model of the layers data must go through to traverse devices over a network.
ANSWER: **OSI**/RM [or: **Open Systems Interconnection** reference model; until "Department of Defense" is read prompt on: **TCP/IP**, **DoD** model, **Deparment of Defense** model] – E4O