1. Real gases behave like ideal gases at low pressure, high/moderate temperature, and low density.
2. Ideal gases cannot be liquefied but real gases can.
3. Fundamental units: kilogram, meter, second, Kelvin, mole, ampere, candela.
4. Vectors: displacement, velocity, acceleration, all forces (including weight), momentum, impulse, all fields (gravitational, electric, magnetic), all gradients (electric field, magnetic field).
5. Electric potential (Ve) and gravitational potential (Vg) are scalars.
6. Light dependent resistor (LDR, light sensor): as light intensity increases, its resistance decreases.
7. Negative Temperature Coefficient Resistor (NTC, thermistor, heat sensor): as temperature increases, its resistance decreases.
8. Defining Equation for Simple Harmonic Motion: a = -ω2 x
9. Simple Harmonic Motion is when

a) the acceleration (or restoring force) is proportional to the displacement and

b) the acceleration (or restoring force) is in the opposite direction of the displacement (directed toward equilibrium).

1. Kelvin = Celsius + 273 (that is, 0o C = 273 K)
2. Thermal equilibrium = objects at same temperature, no thermal energy exchange (Q = 0).
3. During a phase change, internal potential energy changes and kinetic energy (and temperature) remain the same. (Q = mL)
4. During a temperature change, internal kinetic energy changes and potential energy stays the same. (Q = mcΔT)
5. Elastic collision = total KINETIC energy is conserved.
6. All collisions (if isolated system): total energy is conserved (ET = ET) , total momentum is conserved (pT = pT) .
7. 1 kilowatthour (kWh) = 3.6 x 106 J
8. 1 electronvolt (eV) = 1.60 x 10-19 J
9. 3 units for energy: joules (J), electronvolts (eV), kilowatthours (kWh)
10. Internal energy of an ideal gas consists solely of kinetic energy (no potential energy since no intermolecular bonds).
11. For an ideal gas, U α T and ΔU α ΔT.
12. Always use Kelvin temperatures.
13. Assumptions of the Ideal Gas Model:
    1. A gas consists of an extremely large number of very tiny particles (atoms or molecules) that are in continuous random motion with a variety of speeds.
    2. The volume of the particles is negligible compared to the volume occupied by the entire gas.
    3. The size of the particles is negligible compared to the distance between them.
    4. Collisions between particles and collisions between particles and the walls of the container are assumed to be perfectly elastic and take a negligible amount of time. The time for a collision is much less than the time between collisions.
    5. In between collisions, the particles obey Newton’s laws of motion, that is, they travel in straight lines at a constant speed.
    6. No forces act between the particles except when they collide (no intermolecular forces).
14. Addition-Subtraction Rule: When adding or subtracting numbers, ADD their ABSOLUTE uncertainties.
15. Multiplication-Division Rule: When multiplying or dividing numbers, ADD their PERCENT uncertainties.
16. Power Rule: When raising a number to a power, MULTIPLY the PERCENT uncertainty by the power.
17. Logarithmic straightening of y = cxn : slope = n, y-intercept = log c.
18. No work is done moving a charge (or mass) along an equipotential surface.
19. The electric FIELD (E) inside a charged conductor (sphere) is zero.
20. The electric POTENTIAL (V) inside a charged conductor (sphere) is constant (not zero), and the same as it is at the surface.
21. As a satellite is moved further from the surface of a planet, its kinetic energy decreases, and its potential and total energy increases. (Total energy is NOT constant).
22. Distance of closest approach: KE = PE, ½ mv2 = kQq/r
23. Field lines (electric or gravitational) are perpendicular to the equipotential surfaces and point in the direction of decreasing potential.
24. Electric potential & potential energy and gravitational potential & potential energy are zero at infinity.
25. A field (electric or potential) is the negative gradient of the potential with respect to distance.
26. Field, force, gradient = vector; potential, potential energy = scalar.
27. Primary cells are non-rechargeable; secondary cells are rechargeable.
28. To charge a secondary cell, run the current through it in the reverse direction (from negative to positive).
29. An ideal cell has no internal resistance and the potential difference remains constant over time.
30. A real cell has internal resistance and the potential difference loses its initial value quickly, has a stable and constant value for most of its lifetime, followed by a rapid decrease to zero as the cell discharges completely.
31. Capacity (mAh) measures the ability of a cell to release charge.
32. Resistance is the ratio of potential difference to current (R = V/I).
33. A resistor at constant temperature is an ohmic device. Its I-V graph has current increasing at a constant rate. Its slope is R (or 1/R).
34. A filament lamp is a non-ohmic device. Its I-V graph has current increasing at a decreasing rate. Its slope (or even its tangent’s slope) is NOT either R or 1/R.
35. An ohmic device is one that obeys Ohm’s law: potential difference is proportional to current.
36. An ideal voltmeter has infinite internal resistance.
37. An ideal ammeter has zero internal resistance.
38. Voltmeters are placed in parallel; ammeters are placed in series.
39. Short, fat, cold wires are the best conductors (least resistance).
40. Long, hot, skinny wires have the worst conductors (most resistance).
41. Drift speed formula: I = nAvq where n= number of charge carriers per unit volume (charge density).
42. Resistors in series act as a “potential divider” splitting the potential between them in direct proportion. (R1/ R2 = V1 / V2)
43. For emfs (batteries) in series pointing in the same direction: add the voltages.
44. For emfs (batteries) in series pointing in opposite directions: subtract the voltages.
45. For emfs (batteries) in parallel: same emf but add the internal resistance down.
46. Kirchhoff’s Loop Rule (conservation of energy): The sum of the voltage rises and drops around any closed loop is zero.
47. Kirchhoff’s Junction Rule (conservation of charge): The sum of the currents in and out of any junction is zero.
48. For an open circuit, the terminal voltage of the battery equals its emf.
49. For a closed circuit, the terminal voltage of a battery is less than its emf.
50. A diode only allows current to flow in one direction.
51. Right hand rules: use a curled hand to find the field; use a flat hand to find the force.
52. Magnetic flux linkage = N Φ = N B A cos θ
53. **Faraday’s Law:** An induced emf is proportional to the rate of change of magnetic flux linkage.
54. The negative slope of a flux graph is the emf.
55. To get an emf (or current) graph from a flux graph, take the negative derivative.
56. According to Lenz’s law, an induced emf will keep the net flux constant. (Nature doesn’t like change.)
57. Lenz’s Law is an application of the law of Conservation of Energy.
58. Doubling the frequency of rotation of an AC generator’s coils doubles the output AC voltage and its frequency and halves is period.
59. Real transformers are not 100% efficient due to joule heating, eddy current heating, magnetic hysteresis, and flux leakage.
60. For power distribution, first a step-up transformer is used (steps up voltage and steps down current) then a step-down transformer is used (steps down voltage and steps up current.)
61. The basic operating principle of an AC motor is that when coils of wire spin in a magnetic field, a potential difference is induced.
62. Power is stepped up in transmission cables in order to reduce the I2R loss of energy in heating the cables.
63. Inserting a dielectric material (an electrical insulator that is polarized when placed in an electric field) in the space between two parallel plates in a capacitor increase its capacitance.
64. Rectification: process of converting AC to DC.
65. Full-wave rectification circuit: Diode bridge is formed from two sets of parallel diodes. Diodes on parallel sides of the bridge point in the same directions (away from negative and towards positive)
66. Capacitors in series: control = voltage, C1/C2 = Q1/Q2.
67. Capacitors in series: add down like resistors in parallel.
68. Capacitors in parallel: control = charge, C1/C2 = V2/V1.
69. Capacitors in parallel: add up like resistors in series.
70. Time constant for an R-C circuit: τ = RC.
71. Effect of adding a capacitor on diode bridge rectification circuits: smoothes the pulsing of the output voltage and current and makes output more steady.
72. Maximum speed for an object in SHM: vo = ω xo.
73. Maximum acceleration for an object in SHM: ao = ω2 xo.
74. **Isochronous:** same period for any amplitude of swing or oscillation
75. The total energy of a system in simple harmonic motion is proportional to the square of the amplitude of oscillation.
76. The lowest frequency mode of a standing wave is known as the first harmonic.
77. Reflected light is polarized parallel to the reflecting surface.
78. When reflected light is completely polarized, the angle between the reflected and the refracted rays is 90o.
79. When unpolarized light goes through a polarizing filter, its intensity drops to ½ its initial value.
80. Intensity has an inverse quadratic relationship with distance. (I α x-2)
81. Intensity of a mechanical wave is proportional to the square of the amplitude of the wave. (I α A2)
82. Doppler formulas for sound: STS (Source Towards Subtract), OTA (Observer Towards Add)
83. A radio wave is not a sound wave. It is an electromagnetic wave.
84. Doppler Effect: moving source – control variable = speed.
85. Doppler Effect: moving observer – control variable = wavelength.
86. When waves are reflected from a moving object, use the Doppler Shift twice.
87. Doppler Effect can be used in blood flow measurements, radar for weather forecasting, and red-shift for receding galaxies.
88. Single slit pattern: one wide central maximum.
89. Ideal double slit pattern: equally spaced fringes of equal brightness.
90. Real double slit pattern: double-slit pattern is modulated by the single slit pattern.
91. A rainbow produced by a prism/crystal is caused by refraction and dispersion.
92. A rainbow produced by a diffraction grating is caused by diffraction and interference.
93. A rainbow produced by a thin film (soap bubble, oil slick) is caused by reflection and interference.
94. When a light wave hits a substance with a higher index of refraction, it undergoes a 180o phase change (hard refection).
95. When a light wave hits a substance with a lower index of refraction, it undergoes no phase change (soft refection).
96. The approximate ratios of successive intensity maxima for single-slit interference patterns is 5%, 2%, 1%.
97. In order to increase the resolution of an optical device, decrease the wavelength of the light used and increase the size of the opening. (θmin = λ/b)
98. Curves are good. (CURVE! CURVE! CURVE!)
99. If the actual angle between two light sources is greater than the minimum angle, then the two sources can be resolved.
100. If the angle of incidence is greater than the critical angle then total internal reflection will occur.
101. Total internal reflection can only occur when light travels from a low to a high index substance.
102. If the frequency of the light is constant, as the intensity of the light increases: Energy of each photon remains the same, Total energy increases, Number of photons increases. (Nph = ET/Eph)
103. If the intensity of the light is constant, as the frequency of the light increases: Energy of each photon increases, Total energy remains the same, Number of photons decreases. (Nph = ET/Eph)
104. Evidence of the wave nature of electrons: electron diffraction experiments, Davisson-Germer experiment.
105. The energy of a photon emitted or absorbed by an electron is equal to the difference in its energy levels. (Eph = ΔEn)
106. When an electron *absorbs* a photon it jumps up energy levels (absorption spectra, dark-line spectra).
107. When an electron *emits* a photon it jumps down energy levels (emission spectra, bright-line spectra).
108. Bohr’s Model of the Atom: The angular momentum of an electron in a stationary state is quantized in integral values of h/(2π). (mvr = nh/2π)
109. The square of the amplitude of the electron’s wave function is proportional to probability of finding the electron at a particular location.
110. Conjugate quantities for the Heisenberg Uncertainty Principle: position and momentum, or energy and time.
111. The more you know about one conjugate quantity, the less you know about the other.
112. Factors that affect quantum tunneling probability: (a) thickness of the barrier (b) mass of the particle and (c) difference in energy between the particle and the height of the potential barrier.
113. Thermal Neutron = low-energy neutron (≈1eV) that favors fission reactions
114. Moderator is a substance used to **slow down neutrons** to thermal levels to ensure that the fission takes place.
115. Without a moderator, a nuclear reactor would produce no energy and shut down.
116. Control Rods are used to **absorb neutrons** to control the rate of the reaction.
117. Without control rods, a nuclear reactor would produce too much energy and meltdown.
118. A nucleon is a proton or neutron.
119. A nuclide is a particular type of nucleus. (nuclide = nucleus)
120. Atomic number is the number of protons.
121. Mass number is the number of protons and neutrons.
122. The molar mass in grams of a nuclide equals its atomic mass.(eg. – carbon-14 has a molar mass of 14 grams.)
123. The masses of nuclei can be found from mass spectrometer experiments.
124. The existence of isotopes can be found from mass spectrometer experiments.
125. The sizes of nuclei can be found from charged particle scattering experiments (Rutherford-Geiger-Marsden, electron diffraction)
126. Using high energy electrons (electron diffraction) to measure the size of nuclei gives a more accurate value than using alpha particles (Rutherford-Geiger-Marsden).
127. Nuclear densities are approximately the same for all nuclei.
128. The only macroscopic objects with the same density as nuclei are neutron stars.
129. MeV is a unit of energy; MeV c-2 is a unit of mass.
130. Binding energy is energy released when a nuclide (nucleus) is formed.
131. Mass defect (deficit) is the energy equivalent of the binding energy.
132. A nucleus with a *high* binding energy per nucleon is in a *low* energy state which is more stable.
133. 1 u = 1 g/mol
134. Most nuclei have a binding energy per nucleon of approximately 8 MeV, between 7 and 9.
135. The peak of the binding energy per nucleon graph is around Fe-56 (or Ni-62).
136. Fission is the splitting of a heavy nucleus; fusion is the combining of light nuclei.
137. U-238 is the most common isotope but is not easily fissioned.
138. U-235 is the most easily fissioned isotope and so it’s the most common nuclear fuel.
139. Neutrons must be slowed down (by the moderator) to become a thermal neutron in order to fission U-235.
140. In order for two nuclei to undergo fusion, they must have sufficient kinetic energy to overcome the Coulomb repulsion between them. This requires very high temperature plasmas.
141. The major reason that fusion power plants are not yet in use today is magnetic confinement technologies for the high-temperature plasma are not yet feasible.
142. Mr. Guido likes chocolate-covered cashews.
143. Artificial transmutation is when a nucleus is bombarded with a nucleon, an alpha particle or another small nucleus, resulting in a nuclide with a different proton number (a different element). The bombarding particle must have sufficient kinetic energy to overcome the Coulomb repulsion.
144. Ionizing radiation in order of increasing *penetrating* ability: alpha, beta, gamma.
145. Ionizing radiation in order of increasing *ionizing* ability: gamma, beta, alpha.
146. Ionizing radiation can be detected with a Geiger-Muller tube (Geiger counter).
147. A major source of background radiation is radon gas from naturally occurring radioactive decay of uranium in granite rocks.
148. In radioactive decay, energy is released in the form of the kinetic energy of the decay products.
149. In radioactive decay, this kinetic energy comes from the rest mass of the nucleons.
150. Alpha decay occurs by quantum tunneling.
151. Beta-minus (electron) is always accompanied by an anti-neutrino. A neutron turns into an electron and a proton.
152. Beta-plus (positron) is always accompanied by a neutrino. A proton turns into a neutron and a positron.
153. Beta decay occurs due to the weak interaction.
154. In gamma decay, neither the mass number nor the atomic number of the nuclide changes.
155. Evidence for *atomic* energy levels (electron energy levels), comes from absorption and emission line spectra.
156. Evidence for *nuclear* energy levels comes from the decay spectra of alpha and gamma (NOT beta).
157. Alpha and gamma decay have discrete energy spectra; beta is continuous.
158. The decay spectrum for beta decay is continuous because there are two particles (beta and neutrino) which share the energy in any proportion (but the neutrino usually takes most of the energy).
159. Radioactive decay is random, spontaneous, and exponential.
160. The decay constant (λ) gives the probability of decay of a particular nucleus per unit time.
161. The slope (derivative) of a radioactive decay graph gives the activity at that point.
162. Activity is proportional to the number of radioactive nuclei present at any one time. (A = λN)
163. There are two different methods for determining radioactive half-life: one for a long half-life and one for a short half-life.
164. The fundamental particles (which cannot be further subdivided) of the Standard Model are quarks, leptons, gauge bosons (exchange particles) and the Higgs boson.
165. Isolate quarks cannot be observed = quark confinement.
166. The Higgs boson is a particle that gives other particles mass.
167. A muon (μ) is a mu lepton.
168. A tauon (τ) is a tau lepton.
169. Rank the four fundamental forces/interactions from strongest to weakest: Strong, electromagnetic, weak, gravitational
170. The only interaction in which a quark can change into another quark (or a lepton into another lepton) is the weak interaction.
171. The interaction that involves neutrinos is the weak interaction.
172. The strong force acts on all the nucleons (protons and neutrons) while the Coulomb force (EM) acts only on the protons.
173. The weak force acts on quarks and leptons.
174. The photon is the exchange particle mediating the electromagnetic force.
175. A *primary* energy source is a fuel that hasn’t yet been used by the consumer.
176. Primary energy sources are converted into secondary energy sources, usually electricity.
177. Coal, oil, and natural gas are the most common fossil fuels.
178. The major source of degraded energy in a fossil fuel power plant is thermal energy lost during combustion to the environment. It is the biggest arrow in the Sankey diagram.
179. A solar heating panel (active solar heater) converts solar energy to thermal energy (hot water).
180. A solar panel (photovoltaic cell) converts solar energy to electrical energy.
181. The operating principle behind a solar cell is the photoelectric effect.
182. The major source of degraded energy in a wind power turbine is frictional losses in the generator.
183. In thermal conduction in a gas, fast moving molecules transfer energy to slow moving molecules.
184. As the temperature of a black-body increases, the peak of its radiation graph gets higher and moves further to the left (its maximum wavelength decreases and the total power emitted increases).
185. The emissivity of a black-body is 1. Its albedo is 0.
186. The global mean albedo for the Earth is 0.30.
187. Shiny, white objects have a high albedo since they reflect much of the radiation that hit them.
188. Major greenhouse gases are: Water Vapor (H2O),Carbon Dioxide (CO2), Methane (CH4), and Nitrous Oxide (N2O).
189. Resonance is the mechanism by which greenhouse gases absorb infrared radiation.
190. Ultraviolet light passes through greenhouse gases in the atmosphere to be absorbed by the Earth then radiated as infrared radiation which is then absorbed by the greenhouse gases and re-radiated in all directions including back down to Earth. This is the Greenhouse Effect.
191. *Extra* greenhouse gases in the atmosphere lead to *extra* infrared radiation being absorbed and re-emitted, raising the temperature of the Earth. This is the Enhanced Greenhouse Effect (global warming).

Whew!