Physics on the Back of an Envelope

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1 General Estimation (no physics req'd)

1. How many piano tuners are there in Hampton Roads?
2. How many golf balls does it take to fill a suitcase?
3. How many pieces of popcorn does it take to fill a room?
4. How many 1 gallon buckets of water are needed to empty Loch Ness?
5. How much dental floss does a prisoner need to escape over a wall? How long would it take to collect that much?
6. How many cells are there in the human body?
7. What is the volume of human blood in the world? How does this compare to the volume of the valley at Har Meggido (Armaggedon)?
8. How fast does human hair grow (in km/hr)?
9. How fast do humans grow (in km/hr)?
10. How many atoms are in the human body?
11. If all the people of the world were crowded together, how much area would we cover (in m^2 or km^2)? How does this compare to the area of Virginia Beach, Virginia, Texas, the USA?
12. If all the families of the world were given a house and a yard, how much area would we cover (in m^2 or km^2)? How does this compare to the area of Virginia Beach, Virginia, the USA?
13. Assuming one Santa Claus visits all Christian children on Christmas, how fast would he have to travel?
14. What accelerations would be required during his travel? Give your answer in m/s or g or other appropriate units.
15. What forces would be required? Estimate both the forces exerted on Santa Claus and the forces exerted in the sleigh and its contents.
16. How many reindeer would he need to pull his sleigh?
17. What is the flow rate of the James River? Of the Mississippi River?
18. The largest political demonstrations fill the Washington Mall with people. How many people are there?
19. How many dumptruck loads would it take to cart away Mt. Everest?
20. How many nails are used in building a house?
21. How many bricks are there in ODU?

22. How many frames are there in a movie?
23. How many people in the world are picking their nose at this instant?
24. How many people in the world are talking on their cell phones at this instant?
25. How heavy are the pyramids?
26. How many port-a-potties should you plan for the next million-man-march?
27. If the maximum number of monkeys typed at maximum speed for the greatest length of time, what is the largest number of consecutive correct characters of Hamlet that they would type?
28. If all the computers in the world today generated random characters for one year, what is the largest number of consecutive correct characters of Hamlet that they would generate?
29. How much municipal solid waste does the US generate per year?
30. How large a landfill would we need to store 100 years of garbage?
31. How many kernels of popcorn are needed to fill a room?
32. How often does a fly ball land in a glass of beer at a baseball game?
33. How much hair (in m) is clipped every day in the US?
34. What is the length of all fluorescent bulbs in the US?
35. What is the probability that your child will grow up to play major league baseball?
36. How many characters are typed each year in the US?
37. How precisely do we need to know the time of birth to decide which human was born as number seven-billion?

2 Transportation

38. How many miles did Americans drive last year?
39. How many miles did Americans fly last year?
40. How much total time did Americans spend driving last year?
41. How much gasoline does a typical automobile use during its lifetime?
42. What is the relative cost of fuel (per kilometer) of New York City bicycle rickshaws (human-pedalled taxis) and of automobiles?
43. What is the relative waste generated (per kilometer) of horse-drawn carriages and of automobiles? Give your answer in kg/km.
44. Cars are expensive. You have to spend many hours working to pay for the car. If you add all of the time you spend working in order to earn money to pay for your car to all the time that you spend driving the car, what is your average car travel speed? Of a bicycle?
45. How much time would be lost nationwide by decreasing the speed limit from 65 to 55 mph? Express your answer in hours, years and lifetimes. How does this compare to the extra lives that might be saved?
46. How many people are airborne over the US at any given moment?
47. How much did American Airlines annually save by eliminating one olive from each salad served first class?
48. How much rubber is deposited on American roadways every year by automobile tires?

49. How far does a car travel before a one molecule layer of rubber is worn off the tires?
50. What is the cost of transporting all your food for one year across country by truck?
51. How much fuel can airlines save by requiring all passengers to urinate immediately prior to boarding the airplane?
52. How far should you drive to save $0.05 per gallon of gas?
53. At what wind speed will your car tip over?

3 Mechanics

54. How much do you change your potential energy when you climb a mountain (in Joules and in kcal [1 kcal = $4 \cdot 10^3$ J])?
55. How much energy could we get from flattening the Rocky Mountains (ie: how much potential energy is stored in a mountain range)?
56. How much potential energy does a 100-story building have?
57. What is the kinetic energy of a bullet fired from a rifle?
58. What is the kinetic energy of a served tennis ball?
59. What is the kinetic energy of a large truck at highway speed?
60. What is the kinetic energy of a drifting continent? Compare this to the KE of a large truck on the highway.
61. What is the momentum of a drifting continent? Compare this to the momentum of a large truck on the highway and to a super tanker.
62. What is the mass of the Earth (start with the radius and the (estimated) density)?
63. What is the mass of the moon? (Start with the distance to the moon and its apparent size.)
64. What is the orbital speed of the Earth around the Sun?
65. What is the rotational angular momentum of the Earth?
66. What is the rotational angular momentum of the Moon?
67. What is the maximum angular velocity the Earth could have without flying apart?
68. What is the revolutionary angular momentum of the Earth about the sun?
69. What is the revolutionary angular momentum of the Moon about the Earth?
70. What is Roche's limit (the orbital distance inside which a moon will disintegrate)?
71. How long was the day when the moon was at Roche's limit?
72. How long will the day be when it is equal to the month?
73. What is the tidal drag force on the Earth?
74. How long would a beanstalk (elevator to geosynchronous orbit) have to be? What tensile strength would it require? How does this compare to steel, kevlar, spider silk, the maximum theoretical material strength?
75. According to one hypothesis, 20% of the mass of the asteroid that killed the dinosaurs was uniformly deposited over the surface of the Earth at a density of 0.02 gm/cm^2. What was the mass of this asteroid?

76. What is the kinetic energy of a large (1 km^3) meteor? How does this compare to one year's insolation of the Earth? How much is this in megatons?
77. How much would a large (1 km^3) meteor strike change the angular momentum of the Earth?
78. How much energy is required to boil the Earth's oceans?
79. How large a collision is needed to split the moon in half? To split Phobos in half?
80. How long would it take a solar sail powered spaceship to travel to a) the Moon, b) Mars, c) Pluto?
81. How large a perimeter do your feet need for surface tension to support your body weight?
82. How large a moon can you jump off of (ie: can achieve escape velocity from)?
83. How much would the ocean surface rise if the ice caps melted? How much would that change the salinity of the ocean?
84. The ocean is saline because rivers bring in salts (think of the Great Salt Lake or the Dead Sea). Estimate the age of the Earth from the salinity of the oceans. Discuss why this estimate is so wrong.
85. How much would the ocean surface rise due to thermal expansion due to global warming (in addition to ice cap melting)?
86. Astrology claims that the position of the planets at the time of our birth influences our lives. Calculate the relative gravitional attraction and the relative tidal forces on a newborn baby of a) Jupiter, b) the hospital building, c) the obstetrician.
87. What is the maximum theoretical height of a mountain on Earth? On Mars?
88. A car participates in a race. Its tire explodes. What should be the the speed of the car, so that the tire does not become "flat"?

4 The Atmosphere

89. What is the mass of the atmosphere?
90. How many molecules of Julius Caeser's last breath do you inhale with each breath?
91. How long would it take humans to use up 10% of the oxygen in the atmosphere?
92. How much carbon-dioxide does a square kilometer of forest remove from the atmosphere each year (in kg)?
93. How much carbon-dioxide does an automobile add to the atmosphere each year (in kg)?
94. How much carbon-dioxide does a human add to the atmosphere each year (by breathing) (in kg)?

5 Electricity and Magnetism

95. How strong are the magnets in the SSC? In the Fermilab ring?
96. How long would the Earth's magnetic field last without a dynamo?
97. What is the lifetime of a classical atom (before the electron loses 13 eV of energy to synchrotron radiation)?
98. What is the Schwarzchild radius of an electron?
99. At what distance is the magnetic field from high power transmission lines the same as a) the Earth's magnetic field? b) the magnetic field from your electric blanket?

6 Quantum Mechanics

100. What is the probability of an object suddenly jumping up from a surface?
101. How small can a 1 GB memory be?
102. What is the probability of a human diffracting as it jumps through a doorway?
103. What is the probability of a human tunneling through a closed door?
104. You walk off of a cliff. How high does the cliff have to be (assuming constant g) for you to have an appreciable probability of quantum mechanically reflecting?

7 Energy

105. What is the heat output of a human (in Watts)?
106. What is the heat output of the sun (in Watts)?
107. If the Sun were made out of Gerbils, the Earth would be incinerated. Explain. (Hint: compare the power per mass of the Sun and Gerbils.)
108. How long could the sun last without thermonuclear reactions (ie: with just chemical fuel)?
109. How much energy would be released by stellar collapse (ie: by the Sun shrinking from its present size down to a neutron star)?
110. How much electrical power does the US use? Electrical energy per year?
111. How much power do humans use? How does this compare to the solar energy incident on the Earth?
112. What is the energy density of gasoline (J/kg)? Of coal?
113. How much fuel is used by a 1000-MWe coal power plant each year? How many 100-car coal trains? How much waste (solid and gas) is generated?
114. How much acid rain is caused each year by an unscrubbed 1000-MWe coal power plant?
115. How much waste (solid and gas) is created each year by a 1000-MWe oil power plant?
116. How much energy is stored in a D-battery? What is its energy density?
117. Compare the cost of energy (to the consumer) in the form of electricity from your wall socket, electricity from batteries, gasoline, and wood.
118. What is the energy transfer rate when you refuel your car?
119. What is the energy transfer rate at which you can recharge a battery?
120. How much Uranium must the Earth contain to keep the core molten?
121. How long would the Earth's core stay molten without the Uranium?
122. How does the power output of a NOVA laser compare to the sun? In its narrow wavelength band?
123. How much Iron, Glass, and Water does the US use per year?
124. What would be the resource value of a 1km^3 metallic asteroid?
125. How much power would it take to desalinate enough water for Virginia Beach?
126. How much flow is needed for a 1000 MegaWatt hydropower plant?

127. How much cooling water is needed for a 1000 MegaWatt nuclear or coal-fired power plant?

128. How much area would a 1000 Megawatt solar power generator need?

129. How much area would an orbital 1000 Megawatt solar power generator need?

130. How big would the earth-based receiving antenna be for an orbital 1000 MW solar power generator?

131. What would the power density be at the earth-based receiving antenna? Relative to the normal solar power density?

132. How much power can a modern wind turbine generate? Hint: What is the kinetic energy of the air passing through the area swept by the blades of the turbine?

133. You live in a hot climate where the temperature is 98.6^o F or 37^o C. How much water do you perspire every day?

8 Nuclear Physics

134. How many neutrinos from the Surry nuclear power plant pass through you each year? How many interact? Is this harmful?

135. How much Uranium is needed each year for a 1000 MegaWatt nuclear plant?

136. How much high-level nuclear waste is created each year by a 1000-MWe nuclear power plant?

137. If this waste was spread evenly over the surface of the earth, with what depth of soil would you have to mix it so that it would be safe to ingest (ie: within federal guidelines for ingestion of radioactivity)?

138. How long do you have to store the waste until it becomes reasonably safe?

139. What are the radiation levels a) in Norfolk, b) in Denver, c) in a commercial jetliner, d) near Three Mile Island at the time of the accident?

140. Ten neutrinos from Supernova 1987a (which was about 150,000 light years from earth) interacted and were detected in the Kamiokanda detector. If you were standing 2 AU from the supernova, what would have killed you?

141. What is a lower limit on the lifetime of the proton (based on the existence of life on earth)?

142. What is an upper limit on the energy released in cold fusion (based on the fact that it didn't kill its proponents)?

143. A biologist recently claimed to have revived a 30 million year old bacteria. How many cosmic rays would have passed through the bacteria during the last 30 million years? What is the probability that its DNA is scrambled?

144. How accurately can you date dinosaur bones?

145. Someone places 1 Curie of uranium on your chest. What do you die of?

146. How much is the energy content of 10 tons of ^{3}He worth?

147. How dangerous was Three Mile Island? Chernobyl?

9 Optics

148. What is the maximum resolution of the human eye?

149. How large an optical telescope aperture would you need to resolve an Earth-size planet circling the nearest star?

10 Human senses

150. What is the maximum light flux the human eye can tolerate (in W)?
151. What is the minimum light flux the human eye can detect (in W)? What is the dynamic range of the eye?
152. What is the shortest time in which we can separate two visual stimuli?
153. What is the shortest time in which we can separate two aural stimuli?
154. What is the angular resolution of our ears? Is it frequency dependent?
155. What is the minimum force we can detect?
156. What is the maximum force we can tolerate?
157. What is the minimum odor we can detect?

11 Risk Assessment, SETI, etc

158. What is the typical molecular binding energy?
159. What is the maximum size of various objects? Moons, planets, suns, white dwarfs, neutron stars, mammals, reptiles, bugs?
160. How likely is the existence of an extraterrestrial civilization?
161. What is the mean distance between civilizations?
162. How many extraterrestrial visits per year can we expect?
163. What is the risk of death per mile of driving?
164. What is the risk of death per mile of flying?
165. How much, on average, does each cigarette shorten the lifespan of a heavy smoker?
166. How much, on average, does each high-fat meal shorten the lifespan of an obese person?
167. What are the relative risks of a) getting killed by a shark at the beach and b) getting killed in a car accident driving to the beach?
168. What are the relative probabilities of dying (in the United States) of a) motor vehicle accident, b) gunshot, c) nuclear power plant accident and routine operation, d) coal power plant accident and routine operation, e) power line EM radiation, f) lightning strike, g) small meteor strike, h) large meteor strike, i) oil power plant accident and routine operation, j) plane crash?
169. What is the probability of success for the Search for Extra-Terrestrial Intelligence?
170. What is Earth's power output in the radio spectrum relative to the blackbody radiation?

12 Scaling

171. How high can mice and elephants jump? (ie: Assuming same shape bodies, how does jump height scale with size?)
172. How large a perimeter do your feet need for surface tension to support your body weight?
173. How large a moon can you jump off of (ie: can achieve escape velocity from)?

13 Dimensional Analysis

174. What is the estimated miles per gallon of a typical automobile?

175. By how much does starlight bend as it passes the Sun?

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