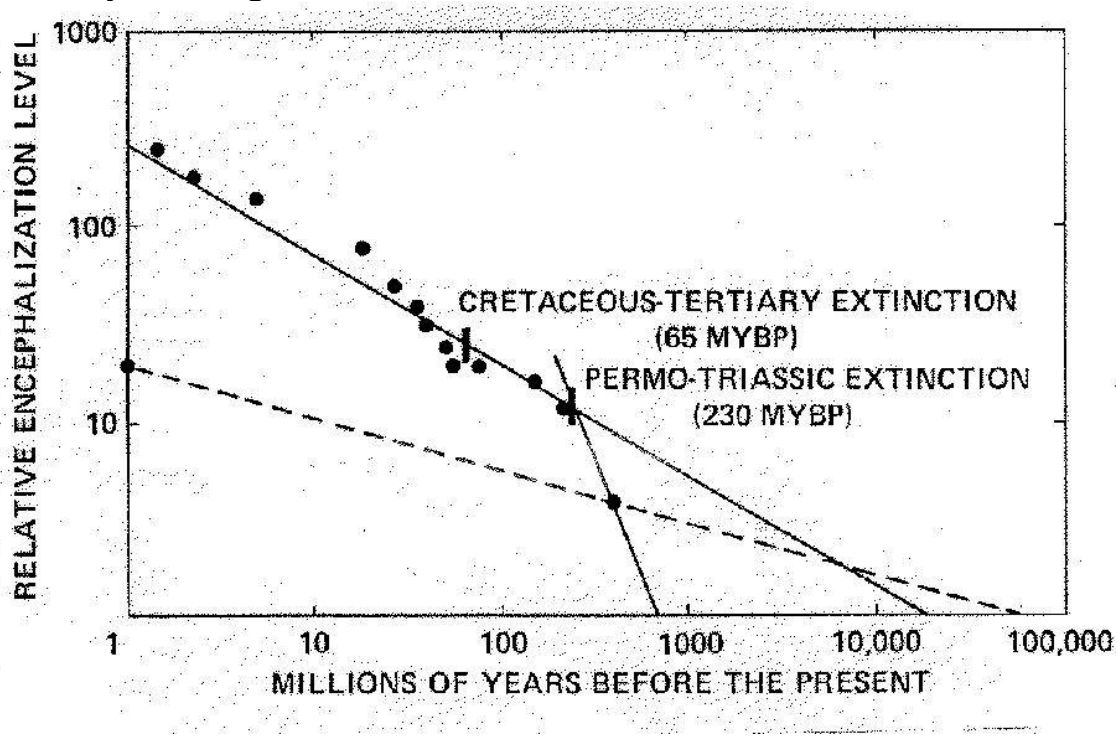
Test #2

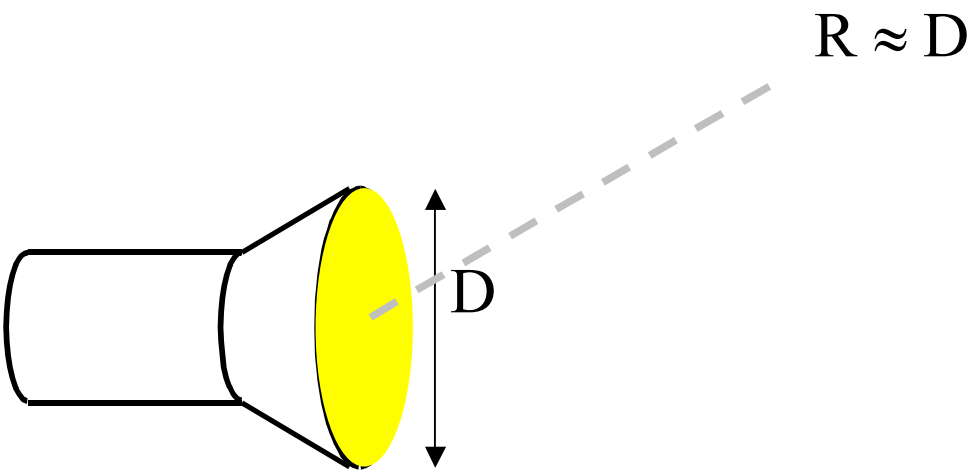
You will have 120 minutes to complete this test.

10 Point Essays – Choose 3 out of 5

1. Give four factors in the use of radio telescopes for wavelengths longer than that of visible light.
2. Give 2 anecdotal reasons why it is believed that the people developed large brains, and see if you can give 2 equally compelling reasons why these factors or others enumerated in LBE and the notes are not "the whole story" (i.e., think of other types of animals). Finally, why is the diagram shown below given as a reason for the "inevitability" of intelligence?



3. What specifically is the problem of "hot Jovians," recently discovered from astrometric measurements, in planetary formation models? How is it believed that they reach their orbits – where do they form, and how do they get to their inner orbits?
4. Consider the following transmitter of diameter D transmitting light of wavelength λ much smaller than D. An observer is located at a distance R from the center of the transmitter, where $R \approx D$. Would you expect that the opening angle of the radiation to be $\theta = \lambda / D$ as seen from this short distance away, and why (or why not)? **Hint**: consider Fraunhofer diffraction and how it was described in class.



some EM transmitter, where λ << D

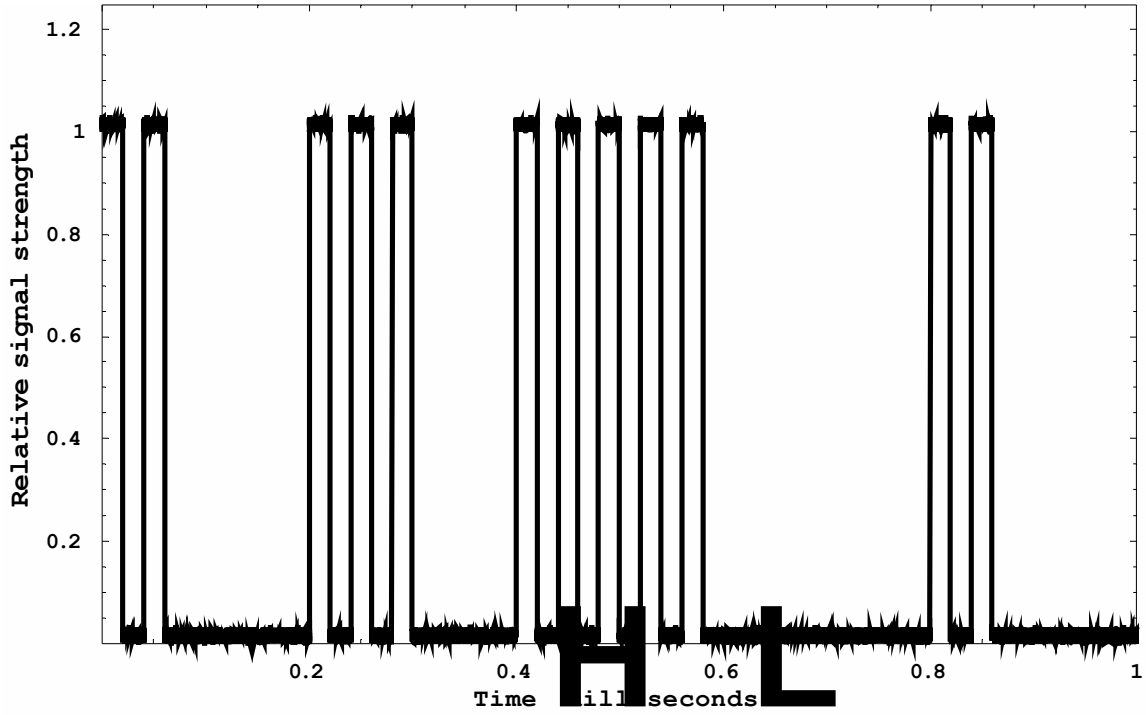
5. Some civilization observes the solar system in the radio. First, what is special about the radio emission from the solar system? Second, although it would be almost impossible to spatially resolve Earth from a nearby star system, how would they go about determining the latitude of various radio sources from Earth? Finally, how would they determine the period of Earth's year?

30 Point Essays – Choose 3 out of 4

1. The neurons within the brain send signals, and stores information, via the synapses within the brain. A typical synaptic "switch" takes 10^{-3} seconds. Now suppose that there are 10^{15} synapses within the brain (each storing a bit), and there are 10^{13} synaptic "switches" per second (corresponding to the number of calculations per second).
    a. 5 points – What fraction of the total number of synapses switch every second?
    b. 10 points – On average, each of the 10^{11} neurons has 10,000 synapses. What is the number of synapses switched by each neuron, on average, each second?
    c. 15 points – Assume that each synaptic connection has a "downtime" associated with it after the switch, preventing the continuous activation of each synapse. Given your answer in (a), the total number of synapses switched every second over the total number of synapse, what is the average "downtime" of each synapse? An easy way to calculate this is to think of the time it would take for all the synapses (on average) in the brain to switch.

    The actual downtime between switches is about 10 seconds. This tells us that only a small fraction of the brain is this active – hence the ~10% of the brain which is extremely active, through which most of the neural activity occurs.

2. Consider the following type of signal sent by a SETI beacon somewhere out in space – the first three prime numbers – with a (somehow) low signal to noise ratio.

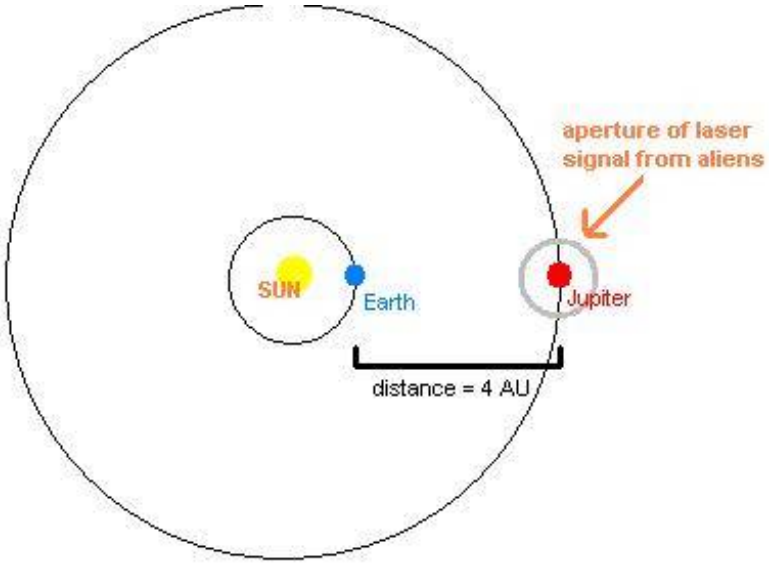


   a. 15 points – given what the SETI community would expect for SETI beacons from space, what area of the electromagnetic spectrum would this signal lie and why?
   b. 5 points – why is it unlikely that this signal would come across within the infrared part of the spectrum?
   c. 5 points – given what you know about the transmission of signals across space, do you think it is likely that a SETI beacon would be pulsed over fractions of a millisecond and why?
   d. 5 points – what is (to our knowledge) an unequivocal way in which we could determine this signal is of extraterrestrial artificial origin? That is, think of something an intelligence could do to this radiation that could not be done naturally?

3. Some aliens want to communicate with us. They do not know where we are and they would not search for planets like Earth, because their chemistry consists of iron-nickel-cobalt crystals in a solution of liquid iron carbonyl and a few hundred atmospheres of carbon monoxide (their homeworld is the stripped core of a gas giant).
   a. 15 points – These aliens might think of searching in radio. Assume an Arecibo-type telescope could "just" detect signals from Earth at 10 pc. Arecibo is a dish approximately 305 meters in diameter. Given the following formula for the power entering the detector, $L_{\det ect} = \frac{L_{source}}{4\pi R^2} A_{\det ect}$, showing that the power entering a detector goes as D^2, the diameter of the detector, and goes as R^{-2}, the distance from the source. Suppose they are located 20

parsecs away; what is the size of their detector, if it can "just" detect signals from Earth?

b. 15 points – Now suppose they use gigantic optical lasers, operating at 500 nanometers 5×10^{-7} meters. However, they point it at Jupiter instead of Earth. What is the maximum size of the laser aperture beyond which Earth will be missed by these aliens? Assume the aliens' homeworld is located at right angles to the Earth's orbit. Earth and Jupiter are separated by 4 AU (6.0×10^{11} km), and the aliens are 20 pc away (65.2 light-year away, where a light-year is 10^{16} meters). Also, the opening angle of the laser (equal to the angular resolution of the telescope of the same diameter) must equal the angular



separation of Earth and Jupiter seen from 20 pc away.

4. The minimum energy required to perform a calculation or to store a bit is determined by the temperature of a system. This minimum energy $E_{\min} = k_B T$, where $k_B = 1.38\times10^{-23}$ Joules/Kelvin is Boltzmann's constant and T is the ambient temperature.

e. 15 pts – Assume some kind of superbrain operating at this limit. It uses up 25 W of power, the same as the human brain. At room temperature, 300 Kelvins, what is the number of calculations per second this brain can do?

f. 10 pts – How many times more is this than the human brain, which can process 10^{13} calculations per second?

g. 5 pts – Consider an intelligent life that uses the spin-flip transition of atomic hydrogen, at 1421 MHz, as a bit switch. Given that the energy of this transition is given by $E = h\nu$, where $h = 6.63\times10^{-34}$ Joules and ν is the frequency in Hertz, what does the temperature T have to be in order for this life to operate?