Pulsars and Simple Equations

The Crab Nebula is all that remains of a supernova explosion 900 years ago. At the center of this picture, taken by the Hubble Space Telescope, is a rapidly spinning pulsar which flashes 30 times a second as it spins.

A pulsar is a rapidly spinning star. It's about the same size as Earth, but it contains as much mass as an entire normal star like the sun.

When they are formed, they spin at an unimaginable pace: nearly 30 times every second. As they grow older, they slow down.

Astronomers have measured the spinning of two pulsars: The Crab Nebula pulsar, and AP 2016+28. They used this data to create two simple equations that predict the pulsar's spin rates in the future.

Crab Nebula Pulsar: $\mathbf{P = 0.033 + 0.000013\,T}$

AP 2016+28 Pulsar: $\mathbf{P = 0.558 + 0.0000000047\,T}$

P is the time, in seconds, it takes the pulsar to spin once-around on its axis. T is the number of years since today.

Problem 1: Evaluate each equation for P for a time that is 10,000 years in the future. How fast are the two pulsars spinning at that time?

Problem 2: How long will it take the Crab Pulsar to slow to a period exactly twice its current period of 0.033 seconds?

Problem 3: How long will it take Pulsar AP 2016+28 to slow to a period of 1.116 seconds (exactly twice its current period of 0.558 seconds)?

Problem 4: How many years ago was the pulsar AP 2016+28 spinning at the same rate as the Crab Pulsar?

Problem 5: How long will it take each pulsar to slow to a period of exactly 2.0 seconds?

Problem 6: In how many years from now will the two pulsars be spinning at exactly the same rates?

Answer Key

Crab Nebula Pulsar: **P = 0.033 + 0.000013 T**

AP 2016+28 Pulsar: **P = 0.558 + 0.0000000047 T**

Problem 1: Evaluate each equation for P for a time that is 10,000 years in the future. How fast are the two pulsars spinning at that time?

Crab: P = 0.033 + 0.000013 (10,000 years) = 0.033 + 0.13 = **0.163 seconds.**
AP 2016+28 Pulsar: P = 0.558 + 0.0000000047 (10,000) = 0.558 + 0.000047 = **0.558047 seconds**.

Problem 2: How long will it take the Crab Pulsar to slow to a period exactly twice its current period of 0.033 seconds?

P = 2 x 0.033 = 0.066 seconds. So 0.066 = 0.033 + 0.000013 T, and solving for T we get T = (0.033/0.000013) = **2,500 years from now**.

Problem 3: How long will it take Pulsar AP 2016+28 to slow to a period exactly twice its current period of 0.558 seconds?
P = 2 x 0.558 = 1.116 seconds. So 1.116 = 0.558 + 0.0000000047 T, and solving for T we get T = (0.558/0.0000000047) = **119 million years from now**.

Problem 4: How many years ago, was the pulsar AP 2016+28 spinning at the same rate as the Crab Pulsar?
P = 0.033 seconds = 0.558 + 0.0000000047 T, so
0.033 - 0.558 = 0.0000000047 T
-0.525 = 0.0000000047 T
-0.525/0.0000000047 = T and so **T = 112 million years ago**.
Note that the negative sign for T means that the time was before today (year-zero).

Problem 5: How long will it take each pulsar to slow to a period of exactly 2.0 seconds?
Crab Pulsar: 2.0 = 0.033 + 0.000013 T so T = **151,000 years**.
AP 2016+28: 2.0 = 0.558 + 0.0000000047 T so T = **307 million years**

Problem 6: In how many years from now A) will the two pulsars be spinning at exactly the same rates? B) What will be their spin rates?

This requires that students set the equation for P in the Crab Nebula Pulsar to the P in the equation for AP 2016+28, and solve for T.

0.558 + 0.0000000047 T = 0.033 + 0.000013 T
0.558 - 0.033 = 0.000013 T - 0.0000000047 T
0.525 = 0.0000129953 T
T = 0.525/0.0000129953 so T = **+ 40,400 years from now.**

B) P = 0.033 + 0.000013 (40400) = **0.558 seconds**.