Purdue Science Olympiad 2016 Regional Tournament
It's About Time Test Answer Key
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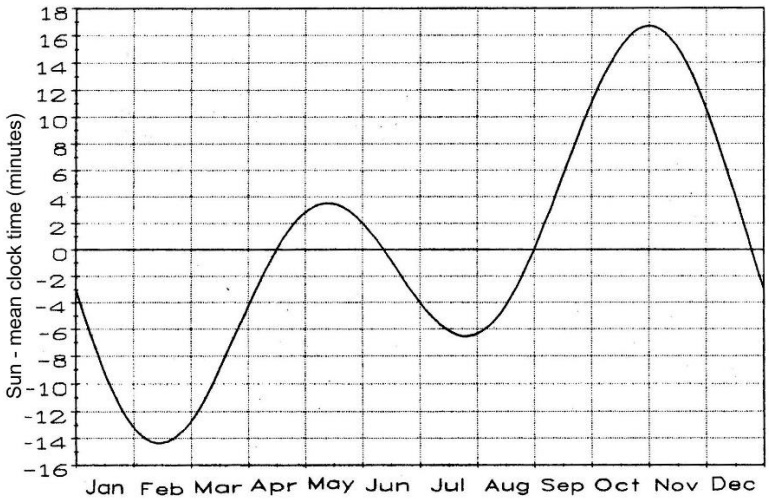
1. What does UTC stand for? (1 pt)
    a. Coordinated Universal Time or Universal Time Coordinate (1 pt)
2. In the USA, Eastern Standard Time is offset from UTC by how much? (answer format UTC±XX:XX) (1 pt)
    a. UTC-05:00 (1 pt)
3. In the USA, Pacific Standard Time is offset from UTC by how much? (answer format UTC±XX:XX) (1 pt)
    a. UTC-08:00 (1 pt)
4. Which has a higher frequency, microwaves or radio waves? (1 pt)
    a. Microwaves (1 pt)
5. Which has a longer period, microwaves or x-rays? (1 pt)
    a. Microwaves (1 pt)
6. Which has a shorter wavelength, red light or blue light? (1 pt)
    a. Blue light (1 pt)
7. What are Kepler's laws of planetary motion? (3 points)
    a. Planets orbit in an ellipse with the sun at one of the foci. (1 pt) A line connecting a planet to the sun will sweep out equal areas over equal times. (1 pt) The square of the orbital period is proportional to the cube of the semi-major axis of the orbit. (T^2=kr^3, where T is orbital period, r is the semi-major axis, and k is a constant) (1 pt)
8. How many vibrations of a Cesium atom are in a second? (1 pt)
    a. 9,192,631,770 Hz (exact)
9. What causes leap seconds, and when are they added (2 pts)?
    a. Leap seconds are necessary because the earth's rotation is slowing down. (1 pt) They are added when UTC approaches being 0.9 seconds ahead of UT1 (mean solar time at the prime meridian). (1 pt)
10. How long will it take for the NIST-F2 atomic clock to accrue 1 second of error? (1 pt)
    a. 300 million years
11. What improvement was made to improve the accuracy from NIST-F1 to NIST-F2, and what source of error did it reduce? (2 pts)
    a. NIST-F1 operated at room temperature, but NIST-F2 uses liquid nitrogen to cool the Cesium chamber. (1 pt) At the warmer temperature, **the walls of the chamber emit radiation that can interfere with the energy states of the Cesium**, **so by cooling the chamber, the effects of the radiation from the chamber walls is greatly reduced**, and the energy states of the atoms are almost exclusively affected by the radiation. (1 pt)
12. If a 15 inch simple pendulum oscillates under earth surface gravity, what is the frequency and the period of the pendulum, in Hz and seconds? (4 points)
    a. 15 in = 1.25 ft, gravity = 32.174 ft/s^2 (convert to appropriate units, 1 pt)
    T = 2pi*sqrt(L/g) = 2pi * sqrt(1.25/32.174) = **1.238 sec** (2 pts)
    f = 1/T = 1/1.238 **= .807Hz** (1 pt)
13. What fraction of a sample is left after 3 half lives? (1 pt)
    a. 1/8 or 12.5%

14. A sample has a half life of 3.56 years. If the sample started with 67g, how much is left after 8.46 years? (5 pts)
    a. N(t) = N(0) * 2^(-t/h) where t is time and h is half-life (1 pt for correct formula)
       N(0) = 67, t = 8.46, h = 3.56 (2 pts)
       N(t) = 67 * 2^(-8.46/3.56) = **12.9g** (2 pts)
15. A sample of a substance begins with 129mg, and after decaying for 27.87 seconds there are 81mg remaining. What is the half-life of the substance? (5 pts)
    a. N(t) = N(0) * 2^(-t/h) where t is time and h is half-life (1 pt for correct formula)
       N(0) = 129, N(t) = 81, t = 27.87 (2 pts)
       81 = 129 * 2(-27.87/h)
       .6279 = 2^(-27.87/h)
       Ln(.6279) = Ln(2^(-27.87/h))
       -.46537 = -27.87/h * Ln(2)
       -.46537 = -27.87/h * .69315
       h = **41.51 seconds** (2 pts)
16. The second harmonic of a string is 440 Hz. What are the frequencies of the first and third harmonics? (2 pts)
    a. 440Hz = 2nd harmonic = 2f
       f = **220 Hz = 1st harmonic** (1 pt)
       3f = **660 Hz = 3rd harmonic** (1 pt)
17. In the southern hemisphere, do shadows move across the face of an equatorial sundial in a clockwise or counter-clockwise fashion? (1 pt)
    a. Counter-clockwise (1 pt)
18. If you took the same picture of the sun at noon each day for a year, and then overlaid all the images, what shape would the different images of the sun form? What is the name of this feature? (2 pts)
    a. The sun would travel in a **figure 8** across the sky (1 pt), a feature called the **analemma** (1 pt).
19. If it is the first of October, and a sundial reads 5:48 pm, what is the actual time? Use the Equation of Time shown in the graph below. (2 pts)



    a. **5:37 pm** from graph, sundials run 11 minutes fast at the start of October

20. List a shortcoming of the sundial, and a shortcoming of water clocks. (2 pts)
    a. Water clocks needed constant pressure to achieve constant flow (1 pt), sundials only worked during the day (1 pt) Other reasonable answers may be acceptable.
21. Who invented the pendulum clock, and in what year? (2 pts)
    a. Christiaan Huygens (1 pt), in 1656 (1 pt)
22. Why would an early model of the pendulum clock run faster in the winter than the summer? (2 pts)
    a. Thermal expansion (1 pt) in the summer causes the mass to be distributed farther from the pivot point, increasing the rotational inertia of the pendulum, slowing it down. (1 pt)
23. Why is it important that the angle in a pendulum be kept to a minimum? (2 pts)
    a. The equation for simple harmonic motion was derived by using the small angle assumption (small angle assumption = 1 pt), which depends on the quantity sin(x) being equal to x (the angular displacement). For large angles, this assumption leads to a lot of error, and the motion is not harmonic. (1 pt)
24. A flight leaves San Francisco (PDT) and travels 6900 miles to Hong Kong (UTC+8). If the plane averages 580mph, and takes off at 7:36pm (local time) on May 15, what is the local time to the nearest minute when the plane arrives in Hong Kong? (5 pts)
    a. Calculate real time elapsed: 6900 miles / 580 mph = 11.89 hrs = **11 hrs 54 minutes** (1 pt)
    b. Identify time zones (Pacific Daylight Time = UTC-7) (1 pt)
    c. 7:36pm PDT = 10:36am (May 16) in Hong Kong + 11:54 = **10:30pm May 16 in HK** (3 pts) Scoring for part c: 2 pts for answer within minute, 1 pt if within 5 minutes. 1 pt for correct date, am/pm
25. A pendulum in simple harmonic motion has a maximum displacement of .2 radians and a length of 18cm. Time t = 0 occurs when there is maximum displacement. What is the equation for the displacement of the pendulum at any time t? (4 pts)
    a. **Equation of form x(t) = x(max)cos(at+p)** where a is 2pi * frequency, p is phase shift (1 pt)
    b. **x(max) = .2** (1 pt)
    c. a = 2pi * f = sqrt(g/L) where g = gravity and L = length; thus **a =** sqrt(9.8/.18) = **54.44** (1 pt)
    d. **p = 0**, or if they used sin instead of cos, p = pi/2 (1 pt)
       Completely correct answers: **x(t) = .2cos(54.44t) = .2sin(54.44t + pi/2)**
26. Which of the following are leap years? Circle all that apply. (4 pts)
    2000 2016 1900 1950
    a) 2000, 2016 are leap years and should be circled, the other two should not. (1 pt each)
27. A planet of mass 7.38*10^23 kg orbits a star of mass 6.19*10^31kg. The average radius of the orbit is 4.2*10^9 km. How long does it take for the planet to complete 1 orbit? The answer should be in terms of earth years. (5 pts)
    a. T = sqrt(4*π^2*r^3/(G*Mstar)) where r is radius and G is gravitational constant (1 pt for formula)
    b. Identify formula components: r=4.2*10^12 m, Mstar = 6.19*10^31 kg, G = 6.67408 * 10^-11 m^3/(kg*s^2) (1 pt for identifying correct components)
    c. T = 8.4142 sec = **26.7 years** (3 pts for answer with ± .3 years tolerance) (3 pts)
28. What is a piezoelectricity and how is it used in timekeeping? (2 pts)

a. Piezoelectricity is an accumulation of charge that some types of materials develop in response to mechanical stress (1 pt). This property is used in quartz timepieces by vibrating the quartz to produce electric pulses with a regular interval. The frequency is dictated by the natural frequency of the quartz (1 pt).

29. Two twins were born on the same day, but when they were 12 Twin 1 boarded a rocket travelling at 60% of the speed of light while Twin 2 stayed on Earth. Twin 1 spends 25 years on the rocket before returning to Earth. How old is Twin 2 when the rocket returns? (5 pts)
    a. Time dilation formula: Tearth = Trocket/(1-v^2/c^2)^1/2 where v is velocity of rocket and c is speed of light in a vacuum. (1 pt for formula)
    b. Trocket = 25 years, v = 1.8*10^8m/s, c = 3.0*10^8 m/s (1 pt for identifying components)
    c. Tearth = 25*sqrt(1-(1.8*10^8)^2/(3.0*10^8)^2) = **31.25 years** (2 pts for time difference)
    d. 12 + 31.25 = **43.25 years** (1 pt for twin 2 age)