

BirdSO Mini Invitational

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11-18 December 2021

Directions:

You got this! This is test only event, and your entire score is based on this test. There is no build component.

Page	Points	Score
2	13	
3	14	
4	11	
5	11	
6	10	
7	16	
8	11	
9	11	
Total:	97	

1. (1 point) How many seconds are in a year? (not leap year)

Solution: 31536000

2. (1 point) 1) How often does a leap year occur?
2) When was the last leap year?

Solution: 1) every 4 years 2) 2020

3. (1 point) Earth's orbital speed is constant.

A. True

B. False

4. (2 points) What day of the week is January 1st, 2000?

A. Monday

B. Tuesday

C. Wednesday

D. Thursday

E. Friday

F. Saturday

5. (2 points) What is the significance of the International Date Line, and how do you interpret your time/day across this location?

Solution: The International Date Line is a line in the mid-Pacific Ocean at 180° longitude, where a calendar day must be added when travelling westward, and a day dropped when travelling eastward (1 point). Used to standardize time (1 point).

6. (1 point) What calendar is used by the majority of the world?

gregorian

7. (1 point) UTC is based on Earth's rotation relative to distant celestial objects.

A. True

B. False

8. (1 point) Which of the 50 US states do not observe daylight saving time?

Solution: Hawaii, Arizona

9. (1 point) How many hours difference is there between PDT and PST?

Solution: 1 hour

10. (2 points) Which of the following are valid ISO 8601 format dates for January 2nd, 2000?

- ☐ 20000201
☒ **20000102**
☐ 01022000
☐ 02012000

11. (2 points) The second is the duration of _____ periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the _____ atom.

Solution: 9,192,631,770 caesium-133

12. (1 point) Which isotopes of these atoms are potentially used in atomic clocks?

- ☒ **hydrogen 1**
☒ **cesium 133**
☒ **rubidium 87**
☒ **strontium 87**

13. (3 points) Calculate the frequency in Hz and energy in J of a photon with wavelength 4.3×10^{-8} m.

Solution: $\text{freq} = 6.97 \times 10^{15} \text{ Hz}$ $E = 4.62 \times 10^{-18} \text{ J}$

14. (1 point) The _____ effect refers to when a voltage is generated from mechanical stress on a crystal. Spelling counts!

piezoelectric

15. (2 points) Calculate the length in meters of a piece of quartz in a watch with Young's modulus of $7.2 \times 10^{10} \text{ N/m}^2$, thickness a of 0.5 mm , fundamental frequency of $30,000 \text{ Hz}$, and a density of 2634 kg/m^3 .

$$f = \frac{1.875104^2}{2\pi} \frac{a}{l^2} \sqrt{\frac{E}{12\rho}}$$

Solution: 0.00375m

16. (1 point) What is the value of quartz on Moh's hardness scale? (Please enter a number)

7

17. (1 point) The atomic clock was invented after the quartz clock.

A. True

B. False

18. (1 point) Atomic clocks are radioactive.

A. True

B. False

19. (2 points) Explain why a quartz clock behaves similarly to a series RLC circuit.

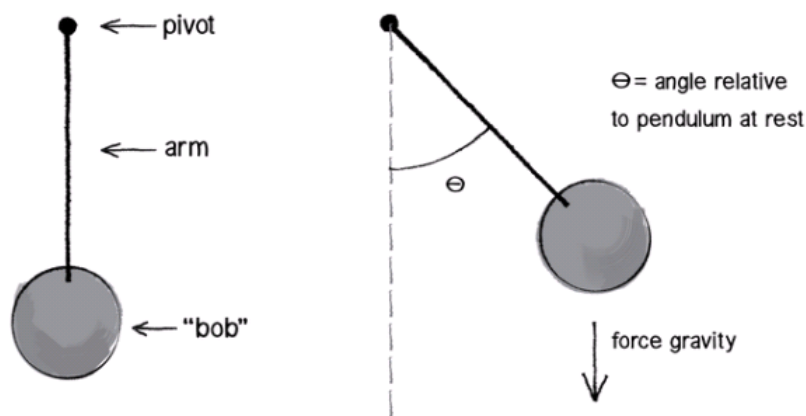
Solution: The equivalent electrical circuit for the quartz crystal shows a series RLC circuit, which represents the mechanical vibrations of the crystal, in parallel with a capacitance, C_p which represents the electrical connections to the crystal. Quartz crystal oscillators tend to operate towards their “series resonance”.

The equivalent impedance of the crystal has a series resonance where C_s resonates with inductance, L_s at the crystals operating frequency. This frequency is called the crystals series frequency, f_s . As well as this series frequency, there is a second frequency point established as a result of the parallel resonance created when L_s and C_s resonates with the parallel capacitor C_p as shown.

20. (1 point) Quartz is an excellent material for timekeeping since its vibrational frequency is not highly affected by temperature and experiences a low amount of hysteresis.

A. True

B. False



21. (4 points)

Assume the angle relative to pendulum at rest θ is 15 degrees at the start. What is the velocity of the bob when that angle θ is 10 degrees? The length of the pendulum arm is 1 meter, and the mass of the bob is 1kg. You may assume $g = 9.8m/s^2$. Show your work for partial credit.

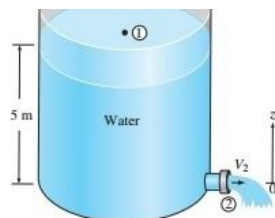
Solution: (starting) $mgh =$ (in the middle) $\frac{1}{2}mv^2 + mgh$ $gh = \frac{1}{2}v^2 + gh(9.81)(1 - \cos(15)) = \frac{1}{2}v^2 + (9.81)(1 - \cos(10))v = 0.608m/s$

22. (2 points) For the same parameters in the question above, what is the frequency of oscillation for this pendulum?

Solution: 0.498 Hz

23. (1 point) What is the earliest known timekeeping device?

Solution: sundial



24. (3 points)

A large tank of water open to the atmosphere on is filled to 5 meters high with respect to the outlet. Using Bernoulli's equation, set up and solve for the water velocity at the outlet v_2 .

Please state any assumptions you make for this problem.

Solution: $\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2$ (1 point) v_1 is very small nearly 0 (1 point) $z_1 = \frac{v_2^2}{2g} \implies v_2 = \sqrt{(2gz_1)}$
 $9.9m/s$ (1 point)

25. (1 point) For the problem above, the exit velocity at the outlet v_2 is constant.

A. True

B. False

26. (2 points) When (what year) and where is the Royal Observatory found?

Solution: The Royal Observatory was founded at Greenwich in 1675/1676

27. (1 point) Who received the first clock-making patent ever issued in the United States?

Solution: Eli Terry

28. (1 point) Who invented the pendulum clock?

Solution: Christian Huygens

29. (1 point) Where was the first sundial discovered?

Solution: Egypt

30. (1 point) What was the primary reason for the development of water clocks from sundials?

Solution: To record time in the absense of sunlight

31. (1 point) Electromagnetic waves are longitudinal waves.

A. True

B. False

32. (2 points) Electromagnetic waves consist of both electric and magnetic field waves. These waves oscillate in ⁽¹⁾planes with respect to each other, and are ⁽²⁾in phase.

☒ (1) perpendicular

☐ (1) parallel

☒ (2) in

☐ (2) out of

33. (1 point) What is the relationship between the amplitude of a wave and its frequency?

Solution: There is none.

34. (2 points) If the sampling rate of a signal is 50 Hz, what is the Nyquist frequency? And, how does the Nyquist frequency relate to aliasing?

Solution: 25Hz, When the highest frequency (bandwidth) of a signal is less than the Nyquist frequency of the sampler, the resulting discrete-time sequence is said to be free of the distortion known as aliasing, and the corresponding sample-rate is said to be above the Nyquist rate for that particular signal.

35. (2 points) The sinc function is as described below.

$$\text{sinc } x = \frac{\sin x}{x}$$

Describe what the result of a Fourier transform on this function results in.

Solution: The result is a rectangular function that starts from frequency 0 and ends at frequency 0.

36. (1 point) The fundamental frequency is also known as the _____ harmonic. (Write out your answer in a word)

first

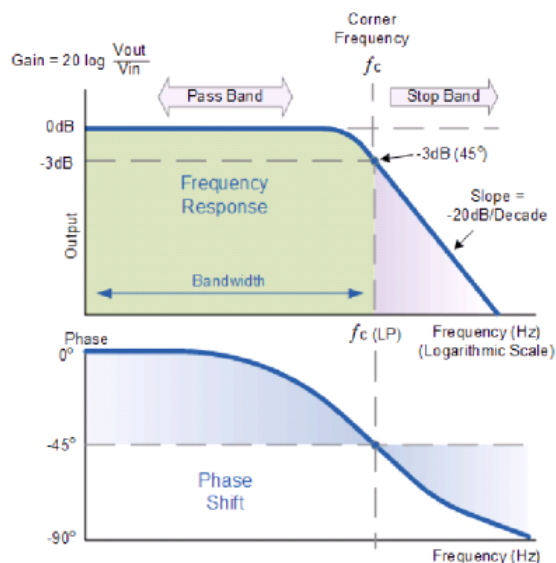
37. (2 points) Suppose a violin has a string of length 40cm, and a third harmonic frequency of 500 Hz. Find the speed of the wave on this violin string.

Solution: wavelength = $2/3 * 40\text{cm}$ speed = freq * wavelength = $500 * 0.66667 * 0.4 = 133.33\text{m/s}$

38. (2 points) In terms of inductance L and capacitance C, what is the equation for resonance frequency of an LC circuit?

Solution: $f = 1/(2 * \pi * \sqrt{LC})$

39. (1 point) The following plot is known as a Bode plot.



bode

40. (1 point) The image above shows an example of a low pass filter.

A. True

B. False

41. (2 points) A comet travels on an eccentric elliptical orbit which carries it as close as about 1AU to the Sun and as far as about 15AU. Compare the gravitational force between the comet and the Sun at these extremes in its orbit.

Solution: The gravitational force is $15^2 = 225$ times weaker when farther away from the sun. Must state 225 multiple for full

42. (2 points) The Earth orbits the Sun at a distance of 1AU with a period of 1 year. How long does it take an asteroid with a distance of 16AU from the Sun to orbit the Sun?

Solution: $\sqrt[3]{16^3} = 64$ years

43. (2 points) The point in the moon's orbit where it is farthest from the earth is called

, while it's closest approach is known as

apogee

44. (1 point) The velocity of a planet orbiting the sun is

when closer to the sun than when farther from the sun.

A. greater

B. lesser

C. the same

45. (2 points) A black hole is an object whose gravitational field is so strong that even light cannot escape. Assuming no change in mass, approximately what radius would our Sun have to have in order to become a black hole?

mass of the sun = 1.9891×10^{30} kilograms

Solution: mass of the sun = 1.9891×10^{30} kilograms $GMm/r = 1/2mc^2$ $r = 2GM/c^2 = 2(6.67 * 10^{-11})(1.9891 \times 10^{30})/(3 * 10^8)^2 = 2948m$

46. (2 points) Two twins are 20 years old. One of them gets on a rocket and travels at 0.8 c, for what they experience to be 10 years. How old is the twin that remained on Earth when the traveling twin returns home?

Solution: $20 + 10/\sqrt{1-.8^2} = 36.67$

47. (2 points) The half life of Uranium-238 is 4.5 billion years. Some ore that solidified around the time of the formation of the Earth contained 0.08% Uranium-238. Determine the percentage of Uranium-238 in this ore that would be measured by a scientist today.

Solution: $0.08\% * 1/2 = 0.04\%$ for 1 half life

48. (2 points) The half life of tritium is 12.3 years. After 49.2 years, a sample of tritium has been reduced to a mass of 4.00mg. Determine the starting mass in milligrams.

Solution: 64mg

49. (1 point) The acceleration due to gravity is constant on all parts of Earth.

A. True

B. False

50. (1 point) Kepler's laws of planetary motion improved the _{theory}.

A. heliocentric

B. geocentric

C. big bang

D. string

51. (1 point) What date is known as the Unix Epoch, and why is it given that name?

Solution: January 1st, 1970 at 00:00:00 UTC is referred to as the Unix epoch. Early Unix engineers picked that date arbitrarily because they needed to set a uniform date for the start of time, and New Year's Day, 1970, seemed most convenient.

52. (1 point) A consequence of poor time synchronization could be deadlock. What is deadlock?

Solution: "I wait for you, you wait for me" A deadlock is a situation in which two computer programs sharing the same resource are effectively preventing each other from accessing the resource, resulting in both programs ceasing to function. The earliest computer operating systems ran only one program at a time.

53. (2 points) Explain how the Network Time Protocol works relative to using a client-server model.

Solution: The NTP client initiates a time-request exchange with the NTP server. As a result of this exchange, the client is able to calculate the link delay and its local offset, and adjust its local clock to match the clock at the server's computer.

54. (1 point) What port number is the Network Time Protocol assigned to?

123

55. (1 point) What is the difference between internal and external time synchronization?

Solution: External synchronization means that all computers in the system are synchronized with an external source of time (e.g., a UTC signal). Internal synchronization means that all computers in the system are synchronized with one another, but the time is not necessarily accurate with respect to UTC.

56. (1 point) Vis-Viva equation provides a relationship between velocity, the mass of the central object, the distance between the two bodies, and the semi-major axis. What motion equation can be derived by taking the limit of the vis-viva equation as the semi-major axis approaches infinity?

Solution: The equation for escape velocity

57. (2 points) Sucrose will dissolve into fructose and glucose when placed in an acidic solution. The rate law of the reaction is given as $r(t) = k[C_{12}H_{22}O_{11}]t$ where $k = 0.216 \text{ h}^{-1}$. Find the amount of time, in seconds, that it will take for 17.5 grams of sucrose to dissolve from an initial 20 grams of sucrose.

Solution: $\frac{\log(2)}{.216} = 3.20901472$ 3 half lives $3.20901472 * 3 = 9.62704416$ hours to seconds 34700 seconds

58. (1 point) What is today's Julian date?

Solution: Accept between 21345 and 21352 (Competition occurred over multiple days) alternate formats accepted. 2,459,559.5-2,459,566.5 accepted. 11/28/2021-12/5/2021 accepted 1/2 point for 11/28-12/5 or 345-352

59. (2 points) What is the mean lifetime (in seconds) and the decay constant (in 1/s) of the decay of Carbon-14?

Solution: 2.609e11 mean lifetime (1 point) 3.833e-12 decay constant (1 point)

60. (2 points) How must both general and special relativity be taken into account in correcting the atomic clocks carried by GPS satellites?

Solution: Special relativity causes the atomic clock to fall behind by about 7 ms/day due to time dilation from the motion of the satellite General relativity causes the clock to become faster by 45 ms/day due to being further from the earth (less effect from the curvature of spacetime)

61. (2 points) Describe what it means for a computer program to have a race condition.

Solution: When two processes attempt to access the same resource—say, some area of memory—and it attempts to change the resource at the same time.

62. (2 points) Time-based side channel attacks are possible on certain implementations of cryptosystems—say, in its encryption algorithm—to recover information, such as the plaintext message. What property of this encryption algorithm allows these timing attacks to be performed?

Solution: When the time it takes to perform the encryption algorithm computation differs based on the input, one can recover secure information. For instance, in RSA, improper implementations of the square-and-multiply algorithm take different amounts of times when encrypting a bit of plaintext.

63. (1 point) When was the Unix epoch?

Solution: 00:00:00 UTC, 1/1/1970

64. (1 point) Two basketballs are dropped from the top of an infinitely tall building; the first basketball, after time t_1 , has dropped x meters, while the second basketball, after time t_2 , has dropped $5x$ meters. What is the ratio t_2/t_1 ?

Solution: $x = 1/2gt_1^2$ $5x = 1/2gt_2^2$ $5 = t_2^2/t_1^2$ $t_2/t_1 = \sqrt{5}$