Crave the Wave

Troy 2021-2022 Invitational

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Team Number:

School/Team Name:

Student Names (optional):

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1. DO NOT OPEN THIS PACKET until you are told to begin. Listen to instructions first.
2. Tiebreakers, in order: 45, 44, 43
3. **You may rip apart the test**, but staple it together again before time is called.
4. **Test-taking Tips:** If you get stuck on a hard question, move on. Guess on questions you don't know. Cross out answers you know are wrong. Mark questions you want to come back to when you're done.
5. Answer in 3 significant figures
6. Answer scientific notation if there are leading or trailing zeroes
7. Answer in SI units unless otherwise specified
8. Have fun and good luck!

Multiple choice (2pts each unless specified):

1. What is the wavelength of a wave with speed 300m/s and frequency 60Hz?
    a. 0.2 m
    b. 5 m
    c. 200 m
    d. 18000 m
2. What is the frequency of a wave with speed 50m/s and wavelength 100m?
    a. 0.5 m
    b. 2 m
    c. 200 m
    d. 5000 m
3. What is the wavenumber of a wave with speed 10m/s and frequency 200Hz?
    a. 0.05 m^{-1}
    b. 5 m^{-1}
    c. 20 m^{-1}
    d. 2000 m^{-1}
4. What type of wave are sound waves?
    a. Transverse
    b. Longitudinal
    c. Electromagnetic
    d. Surface
5. What type of wave are ripples on a pond?
    a. Transverse
    b. Longitudinal
    c. Electromagnetic
    d. Surface
6. Which type of earthquake waves cause the most structural damage?
    a. P-waves
    b. S-waves
    c. Surface waves
    d. Torsional waves
7. What is the speed of light?
    a. $3*10^8$ m/s
    b. $3*10^8$ km/s

c. $3*10^8$ mph
d. $3*10^8$ km/hr

8. Which of the following types of waves has the highest frequency?
    a. Radio waves
    b. Microwaves
    c. Visible light
    d. Ultraviolet
9. When two light waves of the same frequency and amplitude overlap with a 180 degrees phase offset, which is the result?
    a. The resulting light will be twice as bright
    b. The resulting light will be on average sqrt(2) times as bright
    c. The resulting light will be completely dark
    d. The resulting light will have half the frequency
10. If the two light waves above have a 90 degrees phase offset, which is the result?
    a. The resulting light will be twice as bright
    b. The resulting light will be on average sqrt(2) times as bright
    c. The resulting light will be completely dark
    d. The resulting light will have half the frequency
11. Which of these types of waves will you expect to be most impeded by concrete walls?
    a. Radio waves
    b. Microwaves
    c. Visible light
    d. Ultraviolet
12. Which of these types of waves will you expect to be most impeded by steel walls?
    a. Electric waves
    b. Magnetic waves
    c. Sound waves
    d. Love waves
13. Why do farther stars look more red and closer stars look more blue?
    a. Faraday effect
    b. Doppler effect

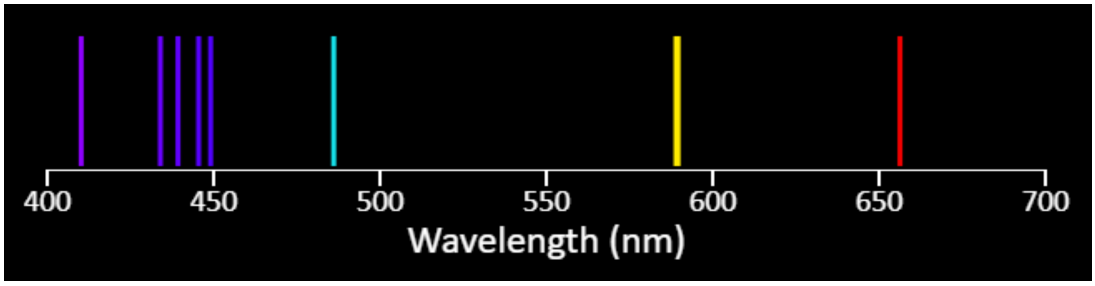
c. Dark matter diffraction
d. Lower power density

14. A cell phone is not able to receive or transmit signals inside a silver box. Why is this the case?
    a. Silver is a conducting material and blocks out electromagnetic waves
    b. Cell phones use a special type of radio wave that silver specifically absorbs
    c. Silver acts as a dielectric, dampening the signal greatly
    d. The photoelectric effect causes the silver to ionize and emit other frequencies that cell phones don't use.
15. Middle C on a piano has a frequency of around 264 Hz. What is the frequency of the C an octave higher?
    a. 252 Hz
    b. 264 Hz
    c. 276 Hz
    d. 528 Hz
16. Middle C on a piano has a frequency of around 264 Hz. What is the frequency of the F directly above it?
    a. 198 Hz
    b. 313 Hz
    c. 352 Hz
    d. 373 Hz
17. If the first harmonic frequency in an open tube on one side has a wavelength of 0.5m, what is the wavelength of the fifth harmonic frequency?
    a. 0.1 m
    b. 0.3 m
    c. 1.5 m
    d. None of the above
18. If the first harmonic frequency in a tube sealed on one side has a wavelength of 0.4m, what is the wavelength of the fourth harmonic frequency?
    a. 0.1 m
    b. 0.4 m
    c. 1.6 m
    d. None of the above

19. What color would you expect an RGB value of (255, 100, 0) to be?
    a. Red
    b. Orange
    c. Yellow
    d. Cyan
20. What color would you expect an RGB value of (50, 255, 255) to be?
    a. Red
    b. Orange
    c. Yellow
    d. Cyan
21. If you layer a red lens with a green lens, what color would you expect to see looking through both of them at a white light source? (3pts)
    a. Red
    b. Yellow
    c. Blue
    d. Gray
22. If you layer a purple lens with a green lens, what color would you expect to see looking through both of them at a white light source? (3pts)
    a. Dark red
    b. Dark gray
    c. Bright Magenta
    d. Bright Cyan
23. If you layer a blue lens with a red lens, what color would you expect to see looking through both of them at an orange light source? (3pts)
    a. Red
    b. Purple
    c. Yellow
    d. Gray
24. Which of these is not a valid reason why we use microwaves instead of gamma rays to heat food? (3pts)
    a. Microwaves have a lower frequency and are easier to produce with electricity
    b. Gamma rays can be dangerous to humans as they are ionizing
    c. Microwaves are less easily blocked by the walls of a microwave

d. Gamma rays have too much energy and can damage the food in addition to heating it

25. A chemical is heated up and emits the following frequencies of light shown in the diagram. What is most likely the identity of the chemical? (3pts)



a. H_2O (water)
b. CH_4 (methane)
c. NaH (sodium hydride)
d. H_2SO_4 (sulfuric acid)

Free Response:

26. What is the energy in Joules carried by a photon at a frequency of 500GHz? (2pts)

27. What is the deBroglie wavelength of a sumo wrestler of mass 200kg lunging forward at a velocity of 3m/s? (3pts)

28. Express the speed of light in terms of permittivity of free space ε_0, and permeability of free space μ_0. (3pts)

29. Which scientist first theorized this phenomenon above? (2pts)

30. A laser is shot at a piece of glass of reflective index 1.5 from free space. If the laser is shot at an angle 60 from the surface, what is the angle beneath the surface that the light travels? (2pts)

31. What is Brewster's angle for the same piece of glass above? (3pts)

32. In a double-slit experiment, two lights are shone through cracks 2mm apart at a wall 4m away. If the light has a frequency of 600THz, what is the distance between the second dark spot and the center bright spot? (4pts)

33. An ideal 10W light bulb shines light in all directions equally. What is the power received by a 2cm x 2cm light sensor positioned 1m away? (4pts)

34. If the same light bulb above is shining light at 400THz, how many photons does it emit per cycle? (3pts)

35. Two electromagnetic waves with the same amplitude have a phase separation of 60 degrees. They each have a wavelength of 6m and amplitudes of 2V/m. What is the amplitude of the resulting wave? (5pts)

36. For the scenario above, at a certain instant, if the first node is at position 1m from the source and the first crest is at position 2.5m from the source, what is the magnitude of the wave in V/m at position 3m? (3pts)

37. What is the average magnitude in V/m of the wave above from interval 0m to 9m? (5pts)

38. A mass of 3kg is hung from the ceiling by a spring of spring constant 12N/m. If the spring has a length of 2m when hung from the ceiling and displaced a very small distance, what is the period of oscillation? (2pts)

39. The same mass is attached to the ceiling, but this time there are two springs of 12N/m connected end-to-end. What is the period of oscillation? (3pts)

40. A ball pendulum has a mass of 15kg and length 12m. The pendulum is displaced at a very small angle. What is the period of oscillation? Assume acceleration due to gravity is $10m/s^2$. (2pts)

41. A rod pendulum of linear density has a mass of 8kg and length 5m. The rod is hung from one end and displaced at a very small angle. What is the period of oscillation? Assume acceleration due to gravity is $10m/s^2$. (4pts)

42. A disk has a uniform density and a mass of 20kg and diameter 4m. The disk is hung from a point on the circumference and displaced at a very small angle. What is the period of oscillation? Assume acceleration due to gravity is $10m/s^2$. (8pts)

43. A cylindrical fishing bobber of radius 2cm, height 5cm, and mass 8g is floating upright in a very still pond. Given that the buoyant force acting on the bobber has a formula $F=\rho gv$, where ρ is the density of water ($1g/cm^3$), g is the acceleration due to gravity ($10m/s^2$), and v the volume of the portion of the bobber under the surface. The bobber is displaced at a very small height. What is the period of oscillation? Assume the movement does not create ripples and that there is no drag due to water. (10pts)

44. A squirrel of mass 2kg (chonky boi) is running on a rod 4m that is tightly fastened in the middle to another rod rotating about an axle 9m above, forming an upside-down T-shape. If the system never rotates, what is the period of oscillation if the squirrel must stay on the rod? Assume acceleration due to gravity is $10m/s^2$. (12pts)

45. A long plate of a certain material has a thickness of 3m. A light is shone perpendicular to the plate at position x=0. The refractive index varies through the material with the proportionality $n=n_0/(1-x/d)$, where k and d are constants. If d=5m, what is the angle from the surface of the material that the light exits? (15pts)

Lab (50 points):

You have been provided with a spring, a ring stand to hang the spring, a stopwatch, and a set of adjustable weights. The mass of the adjustable weight without any additional disks is 50 grams. The largest disks have a mass of 20g. The medium disks have a mass of 10g. The smallest disks have a mass of 5g.

1. Make a table measuring oscillation period (seconds) vs mass (kilograms). Use at least 5 different masses. (10 pts)

2. Linearize the points with period (seconds) as the dependent variable. Plot them with a best fit line on the graph paper attached. (15 pts)

3. Using the slope of your best fit line, calculate the spring constant in N/m. Show appropriate work below. (15 pts)

4. Use the spring and adjustable masses to construct an oscillator with a period of 1.50 +/- 0.02 seconds. The event supervisor will measure the period as the time for ten oscillations divided by 10. They will sign off once you have succeeded. (10 pts)

   Event Supervisor Signature: _____