MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) Radio waves, visible light, and X–rays are all types of electromagnetic radiation.
A) True
B) False
Answer: A

2) The frequency of a water wave gives us its height.
A) True
B) False
Answer: B

3) If a new wave arrives on shore every two seconds, then its frequency is 2 Hz.
A) True
B) False
Answer: B

4) The greater the disturbance of the medium, the higher the amplitude of the wave.
A) True
B) False
Answer: A

5) While gravity is always attractive, electromagnetic forces are always repulsive.
A) True
B) False
Answer: B

6) Changing the electric field will have no effect on the magnetic fields of a body.
A) True
B) False
Answer: B

7) As they move through space, the vibrating electrical and magnetic fields of a light wave must move perpendicular to each other.
A) True
B) False
Answer: A

8) Wave energy can only be transmitted through a material medium.
A) True
B) False
Answer: B

9) As white light passes through a prism, the red (longer) wavelengths bend less than the blue (shorter) wavelengths, so forming the rainbow of colors.
A) True
B) False
Answer: A

10) Observations in the X-ray portion of the spectrum are routinely done from the surface of the Earth.
A) True
B) False
Answer: B

11) In blackbody radiation, the energy is radiated uniformly in every region of the spectrum, so the radiating body appears black in color.
A) True
B) False
Answer: B

12) According to Wein's law, the larger the blackbody, the shorter its peak wavelength.
A) True
B) False
Answer: B

13) A blue star has a higher surface temperature than a red star.
A) True
B) False
Answer: A

14) According to Wein's law, the higher the surface temperature of a star, the redder its color.
A) True
B) False
Answer: B

15) Doubling the temperature of a blackbody will double the total energy it radiates.
A) True
B) False
Answer: B

16) As a star's temperature increases, the frequency of peak emission also increases.
A) True
B) False
Answer: A

17) The spectral lines of each element are distinctive to that element, whether we are looking at emission or absorption lines.
A) True
B) False
Answer: A

18) An absorption line spectrum, with dark lines crossing the rainbow of the continuum, is produced by a low-density hot gas.
A) True
B) False
Answer: B

19) An emission line results from an electron falling from a higher to lower energy orbital around its atomic nucleus.
A) True
B) False
Answer: A

20) The shorter a wave's wavelength, the greater its energy.
A) True
B) False
Answer: A

21) Spectral lines are produced when an electron makes a transition from one energy state to another.
A) True
B) False
Answer: A

22) In the Bohr model of the atom, an electron can only exist in specific, well–defined energy levels.
A) True
B) False
Answer: A

23) When an electron in a hydrogen atom drops from the second to the first excited energy state it emits a bright red emission line called hydrogen alpha.
A) True
B) False
Answer: A

24) The Zeeman effect reveals the presence of strong magnetic fields by the splitting of spectral lines.
A) True
B) False
Answer: A

25) The broader the spectral line, the higher the pressure of the gas that is creating it.
A) True
B) False
Answer: A

26) In the Doppler effect, a redshift of spectral lines shows us the source is receding from us.
A) True
B) False
Answer: A

27) The larger the redshift, the faster the distant galaxy is rushing toward us.
A) True
B) False
Answer: B

28) If a fire truck's siren is rising in pitch, it must be approaching us.
A) True
B) False
Answer: A

29) You would perceive a change in a visible light wave's amplitude as a change in its color.
A) True
B) False
Answer: B

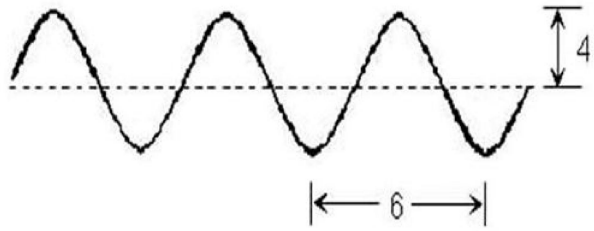
30) Spectroscopy of a star can reveal its temperature, composition, and line–of–sight motion.
A) True
B) False
Answer: A

31) The Doppler effect can reveal the rotation speed of a star by the splitting of the spectral lines.
A) True
B) False
Answer: B

32) Which of these is NOT a form of electromagnetic radiation?
A) X–rays in the doctor's office
B) radio signals
C) DC current from your car battery
D) ultraviolet causing a suntan
E) light from your camp fire
Answer: C

33) A wave's velocity is the product of the
A) frequency times the period of the wave.
B) amplitude times the frequency of the wave.
C) amplitude times the wavelength of the wave.
D) period times the energy of the wave.
E) frequency times the wavelength of the wave.
Answer: E

34) Consider this diagram. Which statement is true?



A) The amplitude is 4 and the wavelength is 12.
B) The amplitude is 8 and the wavelength is 12.
C) The amplitude is 8 and the wavelength is 6.
D) The amplitude is 6 and the wavelength is 4.
E) The amplitude is 4 and the wavelength is 6.

Answer: E

35) If a wave's frequency doubles and its speed stays constant, its wavelength
A) is unchanged, as c is constant.
B) becomes 16× longer.
C) is also doubled.
D) is now 4× longer.
E) is halved.

Answer: E

36) The speed of light in a vacuum is
A) 300,000 km/sec.
B) 186,000 miles per hour.
C) h = E/c.
D) 768 km/hour.
E) none of the above.

Answer: A

37) Which of these is the same for all forms of electromagnetic (E–M) radiation in a vacuum?
A) speed
B) amplitude
C) frequency
D) photon energy
E) wavelength

Answer: A

38) The two forms of electromagnetic (E–M) radiation that experience the least atmospheric opacity are
A) X and gamma radiation.
B) ultraviolet and infrared waves.
C) microwaves and radio waves.
D) visible light and infrared waves.
E) visible light and radio waves.

Answer: E

39) The radiation our eyes are most sensitive to is the color
A) red at 6563 Angstroms.
B) blue at 4,321 nm.
C) black at 227 nm.
D) violet at 7,000 Angstroms.
E) yellow–green at about 550 nm.

Answer: E

40) Medium A blocks more of a certain wavelength of radiation than medium B. Medium A has a higher
A) clarity.
B) albedo.
C) transparency.
D) opacity.
E) seeing.

Answer: D

41) In the Kelvin scale, absolute zero lies at
A) zero K.
B) –373 degrees C.
C) 273 degrees C.
D) Both A and B are correct.
E) Both A and C are correct.

Answer: A

42) What is true of a blackbody?
A) Its energy is not a continuum.
B) Its energy peaks at the wavelength determined by its temperature.
C) It appears black to us, regardless of its temperature.
D) It has a complete absence of thermal energy.
E) If its temperature doubled, the peak in its radiation curve would be doubled in wavelength.

Answer: B

43) What is the name of the temperature scale that places zero at the point where all atomic and molecular motion ceases?
A) Kelvin
B) Fahrenheit
C) Centigrade
D) Celsius
E) Ransom

Answer: A

44) The total energy radiated by a blackbody depends on
A) the cube of its temperature.
B) the fourth root of its temperature.
C) the square of its temperature.
D) the square root of its temperature.
E) the fourth power of its temperature.

Answer: E

45) Increasing the temperature of a blackbody by a factor of 3 will increase its energy by a factor of
A) 3.
B) 6.
C) 9.
D) 12.
E) 81.

Answer: E

46) If a star was the same size as our Sun, but was 81 times more luminous, it must be
A) twice as hot as our Sun.
B) three times hotter than the Sun.
C) four times hotter than the Sun.
D) nine times hotter than the Sun.
E) 81 times hotter than the Sun.

Answer: B

47) The Sun's observed spectrum is
A) a continuum with absorption lines.
B) a continuum with emission lines.
C) only absorption lines on a black background.
D) a continuum with no lines, as shown by the rainbow.
E) only emission lines on a black background.

Answer: A

48) The element first found in the Sun's spectrum, then on Earth 30 years later, is
A) technicum.
B) helium.
C) hydrogen.
D) aluminum.
E) solarium.

Answer: B

49) A jar filled with gas is placed directly in front of a second jar filled with gas. Using a spectroscope to look at one jar through the other you observe dark spectral lines. The jar closest to you contains
A) gas at very high pressure.
B) gas at the same temperature as the other jar.
C) the exact same gas as the other jar.
D) the cooler gas.
E) the hotter gas.

Answer: D

50) Which of these is emitted when an electron falls from a higher to lower orbital?
A) a positron
B) a neutrino
C) another electron
D) a photon
E) a graviton

Answer: D

51) In Bohr's model of the atom, electrons
A) move from one orbit to the next orbit in many small steps.
B) are spread uniformly through a large, positive mass.
C) can be halfway between orbits.
D) are not confined to specific orbits.
E) only make transitions between orbits of specific energies.

Answer: E

52) In general, the spectral lines of molecules are
A) more complex than those of atoms.
B) only absorption lines.
C) the same as the atoms they contain.
D) less complex than those of atoms.
E) nonexistent.

Answer: A

53) Electromagnetic radiation
A) can only travel in a dense medium.
B) is the same as a sound wave.
C) can behave both as a wave and as a particle.
D) has only the properties of waves.
E) has nothing in common with radio waves.

Answer: C

54) In a hydrogen atom, a transition from the 2nd to the 1st excited state will produce
A) a dark absorption line.
B) no emission line.
C) the bright red Balmer alpha emission line.
D) three different emission lines.
E) an ultraviolet spectral line.

Answer: C

55) For hydrogen, the transition from the first to third excited state produces
A) a violet emission line.
B) a red emission line.
C) an infrared line.
D) a blue green absorption line.
E) an ultraviolet line.

Answer: D

56) The observed spectral lines of a star are all shifted towards the red end of the spectrum. Which statement is true?
A) This is an example of the photoelectric effect.
B) This is an example of the Doppler effect.
C) The star has a radial velocity towards us.
D) The star is not rotating.
E) The second law of Kirchhoff explains this.

Answer: B

57) If a source of light is approaching us at 3,000 km/sec, then all its waves are
A) not affected, as c is constant regardless of the direction of motion.
B) redshifted by 1%.
C) redshifted out of the visible into the infrared.
D) blueshifted out of the visible spectrum into the ultraviolet.
E) blueshifted by 1%.

Answer: E

58) If the rest wavelength of a certain line is 600 nm, but we observe it at 594 nm, then
A) the source is spinning very rapidly, at 1% of the speed of light.
B) the source is getting 1% hotter as we watch.
C) the source is receding from us at 10% of the speed of light.
D) the source is approaching us at 1% of the speed of light.
E) the source is approaching us at 0.1% of the speed of light.

Answer: D

59) According to the Zeeman effect, the splitting of a sunspot's spectral lines is due to
A) temperature variations.
B) their magnetic fields.
C) a Doppler shift.
D) their radial velocity.
E) their rapid rotation.

Answer: B

60) A frequency of one hundred _____ means the wave is vibrating one hundred million times per second; this is a typical carrier frequency for FM (frequency modulation) radio.
A) hertz
B) millihertz
C) megahertz
D) gigahertz
E) kilohertz

Answer: C

61) According to Wein's law, the wavelength of the peak energy will be _____ if the temperature of the blackbody is doubled.
A) doubled
B) quadrupled
C) quartered
D) halved
E) unchanged

Answer: D

62) The Sun's blackbody curve peaks in the _____ portion of the spectrum.
A) ultraviolet
B) visible
C) X–ray
D) infrared
E) radio

Answer: B

63) The common element with bright red, blue–green, and violet emission lines is
A) oxygen.
B) helium.
C) carbon.
D) hydrogen.
E) nitrogen.
Answer: D

64) The most energetic photons are
A) visible.
B) infrared.
C) gamma rays.
D) X–rays.
E) radio.
Answer: C

SHORT ANSWER. Write the word or phrase that best completes each statement or answers the question.

65) The distance from a wave's crest to its undisturbed position is the _____.
Answer: amplitude

66) The product of the wavelength times the frequency of a wave is its _____.
Answer: velocity

67) A wave with a period of .01 seconds has a frequency of _____ Hz.
Answer: 100

68) A wave with a frequency of 2 Hz will have a period of _____.
Answer: one–half second (0.5 s)

69) An FM station broadcasts at a frequency of 100 MHz. The wavelength of its carrier wave is _____.
Answer: 3 meters

70) In electromagnetic waves, the electric and magnetic fields vibrate _____ to each other.
Answer: perpendicular

71) A featureless spectrum, such as a rainbow, is said to be _____.
Answer: continuous

72) Stars that appear blue or white in color are _____ than our yellow Sun.
Answer: hotter

73) Knowing the peak emission wavelength of a blackbody allows you to determine its _____.
Answer: temperature

74) Stefan's law notes that total energy radiated is proportional to the _____ power of the temperature of the blackbody.
Answer: fourth

75) A dense, hot body will give off a(n) _____ spectrum.

Answer: continuous

76) Fraunhofer was the German astronomer who first noted _____ lines in the Sun's spectrum.

Answer: absorption

77) The common element discovered in the Sun's spectrum before it was found here is _____.

Answer: helium

78) When an electron moves from a lower to a higher energy state, a photon is _____.

Answer: absorbed

79) An electron has a _____ electric charge.

Answer: negative

80) The energy of the photon depends on its _____.

Answer: frequency or wavelength.

81) Why can't we be certain that the Andromeda Galaxy exists today?

Answer: Since it lies 2.5 million light-years distant, the most recent image we have is still 2.5 million years out of date, so we cannot prove it is still there. It probably is, though.

82) How do sound and light waves differ?

Answer: Sound waves travel much slower, and need a physical medium, such as air, to be transmitted. Light travels best in the vacuum of space.

83) An AM station is broadcasting at 980 kHz, while an FM station up the road is assigned 98 MHz. How do their carrier waves compare?

Answer: As the frequency of the FM station is 100 times higher than the AM station, the FM carrier wave must be 100 shorter in wavelength.

84) No one can hear you scream (or fire a weapon) in space, regardless of the Hollywood special effects. Explain why.

Answer: Sound waves must travel though a material medium, and cannot pass through a vacuum. The blast might be seen, but the boom will not be heard.

85) What two regions of the electromagnetic spectrum are best utilized by ground–based astronomers, and why?

Answer: The atmosphere is opaque to most radiation except visible and radio waves.

86) How can you determine the distance to a spacecraft from the time it takes its radio signal to reach Earth?

Answer: In a vacuum, all electromagnetic radiation, including radio waves, travel at the same speed: 300,000 km/s. Measuring the time it takes the radio signal to reach us and multiplying by 300,000 km/s gives the distance to the spacecraft.

87) Newton found that when light passed through a prism, it was dispersed into the component colors. Which bent the least, and why?

Answer: The red waves are bent less by the glass than are the other colors because they have the longest wavelength. Shorter wavelengths bend more than longer wavelengths.

88) What do infrared and ultraviolet waves have in common? How do they differ?

Answer: Both are forms of electromagnetic radiation, both travel at c in a vacuum, and both are largely absorbed by our atmosphere. They differ greatly in frequency, wavelength, and photon energy, however, with UV much more energetic than IR.

89) What do gamma rays, X–rays, light, and radio waves all have in common?

Answer: While they vary widely in wavelengths and frequencies, they are all forms of electromagnetic radiation and all travel at *c*, the speed of light, in a vacuum.

90) How does human vision's peak in color sensitivity relate to the Sun?

Answer: Our eyes are tuned to utilize best the type of radiation our star produces the most of, and yellow lies in the middle of the visible spectrum.

91) Give at least two advantages of the Kelvin temperature scale for astronomers.

Answer: It is an absolute scale, so there are never any negative readings. Wein's and Stefan's laws are only mathematically correct if Kelvin temperatures are used.

92) The Great Nebula in Orion, M–42, is a low–density cloud of hot gas. Use Kirchhoff's laws to describe its spectrum.

Answer: Kirchhoff's second law notes that a hot thin gas will create an emission spectrum of bright lines through the spectroscope.

93) According to Kirchhoff's first law why do dense, hot bodies create the type of spectrum they do?

Answer: Kirchhoff's first law states that a dense, hot medium emits light of all wavelengths, creating a continuous spectrum.

94) If the magnetic fields are very strong, such as around sunspots, how are spectral lines affected by the Zeeman effect?

Answer: A strong magnetic field will cause the lines to appear split apart.

95) State the relationship between frequency, photon energy, and wavelength.

Answer: The higher the frequency, the greater the energy the photon carries, but the shorter its wavelength.

96) Explain how the Zeeman effect allows us to study stellar magnetic fields.

Answer: The Zeeman effect causes spectral lines to appear split into two. This tells us magnetic fields are present. The greater the observed splitting, the stronger the magnetic fields are.

97) Explain how Bohr's model creates emission and absorption lines in the spectrum.

Answer: Bohr's model has the electron orbitals quantized into discrete energies. Each upward transition to a higher energy state produces an absorption line (energy is absorbed). Each downward transition produces an emission line (energy is emitted). The energy absorbed or emitted is exactly equal to the difference in energy levels.

98) What information about a star can be inferred from its Doppler shift?

Answer: The Doppler shift gives the star's radial velocity, either towards or away from us.

99) A binary star system is one with two stars orbiting each other. How can the Doppler effect be used to find binary stars whose orbital plane is along our line of sight and determine their periods?

Answer: As the two stars orbit each other rapidly, one will approach us, creating a blueshift of its spectral lines, while its retreating companion shows a redshift. The time to go through two splits and recombinations of their lines is their orbital period.

100) Explain what types of information can be obtained from a line spectrum.

Answer: The element which created it, the line–of–sight velocity of the source, its rotation speed, temperature, the pressure of the gas emitting the radiation, and even its magnetic field may also be found.

101) If we increased the pressure in a gas, how will its spectral lines be affected?

Answer: The lines will broaden (or even disappear if the density becomes too great)

102) Contrast the speeds of sound and light in watching a flash of lightning, then listening for the thunder to follow.

Answer: Light travels at 300,000 km/sec, so the flash of light is almost instantaneous from a few miles away; sound travels at about a fifth of a mile per second, so if the thunder follows the lightning by five seconds, the bolt hit about a mile away.

103) How can Wein's law be used to determine the temperature of a star?

Answer: Careful analysis of the blackbody curve of the star's entire radiation spectrum will reveal a peak that is unique to a given temperature. Basically, the bluer the star's radiation, the hotter its surface will be.

104) Why would a hotter star appear blue–white while a cooler star appear red or not be visible at all?

Answer: Stefan's law notes that the higher the temperature, the more luminous the body is, so such stars produce great amounts of visible light. The hotter the star the shorter the wavelength it peaks at. A star that emits light across the entire visible spectrum would appear white. One that peaked beyond the visible would appear blue–white. A cooler star may peak in the red part of the spectrum, or even in the infrared.

105) How does Stefan's law and a knowledge of Earth's history tell us that the Sun's temperature cannot have varied much in the last 3.5 billion years?

Answer: Since even a small change in temperature, raised to the fourth power, would result in a large change in the total solar energy radiated, if the Sun had cooled much, our oceans would have frozen and life would have ceased to exist here.

106) Explain the appearance of the Sun's spectrum, as noted by Fraunhofer.

Answer: The Sun is dense, and gives rise to a continuous spectrum, peaked in the color yellow as dictated by the 5800K temperature of its surface. Then the cooler, less dense gas above the surface absorbs some of the energy in transit, revealing its composition by the particular absorption lines we observe from Earth.

107) How does the energy of a water wave differ from the energy of a photon?

Answer: Amplitudes of sound (and water) waves can differ greatly and still have the same wavelength and frequency, as they are the result of the motions of large numbers of molecules. For photons, the energy is quantized, so that each photon of a given wavelength must carry the same amount of energy.

108) Why do we know that the red Balmer emission line in hydrogen represents a smaller quantum leap than the violet line?

Answer: Red light has a longer wavelength than violet light; therefore a red photon contains less energy than a violet one. Since the photon given off when an electron's energy level changes has an energy equal to the energy difference between the two levels, the less energetic photon represents a smaller difference.

109) Give an example of the Doppler effect being used in a baseball game.

Answer: The Doppler "gun" can focus on the motion of the baseball, and give us the speed that the pitcher is delivering it to the plate.

110) Give and explain an example of the use of the Doppler effect on the highway.

Answer: The radar gun of a highway patrolman sends out a pulsed beam to be reflected back, thus giving the speed of your car and perhaps netting you a ticket.

111) How can the Doppler effect be used to determine if a storm is forming into a tornado?

Answer: Radar can determine the distance to a storm cloud. Since a tornado rotates very rapidly, Doppler radar can measure the difference in velocity between the two sides of the storm to determine if it is rotating.

112) Explain how the Doppler effect has been used to detect invisible planets orbiting other Sun–like stars.

Answer: The planets are massive enough to pull their star slightly off course as they orbit from one side to the other, producing a cycle of redshifts and blueshifts that allow us to deduce that the planet is present, and how long it takes to orbit its star.