Section A – Each question is worth 1 mark

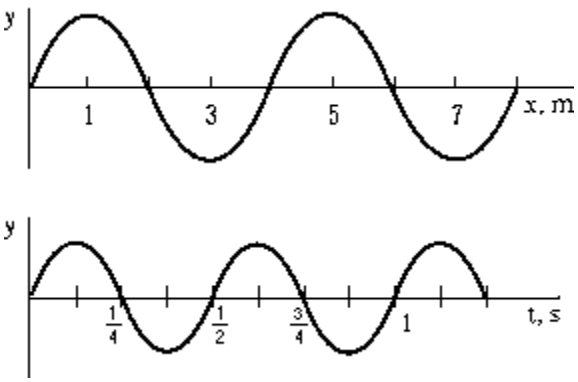
1. When an object is oscillating in simple harmonic motion in the vertical direction, its maximum speed occurs when the object
   A) is at its highest point.
   B) is at its lowest point.
   C) is at the equilibrium point.
   D) has the maximum net force exerted on it.
   E) has a position equal to its amplitude.

2. A clock keeps accurate time when the length of its simple pendulum is *L*. If the length of the pendulum is increased a small amount, which of the following is true?
   A) The clock will run slow.
   B) The clock will run fast.
   C) The clock will continue to keep accurate time.
   D) The answer cannot be determined without knowing the final length of the pendulum.
   E) The answer cannot be determined without knowing the percentage increase in the length of the pendulum.

3. During the passage of a longitudinal wave, a particle of the medium
   A) remains in a fixed position.
   B) moves in a circle.
   C) moves at right angles to the direction of propagation.
   D) moves forward and backward along the line of propagation.
   E) moves forward with the velocity of the wave.

4. A string under tension carries transverse waves traveling at speed *v*. If the same string is under four times the tension, what is the wave speed?
   A) *v* B) 2*v* C) *v*/2 D) 4*v* E) *v*/4

5. A wave is traveling with a speed *v* along the *x* axis in the positive direction. The upper graph shows the displacement *y* versus the distance *x* for a given instant of time. The lower graph shows the displacement *y* versus the time *t* for any given point *x*. From the information in the graphs, what is the wave speed *v*?



   A) 8.0 m/s
   B) 4.0 m/s
   C) 6.0 m/s
   D) There is not enough information to solve the problem.
   E) None of these is correct.

6. We can hear sounds that are produced around a corner but cannot see light that is produced around a corner because
   A) light travels only in straight lines whereas sound can travel in a curved path.
   B) sound has more energy than light.
   C) sound has shorter wavelengths than light.
   D) sound has longer wavelengths than light.
   E) None of these is correct.

7. A sound source of frequency *f* moves with constant velocity (less than the speed of sound) through a medium that is at rest. A stationary observer hears a sound whose frequency is appreciably different from *f* because
   A) the equation that relates velocity of propagation, frequency, and wavelength of a sound traveling through a medium does not apply in this situation.
   B) the sound wave travels through the medium with a velocity different from that which it would have if the source were at rest.
   C) the frequency of the source is changed because of its motion.
   D) the wavelength established in the medium is not the same as it would be if the source were at rest.
   E) interference effects set up a standing-wave pattern that alters the frequency.

8. A string fixed at both ends is vibrating in a standing wave. There are three nodes between the ends of the string, not including those on the ends. The string is vibrating at a frequency that is its
   A) fundamental.
   B) second harmonic.
   C) third harmonic.
   D) fourth harmonic.
   E) fifth harmonic.

9. The velocity of escape of photoelectrons
   A) increases with increasing frequency of the incident light.
   B) decreases with increasing frequency of the incident light.
   C) is independent of the frequency of the incident light.
   D) is directly proportional to the intensity of the incident light.
   E) depends only on the intensity of the incident light.

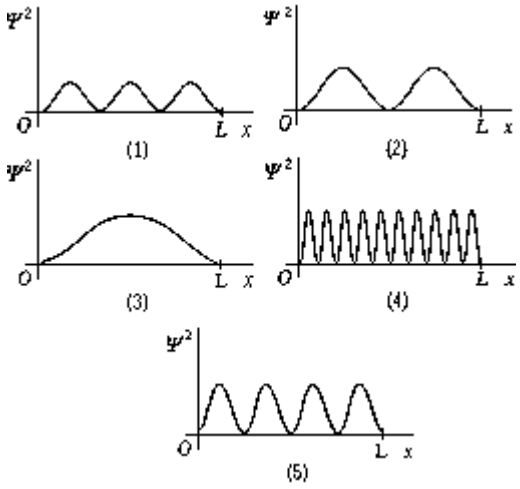
10. The maximum kinetic energy of photoelectrons produced in the photoelectric effect depends directly on the
   A) frequency of the incident photons.
   B) intensity of the incident photons.
   C) area of the metal surface from which the photoelectrons are released.
   D) thickness of the metal.
   E) photoelectric current.

11. An X-ray photon scattering off an electron imparts some of its energy to the electron (the Compton effect). Which of the following statements is true?
A) The wavelength of the scattered photon is unchanged.
B) The wavelength of the scattered photon is decreased.
C) The wavelength of the scattered photon is increased.
D) The scattered photon gains speed.
E) The scattered photon is slowed.

12. Electrons do not exhibit wave properties as readily as light because electrons typically have much _____ momenta than light and hence much _____ wavelengths.
A) greater; longer
B) greater; shorter
C) lesser; longer
D) lesser; shorter
E) greater; the same

13. The uncertainty principle states that
A) only momentum and velocity can be described with unlimited precision.
B) the position of a particle can be described with unlimited precision by using quantum mechanics.
C) nothing is smaller than Planck's constant.
D) the momentum and position cannot be measured simultaneously with unlimited accuracy.
E) either the momentum or the velocity, but not both, can be measured with unlimited accuracy.

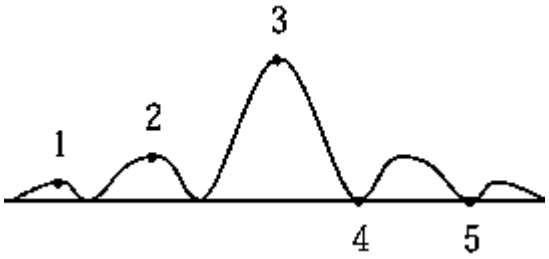
14. The graphs show Ψ^2 as a function of x for a particle in a one-dimensional box of length L. The graph that represents the second excited state is
A) 1 B) 2 C) 3 D) 4 E) 5



15. For us to see interference phenomena in a thin film,
A) the incoming light must be monochromatic.
B) the index of refraction of the thin film must be greater than the index of refraction of the material below it.
C) the index of refraction of the thin film must be less than the index of refraction of the material below it.
D) the incoming light must be multicolored.
E) None of these conditions need exist.

16. The distance between the slits in a double-slit experiment is increased by a factor of 4. If the distance between the fringes is about the same as the distance from the slits to the screen, the distance between adjacent fringes
A) increases by a factor of 2.
B) increases by a factor of 4.
C) decreases by a factor of 2.
D) decreases by a factor of 4.
E) depends on which two fringes are used for the measurement.

17.



The diffraction pattern of a single slit is shown in the figure. The point at which the path difference of the extreme rays is two wavelengths is
A) 1 B) 2 C) 3 D) 4 E) 5

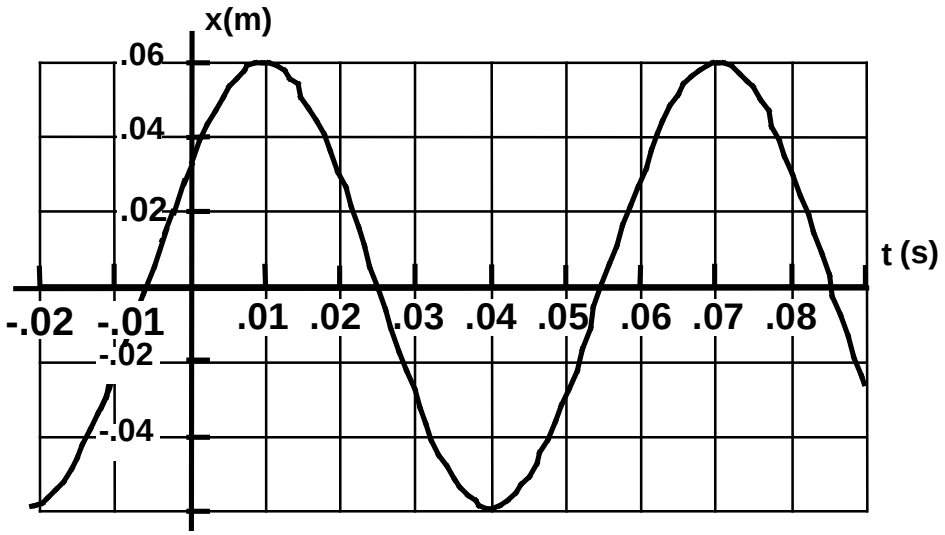
18. Your strange friend flies past you in a relativistic spacecraft holding a clock and a meterstick, oriented so that its length is parallel to the direction of motion. The meterstick appears too _____ to you, and the clock appears _____ to you.
A) short; slow B) long; slow C) short; fast D) long; fast E) short; normal

19. Because the galaxies are moving away from us, the light they emit
A) is shifted toward the shorter, blue wavelengths.
B) is shifted toward the longer, red wavelengths.
C) is of the same wavelength it would be if they were at rest relative to the earth.
D) arrives with increased intensity.
E) None of these is correct.

20. As an object of mass M approaches the speed of light, its momentum approaches
A) zero B) infinity C) Mc D) Mc^2 E) c

Section B – Each question is worth 8 marks

1. A body of mass 4.00 kg is attached to a single spring of force constant k and is undergoing simple harmonic motion along the x-axis. The position vs time graph for this mass is shown below.



(a) What is the angular frequency of the oscillation?
(b) Using either a sine or cosine function write the equation of motion for the body putting in numerical values wherever possible .
(c) What is the position of the body at t = 0.10 s?
(d) What is the acceleration of the body at t = 0.10 s?
(e) What is the force constant, k?

2. A simple pendulum of length 2.00 m with a mass of 1.50 kg is set up on a planet where the acceleration of gravity at the surface is unknown. The astronauts set the pendulum in motion so that it initially makes an angle of 0.100 radians with the vertical and starts from rest. They measure the angular frequency of the pendulum to be 1.186 s^{-1},
   (a) What is the period of the oscillation?
   (b) What is the linear velocity of the pendulum when it passes through the equilibrium position?
   (c) What is the acceleration due to gravity on the surface of this planet?
   (d) What is the total mechanical energy of the oscillation?

3. (A) A string oscillates according to the equation

$$y(x,t) = 0.50 \sin(\frac{\pi}{3} x) \cos(40\pi t)$$, x is in cm and t in sec .

(a) Write the equation of one of the two waves whose superposition gives this oscillation
(b) What is the internodal distance?

3.(B) A cord has two sections with linear densities of 0.10 kg/m and 0.20 kg/m respectively. An incident wave, $y(x,t) = 0.050 \sin (6.0 x - 12.0 t)$, where x is in meters and t in seconds, travels from the lighter cord to the heavier one . What is the wavelength of the wave in each section of the cord?

3.(C) If the amplitude of a sound wave is tripled,
(a) By what factor will the intensity increase ?
(b) By how many dB will the sound level increase ?

4.(A) A bat flying toward a wall at 15 m/s emits high frequency sound at a frequency of 100 kHz . What is the beat frequency heard by the bat? (v_s = 340 m/s)

4. (B) Organ pipe A with both ends open, has a fundamental frequency of 300.0 Hz. The third harmonic of organ pipe B, with one end open, has the same frequency as the second harmonic of organ pipe A. How long are the pipes A and B? (v_s = 340 m/s)

5.(A) A thin film of alcohol (n = 1.36) lies on a flat glass plate (n = 1.51). Monochromatic light, whose wavelength can be changed, is incident normally and the intensity of the reflected light is a minimum for wavelength of 512 nm and a maximum for wavelength of 640 nm. What is the thickness of the film?

5.(B) Two loudspeakers, located at (0, 1 m) and (0, - 1 m) as in the diagram, are emitting sound waves, of the same frequency, in phase. A microphone initially on the x- axis at x = 5.0 m is moved parallel to the y-axis towards point Q. The first minimum occurs at point Q (5 m , 1.5 m). What is the wavelength of the sound waves?

6.(A) In a double-slit experiment, the slit separation is 0.160 mm and the width of each slit is 0.020 mm. The slits are illuminated at normal incidence with light of wavelength 600 nm and the resulting interference pattern is viewed on a screen located 2.00 m from the plane of the slits.

(a) How many bright fringes are there in the central diffraction maximum?

(b) The intensity of the light is measured at a point where X = 72.25 cm from the central maximum measured along the screen. What is the ratio of the intensity at this point to the intensity of the central maximum?

(c) Draw the diagram showing the intensity as a function of the position.

6. (B) Two satellites at an altitude of 1200 km are separated by 28 km. If they broadcast 3.6 cm microwaves, what minimum receiving dish diameter is needed to resolve the two transmissions?

7.(A) For a rectangular metal surface with dimensions 5 cm by 3 cm, the threshold wavelength for the photoelectric emission of electrons is 246.0 nm.

(a) Calculate the work function of the metal surface.

(b) Calculate the wavelength of light that must be used in order for electrons with a maximum kinetic energy of 2.3 eV to be ejected.

(c) If light of wavelength 300 nm and intensity 1.75 W/m^2 is incident normally on the metal surface, calculate the number of photons that strike the surface in a time of 30 seconds.

7.(B) After colliding with a free electron an x-ray photon is scattered through an angle of 70^0. The wavelength of the scattered photon is 3.910×10^{-12} m .

(a) Calculate the Compton shift in wavelength.

(b) What is the kinetic energy of the scattered electron?

8.(A) Consider an electron confined to move back and forth along a line of length 0.090 nm.
(a) What is the energy of the electron when it is in the second excited state?
(b) What is the de Broglie wavelength of the electron in the second excited state?
(c) Sketch the standing wave that represents the wave function of the electron in its second excited state.

8.(B) A hydrogen atom in an excited state has an energy, E = - 0.85 eV. It makes a transition to a different state where its energy is E = - 3.4 eV.
(a) What are the quantum numbers of the two states?
(b) What is the wavelength of the emitted photon?
(c) Show this transition on an energy level diagram for hydrogen.

9.(A) A spaceship from another galaxy passes over the solar system directly above and parallel to a radial line from the Sun to the Earth. We, on Earth, measure the Earth-Sun distance to be 1.50×10^{11} m and measure the speed of the spaceship to be 0.8c.

(a) What does a scientist in the spaceship measure the Earth-Sun distance to be?

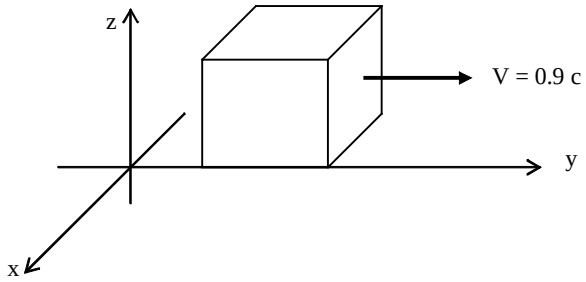
(b) How long does the trip take according to a clock in the spaceship?

9.(B) In the TV series, Star Trek, the Next Generation, Captain Picard and his crew often encountered the dreaded Borg who were cybernetic beings bent on conquering the galaxy by assimilating civilizations into the Borg collective. A Borg spaceship is typically a cube of 100 m on a side with a mass of 1.00×10^9 kg.

(a) If a Borg spaceship is determined to be traveling at 0.9c relative to the Earth with one face parallel to the x-axis, what is the mass of this vessel measured by observers at rest on the Earth? (See the diagram)

(b) What are the dimensions of the Borg spaceship as measured by observers at rest on Earth?

(c) What is the average density of a Borg spaceship as measured by observers on Earth?



10. (A) An electron is accelerated from rest through a potential difference of 1.40×10^5 V. What is,
    (a) its relativistic kinetic energy in eV?
    (b) its relativistic total energy in eV?
    (c) its speed?

10.(B) A nuclear bomb containing 12.0 kg of plutonium explodes. The sum of the rest masses of the products of the explosion is less than the original rest mass by 1.20 grams.
    (a) How much energy is released in the explosion?
    (b) If the explosion takes place in 4.00 μs, what is the average power developed by the bomb?