Section A – Each question is worth 1 mark

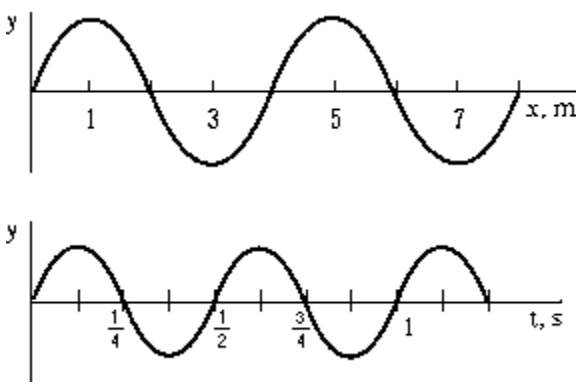
1. When an object is oscillating in simple harmonic motion in the vertical direction, its maximum speed occurs when the object
   A) is at its highest point.
   B) is at its lowest point.
   C) is at the equilibrium point.
   D) has the maximum net force exerted on it.
   E) has a position equal to its 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) $2v$ C) $v/2$ D) $4v$ 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.

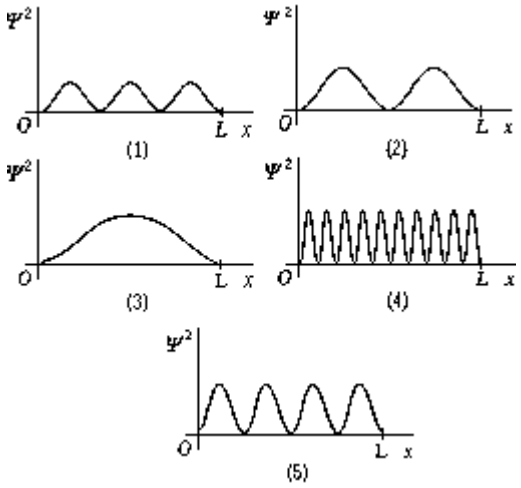
10. The maximum kinetic energy of photoelectrons produced in the photoelectric effect depends directly on the
   A) frequency of the incident photons.
   B) intensity of the incident photons.
   C) area of the metal surface from which the photoelectrons are released.
   D) thickness of the metal.
  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

11. If plane polarized light is sent through two polarizers, the first at 45° to the original plane of polarization and the second at 90° to the original plane of polarization, what fraction of the original polarized intensity passes through the last polarizer?
A) 0
B) 1/4
C) 1/2
D) 1/8
E) 1/10

12. A baseball does not exhibit wave properties as readily as light because baseballs 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.

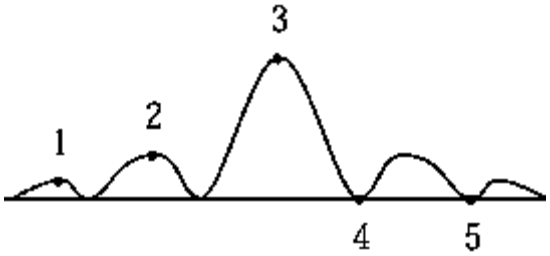
14. The graphs show Ψ^2 as a function of x for a particle in a one-dimensional box of length L. The graph that represents the second excited state is
A) 1 B) 2 C) 3 D) 4 E) 5



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

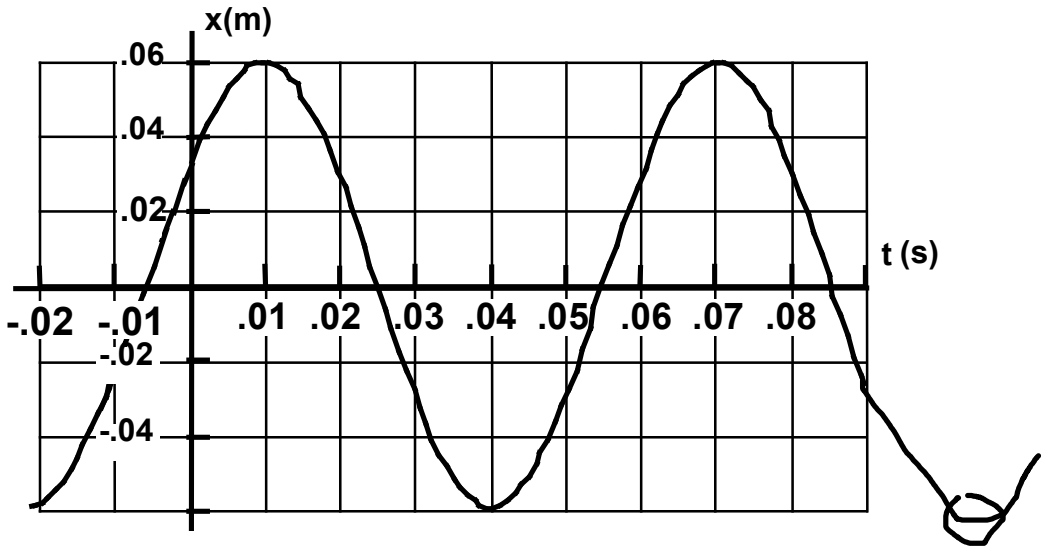
18. Two spherical bodies A (radius $6\ cm$) and B (radius $18\ cm$) are at temperature T_A and T_B respectively. The maximum intensity in the emission spectrum of A is at $500\ nm$ and in that of B is at $1500\ nm$. Considering them to be blackbodies, what will be the ratio fo the rate of total energy radiated by A to that of B?
A) 9 B) 3 C) 1/9 D) 81 E) 1/3

19. A certain isotope of tin has atomic number Z=50 and mass number A=120. Based on the trend in the neutron-to-proton ratio for stable isotopes, which of the following best estimates the number of neutrons in this isotope?
A) 50
B) 60
C) 70
D) 90

20. A radium-226 nucleus undergoes five alpha decays followed by two beta-minus decays. What is the resulting daughter nucleus?
A) Pb-208
B) Po-216
C) Rn-218
D) Hg-206

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) Light of wavelength 620 nm illuminates a diffraction grating. The second-order maximum is at angle 39.5°.

(a) How many lines per millimeter does this grating have?

(b) What is the highest-order maximum that can be seen?

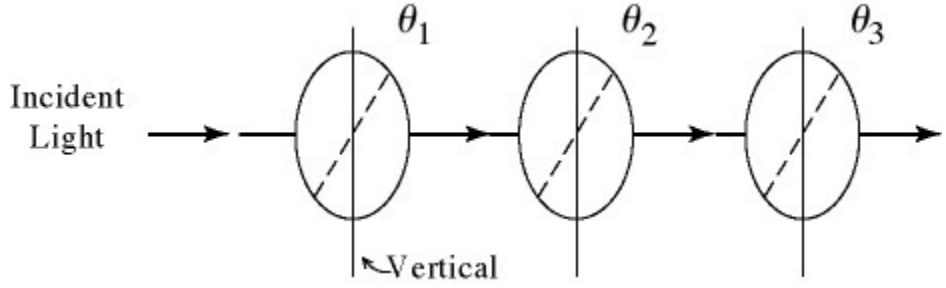
7.(A) For a rectangular metal surface with dimensions 5 cm by 3 cm, the threshold wavelength for the photoelectric emission of electrons is 246.0 nm.

(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) In the following figure, the orientation of the transmission axis for each of three polarizing sheets is labeled relative to the vertical direction. Initially unpolarized light is sent into a system of three polarizing sheets where the polarizing directions are at angles of $\theta_1 = 20°$, $\theta_2 = 40°$ and $\theta_3 = 60°$. What fraction of the light's initial intensity is transmitted by the system?



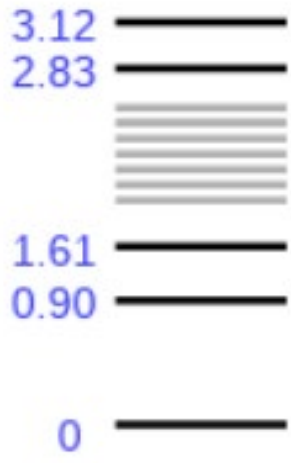
8.(A) Consider an electron confined to move back and forth along a line of length 0.090 nm.
(a) What is the energy of the electron when it is in the second excited state?
(b) What is the de Broglie wavelength of the electron in the second excited state?
(c) Sketch the standing wave that represents the 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. The outside wall of the north end of the AME building is pretty cool – it is made of rusting steel, which has an emissivity of 0.65. Let's assume that the inside walls of the AME building are kept at a comfortable 22°C and that the effective conductivity of the 25-cm-thick walls is 0.45 W/m°C. Let's simplify the wall into a rectangle, dimensions 12 m by 25 m.
a) If the temperature of the outside surface of the wall is 15°C, what is the rate of heat loss through the wall?
b) If all the heat is radiated to the surrounding area, what is the temperature of the surrounding area?
c) What is the peak wavelength of the radiative waves emanating from the wall?

10.(A) For this problem, use the information in the following table
(Also $m_{{}_1^1H} = 1.0078\ Da$)

isotope	Mass, m (Da)	Type of decay	Half-life
$^{209}_{83}Bi$	208.9804	stable	stable
$^{211}_{83}Bi$	210.9875	α	2.14 min
$^{215}_{83}Bi$	215.0018	β^-	7.40 min



a) Calculate the binding energy per nucleon of $^{209}_{83}Bi$ and of $^{211}_{83}Bi$. What can we explain from examining the binding energy per nucleon of these two isotopes?

b) What is the result of the α decay of $^{211}_{83}Bi$? Answer with an appropriate equation.

c) What is the result of the β^- decay of $^{215}_{83}Bi$? Answer with an appropriate equation.

d) The isotope $^{209}_{83}Bi$ is stable, but the excited nucleus can undergo γ-decay. The energy levels of $^{209}_{83}Bi$ in MeV are illustrated on the left. What is the longest wavelength that can be emitted by an excited $^{209}_{83}Bi$ nucleus??

10.(B) Rocks can be dated by looking at the electron capture decay of potassium 40, which is given by the following equation:

$$_{-1}^{0}e^- + {}_{19}^{40}K \rightarrow {}_{18}^{40}Ar + \nu$$

The half-life of $^{40}_{19}K$ is 1.248 billion years. In a rock, the ratio of argon 40 to potassium 40 is measured to be 0.15. What is the age of the rock? Argon is a gaz: we assume that there was no argon in the rock when it was first formed, and that the argon trapped in the rock is the result of decay after the rock was formed.