Waves and Fields (PHYS 195)

Spring 2018

1. Clicker Questions: Oscillations

(1) What does the solution $x(t)$ look like?
   (a) Growing exponentially so it should be related to e^t
   (b) Curvy so it should be related to t^2
   (c) Wiggly so it should be related to sine or cosine.
   (d) Why don't we integrate the equation of motion to find out?
   ANSWER: (c)

(2) What is this "regular interval" or period?
   (a) Time is in only one parameter, ω_o ,so it must be

$$\frac{1}{\omega_o}$$

   (b) Time is in the parameter, ω_o and this is radians per unit time so to find *time per cycle* we need the number of radians in a full circle... 2π! Thus, the time is

$$\frac{2\pi}{\omega_o}$$

   (c) The system has to get back to where it was after a time T so

$$\cos(\omega_o t) = \cos(\omega_o(t+T)) \text{ hence } \omega_o T = 2\pi \implies T = \frac{2\pi}{\omega_o}$$

   (d) It is related to x_m since the system has to return to the same state.
   (e) None of the above.
   ANSWER: (b) and (c)

(3) What is the total force on the glider when it is displaced to the right ($x > 0$)?
   (a) $F = -kx$
   (b) $F = -k_1(x_1 + x) - k_2(x_2 - x)$
   (c) $F = k_1(x_1 + x) + k_2(x_2 + x)$
   (d) $F = -k_1(x_1 + x) + k_2(x_2 - x)$
   (e) $F = k_1(x_1 - x) + k_2(x_2 - x)$
   ANSWER: (d)

(4) What is the equation of motion, derived from dynamics ($F = ma$ or $\tau = I\alpha$), for simple harmonic motion? Let's suppose the coordinate is x.

(a)
$$\frac{d^2x}{dt^2} - \omega_o^2 x = 0$$
(b)
$$\frac{d^2x}{dt^2} + \omega_o^2 x = 0$$
(c)
$$x(t) = x_m \cos(\omega_o t + \phi)$$
(d)
$$\frac{dx}{dt} + \omega x = 0$$
(e)
$$x(t) = x_m e^{(\omega_o t + \phi)}$$

(5) Ok, now from $F = ma$ what is the equation of motion for a pendulum, in final form?

(a)
$$\frac{d^2\theta}{dt^2} + \frac{g}{\ell}\theta = 0$$
(b)
$$\frac{d^2x}{dt^2} + \frac{g}{m}\theta = 0$$
(c)
$$\frac{d^2x}{dt^2} - g\theta = 0$$
(d)
$$\frac{d^2\theta}{dt^2} + \frac{g}{\ell}\sin\theta = 0$$
(e)
$$\frac{d^2\theta}{dt^2} - \frac{g}{\ell}\sin\theta = 0$$

ANSWER: (d)

(6) What is the equation of motion for a simple pendulum, in final form?

(a)
$$\frac{d^2\theta}{dt^2} + \omega_o^2\theta = 0$$
(b)
$$\frac{d^2x}{dt^2} - \omega_o^2\theta = 0$$

(c)

$$\frac{d^2x}{dt^2} - g\theta = 0$$

(d)

$$\frac{d^2\theta}{dt^2} + \frac{g}{\ell}\sin\theta = 0$$

(e)

$$\frac{d^2\theta}{dt^2} - \omega_o^2\sin\theta = 0$$

ANSWER: (a)

(7) What is the general solution, which describes the angle $\theta(t)$, for a simple pendulum? Let's suppose the coordinate is θ.

(a)
$$\frac{d^2\theta}{dt^2} - \omega_o^2\theta = 0$$

(b)
$$\frac{d^2\theta}{dt^2} + \omega_o^2\theta = 0$$

(c)
$$\theta(t) = \theta_m \sin(\omega_o t + \phi)$$

(d)
$$\frac{d\theta}{dt} + \omega\theta = 0$$

(e)
$$\theta(t) = \theta_m e^{(\omega_o t + \phi)}$$

ANSWER: (b)

(8) What do we change about our problem solving method when we have torques or extended objects?

(a) Nothing!
(b) Add torques free body diagrams; use our right hands; include $\sum \tau = I\alpha$, adding to the equations of motion; and then incorporate these into the desired solution.
(c) Spice with appropriate Greek letters.
(d) Add torques free body diagrams; use our left hands; include $\sum \tau = I\alpha$, adding to the equations of motion; and then incorporate these into the desired solution.

ANSWER: (b) is best

(9) Where is the origin for the moment arm?

(a) Hey, it is my choice! It could be anywhere.
(b) Ok, ok, but there is a best choice and it is where the whale is suspended from the support.
(c) I think it should be at the center of mass, then we have fewer torques to worry about.
(d) Help!

ANSWER: (b) is best

(10) What is the torque on the mass?

(a) $\tau = r \times F = rmg$
(b) $\tau = r \times F = -\ell mg \cos\theta$
(c) $\tau = r \times F = -\ell mg \sin\theta$

(d) $\tau = r \times F = \ell mg \cos\theta$
(e) $\tau = r \times F = \ell mg \sin\theta$
ANSWER: (c)

(11) What is the total energy of the mass-on-a-spring oscillator at a turning point?
(a) $E = 1/2mv^2$
(b) $E = 1/2kx^2$
(c) $E = 1/2kx_m^2$
(d) $E = 0$
ANSWER: (c) is best

(12) In SHM what is the energy *always*?
(a) $E = 1/2mv^2$
(b) $E = 1/2kx^2$
(c) $E = 1/2kx_m^2$
(d) $E = 0$
(e) $E = 1/2m\omega_o^2 x_m^2$
ANSWER: (e)

(13) What does

$$U(x_o)$$

mean physically? (i.e. What does it do for the dynamics of a system?)
(a) Nothing - only the change in the potential is physical
(b) It determines the number of ewes at x_o.
(c) It sets the zero of U and is physically meaningful.
(d) It tells me how many joules of potential energy I have at x_o.
ANSWER: (a)

(14) What is this

$$\left.\frac{dU}{dx}\right|_{x_o}$$

quantity? Assume that x_o is an equilibrium point.
(a) Well that's obvious! Its's a derivative and function of x!
(b) zero
(c) the slope at any point x
(d) a non-vanishing force at the position x_o
(e) a derivative evaluated at a single point and so some number!
ANSWER: (b) is best

(15) What does

$$\left.\frac{d^2U}{dx^2}\right|_{x_o}$$

mean physically?
(a) Nothing
(b) It determines how the number of ewes changes at x_o.
(c) It is k_{eff}!
(d) It is a second derivative evaluated at a single position - so a number!
ANSWER: (c)

(16) Since

$$k_{eff} = \left.\frac{d^2U}{dx^2}\right|_{x_o}$$

what is k_{eff} for

$$U(x) = \frac{1}{2}kx^2 \text{ ?}$$

(a) $k_{eff} = \omega$
(b) $k_{eff} = 2k$
(c) $k_{eff} = k/2$
(d) $k_{eff} = k$ - and it would be a bummer if it wasn't!
(e) Help! How do I do this?
ANSWER: (d)

(17) A block of material whether it be Jell-O, skyscraper, or ruler once nudged away from stable equilibrium will enjoy a force
(a) that could be just about anything.
(b) that is linear in the displacement away from equilibrium.
(c) that is usually quadratic, like this -

$$\frac{1}{2}k_{eff}\, x^2.$$

(d) Hmm, I'm not sure. What is this question based on?
ANSWER: (b)

(18) The Jell-O when nudged away from stable equilibrium will
(a) wiggle!
(b) oscillate with damped, harmonic motion.
(c) undergo simple harmonic motion.
(d) oscillate with harmonic motion of some form.
ANSWER: All

(19) How would you describe this motion and the solution '$x(t)$'?
(a) It is altogether a new beast.

(b) It is harmonic but beyond that I am not sure.
(c) It is SHM with a decreasing amplitude.
(d) It is similar to SHM motion but with a new angular frequency and exponentially decaying amplitude.
(e) None of the above.
ANSWER: (d) is best

(20) Ok, based on that observation how should we write the trial solution?
(a)
$$x(t) = e^{\alpha t} \text{ with the to-be-determined constant } \alpha$$
(b) Our usual SHM solution multiplied by a new function, like this
$$x(t) = f(t) \cdot x_{\mathrm{SHM}}(t)$$
and find $f(t)$.
(c)
$$x(t) = e^{\beta t} x_{\mathrm{SHM}}(t)$$
and we'll find β.
(d)
$$x(t) = x_m e^{-\beta t} \cos(\omega t + \phi)$$
(e) I'm not sure.
We used (d), which worked!

(21) The $\dot{x}$ notation in K&K means
(a) some sort of derivative.
(b) an alternate coordinate x
(c) a staccato displacement
(d) the velocity!
$$\dot{x} = v_x = \frac{dx}{dt}$$
ANSWER: (d)

(22) To find the damping coefficient b from the initial amplitude and the amplitude at 10.5 s (and the mass m) I would
(a) First, use the general solutions to set
$$A(10.5s) = x_m e^{-\beta(10.5)} \cos(\omega \cdot 10.5 + \phi).$$
Second, solve for β. From that I could obtain b.
(b) Find β using
$$\frac{A(0)}{A(10.5s)} = \frac{x_m}{x_m e^{-\beta t}}$$
and then solve for b.
(c) Just use $b = 2m\beta$.

(d) Set the specific solution to half the amplitude at $t_* = 10.5$ s and solve for β then b.
(e) Can you remind me what the damping coefficient b is?

(23) What did the Millennium Bridge do?
(a) Nothing odd at all but the people appear to be walking like penguins, curious.
(b) Some side to side motion
(c) Hey, the motion is very much like SHM as it must be!
(d) No clue but I don't want to be on that bridge
ANSWER: (c) is best

(24) Why might the Tacoma narrows bridge *not* be an example of "resonance"?
(a) There may be a periodic driving force from the shedding of vortices but it is not obviously a wiggly function like cosine.
(b) The cables act as springs only when they are stretched so when they are loose they no longer provide a $F = -kx$ restoring force.
(c) The damping might not be a linear $F = -bv$.
(d) The oscillations are large.
(e) All of the above
ANSWER: (e)

(25) What is the physics are we about to see?
(a) Perhaps a breaking wine glass?
(b) As the driving frequency approaches the natural frequency of the glass the amplitude of oscillation of the glass decreases
(c) Increasing volume at any frequency results in a higher amplitude of oscillation of the glass
(d) Resonance!
(e) None of the above
ANSWER: (d)

(26) I plan to take the mid-term during the lab section on
(a) tuesday
(b) wednesday
(c) thursday
(d) Ah, I'm not sure yet.

(27) Every system set in motion around a stable equilibrium point, will
(a) undergo harmonic motion
(b) undergo simple harmonic motion
(c) undergo exponential decay to equilibirum
(d) wiggle continuously

since the potential is always in the form of

$$U(x) = \frac{1}{2}k_{eff}x^2$$

in that neighborhood. ANSWER: (a) is best

(28) When playing an instrument like a flute the "attack" or how the first note is achieved instrument can make a big difference on the impression we hear. Why?
  (a) It takes a while for the flute to warm up.
  (b) The damped or transient solution can be heard for awhile if the initial amplitude is large.
  (c) Only the resonant late time solution is heard so this statement is a miss-impression.
  (d) The transient solution always dies away quickly. The effect is the building up of the final resonant amplitude.
  (e) None of the above
  ANSWER: (b)

(29) Modern large towers often have large damped oscillators on the top of them. Why would you put such a huge mass (100's of tons) so high in a building?
  (a) For the engineering challenge
  (b) If you tune the oscillating masses to the natural frequency of the building they will resonate at that frequency pulling energy out of the building's oscillation and reducing the building's motion.
  (c) Such installations reduce the amplitude of motion at all frequencies.
  (d) To save money in concrete and steel.
  (e) (b) and (d)
  ANSWER: (e)

(30) What happens in the first 18 seconds in the three masses video?
  (a) The mass in the middle is driven at resonance.
  (b) The mass on the left has a large amplitude and drives the mass on the right. The left mass looses energy and amplitude as it drives the right mass.
  (c) The mass on the right has a large amplitude and drives the mass on the left. The right mass looses energy and amplitude as it drives the left mass.
  (d) All the masses oscillate in resonance!
  ANSWER: (b)

(31) What is going to happen next in the video?
  (a) The mass in the middle is driven at resonance.
  (b) The mass on the left has a large amplitude and drives the mass on the right. The left mass looses energy and amplitude as it drives the right mass.

(c) The mass on the right has a large amplitude and drives the mass on the left. The right mass looses energy and amplitude as it drives the left mass.
(d) All the masses oscillate in resonance!
ANSWER: (c)

(32) What is going to happen next?
(a) We'll hear a nice sound from a high Q system.
(b) We'll hear a nice sound but it will die away quickly due to damping.
(c) We'll hear a nice sound but ... hmmm so we *hear* it so the energy must be going to our ears and away from the oscillator so the amplitude will die away quickly.
(d) I'm not sure.
ANSWER: (c)

(33) What is going to happen as the first tuning fork is stopped?
(a) We'll hear a nice sound but it will die away quickly due to damping. We'll hear nothing after the first tuning fork is stopped.
(b) We'll hear a nice sound but ... hmmm so we *hear* it so the energy must be going to our ears and away from the oscillator so the amplitude will die away quickly after the first tuning fork is stopped.
(c) It's the three mass video all over again!
(d) I'm not sure.
ANSWER: (c) is best although the energy stored in the oscillation is transferred to our ears.

(34) What is going to happen?
(a) It's the three mass video all over again!
(b) We'll see the first mass oscillate.
(c) All the masses will oscillate together since they are connected.
(d) The masses will wiggle in some more or less random way.
(e) I'm not sure.
ANSWER: (a)

(35) As time passes the energy of the planetary orbit
(a) decreases due to viscous damping.
(b) increases due to gravitational driving.
(c) is conserved for long times, making such motion one of the best clocks in the universe.
(d) stays the same because the central mass is stationary.
(e) decreases due to the gravitational waves that are produced.
ANSWER: (c)

(36) As time passes the energy of the binary black hole system

(a) decreases due to viscous damping.
(b) increases due to gravitational driving.
(c) is conserved for long times, making such motion one of the best clocks in the universe.
(d) stays the same because the central mass is stationary.
(e) decreases due to the gravitational waves that are produced.
ANSWER: (e)

(37) In the co-moving reference frame $F = ma$ for this pulse is
(a)
$$\mu\, y_m\, 2\theta\, a_x = 2F_T$$
(b)
$$\mu\, y_m\, 2\theta\, a_x = 2F_T\theta$$
(c)
$$\mu\, y_m\, 2\theta\, \frac{v^2}{y_m} = 2F_T\theta$$
(d)
$$\mu\, y_m\, 2\theta\, \frac{v^2}{y_m} = F_T\theta$$
(e)
$$\mu\, y_m\, 2\theta\, a_x = F_T\theta$$
ANSWER: (c)

(38) How could we make the wave on a string go faster?
(a) Decrease frequency.
(b) Increase frequency.
(c) Decrease tension
(d) Increase tension
(e) We can't. There is no speed control.
ANSWER: (d)

(39) A *wee length of string at one point* undergoes
(a) exponential decay
(b) exponential growth
(c) simple harmonic motion
(d) some other version of wiggling
ANSWER: (c)

(40) In a single snapshot the whole string has a shape described by
(a) exponential decay
(b) exponential growth
(c) simple harmonic motion *in space*

(d) some other version of wiggling
ANSWER: (c)

(41) Why isn't there wavelength control?
(a) Editorial discretion! They just left it out.
(b) We can control λ with frequency.
(c) We can control λ with tension.
(d) We can control λ with amplitude.
(e) (b) and (c)
ANSWER: (e)

(42) What is the acceleration of the string at a point x_*?
(a)
$$\frac{\partial y}{\partial x}(x_*)$$
(b)
$$\frac{\partial y}{\partial t}(x_*)$$
(c)
$$\frac{\partial^2 y}{\partial t^2}(x_*)$$
(d)
$$\frac{\partial^2 y}{\partial x^2}(x_*)$$
(e) None of the above
ANSWER: (c)

(43) What is the slope of the string at a point x_*?
(a)
$$\frac{\partial y}{\partial x}(x_*)$$
(b)
$$\frac{\partial y}{\partial t}(x_*)$$
(c)
$$\frac{\partial^2 y}{\partial t^2}(x_*)$$
(d)
$$\frac{\partial^2 y}{\partial x^2}(x_*)$$
(e) None of the above
ANSWER: (a)

(44) Is this a function of time t?
  (a) Yes!
  (b) No!
  (c) I don't know!

(45) What is the velocity of the string at a point x_*?
  (a)
$$\frac{\partial y}{\partial x}(x_*)$$
  (b)
$$\frac{\partial y}{\partial t}(x_*)$$
  (c)
$$\frac{\partial^2 y}{\partial t^2}(x_*)$$
  (d)
$$\frac{\partial^2 y}{\partial x^2}(x_*)$$
  (e) None of the above
  ANSWER: (b)

(46) What is the curvature of the string at a point x_*?
  (a)
$$\frac{\partial y}{\partial x}(x_*)$$
  (b)
$$\frac{\partial y}{\partial t}(x_*)$$
  (c)
$$\frac{\partial^2 y}{\partial t^2}(x_*)$$
  (d)
$$\frac{\partial^2 y}{\partial x^2}(x_*)$$
  (e) None of the above
  ANSWER: (d)

(47) We found a solution for the wave equation last time, $y(x,t) = y_m \sin(kx - \omega t)$. Are there others?
  (a) Sure! Another one is $y(x,t) = y_m \sin(kx + \omega t)$, a right moving wave.
  (b) Oh yes! For instance *any* function of $kx \pm \omega t$, $f(kx \pm \omega t)$ will work.
  (c) Nope! This expression of simple harmonic motion in space and time is all we have.

(d) No. We showed that this was the only solution.
ANSWER: (b)

(48) A string supports a right moving wave. A wee section of this string with length Δx stores energy
$$E = \frac{1}{2}\mu \Delta x \omega^2 y_m^2.$$
Where does this energy come from most directly?
(a) directly from the driver.
(b) from its neighboring sections of string.
(c) from the wave.
(d) none of the above.
ANSWER: (b)

(49) What are the resonant frequencies for waves on a string with two fixed ends? With $n = 0, 1, 2, \ldots,$
(a) $f_n = \frac{nv}{L}$
(b) $f_n = \frac{nv}{2L}$.
(c) $f_n = \frac{3nv}{2L}$.
(d) Any frequency will work.
(e) None of the above.
ANSWER: (b)

(50) A violin string has a fundamental harmonic at 196 Hz (G). The string has a length of 23 cm and mass of 0.68 g, what is the tension? We'll model the boundary conditions with two fixed ends.
(a) $F_T = mLf^2 = 6$ N
(b) $F_T = 2mLf^2 = 12$ N
(c)
$$F_T = \frac{16}{9}mLf^2 = 11 \text{ N}.$$
(d) $F_T = 4mLf^2 = 33$ N
ANSWER: (d)

(51) What are the resonant frequencies for waves on a string with two open ends? With $n = 0, 1, 2, \ldots$
(a) $f_n = \frac{nv}{L}$
(b) Same as two fixed ends $f_n = \frac{nv}{2L}$.
(c) $f_n = \frac{3nv}{2L}$.
(d) Any frequency will work.
(e) None of the above.

(52) What are the resonant frequencies for waves on a string with one open end and one fixed end? With $n = 0, 1, 2, \ldots$

(a)
$$f_n = \frac{nv}{L}$$

(b) Same as two fixed ends
$$f_n = \frac{nv}{2L}$$

(c)
$$f_n = \frac{(2n+1)v}{4L}$$

(d)
$$f_n = \frac{(2n+1)v}{2L}$$

(53) The mass of the plug of particles is

(a) $m = \rho A$
(b) $m = \mu \Delta x$
(c) $m = \rho A \Delta x$
(d) $m = \mu A \Delta x$

(54) The *change in volume*, ΔV, of the plug of particles is

(a)
$$\Delta V = A\left[D(x+\Delta x) + D(x)\right]\Delta x$$

(b)
$$\Delta V = AD(x)\Delta x$$

(c)
$$\Delta V = A\left[D(x) - D(x+\Delta x)\right]\Delta x$$

(d)
$$\Delta V = A\left[D(x+\Delta x) - D(x)\right]\Delta x$$

(e)
$$\Delta V = A\Delta x$$

(55) So the wave speed of 'phase velocity' of sound is

(a)
$$v = \sqrt{\frac{B}{\rho}}$$

(b)
$$v = \sqrt{\frac{\rho}{B}}$$

(c)

$$v = \sqrt{\frac{F_T}{\mu}}$$

(d)

$$v = \sqrt{\frac{\gamma RT}{M}}$$

(e)

$$v = \sqrt{\text{ZooM}}$$

(56) To find a location for an interference maximum we should move so that
(a) the phase difference is an integral number times 2π
(b) the phase is a odd number times 2π
(c) the difference in path length is an integral number of wavelengths
(d) the difference in path length is a odd number of 1/2 -wavelengths
(e) both (a) and (c)

(57) To find a location for an interference minimum we should move so that
(a) the phase difference is an integral number times 2π
(b) the phase is a odd number times 2π
(c) the difference in path length is an integral number of wavelengths
(d) the difference in path length is a odd number of 1/2 -wavelengths
(e) both (a) and (c)

(58) We found that the energy stored in an oscillator is

$$E = \frac{1}{2} m\omega_o^2 x_m^2$$

For a sinusoidal wave on a string with angular frequency ω how much energy is stored in a length Δx?

(a)

$$E = \frac{1}{2} m\omega_o^2 y_m^2$$

(b)

$$E = \frac{1}{2}\mu\Delta x\omega^2 x_m^2$$

(c)

$$E = \frac{1}{2}\mu\omega^2 y_m^2$$

(d)

$$E = \frac{1}{2}\mu\omega^2 x_m^2$$

(e) None, the wave has it all.

(59) At an outdoor concert you find yourself next to a speaker. Your ears hurt and you forgot to bring earplugs. But you can reduce the intensity of sound by -

(a) moving away from the speaker, in an open space the volume goes down as $1/r^2$
(b) moving away from the speaker, in an open space the volume goes down as $1/r$
(c) moving toward the speaker
(d) forget it! It is hopeless

(60) What is the intensity of a whisper at 40 dB?

(a) 10^{12} W/m^2
(b) 10^4 W/m^2
(c) 10^{-8} W/m^2
(d) 10^{16} W/m^2
(e) Ah, well that depends on what is said!

(61) What is happening?

(a) With both ends open, the wind across the open end sets up resonances at
$$f_n = \frac{nv}{2L}$$
(b) With one end closed, the wind across the open end sets up resonances at
$$f_n = \frac{(2n-1)v}{4L}$$
(c) Just noise.
(d) With both ends open, the wind across the open end sets up resonances at
$$f_n = \frac{nv}{4L}$$
(e) With one end closed, the wind across the open end sets up resonances at
$$f_n = \frac{(2n-1)v}{5L}$$

(62) I expect that the plate will

(a) wiggle back and forth a bit with the sand bouncing all around the surface
(b) be really loud at all frequencies
(c) wiggle at all frequencies except at the nodes
(d) Wait! This is steel, right? It is not going to bend! Try something else like plexiglass.
(e) wiggle vigorously only at certain frequencies and only along the lines (or curves) of the anti-nodes.

(63) At higher frequencies I expect that the sand will, at resonance,

(a) settle into more simple nodal patterns, since the wavelength will increase
(b) settle into a grid pattern, since the wavelength will decrease
(c) settle into more curly patterns, since it will be asymmetric
(d) settle into more complex nodal patterns, since the wavelength will decrease

(64) Why is the person holding two fingers to the plate?
(a) The hand is of the person who is saying, "Look at that!"
(b) It is not necessary, the patterns will appear as we just saw.
(c) Violin bows excite one mode so it is not necessary.
(d) The hand was included to guide the artist in drawing the pattern
(e) Through the slip-skid friction of the bow many frequencies are excited so to pick one resonant frequency and mode the person fixes the boundary conditions for that mode.

(65) When we derived the wave equation we found

$$v = \sqrt{\frac{B}{\rho}}.$$

What was this phase velocity relative to?
(a) any observer.
(b) any source.
(c) (a) and (b)
(d) the medium through which the wave propagates.
(e) a stationary observer.

(66) If the **source** of sound is **receding** from the observer then the
(a) the wavelength is squished and the frequency goes up
(b) the wavelength is stretched out and the frequency goes down
(c) wave fronts remain the same but the speed increases so the frequency increases
(d) wave fronts remain the same but the speed decreases so the frequency decreases

(67) In the general Doppler shift equation for sound
(a) there is one case
(b) there are two cases; the sign choices are tied together
(c) there are three cases
(d) there are four cases; the sign choices are independent

(68) A police car traveling at 150.0 km/hr = 41.67 m/s pursues a speeding whale-driven auto. The speeding whale travels at 145 = 40.28 m/s in the same direction. The siren on the police car emits a frequency of 2.000×10^3 Hz. What

is the frequency heard by the whale? Assume 4 sig figs and that the speed of sound is 343.0 m/s.
(a) 2007 Hz
(b) 1572 Hz
(c) 2541 Hz
(d) 1991 Hz
(e) Erf, what?

(69) If the source and observer are moving as shown then which signs do we use? (c_s is the speed of sound)
(a) top signs:
$$f' = f\left(\frac{c_s + v_O}{c_s - v_S}\right)$$
(b) bottom signs:
$$f' = f\left(\frac{c_s - v_O}{c_s + v_S}\right)$$
(c) - above - below
$$f' = f\left(\frac{c_s - v_O}{c_s - v_S}\right)$$
(d) + above + below
$$f' = f\left(\frac{c_s + v_O}{c_s + v_S}\right)$$

(70) In special relativity and light the situation changes since
(a) it is more complicated.
(b) there is no medium so the effect only depends on the relative velocity.
(c) since for light the speed greater than sound, it happens faster.

(71) In the relativistic frequency shift for light
(a) there is one case
(b) there are two cases; the sign choices are tied together
(c) there are three cases
(d) there are four cases; the sign choices are independent

(72) Electric field lines just outside a conductor are
(a) at any angle with respect to the surface since the distribution of charge varies.
(b) at any angle with respect to the surface since the shape of the surface varies.
(c) only perpendicular to the surface since field lines push against each other.
(d) only perpendicular to the surface since if there was any tangential field component the resulting force would move the charges.

(73) The speed of the electron is given by

(a)
$$v = \frac{eE}{m_e}$$

(b)
$$v = \sqrt{\frac{mgd}{m_e}}$$

(c)
$$v = \sqrt{\frac{2eEd}{m_e}}$$

(d) Gee, I wish I had energy to solve this!

(74) As I charge up the conductors in the oil what will we see happen to the rice?

(a) The grains of rice will heat up.
(b) Nothing since the oil and rice are insulators.
(c) Oh! The charge will separate a little in the rice grains. This will cause a torque and since the grains are free to rotate they will align with the electric field lines.
(d) The charge will separate a little in the rice grains. This will cause a torque and since the grains are free to rotate they will align with the electric potential.

(75) When asked to find the electric potential V of a point charge I would

(a) just plug in the radius.
(b) integrate to find
$$-\int \mathbf{E} \cdot d\ell$$
(c) write down the analogous expression in gravity and then check the field by computing $-dV/dr$.
(d) say, "Oh dear, I have no idea how to do this!"

(76) The electric potential V at the center of a square with magnitudes q_1, q_2, q_3, q_4 is

(a) some complicated expression using units vectors - can we do something else?
(b) the sum of the charges
(c) sum each charge's contribution to the potential
$$V(center) = \frac{1}{4\pi\epsilon_o}\left(\frac{\sqrt{2}}{a}\right)(q_1 + q_2 + q_3 + q_4)$$
(d) It is
$$V(center) = \frac{1}{4\pi\epsilon_o}(q_1 + q_2 + q_3 + q_4)$$

(77) What is the electric potential V in the center of a hexagonal charge distribution?
(a) Since charges on opposite sides cancel
$$V = 0$$
(b) Add to find
$$V = \frac{1}{4\pi\epsilon_o}\frac{6Q}{a}$$
(c) Differentiate to find
$$V = \frac{1}{4\pi\epsilon_o}\frac{6Q}{a^2}$$
(d) Intergrate to find
$$V = \frac{1}{4\pi\epsilon_o}6Q\ln a$$

(78) How would this change is we found the gravitational potential of a hexagonal distribution of planets?
(a) (Essentially) none at all.
(b) The method would be completely different.
(c) The overall constants would change but still we would have $6m/a^2$ in the result.
(d) Do we know how to do this?

(79) To find the electric potential V at a height z above a ring of charge I would
(a) 'sum up' or 'integrate up' the contribution from each little bit of the ring.
(b) find the electric field first.
(c) find the electric potential energy first.
(d) not know where to start.

(80) The speed of a positively charged particle, released from rest and traveling a distance d along the field lines of a uniform electric field $E = |\vec{E}|$ is
(a) $v = qEd$, which has a nice ring to it.
(b) $v = \sqrt{qEd}$
(c) $v = \sqrt{\frac{2qEd}{m}}$
(d) $v = \sqrt{\frac{qEd}{m}}$
(e) $v = \sqrt{\frac{mqEd}{2}}$

(81) In this demo the ping-pong ball will undergo
(a) crazy bouncing motion in which it accelerates away from the plate once it changes charge.
(b) no motion once it becomes glued to one plate due to electrostatic attraction.

(c) lazy bouncing motion in which it bounces and is attracted to the plate it just bounced off.
(d) no motion since it will be equally attracted to each plate.
(e) simple harmonic motion.

(82) I plan on taking mid-term II
(a) tomorrow.
(b) Wednesday
(c) Thursday

(83) What is the torque on the electric dipole?
(a)
$$\tau = \sum r \times F = \frac{d}{2} qE \sin\theta$$
(b)
$$\tau = \sum r \times F = -\frac{d}{2} qE \sin\theta$$
(c)
$$\tau = \sum r \times F = dqE \sin\theta$$
(d)
$$\tau = \sum r \times F = -dqE \sin\theta$$
(e) none of the above

(84) If the electric dipole was displaced a small angle away from equilibrium and released from rest is would
(a) stay put
(b) undergo SHM!
(c) move like a pendulum with large amplitude
(d) move like a student on the first day after spring break
(e) (b) and (c)

(85) In this new electric field the dipole would
(a) accelerate left and rotate.
(b) accelerate right and rotate.
(c) accelerate left in this orientation.
(d) accelerate right in this orientation.
(e) stay put and rotate.

(86) Far away the electric potential due to a dipole should fall off as
(a) - Wait, what does ‘fall off’ mean?
(b) $1/r$ since that’s what the potential of a point charge does
(c) No, $V = 0$ since the total charge is zero.

(d) $1/r^n$ with $n > 1$ since the total charge is zero so it has to fall off faster than $1/r$
(e) It's complicated, involving both θ and r, so there is no simple expression for it.
ANSWER: (d) As we saw $n = 2$.

(87) To find the energy stored in the configuration we need to
(a) 'integrate up' the contribution from each little bit charge
$$U = \int_0^Q dU$$
(b) 'integrate up' the work on each charge brought in from far away
$$U = \int F dr$$
(c) Haven't we found this already? It's
$$U = \frac{Q^2}{d}\epsilon_o A$$
(d) Haven't we found this already? It's
$$E = \frac{Q}{\epsilon_o A}$$
(e) None of the above.

(88) Since energy is stored in the electric field I'd expect waves
(a) in the electric field to move at finite speed through some local interaction.
(b) in the electric field to exist and move at infinite speed.
(c) in the electric field not to exist.
(d) in the electric field to store energy only.

(89) Shall we do a cross product review?
(a) Yes!
(b) no.

(90) The bit of magnetic field $d\mathbf{B}$ points
(a) to the left
(b) to the right
(c) to the upper left
(d) to the upper right
(e) none of the above

(91) The magnetic field points
(a) into the page

(b) out of the page
(c) up (on the page)
(d) down
(e) left
(f) right (raise your clicker for this answer)

(92) The cross product $\hat{\imath} \times \hat{k}$ is equal to
(a) $\hat{\jmath}$
(b) $\hat{\imath}$
(c) $\hat{k}$
(d) $-\hat{\jmath}$
(e) $-\hat{\imath}$

(93) On a cross product as a matrix:
(a) I haven't seen this before.
(b) I have done the determinant method of finding cross products myself
(c) Ah no. I use the right hand rule and then magnitude
(d) Well, I have seen the movie!

(94) The magnetic field lines
(a) make a box shape around the wire
(b) make a box shape with the wire on one side
(c) circle the wire
(d) end or start at the wire, like the electric field ends on a charge
(e) makes an oval shape around the wire

(95) The magnetic field lines around a loop of current look like
(a) straight lines
(b) a magnet!
(c) circles
(d) squares
(e) rombi

(96) The magnetic field lines outside solenoid looks like
(a) a bunch of straight lines - the magnetic field is uniform
(b) a magnet
(c) circles
(d) ovals-ish curves
(e) a bunch of crossed lines

(97) The magnetic force points:
(a) into the board
(b) out of the board

(c) up
(d) down
(e) left or right

(98) When we turn the current on the heavy wires will
(a) move apart
(b) move together
(c) do nothing
(d) release smoke

(99) The force on side 3 is then
(a) $\vec{F}_3 = IaB\hat{\imath}$
(b) $\vec{F}_3 = -IaB\hat{\jmath}$
(c) $\vec{F}_3 = 0$
(d) $\vec{F}_3 = IaB\hat{\jmath}$
(e) $\vec{F}_3 = -IaB\hat{\imath}$

(100) The net force on the whole loop is
(a) $\sum \vec{F} = IB(a\hat{\imath} + b\hat{\jmath})$
(b) $\sum \vec{F} = IB(-a\hat{\imath} + b\hat{\jmath})$
(c) $\sum \vec{F} = IB(a\hat{\imath} - b\hat{\jmath})$
(d) $\sum \vec{F} = IB(-a\hat{\imath} - b\hat{\jmath})$
(e) $\sum \vec{F} = 0$

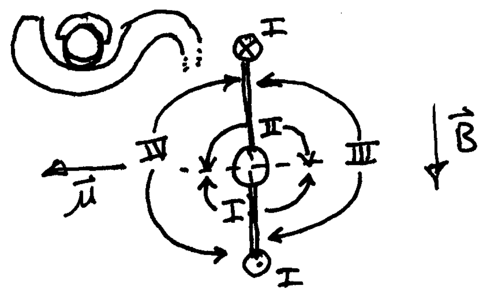
(101) The net torque on the whole loop is
(a) $\sum \vec{\tau} = IabB\sin(\theta)\hat{\jmath}$
(b) $\sum \vec{\tau} = IabB\cos(\theta)\hat{k}$
(c) $\sum \vec{\tau} = -IabB\sin(\theta)\hat{\jmath}$
(d) $\sum \vec{\tau} = IabB\cos(\theta)\hat{\imath}$
(e) $\sum \vec{\tau} = 0$

(102) If you wrap the wire, which carries current I, N times around the loop then the magnetic dipole moment and torque
(a) remain the same since $\mu = I\vec{A}$ independent of the number of windings
(b) increase by a factor of N
(c) decrease by a factor of $1/N$
(d) the moment increases but the torque remains the same
(e) change but in manner different than the above choices

(103) At an angle of $\theta = \pi/2$ the torque is
- (a) at a maximum and points out of the board
- (b) zero
- (c) at a maximum and points into the board
- (d) has a intermediate value between max and min pointing along $\hat{\jmath}$ direction.

(104) To build a continually rotating motor made from a loop in a uniformish magnetic field you can
- (a) simply attach the wire loop to a current source and let it run.
- (b) turn on and off the current at the correct times.
- (c) alternate the current, so it flows one way through the wire, then the other way.
- (d) use the non-uniform field of the magnet to attract the wire loop.
- (e) (b) or (c)

(105) To accomplish this simple solution you need to remove the insulation from the wire on which side?
(a) I
(b) II
(c) III
(d) IV
(e) (a) or (b)



ANSWER: (a)

(106) This magnetic field increases in the
(a) $\hat{\imath}$-direction
(b) $-\hat{\imath}$-direction
(c) $\hat{k}$-direction
(d) $-\hat{k}$-direction
(e) Er, no, it is actually a uniform field.

(107) This magnetic force points in the
(a) $\hat{\imath}$-direction
(b) $-\hat{\imath}$-direction
(c) $\hat{k}$-direction
(d) $-\hat{k}$-direction
(e) some other direction

(108) Working hard one day you derive the equation

$$\frac{\partial^2 \mathbf{E}}{\partial t^2} = \frac{1}{\mu_o \epsilon_o} \frac{\partial^2 \mathbf{E}}{\partial x^2}$$

What is the phase velocity?

(a)

$$v = \sqrt{\mu_o \epsilon_o}$$

(b)

$$v = \sqrt{\frac{1}{\mu_o \epsilon_o}}$$

(c)

$$v = \frac{1}{\mu_o \epsilon_o}$$

(d)

$$v = 1$$

(e) This velocity is not relevant since this is not a wave equation.

(109) For a wave on how is intensity related to wave amplitude?
(a) I is proportional to amplitude cubed, like $I \propto y_m^3$.
(b) I is proportional to amplitude squared, i.e. $I \propto y_m^2$.
(c) I is proportional to amplitude, i.e. $I \propto y_m$.
(d) I is unrelated to amplitude.

(110) Where does the image appear?
(a) At the surface of the mirror.
(b) Far away.
(c) At a distance equal to the distance of the object.
(d) This answer depends on the mirror.

(111) What is going to happen?
(a) The candle will be extinguished by the water obviously!
(b) Hmmm, what is the role of the box?
(c) Pour the water and let's see!

(112) For three polarization filters tilted at 45° from each other the amount of light passing through the collection of filters is
(a) None since two of the filters are at 90° respect to each other
(b) About $(\sqrt{2}/2)^2$ makes it through

(c) About

$$\frac{1}{2}\left(\frac{\sqrt{2}}{2}\right)^4 = \frac{1}{8}$$

makes it through
(d) Some!
(e) None since there are so many filters.

(113) When we increase the wavelength λ of the waves then
(a) nothing will happen. Ray tracing will work beautifully.
(b) nothing will happen to the rays but the wavefronts will be farther apart.
(c) wait, this is different, but I'm not sure what the difference is.
(d) rays (and geometric optics) fails and the rays *curve* away from the barrier.
(e) rays (and geometric optics) fails and the rays *curve* toward from the barrier.

(114) What do you expect to see from the light of wavelength λ passing through two slits d apart?
(a) Two bright spots. Geometric optics and ray drawings work beautifully.
(b) One big schmear.
(c) I know! I know! We're talking waves so $d \sin\theta = m\lambda$ gives the bright spots!! θ is the angular position on the distant screen.
(d) I know! I know! We're talking waves so $d \sin\theta = m\lambda$ gives the dark bands!! θ is the angular position on the distant screen.

(115) Er, this

$$I = I_o \cos^2\left(\frac{\varphi}{2}\right)$$

is not what we actually saw. What do we have to do?
(a) No idea. Let's experiment.
(b) Make our model more realistic and model the beam of light correctly.
(c) Make our model more realistic and model the finite width of the slits
(d) Let's use Huygens' principle in phasor-land.
(e) (b) and (c)
ANSWER: (e)

(116) Now, to realistically model the intensity of the double slit pattern we need to -
(a) erf?!?
(b) add up all phasors, find their magnitide and - presto! - we have the pattern.
(c) just multiple the double slit cosine times the single slit sine and - presto! - we have the pattern.
(d) just fine one bright central maximum
(e) add up two single slit phasors, find the resulting magnitude and - presto! - we have the pattern.

(117) Now, what do you see?
- (a) light and dark fringes in a uniform pattern
- (b) same as we had for a point source double-slit interference pattern
- (c) a schmear of double slit interference that fades linearly to nothing
- (d) one bright central maximum
- (e) a double slit interference pattern in an envelope of a single slit diffraction pattern

(118) I expect that the electrons will form a pattern
- (a) two distinct distributions like tennis balls or the Stern-Gerlach experiment of Guide 12.
- (b) as we expect from double slit interference and diffraction.
- (c) like a bell curve.
- (d) None of the above.

(119) What is the relative difference between the two reflected waves in wavelength and phase?
- (a) $\lambda/4$ and $\pi/4$
- (b) $\lambda/4$ and $\pi/2$
- (c) $\lambda/2$ and $\pi/4$
- (d) $\lambda/2$ and $\pi/2$
- (e) λ and π

(120) How many bright bands do you see if the ends of the glass plates are spaced $d =$48.0 μm apart and the wedge is illuminated by $\lambda = 683$ nm light?
- (a) $m = 2d/\lambda = 140$
- (b) $m = 2d/\lambda - 1/2 = 140$
- (c) $m = 2d/\lambda + 1/2 = 141$
- (d) 0 since this is too thick for interference to happen.
- (e) none of the above.

(121) In a soap film what is the *relative* phase for the two reflected rays when the film thickness is t and the color has wavelength λ?

(a)
$$\frac{2t}{\lambda}$$
since there is no phase shift

(b) Oh, same as for the air gap
$$\frac{2t}{\lambda} + \pi$$

(c)
$$\frac{2nt}{\lambda} + \pi$$
since the wavelength *in the film* is the phase change in the water

(d) Yikes! How do I derive such a relation ?!?

(122) What color is visible when white light is directly incident on a soap film of thickness 120 nm? Assume that n=1.33.

(a) $(4)(1.33)(120) \simeq 640$ nm or red-orange
(b) $(3.5)(1.33)(120) \simeq 560$ nm or yellowy-green
(c) $(3)(1.33)(120) \simeq 480$ nm or blue
(d) $(2)(1.33)(120) \simeq 320$ nm or black since we can't see that color
(e) What would m be?

(123) Best time for QLit review session?
(a) Tuesday evening
(b) Wednesday afternoon
(c) Wednesday evening
(d) Thursday afternoon
(e) Thursday evening

(124) How would you determine whether light is a wave? (one wrong answer, many correct answers)
(a) Measure its velocity.
(b) Find what is waving and check whether it satisfies the wave equation.
(c) Check that it satisfies resonance.
(d) Check whether it has constructive and destructive interference
(e) Check whether light transports energy

(125) Suppose we see a bright spot (constructive interference) from a Michelson interferometer. What happens if one mirror moves a distance $\lambda/4$?
(a) We suddenly see destructive interference - a dark spot .
(b) We still see constructive interference or a bright spot.
(c) A bunch of interference fringes go by but the result its neither complete destructive or constructive interference.
(d) The light goes dark then bright and we see constructive interference.
(e) Nothing happens.

(126) What is the general solution, which describes the angle $\theta(t)$, for a simple pendulum? Let's suppose the coordinate is θ.
(a)
$$\frac{d^2\theta}{dt^2} - \omega_o^2\theta = 0$$
(b)
$$\frac{d^2\theta}{dt^2} + \omega_o^2\theta = 0$$
(c)
$$\theta(t) = \theta_m \sin(\omega_o t + \phi)$$
(d)
$$\frac{d\theta}{dt} + \omega\theta = 0$$
(e)
$$\theta(t) = \theta_m e^{(\omega_o t + \phi)}$$

(127) MC Escher drew a reflecting ball, perhaps you are familiar with it,

Suppose the ball has a diameter of 14 cm and that Escher holds the ball about 40 cm away from is face. (The focal length is half the radius.) Did Escher make a mistake? Should the image of his hand be inverted?

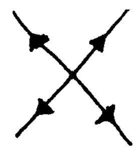
(a) Yes. The image should be inverted
(b) No. The image is correct as drawn

(128) Two identical current carrying loops, when placed close together

(a) will do nothing special
(b) will push apart
(c) will pull together
(d) one will flip and they will push apart
(e) one will flip and they will pull together

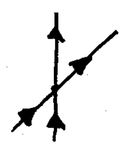
(129) When we place the object at the focal point of a concave mirror the image appears
- (a) oops! It's is gone!
- (b) at infinity.
- (c) at the other focal point.
- (d) right at the lens
- (e) on the same side as the object.

(130) If you have crossing field lines like this



then
- (a) Ooops! This field configuration is not possible.
- (b) It is a magnetic field. There is current at the intersection.
- (c) It is a electric field. There is positive charge at the intersection.
- (d) It is either a gravitational or electric field. There is mass or negative charge at the intersection.
- (e) It doesn't mean anything special.

(131) If you have crossing field lines like this



then
- (a) Ooops! This field configuration is not possible.
- (b) It is a magnetic field. There is current at the intersection.
- (c) It is a electric field. There is positive charge at the intersection.
- (d) It is either gravitational or electric. There is mass or negative charge at the intersection.
- (e) It is either gravitational or magnetic. There is mass or current at the intersection.

(132) If you have crossing field lines like this

then
(a) Ooops! This field configuration is not possible.
(b) It is a magnetic field. There is current at the intersection.
(c) It is a electric field. There is positive charge at the intersection.
(d) It is either gravitational or electric. There is mass or negative charge at the intersection.
(e) It is either gravitational or magnetic. There is mass or current at the intersection.

(133) What is this
$$\left.\frac{dU}{dx}\right|_{x_o}$$
quantity? Assume that x_o is an equilibrium point.
(a) Well that's obvious! Its's a derivative and function of x!
(b) zero
(c) the slope at any point x
(d) a non-vanishing force at the position x_o
(e) a derivative evaluated at a single point and so some number!

(134) What does
$$\left.\frac{d^2U}{dx^2}\right|_{x_o}$$
mean physically if it is positive?
(a) Nothing
(b) It determines how the potential curves at x_o.
(c) This is k_{eff} of the restoring force "$F = -k_{eff}x$"!
(d) It is a second derivative evaluated at a single position - so a number!