Waves and Fields (PHYS 195) Spring 2020

1. Clicker Questions: Oscillations

(1) 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)

(2) What is

$$\frac{d}{dt}\left[x_m \cos(\omega_o t + \varphi)\right]?$$

 (a) The velocity dx/dt is

$$-x_m \sin(\omega_o t + \varphi)$$

 (b) The velocity dx/dt is

$$x_m \omega_o \cos(\omega_o t + \varphi)$$

 (c) The velocity dx/dt is

$$-x_m \omega_o \sin(\omega_o t + \varphi)$$

 (d) The velocity dx/dt is

$$x_m \varphi \cos(\omega_o t + \varphi)$$

 ANSWER: (c)

(3) Is class (and the reading) we found that

$$x(t) = x_m \cos(\omega_o t + \varphi)$$

solved the simple harmonic equation of motion. Are there any other ways to express the solution?
 (a) No. It is unique once the initial position and velocity are specified.
 (b) Sure! $x(t) = x_m \sin(\omega_o t + \phi)$ works!
 (c) Sure! $x(t) = A\sin(\omega_o t) + B\cos(\omega_o t)$ works!
 (d) Sure! The real or imaginary parts of $x_m\, e^{i(\omega_o t + \varphi)}$ will work fine.
 (e) All of the above except (a)

ANSWER: (e)

(4) Neglecting any sort of drag or friction, is the total energy of the mass-on-a-spring oscillator constant?
 (a) Yes, since energy is conserved.
 (b) No, since the functions $x(t)$ and $v(t)$ are not constant
 (c) Yes, since the functions $x(t)$ and $v(t)$ not constant
 (d) No, since the kinetic and potential energies vary with time
ANSWER: (a)

(5) 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)

(6) 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) $E = 1/2m\omega_o^2 x_m^2$
 (d) $E = 0$
ANSWER: (c) is best

(7) In SHM what is the energy *always*?
 (a) $E = 1/2mv^2$
 (b) $E = 1/2kx^2$
 (c) $E = 1/2m\omega_o^2 x_m^2$
 (d) $E = 0$
 (e) ?!? Energy depends on initial conditions, doesn't it??
ANSWER: (c)

(8) 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)

(9) What is the equation of motion for a pendulum oscillating with a small angular amplitude?

(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: (a)

(10) 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 (although I have a soft spot for c)

(11) 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

(12) 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)

(13) 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

(14) Why are all these systems oscillating in the same way?
  (a) That's just what this select group of examples does - nothing more to it!
  (b) That is just what systems in motion around a stable equilibrium do!
  (c) There seems to be an element of universality in all this - but I don't see why...
  (d) Oscillators oscillate. Is there anything more to this?
  ANSWER: (b)

(15) What does the constant

$$U(x_o)$$

mean physically? (i.e. What does it do for the dynamics of a system?)
  (a) It doesn't have a physical meaning - 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 determines the motion
  (d) It tells me how many joules of energy I have at x_o.
  (e) It has a physical meaning - only I can't recall what it is...
  ANSWER: (a)

(16) 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) It is 0.
(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 non-vanishing number!
ANSWER: (b)

(17) What does

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

mean physically? Assume that x_o is a stable equilibrium point.
(a) Nothing
(b) It determines how the number of ewes changes as you move away from the valley at x_o.
(c) It is a second derivative evaluated at a single position - so a number!
(d) It determines the slope at x_o.
(e) It is k_{eff}!
ANSWER: (e)

(18) Since

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

what is k_{eff} for

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

(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)

(19) How do we find k_{eff} for this potential?
(a) Take derivatives! And

$$k_{eff} = \frac{d^2U}{dx^2}$$

(b) Yes, take derivatives but first find the equilibrium point(s), then find k_{eff} at the stable equilibrium point via the second derivative.
(c) I am not sure.
(d) I don't know what is going on. How are U and k related physically?
ANSWER: (b)

(20) 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

(21) 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 amplitude function, like this
$$x(t) = A(t) \cdot x_{\text{SHM}}(t)$$
and find $A(t)$.
(c)
$$x(t) = e^{-\beta t} x_{\text{SHM}}(t)$$
and we'll find check that everything works.
(d)
$$x(t) = x_m e^{-\beta t} \cos(\omega t + \varphi)$$
(e) I'm not sure.
ANSWER: We used (d) and it worked when $\omega = \omega_d = \sqrt{\omega_o^2 - \beta^2}$.

(22) To find the coefficient β from the initial amplitude $A(0)$ and the amplitude at $t = 10.5$ s, $A(10.5)$, we can:

(a) First, use the general solutions to set

$$A(10.5s) = x_m e^{-\beta(10.5)} \cos(\omega_d \cdot 10.5 + \phi).$$

Second, solve for β.

(b) Find β using

$$\frac{A(0)}{A(10.5s)} = \frac{x_m}{x_m e^{-\beta t}}$$

(c) Just use $b = 2m\beta$.

(d) Set the solution to half the amplitude $x_m/2$ at $t_* = 10.5$ s and solve for β.

(e) Can you remind me what thsi coefficient is?

The mass is $m = 106$ g.

ANSWER: (b)

(23) What are you about to see? The glider starts from equilibrium, what do you expect for the solution '$x(t)$'?

(a) The motor is not connected directly to the glider so it just stays there; $x(t) = 0$.

(b) It begins to move a bit then settles down to equilibrium at $x(t) = 0$ at late times.

(c) After some time it looks like SHM with a decreasing amplitude.

(d) At first it looks like SHM with a increasing amplitude, then just like SHM, in fact

$$x(t) = A\cos(\omega_D + \text{ some phase}).$$

(e) It looks like SHM with an ever increasing amplitude.

ANSWER: (d) is best

(24) What are you about to see? What do you expect for the solution '$x(t)$' when the glider starts away from equilibrium?
(a) There will be some funny stuff at the start then it will settle into SHM oscillating at the driving angular frequency ω.
(b) There will be some funny stuff at the start then it will settle into SHM oscillating at ω_o.
(c) It will be SHM with an increasing amplitude.
(d) At first 'wha-wha'-like motion then it will settle into SHM.
ANSWER: (a) and (d) are best

(25) 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

(26) 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 and restores the object toward equilibrium
(c) that is usually quadratic, like this -

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

(d) Hmm, I'm not sure. How could we know something about buildings like office towers?
ANSWER: (b)

(27) 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)

(28) The Citiccorp building has a resonant period of about 6.5 s. If the mass of the oscillator is 3.7×10^5 kg then what is the spring constant k_{eff}, roughly?
(a) 3.4×10^5 N/m
(b) 5.4×10^4 N/m
(c) 8.7×10^3 N/m
(d) None of the above

(29) For tuned mass dampers what sort of motion should you select?
(a) lightly damped oscillation
(b) critically damped motion
(c) over-damped motion
(d) None of the above
ANSWER: (b)

(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 the point of the paperclips on the right mass?
(a) They perform no substantial role.
(b) For tuning to ω_o of the left mass.
(c) For de-tuning from ω_o of the center mass.
(d) For tuning to ω_o of the support.
ANSWER: (b)

(33) 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)

(34) What is going to happen?
(a) All the masses will start to move but only when the oscillation reaches them
(b) We'll see the first mass oscillate all by itself.
(c) Right away all the masses will oscillate together since they are connected.
(d) The masses will wiggle in some more or less random way.

ANSWER: (a)

(35) 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)

(36) 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)

(37) 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) and (a)!

(38) We found a trial solution for the wave equation, which is on the board. How shall we check this?
(a) Take lots of partial derivatives! Once we found the first three non-vanishing terms we'll know.
(b) Oh! We substitute $y(x, t)$ into the wave equation and check whether the equation is satisfied.
(c) We know this SHM in space and time works already. In checking it we won't learn anything new.
(d) See it if describes all waves by plotting it.
(e) None of the above
ANSWER: (b)

(39) We found a solution for the wave equation. Are there other solutions?
   (a) Sure! The other one is $y(x,t) = y_m \cos(kx - \omega t)$.
   (b) Oh yes! For instance *any* function of $kx \pm \omega t$, $f(kx \pm \omega t)$ will work - as long as the k, v, ω condition is met.
   (c) Nope! This expression of simple harmonic motion in space and time is all we have.
   (d) No. This right moving wave is the only solution.
   ANSWER: (b)

(40) 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)

(41) What is going to happen as I stop the first tuning fork?
   (a) We'll hear nothing after the first tuning fork is stopped.
   (b) We'll hear the second tuning fork because they are in resonance and the energy transferred from the first to the second. The sound will fade away as the energy in the second fork dissipates and travels to our ears.
   (c) I'm not sure.
   ANSWER: (b)

(42) 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.

(43) 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)

(44) 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: (c)

(45) Neglecting damping every system set in motion around a stable equilibrium point, will
(a) undergo exponential decay to equilibrium
(b) undergo simple harmonic motion
(c) wiggle continuously
since the potential is always in the form of

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

in that neighborhood. ANSWER: (b) is best

(46) When the wave pulse arrives at the end what is going to happen?
(a) Nothing special. It keeps on going.
(b) The wave pulse reflects upright, without a phase shift.
(c) The wave pulse reflects inverted, with a phase shift of π.
(d) The wave pulse reflects with a phase shift of $\pi/2$.
(e) We'll hear a nice sound from this high Q system.
ANSWER: depends on boundary condition

(47) What are the resonant frequencies for waves on a string with two fixed ends? With $n = 1, 2, 3 \ldots,$
(a) $f_n = \frac{nv}{L}$
(b) $f_n = \frac{3nv}{2L}$.
(c) $f_n = \frac{nv}{2L}$.
(d) $f_n = \frac{4nv}{2L}$.
(e) None of the above.
ANSWER: (c)

(48) By turning the knob to wrap more string around the axle we expect
(a) the effective length to decrease and the frequency to increase
(b) the effective length to increase and the frequency to decrease
(c) the tension to increase and the frequency to increase
(d) the tension to decrease and the frequency to decrease
(e) the tension to increase and the frequency to decrease
ANSWER: (c)

(49) By pressing the string down on a fret we expect
(a) the effective length to decrease and the frequency to increase
(b) the effective length to increase and the frequency to decrease
(c) the tension to increase and the frequency to increase
(d) the tension to decrease and the frequency to decrease
(e) the tension to increase and the frequency to decrease

ANSWER: (a)

(50) 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.

(51) 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
ANSWER: (d)

(52) 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.
ANSWER: (e)

(53) 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.