

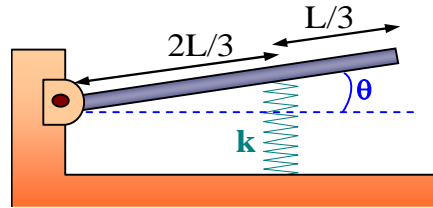
PHYSICS 213

Exam #1

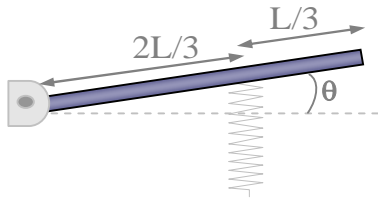
NAME _____

Please write down your name **also** on the back side of the last page

- 1 The figure shows a horizontal planks of length $L=50$ cm, and mass $M= 1$ Kg, pivoted at one end. The planks' is also supported by a spring at $2/3$ of its length, as shown in the figure; the spring constant has a value of $k=10$ N/cm. The spring is neither compressed nor stretched when the plank is horizontal. Assume that the plank undergoes small amplitude oscillations?



- 1.A Draw the corresponding free body diagram for the plank (Indicate explicitly all the forces acting on the plank, draw the corresponding arrows representing them, and name them properly).



- 1.B Indicate also the magnitude of the torque (calculated around the pivot point) produced by each of the forces when $\theta = 0.01$ radians.

Torque 1: _____

Torque 2: _____

Torque 3: _____

-
- 2 Consider the same mechanical system described in question #1 above.

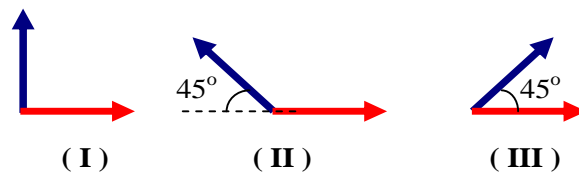
- 2.A The frequency of the small oscillations is (in Hz)

a) 0.7 b) 6.0×10^{-2} c) 5.8 d) 4.1×10^{-2} e) NA

- 2.B Neglecting the effects of friction, if this mechanical system were to be taken to the Moon, the period of the small oscillations would

a) increase b) decrease c) remain the same as in the Earth
d) there is no enough information to decide

3. The figure shows phasor diagrams for three situations in which two waves travel along the same string and in the same direction. (All the individual waves in the diagram have the same amplitude).



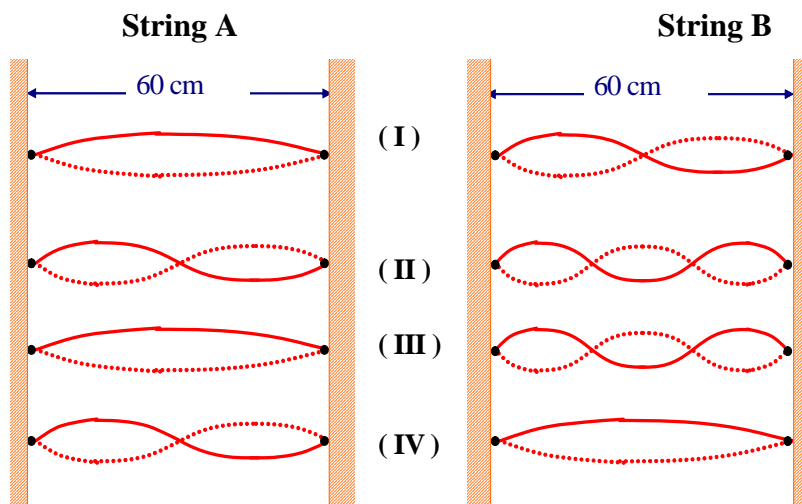
- 3A. Rank the three situations according to the amplitude of the net wave on the string, greatest first.

a) III, I, II b) II, I, III c) II, III, I d) I, II, III e) NA

- 3B. Consider the case (I) described above. If one of the waves is described by $y_1(x,t) = 3\text{cm} \cos(0.25 \text{ cm}^{-1} x - 16\text{s}^{-1} t)$, provide an expression for the net wave

ANSWER: $y(x,t) = 4.2 \text{ cm} \cos(0.25 \text{ cm}^{-1} x - 16\text{s}^{-1} t + \pi/4)$

4. Strings A and B have identical length and linear mass density, but string B is under greater tension than string A. The figure shows four situations, (I) through (IV), in which standing waves patterns exist on the two strings.



- 4A. In which situation(s) is there the possibility that strings A and B are oscillating at the same resonant frequency?

Answer:

- 4B. Consider string B. If the resonance frequency in case (I) is 60 Hz, what is the resonance frequency for case (II)?

- a) 120 Hz **b) 90 Hz** c) 30 Hz d) 40 Hz e) NA

5. The radar unit in a police car sends out electromagnetic waves of frequency $f_0 = 1.5 \times 10^9$ Hz that travel at the speed of light $c = 300,000$ Km/s. The waves reflect from a speeding car moving at speed u away from the police.

5A. If the police detects a change of frequency equal to $\Delta f = 500$ Hz, was the car speeding up? (Consider speed limits of 70 mi/h; 1 mi = 1.609 Km). Do not consider the relativistic correction.

5B. If the car's speed is $u = 18$ Km/h, what would be the change in frequency Δf detected by a radar attached to that car? Do not consider the relativistic correction.

- a) 70 Hz b) 100 Hz c) 35 Hz **d) 50 Hz** e) NA

6. When middle C on the piano (frequency 262 Hz) is struck, it loses half its energy after 4 seconds.

6A What is the decay time constant τ (in seconds)?

- a) 3.2 b) 9.1 **c) 5.8** d) 4 e) NA

6B What is the Q factor for this piano wire?

- a) 200 **b) 9500** c) 720 d) 4300 e) NA

7. An object of mass 1.5 Kg on a spring of force constant 600 N/m loses 3% of its energy in each cycle. The system is driven by a sinusoidal force with a maximum value of $F_0 = 0.5$ Newtons.

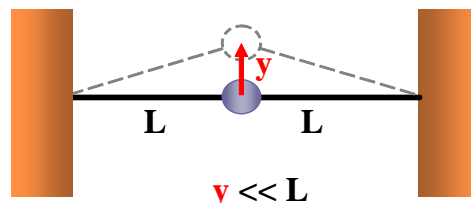
7A What is the Q factor for this system?

- a) 210** b) 6507 c) 572 d) 31 e) NA

7B What is the energy resonance frequency ω_{res} (in rad/sec)?

- a) 49 b) 523 **c) 20** d) 3103 e) NA

8. A ball of mass m is connected to two



rubber bands of length L , each under tension T . The ball is displaced by a small distance y perpendicular to the length of the rubber bands. Assuming that the tension does not change and that $y \ll L$, find out:

8A The restoring force acting on the mass

a) $-\sqrt{\frac{T^2}{6L^4}} y^2$ b) $-\frac{L}{3T} y$ c) $-\sqrt{\frac{2y}{L}} T$ **d) $-\frac{2T}{L} y$** e) NA

8B The angular frequency of the harmonic motion

a) $\omega_0 = \sqrt{\frac{6T}{m}} L$ **b) $\omega_0 = \sqrt{\frac{2T}{mL}}$** c) $\omega_0 = \sqrt{\frac{T}{m}}$
 d) $\omega_0 = 2\pi\sqrt{\frac{mL}{6T}}$ e) NA

9. Waves along a particular string of uniform linear mass density are described by the following Wave Equation $\frac{\partial^2 y}{\partial x^2} - \frac{1}{(2 \text{ m/s})^2} \frac{\partial^2 y}{\partial t^2} = 0$, where all the quantities are expressed in MKS system.

9A Which of the following waves is (are) solutions of the wave equation given above?

- a) $y_1 = 12 \text{ SIN}(4x - 2t)$,
- b) $y_2 = 5 \text{ COS}(6x - 0.3t)$,
- c) $y_3 = \text{SIN}(2x + 1.0t)$
- d) None of the above waves satisfy the given wave equation**

9B If the tension and the linear mass density of the string are kept constant, which of the following expressions is true?

- a) Waves of higher frequency travel faster than the waves of lower frequency
- b) The higher the frequency of the wave, the greater its wavelength
- c) The speed of the wave depends on its wavelength. The greater the wavelength the slower the wave.
- d) All the statements above are incorrect.**

BONUS QUESTION (5 extra points if answered correctly)

The diagram shows a pendulum at a point in its swing at which it is moving with speed v . Which **arrow** correctly shows the direction of its **acceleration** ?

FORMULAS THAT MIGHT HELP

$$\omega = 2\pi f$$

$$\cos(A) + \cos(B) = 2 \cos\left(\frac{A+B}{2}\right) \cos\left(\frac{A-B}{2}\right)$$

Simple Pendulum: Period $T = 2\pi \sqrt{\frac{L}{g}}$ Use $g = 10 \text{ m/s}^2$ in this exam

Physical Pendulum: Period $T = 2\pi \sqrt{\frac{I}{mgh}}$ Use $g = 10 \text{ m/s}^2$ in this exam
Where h is the distance from the pivot to the center of mass

Momentum of inertia:

Thin bar of length L $I_{CM} = \frac{1}{12} ML^2$ (Axis perpendicular to the bar)

Disk of radius R $I_{CM} = \frac{1}{2} MR^2$ (Axis perpendicular to the plane of the disk)

Damped simple harmonic oscillator $\frac{d^2x}{dt^2} + \frac{b}{m} \frac{dx}{dt} + \frac{k}{m} x = 0$

Solution: $x(t) = Ae^{-\alpha t} \cos(\omega t + \phi)$

where $\alpha = \frac{b}{2m}$ $\omega^2 = \omega_0^2 - \left(\frac{b}{2m}\right)^2$

and $\omega_0 = \sqrt{\frac{k}{m}}$ is the natural frequency of the oscillator (in rad/sec)

Quality factor: $Q = \frac{m}{b} \omega_0$

In terms of Q, the solution to the damped simple harmonic oscillator is:

$$x(t) = A e^{\left(-\frac{\omega_0}{2Q}t\right)} \cos(\omega t + \phi)$$

Waves traveling along a string: speed $v = \sqrt{\frac{T}{\mu}}$, where T is the tension and μ is the linear mass density.

The Wave Equation $\frac{\partial^2 Y}{\partial x^2} - \frac{1}{v^2} \frac{\partial^2 Y}{\partial t^2} = 0$

Doppler Effect

- **OBSERVER stationary and SOURCE in motion approaching the Observer with speed u**

$$f_A = \underbrace{\sqrt{1 - \left(\frac{u}{c}\right)^2}}_{\text{Re relativistic correction}} \frac{1}{\left(1 - \frac{u}{c}\right)} f_B$$

- **OBSERVER in motion with speed u and approaching a SOURCE stationary**

$$f_A = \left(\frac{1}{\underbrace{\sqrt{1 - \left(\frac{u}{c}\right)^2}}_{\text{Re relativistic correction}}} \right) \left(1 + \frac{u}{c} \right) f_B$$

Electromagnetic waves

$$\frac{E}{B} = c$$

Snell's law

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$$
