2-2A-1

PHYS 101 Midterm examination #2 (vers. 2A)

15 Nov., 2002 Name Key .

Time: 50 minutes Student No._____

For questions 2 and 3, please show complete solutions and explain your reasoning, stating any principles that you have used.

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1 (10 marks). For each of the following five questions, please circle one answer only.

(i) A disk, a hoop, and a solid sphere are released at the same time at the top of an inclined plane. They all roll without slipping. In what order do they reach the bottom?

(b)
a. disk, hoop, sphere
b. sphere, disk, hoop
c. hoop, sphere, disk
d. hoop, disk, sphere
e. They all reach the bottom at the same time.

$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$. 

$\omega = \frac{v}{r}$. $v^2 = 2gh \Big/ \left(1 + \frac{I}{mr^2}\right)$

The smaller the I/mr^2, the faster.

(ii) A figure skater is spinning slowly with arms outstretched. She brings her arms in close to her body and her moment of inertia decreases by 1/2. By what factor does her rotational kinetic energy change?

(d)
a. 8
b. 4
c. $\sqrt{2}$
d. 2
e. 1

$L_f = L_i$.

$I_f \omega_f = I_i \omega_i$.

Now: $I_f / I_i = \frac{1}{2}$.

$K_f = \frac{1}{2} I_f \omega_f^2$, $K_{in} = \frac{1}{2} I_i \omega_i^2$

$K_f / K_i = \frac{I_f \omega_f^2}{I_i \omega_i^2} = \frac{\omega_f}{\omega_i} = \frac{I_i}{I_f} = 2$

(iii) For a simple harmonic oscillator, if the frequency is doubled and the amplitude tripled, by what factor does the maximum speed change?

(a)
a. 6
b. 12
c. 4
d. 3
e. 2

$v_{max} = A\omega$.

$v'_{max} = (3A)(2\omega) = 6A\omega = 6 v_{max}$

(iv) The vertical displacement of a string is given by y(x,t) = 0.006 cos(3.25x - 7.22 t), where all quantities are in SI units. What is the wavelength of the wave?

(a)
a. 1.93 m
b. 0.870 m
c. 0.308 m
d. 0.139 m
e. 2.22 m

$y(x,t) = A \cdot \cos(kx - \omega t)$.

$k = \frac{2\pi}{\lambda} = 3.25$. $\lambda = \frac{2\pi}{3.25} = 1.93$ m.

(v) By what amount does the intensity level decrease when you triple your distance from a source of sound?

(e)
a. 4.0 dB
b. 4.8 dB
c. 6.0 dB
d. 3.0 dB
e. 9.5 dB

$\beta = 10 \log_{10}\left(\frac{I}{I_0}\right)$.

$\beta_1 = 10 \log_{10}\left(\frac{I_1}{I_0}\right)$

$\beta_2 = 10 \log_{10}\left(\frac{I_2}{I_0}\right)$

$\Delta\beta = \beta_2 - \beta_1 = 10 \log_{10}\left(\frac{I_2}{I_1}\right)$.

$I_1 = \frac{P}{4\pi r_1^2}$, $I_2 = \frac{P}{4\pi r_2^2}$.

$= \frac{P}{4\pi (3r_1)^2}$

$= \frac{1}{9} \frac{P}{4\pi r_1^2} = \frac{I_1}{9}$.

$\therefore$ $\Delta\beta = 10 \log_{10}\left(\frac{1}{9}\right) = -9.5$ dB.

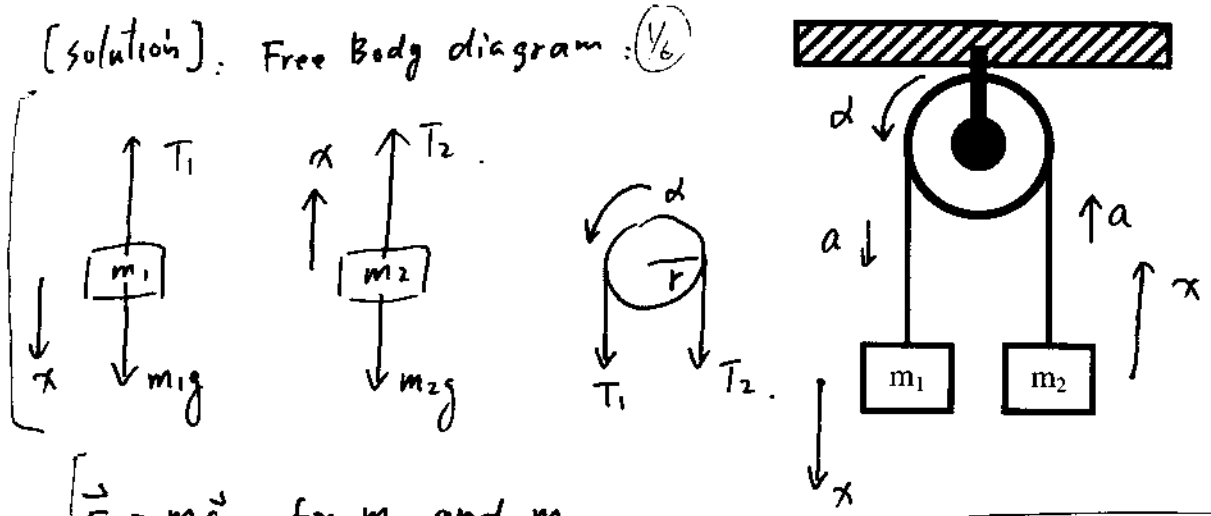
"-" means decreasing.

2 (6 marks). A mass of 375 g hangs from one end of a string that goes over a pulley with a moment of inertia of 0.0125 kg·m^2 and a radius of 15.0 cm. A mass of 800 g hangs from the other end. When the masses are released, the larger mass accelerates downward, the lighter mass accelerates upward, and the pulley turns without the string slipping on the pulley.

(a) What is the tension in the string on the side of the 800-g mass?

(b) What is the angular acceleration of the pulley?

[solution]: Free Body diagram: (1/6)



$\vec{F} = m\vec{a}$ for m_1 and m_2:

(1/6) $\begin{cases} m_1 g - T_1 = m_1 a \quad ① \\ T_2 - m_2 g = m_2 a \quad ② \end{cases}$

$\vec{\tau} = I\vec{\alpha}$ for the pulley:

(1/6) $\begin{cases} T_1 r - T_2 r = I\alpha \quad ③ \\ a = \alpha r \quad ④ \end{cases}$

①+②:

$(m_1 - m_2)g + (T_2 - T_1) = (m_1 + m_2)a$

④ ⇒ ③: $T_1 - T_2 = \dfrac{Ia}{r^2}$

Then: $(m_1 - m_2)g - \dfrac{Ia}{r^2} = (m_1 + m_2)a$

(1/6)
$$a = \frac{(m_1 - m_2)g}{m_1 + m_2 + \frac{I}{r^2}} = \frac{(0.8 - 0.375)(9.8)}{0.8 + 0.375 + \frac{0.0125}{(0.15)^2}} = 2.41 \ m/s^2$$

a): (1/6) from ①,

$T_1 = m_1(g - a)$

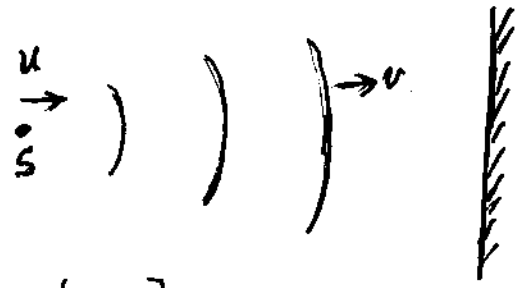
$= (0.8)(9.8 - 2.41)$

$= 5.91 \ N$

b): (1/6)
$$\alpha = \frac{a}{r} = \frac{2.41}{0.15} = 16.1 \ rad/s^2$$

3 (4 marks). A bat emits a sound at a frequency of 35.0 kHz as it approaches a wall. The bat detects beats with a frequency of 827 Hz between the sound it emits and the echo bouncing from the wall. What is the speed of the bat? The speed of sound in air is 343 m/s.

[Solution]:



To the wall, the bat is a moving source, i.e.:

(1/4) $f' = f/(1-u/v)$. [approaching]

Then, when the bat receives the reflected wave, the bat is a moving observer. i.e, [also approaching]

(1/4) $f'' = f'(1+u/v) = f(1+u/v)/(1-u/v)$.

The frequency of beat:

(1/4) $f_B = f'' - f = f\left[\frac{1+u/v}{1-u/v} - 1\right] = f\,\frac{2u/v}{1-u/v}$

$f_B(1-\frac{u}{v}) = 2f\,u/v$.

$v f_B - f_B u = 2fu$.

(1/4) $u = \frac{v f_B}{2f + f_B} = \frac{(343\ m/s)\cdot(827\ Hz)}{(2)(3.5\times10^4\ Hz)+(827\ Hz)} = 4.00\ m/s$.