UNIVERSITY OF GAZIANTEP
DEPARTMENT OF ENGINEERING PHYSICS
EP 105 General Physics I
Final Exam Questions
25/01/2006 - Duration 100 min.

Ques.	Mark
1	
2	
3	
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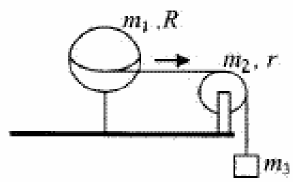
6	
Total	
Out of	100 %

Name	Surname	Dep.	Signature
	Solutions !		

- The steps of solution of each problem should be shown clearly in the space provided.
- Write your answers in boxes provided, otherwise your answer will not be considered.
- Useful constants: $g = 9.8\ m/s^2$, sin30=cos60=0.5, sin60=cos30=0.866

QUESTION [1] (25%)

A uniform spherical shell rotates about a vertical axis on frictionless bearings. A light cord passes around the equator of the shell, over a pulley, and is attached to a small object that is otherwise free to fall under the influence of gravity. What is the speed of the object after it has fallen a distance h from rest? Use energy methods. Take $h = 20$ cm, $m_1 = 3$ kg, $m_2 = m_3 = 2$ kg. (For spherical shell $I_s = 2m_1R^2/3$ and for a pulley $I_p = m_2 r^2/2$)

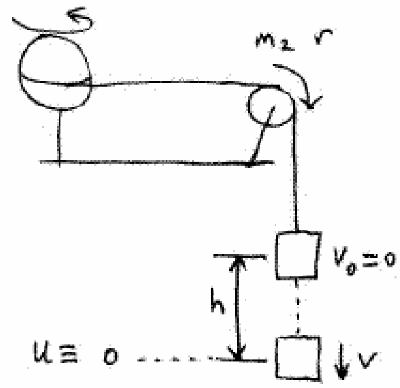


Conservation of energy:

$$m_3 g h = \frac{1}{2} I_1 w_1^2 + \frac{1}{2} I_2 w_2^2 + \frac{1}{2} m_3 v^2$$

$$= \frac{1}{2}\left(\frac{2}{3} m_1 R^2\right)\left(\frac{v}{R}\right)^2 + \frac{1}{2}\left(\frac{m_2 r^2}{2}\right)\left(\frac{v}{r}\right)^2 + \frac{1}{2} m_3 v^2$$

$$= \frac{m_1 v^2}{3} + \frac{m_2 v^2}{4} + \frac{m_3 v^2}{2}$$



Solving for v:

$$v = \sqrt{\frac{m_3 g h}{\frac{m_1}{3} + \frac{m_2}{4} + \frac{m_3}{2}}}$$

$$= \sqrt{\frac{(2)(9.8)(0.2)}{\frac{3}{3} + \frac{2}{4} + \frac{2}{2}}}$$

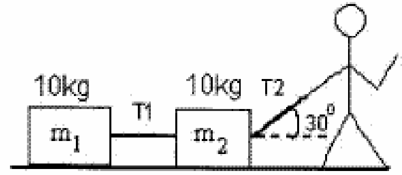
$$= 1.25\ m/s$$

$v =$ 1.25 m/s

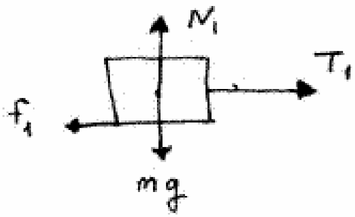
26/01/2006

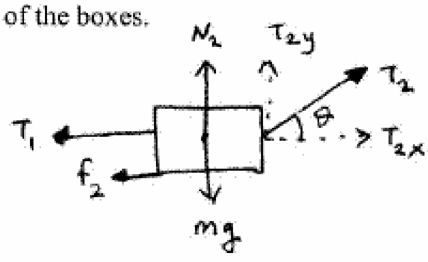
QUESTION [2] (25%)

You see you friend pulling pairs of $m_1 = m_2 = m = 10$ kg experiment-set-up boxes across the floor with an inflexible string that is making an angle of 30^0 horizontally. There is kinetic friction coefficient, 0.1, between each box and the ground and the boxes are accelerating at 2.0 m/s^2.



(a) Draw the free body diagram of each of the boxes.





$T_{2x} = T_2 \cos\theta$

$T_{2y} = T_2 \sin\theta$

$N_1 = mg$ $\qquad$ $N_2 = mg - T_{2y}$

(b) What is the tension on the rope that is between two boxes (T_1)?

Newton's 2nd law for m_1:

$$\left.\begin{aligned} T_1 - f_1 &= ma \\ T_1 - \mu m g &= ma \end{aligned}\right\} \rightarrow T_1 = m(a + \mu g)$$

$$= 10\,(2 + (0.1)(9.8))$$

$$= 29.8\ N$$

$T_1 = 29.8\ N$

(c) What is the tension on the rope of which one end is connected to first box and the other one is at your friend's hand (T_2)?

Newton's 2nd law for m_2:

$$T_{2x} - T_1 - f_2 = ma$$

$$T_2 \cos\theta - ma - \mu m g - \mu(mg - T_2 \sin\theta) = ma$$

Solving for T_2:

$$T_2 = \frac{2m(a + \mu g)}{\cos\theta + \mu \sin\theta} = \frac{(2)(10)[2 + (0.1)(9.8)]}{\cos 30 + (0.1)\sin 30}$$

$$T_2 = 65\ N$$

$T_2 = 65\ N$

26 / 01 / 2006

QUESTION [3] (25%)
A block of mass 0.1 kg moves under the action of elastic force. Initial position of system at $x = 0$ corresponds to the instant of time $t = 0$ s. At $t = 1$ s system position is $x = 2$ cm and system acceleration is 1 m/s^2.

(a) Calculate the force constant

at $t = 1$ s $a = 1\ m/s^2$ and $x = 2\text{cm} = 0.02\ m$

$$F = ma = |-kx| \rightarrow k = \frac{ma}{x} = \frac{(0.1)(1)}{0.02}$$

$$= 5\ N/m$$

$k =$ 5 N/m

(b) Find the force acting on the block at $x = -2$ cm

$$F = -kx = -(5)(-0.02)$$

$$= 0.1\ N$$

$F =$ 0.1 N

(c) Find the potential and kinetic energies at $x = 2$ cm if maximum potential energy is 10^{-2} J.

mechanical energy:

$$E = U_{max} = 10^{-2}\ J$$

at $\underline{x = 2cm}$: $U = \frac{1}{2} kx^2 = \frac{1}{2}(5)(0.02)^2 = 10^{-3}\ J$

$$K = U_{max} - U \qquad (\text{since } E = K + U)$$

$$= 10^{-2} - 10^{-3}$$

$$= 9 \times 10^{-3}\ J$$

$K =$ 9×10^{-3} J
$U =$ 1×10^{-3} J

QUESTION [4] (25%)

A particle oscillates about $x = 0$ on the x-axis and its displacement is given by

$$x(t) = (10\text{ cm})\cos(4t + \pi/2)$$

where t is measured in seconds.

(a) What is the period of the oscillation?

$$x = A\cos(\omega t + \phi), \quad x = 10\cos\left(4t + \tfrac{\pi}{2}\right) \;\rightarrow\; A = 10\text{ cm}, \quad \omega = 4\text{ rad/s}, \quad \phi = \pi/2$$

period:

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{4} = \frac{\pi}{2} \approx 1.57\text{ s}$$

$$\boxed{T = 1.57\text{ s}}$$

(b) What is the velocity of the particle at $x = 5$ cm?

at $x = A \rightarrow K = 0$ and $U = U_{max} = \frac{1}{2}kA^2 = E$

$$E = K + U$$

$$\frac{1}{2}kA^2 = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$$

$$\Rightarrow v^2 = \frac{k}{m}(A^2 - x^2)$$

since $\omega^2 = k/m$

$$v = \mp\,\omega\sqrt{A^2 - x^2} = \mp\,4\sqrt{(0.1)^2 - (0.05)^2} = \mp\,0.35\text{ m/s}$$

$$\boxed{v = \mp\,0.35\text{ m/s}}$$

(c) Find a value of x such that kinetic energy of the particle is equal to its potential energy

$$\frac{1}{2}kx^2 = \frac{1}{2}mv^2 = \frac{1}{2}m\left[\frac{k}{m}(A^2 - x^2)\right] = \frac{1}{2}kA^2 - \frac{1}{2}kx^2$$

solving for x^2:

$$x^2 = \frac{A^2}{2}$$

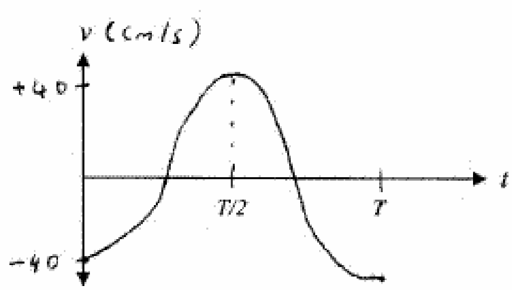
$$x = \mp\frac{A}{\sqrt{2}} = \mp\frac{10\text{ cm}}{\sqrt{2}} = \mp\,7.07\text{ cm}$$

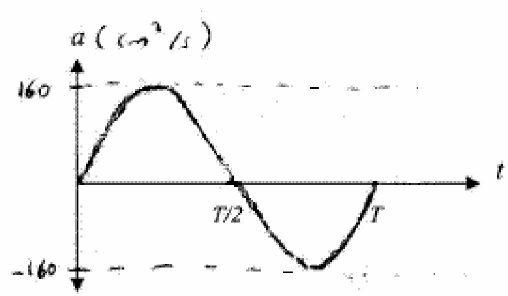
$$\boxed{x = \mp\,7.07\text{ cm}}$$

(d) Express velocity and acceleration of the particle as a function of time and plot velocity versus time (v-t) and acceleration versus time (a-t) graphs of the block

$$v = \frac{dx}{dt} = \frac{d}{dt}\left[10\cos(4t + \pi/2)\right] = -(40\text{ cm/s})\sin(4t + \pi/2)$$

$$a = \frac{dv}{dt} = \frac{d}{dt}\left[-40\sin(4t + \pi/2)\right] = -(160\text{ cm/s}^2)\cos(4t + \pi/2)$$





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