EXAM 2 [FORM - A]
PHYS-2050 (KALDON-17)
SUMMER I 2006
WMU

PHYS-2050 (Kaldon-20619)
Name ____________________________ S O L U T I O N ____________________________
WMU-Summer I 2006
Exam 2A - 100,000 points + 20,000 √ points
Book Title ____________________________
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State Any Assumptions You Need To Make – Show All Work – Circle Any Final Answers
Use Your Time Wisely – Work on What You Can – Be Sure to Write Down Equations
Feel Free to Ask Any Questions

Problem One – “The One That Goes Up and Down” (35,000 points)
1.) (a) A cargo elevator at an open mine shaft is being pulled on by means of
a rope. Draw the Free Body Diagram of the loaded elevator car at rest.
Assume all the cable tensions are the same.

(b) The weight of the loaded elevator at rest is 10,500 N. With what force must the guy pull on the rope?

\[ \sum F_y = 3T_i - w = 0 \]
\[ 3T_i = w \]
\[ T_i = \frac{w}{3} = \frac{10,500 \text{ N}}{3} = 3500 \text{ N} \]

(c) If the elevator is to be lowered at 1.11 m/s², with what force must the guy pull on the rope?

\[ w = mg \]
\[ m = \frac{w}{g} = \frac{10,500 \text{ N}}{9.81 \text{ m/s}^2} = 1070 \text{ kg} \]
\[ \sum F_y = 3T_i - w = ma_y \]
\[ 3T_i = w + ma_y \]
\[ T_i = \frac{w + ma_y}{3} = \frac{10,500 \text{ N} + (1070 \text{ kg})(-1.11 \text{ m/s}^2)}{3} = 3104 \text{ N} \]

(d) If the elevator is to be lowered at 1.11 m/s, with what force must the guy pull on the rope?

\[ \sum F_y = 3T_i - w = 0 \]
\[ 3T_i = w \]
\[ T_i = \frac{w}{3} = \frac{10,500 \text{ N}}{3} = 3500 \text{ N} \]

Same answer as (b)!
(e) If there was no air resistance, then the elevator would be in free fall the whole way. Use conservation of energy to find the speed of the elevator after it has fallen 933 meters.

NOTE: Missing part of the sentence here! If the cable breaks and there was no air resistance…

\[
mgh_i + \frac{1}{2}mv_i^2 = mgh_f + \frac{1}{2}mv_f^2
\]

\[
mgh_i = \frac{1}{2}mv_i^2
\]

\[
gh_i = \frac{1}{2}v_i^2
\]

\[
v_i^2 = 2gh_i
\]

\[
v_2 = \sqrt{2gh_i}
\]

\[
= \sqrt{2(9.81m/s^2)(933m)}
\]

\[
= 135.3m/s
\]

NOTE: OK if student starts with \(v_1 = -1.11\) m/s from part (d) rather than from rest…

\[
mgh_i + \frac{1}{2}mv_i^2 = mgh_f + \frac{1}{2}mv_f^2 ; h_f = 0
\]

\[
mgh_i + \frac{1}{2}mv_i^2 = \frac{1}{2}mv_f^2
\]

\[
gh_i + \frac{1}{2}v_i^2 = \frac{1}{2}v_f^2
\]

\[
v_f^2 = 2gh_i + v_i^2
\]

\[
v_f = \sqrt{2gh_i + v_i^2}
\]

\[
= \sqrt{2(9.81m/s^2)(933m) + (-1.11m/s)^2}
\]

\[
= 135.3m/s
\]
A (c) A block of mass \( m = 1.00 \text{ kg} \) starts out at rest at a position \( x_0 = 4.00 \text{ meters} \), and moves with a force \( F_x(t) = \left(20.0 \frac{m}{s^2}\right)t^2 \). Find the position \( x \) of the block after 5.00 seconds. Assume any other constants are zero.

\[
F_x(t) = \left(20.0 \frac{m}{s^2}\right)t^2
\]

\[
F_x = ma_x
\]

\[
a_x = \frac{F_x}{m} = \frac{\left(20.0 \frac{m}{s^2}\right)t^2}{1.00 \text{kg}} = (20.0 \text{m/s}^2)t^2 = \frac{d^2 x}{d t^2}
\]

\[
v_x = \frac{d x}{d t} = \int \frac{d^2 x}{d t^2} dt = \int (20.0 \text{m/s}^2)t^2 dt
\]

\[
= \frac{1}{4} (20.0 \text{m/s}^4)t^3 + C \quad (C = 0)
\]

\[
x = \int \frac{d x}{d t} dt = \int \frac{1}{4} (20.0 \text{m/s}^4)t^3 dt
\]

\[
= \frac{1}{4 \times 4} (20.0 \text{m/s}^4)t^4 + C \quad (C = x_0 = 4.00 \text{m})
\]

\[
= \left(\frac{1.667 \text{m/s}^4}{4.00}\right)t^4 + 4.00 \text{m}
\]

\[
x(t = 5.00 \text{sec}) = \left(\frac{1.667 \text{m/s}^4}{4.00}\right)(5.00 \text{sec})^4 + 4.00 \text{m} = 1046 \text{m}
\]

(d) Jerry is putting grocery carts away at Meijer. He takes one of the carts (\( m = 10.2 \text{ kg} \)) and gives it a shove so it is traveling at 4.75 \text{ m/s}. It crashes into and sticks with a group of five grocery carts that were just sitting there. Find the speed \( v \) of the new group of grocery carts.

\[
p_{\text{before}} = p_{\text{after}}
\]

\[
m_1v_1 + m_2v_2 + m_3v_3 + m_4v_4 + m_5v_5 = (m_1 + m_2 + m_3 + m_4 + m_5)v
\]

\[
v = \frac{mv}{6m} = \frac{4.75 \text{m/s}}{6} = 0.7917 \text{m/s}
\]

\[
K_f = \frac{1}{2}mv^2 = \frac{1}{2}(1.00 \text{kg})(-1380 \text{m/s})^2 = 952,200 \text{J}
\]

\[
W = \Delta K = K_f - K_i = 952,200 \text{J} - 0 = 952,200 \text{J}
\]
Problem Three – “The One With All The Angles” (35,000 points)

3.) Frida has to get a refrigerator ($m = 135 \text{ kg}$) loaded onto a truck, using a ramp that is angled at 22°. If the refrigerator glides on frictionless rollers, find (a) the force needed to push the refrigerator up the ramp at a constant speed.

\[
\sum F_y = F_i - w_y = 0 \\
F_i = w_y = mg \sin \theta \\
= (135 \text{ kg})(9.81 \text{ m/s}^2) \sin 22° \\
= 496.1 \text{ N}
\]

(b) The ramp is 1.50 m tall, while the angled part is 4.00 m long. Show that the work to raise the refrigerator 1.50 m is the same as the work in pushing the refrigerator up the slope without friction.

\[
W = mgh = (135 \text{ kg})(9.81 \text{ m/s}^2)(1.50 \text{ m}) = 1987 \text{ J}
\]

\[
W = Fd = (496.1 \text{ N})(4.00 \text{ m}) = 1984 \text{ J}
\]

(c) If the elevator did not have the rollers, that it could sit on the ramp and be held in place by static friction without being held by Frida. Find the minimum coefficient of static friction, $\mu_s$.

\[
\sum F_y = F_N - w_y = 0 \\
\sum F_x = F_{f,x,\text{max}} - w_x = 0 \\
F_{f,x,\text{max}} = \mu_s F_N = \mu_s w_y = w_x \\
\mu_s mg \cos \theta = mg \sin \theta \\
\mu_s = \frac{mg \sin \theta}{mg \cos \theta} = \tan \theta = \tan 22° = 0.4040
\]

(d) The actual coefficients of friction between the refrigerator and the ramp are 0.857 and 0.657. What is the maximum force Frida can push the stopped refrigerator without having it move up the ramp?

\[
\sum F_y = F_N - w_y = 0 \\
\sum F_x = F_i - F_{f,x,\text{max}} - w_x = 0 \\
F_i = F_{f,x,\text{max}} + w_y \\
= \mu_s w_y + w_x \\
= \mu_s mg \cos \theta + mg \sin \theta \\
= mg(\mu_s \cos \theta + \sin \theta) \\
= (135 \text{ kg})(9.81 \text{ m/s}^2)((0.857) \cos 22° + \sin 22°) \\
= 1548 \text{ N}
\]

(e) What is the force that Frida needs to apply to the refrigerator to get it up the ramp if is sliding at a constant speed with friction?

\[
\sum F_y = F_N - w_y = 0 \\
\sum F_x = F_i - F_{f,x} - w_x = 0 \\
F_i = F_{f,x} + w_y \\
= \mu_s w_y + w_x \\
= \mu_s mg \cos \theta + mg \sin \theta \\
= mg(\mu_s \cos \theta + \sin \theta) \\
= (135 \text{ kg})(9.81 \text{ m/s}^2)((0.657) \cos 22° + \sin 22°) \\
= 1303 \text{ N}
\]