Massachusetts Institute of Technology
Department of Physics

Physics 8.01L

SAMPLE FINAL EXAM SOLUTIONS January 25, 2006

Problem 1

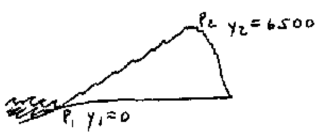
a) $V = \frac{NkT}{P}$, $V_{NEW} = \frac{Nk\frac{T}{3}}{\frac{P}{10}} = \frac{10}{3}\frac{NkT}{P}$, $\boxed{\Rightarrow \text{V goes up}}$
b) (i) $F = mg = 8(10) = \boxed{80N}$
(ii)$F_{Buoy} = (1000)(.002)(10) = 20N$,
$\therefore F = 80 - 20 = \boxed{60N}$
c) $\boxed{\text{Velocity goes down, pressure goes up.}}$

Problem 2

a) Equilibrium, so $F_{Buoyant} - w = 0 \Rightarrow F_B = w$.
$F_B = V_f \rho_f g = (\pi r^2 d)\rho g = w$, $d = \frac{w}{\pi r^2 \rho g}$
b) $F_{TOT} = Ma = F_B - w$, $F_B = \pi r^2(\frac{d}{2})\rho g = d(\frac{\pi r^2 \rho g}{2})$
From **(a)**, $d = \frac{w}{\pi r^2 \rho g} \Rightarrow F_B = \frac{w}{\pi r^2 \rho g}(\frac{\pi r^2 \rho g}{2}) = \frac{w}{2}$
Half as deep $\Rightarrow$ half as large buoyancy force.
$F_{TOT} = Ma = \frac{w}{2} - w = \frac{-w}{2}$, $a = \frac{-w}{2m}$, but $w = Mg$.
$\Rightarrow a = \frac{-g}{2}$, accelerating downward at $\frac{g}{2}$.

Problem 3

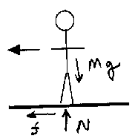
a) $P + \rho g y = \text{constant}$, $P_1 + \rho g(0) = P_2 + \rho g(6500)$
$P_2 = P_1 - \rho g(y_2) = 1.013 \times 10^5 - (0.95)(9.8)(6500)$,
$P_2 = 4.08 \times 10^4 N/m^2 = 0.40\, atm$



b) $N = \text{const}$, $V = \text{const}$, $PV = NkT$
$\Rightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2}$, $T_1 = 293$, $P_1 = 1.5 \times 10^7$, $T_2 = 253$, $\boxed{P_2 = \frac{P_1 T_2}{T_1} = 1.30 \times 10^7 N/m^2}$

Problem 4

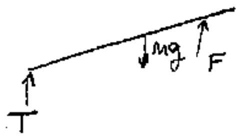
ii) f exerts torque around center of mass, so you fall over.



iii) Now N exerts torque which can balance torque due to friction.

Problem 5

a)



b) Take torques around toes: $MgL\cos(\theta) - F(\frac{4L}{3})\cos(\theta) = 0$, $\boxed{F = \frac{3}{4}Mg}$

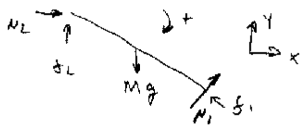
c)$T + F = Mg$, $\boxed{T = \frac{1}{4}Mg}$.

Problem 6

a) $3Mg + Mg = 4Mg$.
b) Take torques about left end: $4MgD - LMg = 0,\ D = \frac{L}{4}$.
Check torque around weight: $0 = D(3Mg) - Mg(L - D),\ D(4Mg) = MgL,\ D = \frac{L}{4}$.

Problem 7

a)



b) $\sum F_x = N_2 + N_1\sin(\theta) - f_1\cos(\theta) = 0$
$\sum F_y = f_2 - Mg + N_1\cos(\theta) + f_1\sin(\theta) = 0$

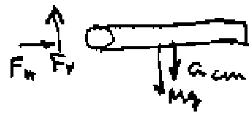
c) $\sum \tau = Mg(\frac{L}{2}\cos(\theta)) - N_1 L = 0$.

d) $\sum \tau = N_2 L\sin(\theta) + f_2 L\cos(\theta) - Mg\frac{L}{2}\cos(\theta) = 0$.

Problem 8

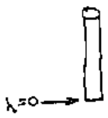
a) $\tau = I\alpha$, take torques about hinge.
$(Mg)(\frac{L}{2})(\sin(90°)) = (\frac{ML^2}{3})(\alpha)\ \Rightarrow \alpha = \frac{\frac{gL}{2}}{\frac{L^2}{3}} = \frac{3g}{2L}$, $\boxed{\alpha = \frac{3g}{2L}}$

b)



$F = Ma_{cm},\ a_{cm} = \alpha(\frac{L}{2})$, downward.
All forces and acceleration are vertical $\Rightarrow \boxed{F_H = 0}$.
$F_V - Mg = -Ma = -M\alpha(\frac{L}{2}) = -M(\frac{3g}{2L})(\frac{L}{2}) = \frac{-3Mg}{4}$
$F_V = Mg - \frac{3Mg}{4} \Rightarrow \boxed{F_V = \frac{Mg}{4}}, \boxed{F_{TOT} = \frac{Mg}{4},\ up}$.

c) Used fixed pivot:



$KE_I = 0,\ PE_I = MgL,\ KE_F = \frac{1}{2}I_{end}\omega^2,\ PE_F = Mg(\frac{L}{2}),$ Work $= 0$.
$\frac{1}{2}(\frac{ML^2}{3})\omega^2 + Mg\frac{L}{2} = MgL,\ \frac{ML^2\omega^2}{6} = \frac{MgL}{2},\ \boxed{\omega^2 = \frac{3g}{L} \text{ or } \omega = \sqrt{\frac{3g}{L}}}$.
Used center of mass:
$KE_I = 0,\ KE_F = \frac{1}{2}Mv_{CM}^2 + \frac{1}{2}I_{CM}\omega^2,\ v_{CM} = \omega(\frac{L}{2})$
$KE_F = \frac{1}{2}M(\frac{L}{2})^2\omega^2 + \frac{1}{2}(\frac{ML^2}{12})\omega^2 = ML^2\omega^2(\frac{1}{8} + \frac{1}{24}) = ML^2\omega^2(\frac{3}{24} + \frac{1}{24})$
$= ML^2\omega^2(\frac{1}{6}) \Rightarrow$ Same answer.

Problem 9

a) L is conserved: $mvR = (I_0 + mR^2)\omega_f$
$\boxed{\omega_f = \frac{mvR}{I_0 + mR^2}}$
b) $KE_I = \frac{1}{2}mv^2$, $KE_F = \frac{1}{2}(I_0 + mR^2)(\frac{mvR}{I_0+mR^2})^2 = \frac{1}{2}(\frac{m^2v^2R^2}{I_0+mR^2})$
$\boxed{\frac{KE_F}{KE_I} = \frac{mR^2}{I_0 + mR^2}}$

Problem 10

a) Left
b) Yes, gravity.
c) Out of the page; Counter-clockwise.
d) Yes, pivot force.
e) Out of the page; Counter-clockwise.
f) Out of the page.

Problem 11

Take clockwise to be positive. Angular momentum is conserved: $I\omega_I - mv_Id = I\omega_f + mv_fd$
$0.30(\omega) - 0.15(50)(0.8) = 0.3(0.35\omega) + 0.15(40)(0.8)$
$0.20\omega = 6 + 4.8 \Rightarrow \boxed{\omega = 54 rad/s}$. Period $= 0.12$ *sec*.