M 2-41

(a) T_{GAIN} (wrt TRAIN) $= \frac{1}{2} m v^2$

(b) T_{GAIN} (wrt TRACK) $= T_f - T_i = \frac{1}{2} m (u+v)^2 - \frac{1}{2} m u^2 = \frac{1}{2} m v^2 + m u v$

(c) W (BY WOMAN) $= \frac{1}{2} m v^2$

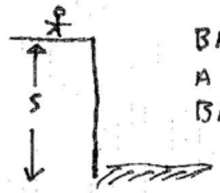
DOESN'T MATTER IF TRAIN IS MOVING OR STILL.

(d) W(BY TRAIN) $= T_{GAIN}$ (wrt TRACK) $-$ W (WOMAN)

$= m u v$

NOTE THAT TRAIN MUST DO WORK TO STAY MOVING AT SPEED U. IF IT DIDN'T DO WORK, CONS. OF MOMENTUM WOULD CAUSE IT TO SLOW DOWN WHEN THE WOMAN THREW THE BALL FORWARD.

M 2-30



BALLOON FALLS A DISTANCE S & THEN A SOUND WAVE MUST TRAVEL BACK UP THE BLDG.

LET $S \equiv$ BLDG HEIGHT

$t \equiv$ elapsed time $= 4.021$ SEC

$t =$ DROP TIME + SOUND TRAVEL TIME

$= \sqrt{\dfrac{2s}{g}} + \dfrac{s}{v_0}$; $v_0 =$ sound speed.
$g =$ accel. DUE TO GRAVITY

SOLVE FOR S. LET $S = Z^2$, THEN WE HAVE QUADRATIC EQN.

$$t = \sqrt{\frac{2}{g}}\, z + z^2/v_0$$

$$z^2 + \sqrt{\frac{2v_0^2}{g}}\, z - v_0 t = 0$$

$$\Rightarrow z = \frac{-\sqrt{\dfrac{2v_0^2}{g}} \pm \left[\dfrac{2v_0^2}{g} + 4v_0 t\right]^{1/2}}{2}$$

CHOOSE + SIGN SINCE Z MUST BE > 0.

So,

$$s = z^2 = \frac{1}{4}\left[\frac{2v_0^2}{g} + \frac{2v_0^2}{g} + 4v_0 t - 2\sqrt{\frac{2v_0^2}{g}}\left[\frac{2v_0^2}{g} + 4v_0 t\right]^{1/2}\right]$$

$$= \frac{1}{4}\left[4v_0^2/g + 4v_0 t - \frac{4v_0^2}{g}\left[1 + \frac{2gt}{v_0}\right]^{1/2}\right]$$

$$\therefore S = \left[v_0^2/g + v_0 t - \frac{v_0^2}{g}\left[1 + \frac{2gt}{v_0}\right]^{1/2}\right]$$

SUBSTITUTING $t = 4.021$ s, $g = 9.8\ m/s^2$, $v_0 = 331$ m/s

$$\boxed{S = 71 \text{ M}}$$

M 2-38

(a) $v(x) = \alpha x^{-n}$

$$F = m\frac{dv}{dt} = m\frac{dv}{dx}\frac{dx}{dt} = m v \frac{dv}{dx}$$

BUT $v(x) = \alpha x^{-n}$ & $dv/dx = -\alpha n x^{-(n+1)}$, so

$$F = m v \frac{dv}{dx} = m \alpha x^{-n}\left(-\alpha n x^{-(n+1)}\right)$$

$$\boxed{F(x) = -m n \alpha^2 x^{-(2n+1)}}$$

(b)

$$\dot{x} = v = \alpha x^{-n}$$

$$\int x^n dx = \int \alpha\, dt$$

$$\frac{x^{n+1}}{n+1} = \alpha t + \cancel{C_0}^{\,0}, \text{ since } x=0 \text{ @ } t=0$$

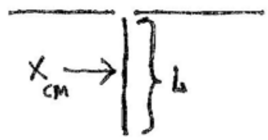
$$\Rightarrow \boxed{x = [(n+1)\alpha t]^{1/n+1}}$$

(c) $F(t) = F(x(t))$. BY DIRECT SUBSTITUTION,

$$\boxed{F(t) = -m n \alpha^2 \left[(n+1)\alpha t\right]^{-\frac{2n+1}{n+1}}}$$

M9-15

$E_i = T_i + U_i = 0$, ROPE AT REST & DEFINE TABLE TOP TO BE $U=0$.



$$E_F = T_F + U_F$$
$$= \frac{1}{2} M v_F^2 - \frac{mgL}{2}$$
$$= \frac{1}{2} M\left(\frac{2}{3} gL\right) - \frac{MgL}{2}$$
$$= -\frac{1}{6} MgL$$

$$\boxed{\text{ENERGY } \underline{\underline{\text{LOST}}} = -(E_F - E_i) = \frac{1}{6} MgL}$$

M 9-7

BY INSPECTION, H ATOMS ARE SYMMETRICALLY PLACED ON EITHER SIDE OF + X AXIS & O ATOM IS AT ORIGIN. HENCE $\bar{Y} = 0$.

FOR $\bar{X}$,

$$\bar{X} = \frac{\sum M_i X_i}{\sum_i M_i}$$

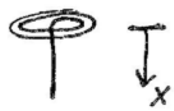
$$= \frac{2\,a \cos 52^\circ}{1 + 1 + 16}$$

$$\frac{m_O}{m_H} = 16$$

$$\boxed{\begin{aligned} \bar{X} &= 0.068\, a \\ \bar{Y} &= 0 \end{aligned}}$$

M 9-15

MULTIPLE SOLUTIONS POSSIBLE.



I SOLVED IT BY ASKING HOW DOES THE ROPE CM MOVE. LET $X=0$ BE THE TABLE TOP. THEN

$$\bar{X}_{cm} = \frac{m(\text{rope on table})\cdot 0 + m(\text{rope hanging})\cdot \frac{X}{2}}{M_{ROPE}}$$

$$= \frac{\frac{\rho X^2}{2}}{M}, \quad \rho = M/L$$

$$\bar{X}_{cm} = \frac{X^2}{2L}.$$

RECALL THAT FOR MULTI-PARTICLE SYSTEMS,

$$M\ddot{R} = F_{NET} \quad ; \; M = \text{ROPE TOTAL MASS}$$
$$R = \text{rope cm}$$

$$M\frac{dV_{cm}}{dt} = F_N$$

$$M\frac{dV_{cm}}{dX_{cm}}\cdot\frac{dX_{cm}}{dt} = F_N$$

$$M\frac{dV_{cm}}{dX_{cm}}\cdot V_{cm} = F_N$$

BUT F_N = FORCE DUE TO HANGING ROPE

$$= \rho X g$$
$$= \rho g\,[2L\,X_{cm}]^{1/2}$$

M 9-15, CON'T.

SO,
$$M V_{cm} \frac{dV_{cm}}{dX_{cm}} = \rho g \left[2L X_{cm}\right]^{1/2}$$

$$\int V_{cm}\, dV_{cm} = \int \left[\frac{2g^2}{L} X_{cm}\right]^{1/2} dX_{cm}$$

$$\frac{V_{cm}^2}{2} = \sqrt{\frac{2g^2}{L}}\ \frac{2}{3} X_{cm}^{3/2} + \cancel{C_0}^{\,0}, \quad V_{cm} = 0 \text{ @ } X_{cm} = 0$$

$$V_{cm} = \left[\frac{32}{9}\frac{g^2}{L}\right]^{1/4} X_{cm}^{3/4}$$

NOW, WE REALLY WANT $v(x)$ NOT $V_{cm}(X_{cm})$.
BUT $X_{cm} = \frac{X^2}{2L}$ SO WE CAN PROCEED.

FROM ABOVE, $x_{cm} = x^2/2L$

$$\Rightarrow V_{cm} = \frac{\dot{x}x}{L} = \left[\frac{32}{9}\frac{g^2}{L}\right]^{1/4} \left(\frac{x^2}{2L}\right)^{3/4}$$

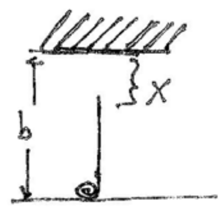
$$\boxed{\dot{x} = v = \left[\frac{2}{3} g x\right]^{1/2}}$$

NOTE: $v = \sqrt{2gx}$
FOR FREE FALL.

FOR FREE FALL $\quad v = \sqrt{2gx}$

$$\Rightarrow \boxed{a_{rope} = g/3}$$

M 9-19



$\underset{\sim}{F}_{CHAIN} = \underset{\sim}{F}_{GRAVITY} + \underset{\sim}{F}_{TABLE}$

$\underset{\sim}{F}_{CHAIN}$ = NET FORCE ON CHAIN

$\underset{\sim}{F}_{GRAVITY}$ = GRAVITY FORCE ON CHAIN

$\underset{\sim}{F}_{TABLE}$ = FORCE OF TABLE ON CHAIN

$$F_c = \frac{dP_c}{dt} = \rho b g - F_T \quad ; \quad \rho = M/b$$

P_c = CHAIN MOMENTUM

$P_c = m_c v_c$; m_c = MASS OF MOVING CHAIN ONLY

$$= \rho(b-x)\dot{x}$$

$$\Rightarrow F_c = \dot{P}_c = -\rho\dot{x}^2 + \rho(b-x)\ddot{x}$$

SINCE CHAIN IS IN FREE FALL, $\dot{x}^2 = v^2 = 2gx$

$$\ddot{x} = g$$

So,

$$F_c = F_G - F_T$$

$$-\rho(2gx) + \rho(b-x)g = \rho b g - F_T$$

$$F_T = 3g\rho x$$

$$\therefore \quad \boxed{F_T = 3mg\left(x/b\right)}$$