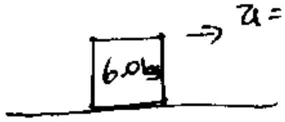
AP PHYSICS - CH 4

Q2: CONSTANT SPEED IN A CONSTANT DIRECTION MEANS CONSTANT VELOCITY. CONSTANT VELOCITY MEANS NO ACCELERATION. NO ACCELERATION MEANS NO FORCE (WELL... NO NET FORCE OR NO UNBALANCED FORCE...)

Q5: AT FIRST YOU ARE BREAKING STATIC MOLECULAR BONDS - STATIC FRICTION. AFTER THE BOX BEGINS MOVING YOU ONLY HAVE TO BREAK "ON-THE-FLY" BONDS - KINETIC FRICTION - WHICH IS LESS THAN STATIC FRICTION. (IMAGINE THE ALTERNATIVE....)

Q17: EVEN THOUGH IT SEEMS COUNTER-INTUITIVE, SKIDDING TIRES ARE MOVING ACROSS THE GROUND $\Rightarrow$ KINETIC FRICTION. ROLLING TIRES ARE ACTUALLY AT REST RELATIVE TO THE GROUND $\Rightarrow$ STATIC FRICTION. $F_k < F_s$!

(1) $\rightarrow a = 2.0\,m/s^2$



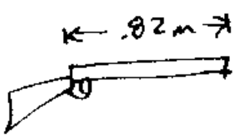
$$F_{NET} = ma = (6.0\,kg)(2.0\,m/s^2) = 12\,N$$

$$F_{NET} = ma \Rightarrow a = \frac{F_{NET}}{m} = \frac{12\,N}{4.0\,kg} = 3.0\,m/s^2$$

(3) 2 TONS = 2000 lbs

$$2000\,lbs\left(\frac{1\ kg}{2.2\ lb}\right)\left(\frac{9.8\ N}{1\ kg}\right) = 8909\,N$$

(8)



$F_{NET} = ma$ BUT WHAT IS a?

$X = .82\,m$

$V_i = 0$

$V_f = 320\,m/s$

$a = ?$

$t = ?$

$$V_f^2 = V_i^2 + 2ax$$

$$320^2 = 0^2 + 2a(.82)$$

$$a = 6.24 \times 10^4\,m/s^2$$

SO $F_{NET} = (.005\,kg)(6.24 \times 10^4)$

$F_{NET} = 312\,N$

(11)

$\Rightarrow F_{NET} = 200N = ma$

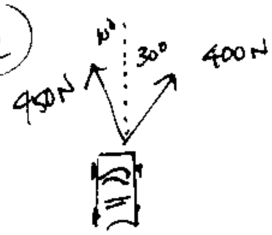
$a = \frac{200N}{1000\,kg} = .2\ m/s^2$

$x = ?$
$v_i = 0$
$v_f = ?$
$a = .2\ m/s^2$
$t = 10s$

$x = v_i t + \frac{1}{2}at^2$
$x = 0 + \frac{1}{2}(.2)(10)^2$
$= .1(100)$
$= 10\,m$

$v_f = v_i + at$
$v_f = 0 + (.2)(10)$
$v_f = 2\ m/s$

(12)



COMPONEMATIZE!

X-DIR:

$400N \cdot \sin 30° - 450N \cdot \sin 10° = 122N$ TO THE RIGHT

Y-DIR

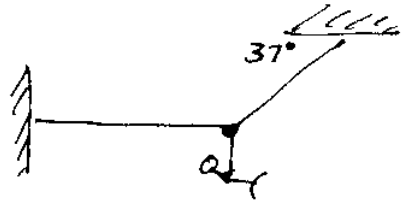
$400 \cos 30° + 450 \cos 10° = 790N$ UP

SO DE-COMPONEMATIZING (SP?)

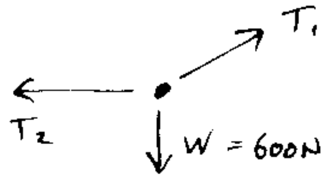
$F_{NET} = \sqrt{790^2 + 122^2} = 800N \qquad \theta = \tan^{-1}\left(\frac{122}{790}\right) = 8.77°$

$a = \frac{F_{NET}}{m} = \frac{800N}{3000\,kg} = .27\ m/s^2$

(15)



FREE BODY DIAGRAM



Y-DIR

$T_1 \sin 37° = 600N$

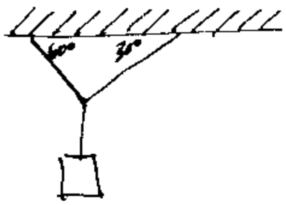
$T_1 = \frac{600N}{\sin 37°} = 997N$

X-DIR

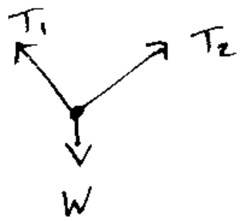
$T_1 \cos 37 - T_2 = 0$

$997N \cos 37° = T_2 = 796 N$

(17)



F.B.D.



X-DIR

$T_1 \cos 60° = T_2 \cos 30°$

$T_1 = T_2 \frac{\cos 30°}{\cos 60°}$ SUB $\rightarrow$

$T_1 = 75N \left(\frac{\cos 30°}{\cos 60°}\right)$

$T_1 = 130N$

Y-DIR

$T_1 \sin 60° + T_2 \sin 30° = W$

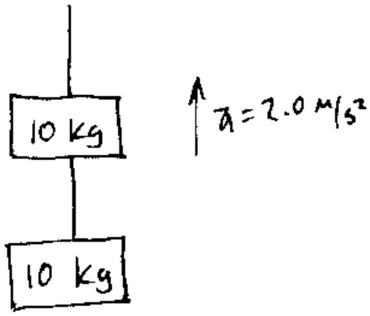
$T_2 \frac{\cos 30°}{\cos 60°} \sin 60° + T_2 \sin 30° = W$

$T_2 (\cos 30° \tan 60° + \sin 30°) = W$

$T_2 = \frac{W}{\cos 30° \tan 60° + \sin 30°} = \frac{150N}{(\text{STUFF})} = 75N$

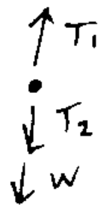
SUB BACK

(19)



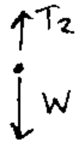
DRAW AN FBD FOR EACH MASS...

UPPER...



SO $T_1 - T_2 - W = ma$

LOWER....



SO

$T_2 - W = ma$

$T_2 = ma + W = ma + mg = m(a+g)$

$= 10(11.8)$

$= 118N$

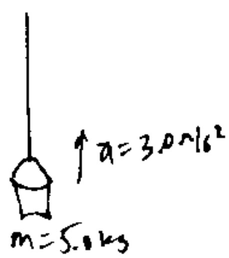
$T_1 = ma + W + T_2$

$= m(a+g) + T_2$

$118N + 118N = 236N$

WHICH MAKES SENSE! ROPE 2 HAS TO HOLD UP A 10kg BLOCK PLUS ACCELERATE IT AT 2.0 m/s² AND ROPE 1 HAS TO HOLD UP 2 10kg BLOCKS AND ACCELERATE THEM BOTH!

(28)



$F_{NET} = ma$

$T_1 - W = F_{NET}$

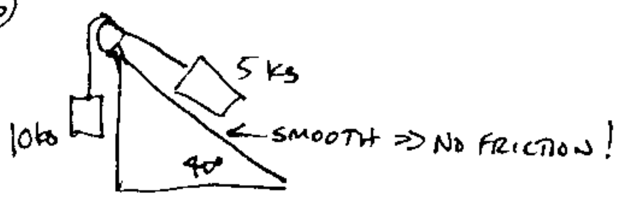
$T_1 - W = ma$

$T_1 = ma + W$

$= ma + mg$

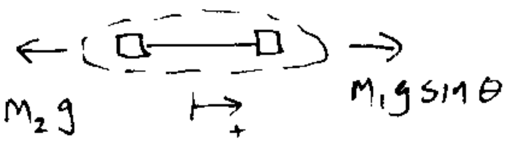
$= m(a+g) = 5.0\,kg\,(12.8\,m/s^2) = 64\,N$

(26)



THERE ARE 2 WAYS TO DO THIS, THE "SYSTEM" WAY AND THE "FBD" WAY

"SYSTEM" WAY



$$F_{NET} = Ma$$

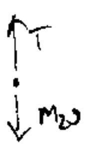
$$M_1 g \sin\theta - M_2 g = (M_1 + M_2)\, a$$

$$\frac{(M_1 \sin\theta - M_2)\, g}{(M_1 + M_2)} = a$$

$$\frac{(5 \sin 40° - 10)\, 9.8}{(15)} = a$$

$$-4.4\ \mathrm{m/s^2} = a$$

LOOK AT M_2 FOR TENSION



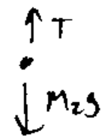
$$T - M_2 g = (-4.4\ \mathrm{m/s^2})(10)$$

$$T = 10\,(-4.4 + 9.8)$$

$$T = 54\,N$$

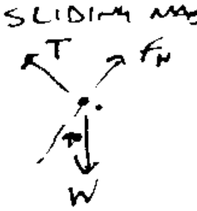
"FBD" WAY

HANGING MASS



$$M_2 g - T = M_2 a$$

SLIDING MASS



$$T - M_1 g \sin 40 = M_1 a$$

2 EQNS W/2 UNKNOWNS

$$a = g - \frac{T}{M_2}$$

$$T - M_1 g \sin 40° = M_1 g - \frac{M_1 T}{M_2}$$

$$T\left(1 + \frac{M_1}{M_2}\right) = M_1 g (1 + \sin 40°)$$

$$T = \frac{M_1 g (1 + \sin 40°)}{\left(\frac{M_1}{M_2} + 1\right)}$$

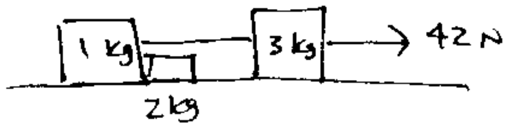
$$T = 54\,N$$

SO

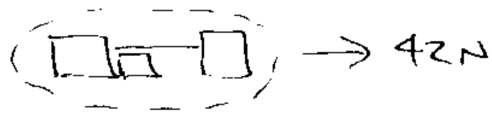
$$a = 9.8 - \frac{54}{10} = 4.4\ \mathrm{m/s^2}$$

WHY IS THE SIGN DIFFERENT? A DIFFERENT CHOICE OF COORDINATE SYSTEM.

(27)



USE THE SYSTEM METHOD . . .



$F_{NET} = ma$

$42\,N = (1+2+3)\,a$

$\frac{42\,N}{6\,kg} = 7\,m/s^2 = a$

LOOK AT THE 3 kg MASS TO FIND THE TENSION . . .

$T \leftarrow \bullet \rightarrow 42\,N$

$42 - T = ma$

$42 - T = (3)(7)$

$42 - 21 = T$

$21\,N = T$

WHAT'S GOING ON WITH THE 2 kg BLOCK ?

$\bullet \rightarrow F$

SO $F = ma$

$F = (2)(7) = 14\,N$

TRIPPLE CHECK WITH THE LAST BLOCK.

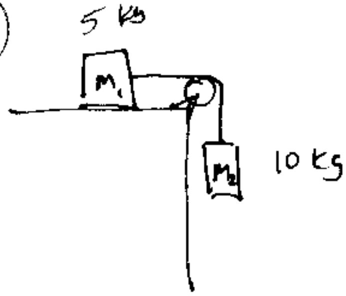
$F \leftarrow \bullet \rightarrow T$

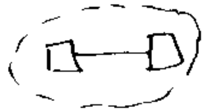
$T - F = ma$

$21 - 14 = (1)(7)$

$7 = 7$ YUP!

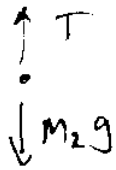
(30)





$$M_2 g = (M_1 + M_2)\,a$$

$$a = \left(\frac{m_2}{M_1+M_2}\right) g = \frac{10}{15}(9.8) = 6.5\ m/s^2$$



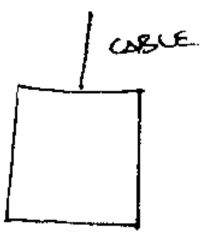
$$M_2 g - T = M_2 a$$

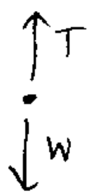
$$M_2(g - a) = T$$

$$10(9.8 - 6.5) = T$$

$$33\text{N} = T$$

(32)





a) IF ACCEL IS UP, $T > W$

b) IF CONSTANT VEL, ACCEL IS ZERO SO $T = W$

c) IF ACCEL IS DOWN (REGARDLESS OF DIRECTION OF MOTION) $T < W$

d) $M = 1500$ kg
$a = 2.5\ m/s^2$ UP

SO
$$T - W = ma$$
$$T - mg = ma$$
$$T = m(a+g)$$
$$= 1500(2.5 + 9.8)$$
$$T = 18{,}450\text{N}$$

WHICH IS MORE THAN

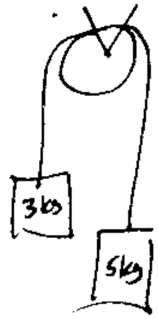
$W = Mg = 14{,}700$ N

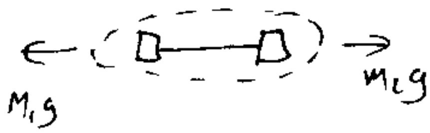
e) V = CONSTANT
$T = W = 14700$ N

f)
$$T - W = ma$$
$$T = m(a+g)$$
$$= 1500(-1.5 + 9.8)$$
$$= 12{,}450\text{N}$$

WHICH IS LESS THAN $W = 14{,}700$N

39 ATWOOD'S MACHINE



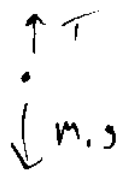


$$M_2 g - M_1 g = (M_1+M_2)\,a$$

$$a = \frac{M_2 - M_1}{(M_1+M_2)}\,g = \frac{5-3}{5+3}\,(9.80) = \frac{2}{8}\,9.80$$

$$a = 2.45\ m/s^2$$

FIND TENSION BY LOOKING AT ONE OF THE MASSES - ..



$$T - m_1 g = m_1 a$$

$$T = m_1 (a+g) =$$

$$= 3\,(2.45 + 9.80)$$

$$T = 36.75\ N$$

IN THE FIRST SECOND

$X = ?$

$V_i = 0$

$V_f = ?$

$a = 2.45$

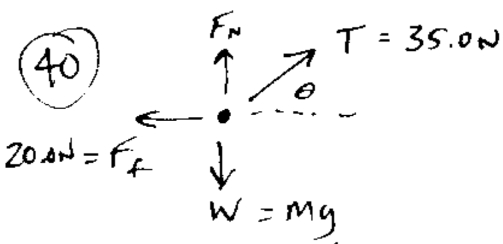
$t = 1.0$

$$X = V_i t + \tfrac{1}{2} a t^2$$

$$X = 0 + \tfrac{1}{2}(2.45)(1$$

$$X = 1.225\ m$$

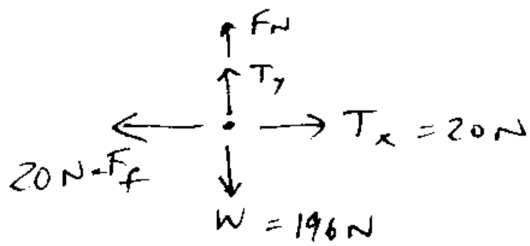
40



$= 20(9.80)$

$= 196$

SO



SO $T_x = 20N$ BUT ALSO $= 35.0N \cos\theta$

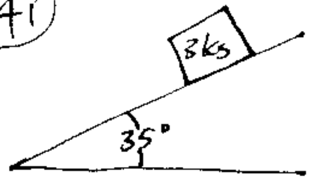
SO $\cos\theta = \frac{20}{35}$ AND $\theta = 55^\circ$

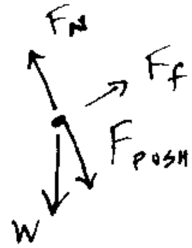
NOW $T_y = 35 \sin 55^\circ = 28.6N$ AND $F_N + T_y = W$

$F_N + 28.6N = 196N$

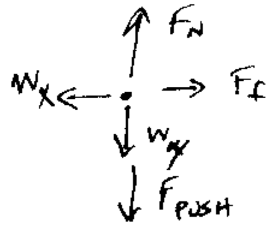
$F_N = 167N$

(41)





SO



$$W = mg = 3(10) = 30\,N$$

$$W_x = W\sin\theta = 30\sin 35^\circ = 17.2\,N$$

$$W_y = W\cos\theta = 30\cos 35^\circ = 24.6\,N$$

<u>X-DIR</u>

$$W_x = F_f = \mu F_N$$

<u>Y-DIR</u>

$$F_N = W_y + F_{PUSH}$$

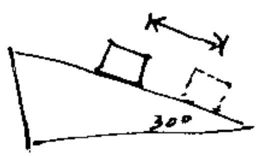
SUB

$$W_x = \mu\left(W_y + F_{PUSH}\right)$$

$$\frac{W_x}{\mu} - W_y = F_{PUSH}$$

$$\frac{17.2}{.3} - 24.6 = F_{PUSH} \Rightarrow F_{PUSH} = 32.7\,N$$

(47)



a)

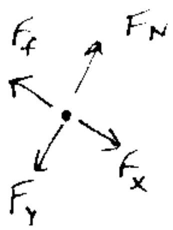
$x = 2.0\,m$
$V_i = 0$
$V_f = ?$
$a = ?$
$t = 1.5\,s$

$$x = V_i t + \tfrac{1}{2}at^2$$

$$2.0 = 0 + \tfrac{1}{2}a(1.5)^2$$

$$4.0 = 2.25\,a$$

$$a = 1.78\,m/s^2$$



$$F_x - F_f = ma$$

AND $F_N = F_y$

$$F_x - \mu F_N = ma$$

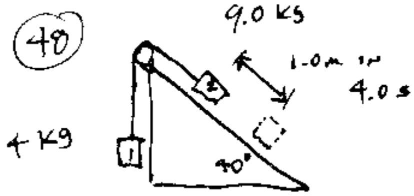
$$F_x - \mu F_y = ma$$

$$F_x - ma = \mu F_y$$

$$\mu = \frac{F_x - ma}{F_y} = \frac{mg\cos\theta - ma}{mg\sin\theta} = \tan\theta - \frac{a}{g\sin\theta}$$

$$= .214$$

(48)

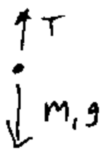


a) THE ACCELERATION IS . .

$X = 1.0m \quad V_i = 0 \quad V_f = ? \quad a = ? \quad t = 4.0s$

$$X = \frac{1}{2}at^2 \text{ so } a = \frac{2x}{t^2} = \frac{2(1)}{4^2} = \frac{2}{16} = .125 \, m/s^2$$

TENSION FROM LOOKING AT MASS ONE . . .

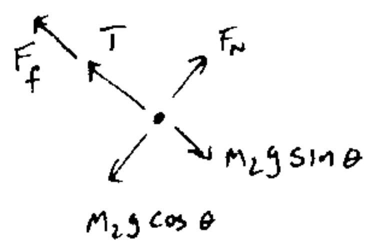


$$T - m_1 g = m_1 a$$

$$T = m_1 (g + a) = 4(9.8 + .125)$$

$$T = 39.7N$$

NOW LOOK AT MASS TWO . . .



AND $F_N = m_2 g \cos\theta = 67.6N$

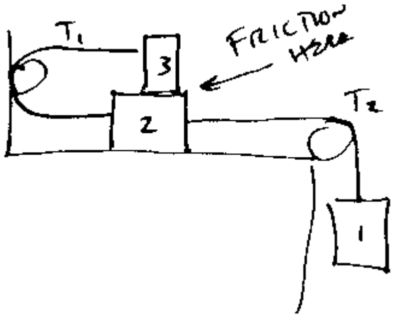
$$-F_f - T + m_2 g \sin\theta = m_2 a$$

SO $F_f = m_2 g \sin\theta - T - m_2 a$

$$= 15.9N$$

WHICH MAKES $\mu = \frac{F_f}{F_N} = \frac{15.9}{67.6} = .23$

(53)

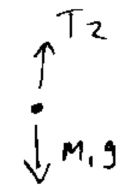


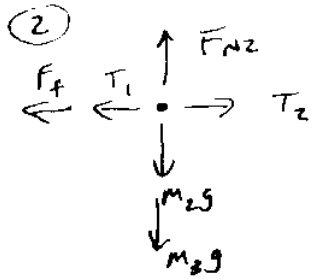
$M_1 = 10$ KG

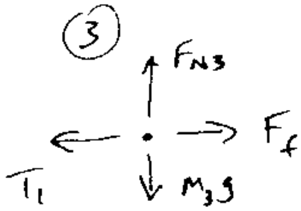
$M_2 = 3$ KG

$M_3 = 2$ KG

FBDs







THE KICKER HERE IS THAT BLOCK 2 FEELS A REACTION FORCE FROM THE FRICTION (EQUAL & OPPOSITE) PLUS IT HAS BLOCK 3 ON TOP OF IT!

LETS DO THIS ALGEBRA STYLE

(1) $M_1 g - T_2 = M_1 a$

(2) $F_{N2} = (M_2 + M_3) g$

(2.5) $T_2 - T_1 - F_f = M_2 a$

(3) $F_{N3} = M_3 g$

(3.5) $T_1 - F_f = M_3 a$

OOPS!

~~SUB 2 INTO 2.5 & 3 INTO 3.5 ...~~

~~(A) $T_2 - T_1 - \mu(M_2 + M_3) g = M_2 a$~~

~~(B) $T_1 - \mu M_3 g$~~

WAIT! $F_f = \mu M_3 g$

SOLVE (1) FOR T_2

$$T_2 = M_1 (g - a)$$

SOLVE (3.5) FOR T_1

$$T_1 = M_3 (a + \mu g)$$

PLUG INTO (2.5)

$$M_1 (g - a) - M_3 (a + \mu g) - \mu M_3 g = M_3 a$$

$$\frac{M_1}{M_3} g - \frac{M_1}{M_3} a - a - \mu g - \mu g = a$$

$$\frac{M_1}{M_3} g - 2\mu g = \left(2 + \frac{M_1}{M_3}\right) a$$

$$a = \frac{\left(\frac{M_1}{M_3} - 2\mu\right) g}{\left(\frac{M_1}{M_3} + 2\right)} = .62 g = 6.16\ \text{m/s}^2$$

SO $T_1 = 10(6.16 + .3(9.8)) = 91$ N

$T_2 = 36.4$ N