Unit 3 Handout
Friction and Forces on Inclines

Name: Key

Physics 200

Part 1: Friction

1. What is friction? A force that resists the sliding of two surfaces across one another.

2. When there is relative motion between objects in contact, the friction is called kinetic friction. The symbol for its "coefficient" is μ_k.

3. When there is no motion between objects in contact, the friction is called static friction. The symbol for its "coefficient" is μ_s.

4. According to the table, which type of friction is stronger? Static

5. Aside from the materials involved, what else affects the force of friction between two surfaces? The force with which they are pressed together (F_N)

System	Static Friction μ_s	Kinetic Friction μ_k
Rubber on dry concrete	1.0	0.7
Rubber on wet concrete	0.5-0.7	0.3-0.5
Wood on wood	0.5	0.3
Waxed wood on wet snow	0.14	0.1
Metal on wood	0.5	0.3
Steel on steel (dry)	0.6	0.3
Steel on steel (oiled)	0.05	0.03
Teflon on steel	0.04	0.04
Bone lubricated by synovial fluid	0.016	0.015
Shoes on wood	0.9	0.7
Shoes on ice	0.1	0.05
Ice on ice	0.1	0.03
Steel on ice	0.04	0.02

Table 6.1 Approximate Coefficients of Static and Kinetic Friction

6. Write the equation for the magnitude of static friction.

$$F_{Fr(static)} \leq \mu_s F_N$$

7. Write the equation for the magnitude of kinetic friction.

$$F_{Fr(kinetic)} = \mu_k F_N$$

1. Someone slides a 20kg rock across a horizontal floor. If the person does this by applying a 150N horizontal force, and the rock accelerates at 3.5m/s², what is the coefficient of friction between the desk and the floor?

$w = 20kg(9.8m/s^2)$

$w = 196N$

$\Sigma F = 20kg(3.5m/s^2) = 70N$

$\Sigma F = 150N - F_{Fr} = 70N$

$F_{Fr} = 80N$

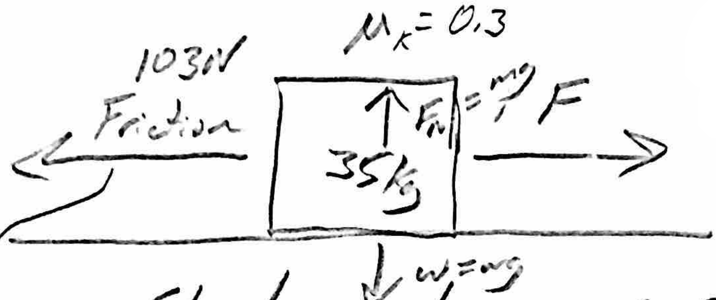
$80N = \mu F_N = \mu(196N)$

$\mu = 0.408$

... of kinetic friction between a 35-kg crate and the floor is 0.30...

2b.

a)



$F_{Fr} = \mu_K F_N$
$= \mu_K mg$
$= 0.3(35kg)(9.8\,m/s^2)$
$= 103N$

We know $F_N = mg$ because box is not moving in Y dimension

Steady speed means $a = 0$

$\Sigma F = ma$

If $a = 0$, then $\Sigma F = 0$,

So forces are balanced, and

$F = F_{Friction}$

$$\Sigma F = ma$$
$$\Sigma F = F - F_{Fr}$$

$ma = F - F_{Fr}$

$35kg(0\,m/s^2) = F - 103N$

$F = 103N$

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b) If $\mu = 0$, then $F_{Fr} = 0$

$\Sigma F = ma$

$\Sigma F = F - F_{Fr}$

$ma = F - F_{Fr}$

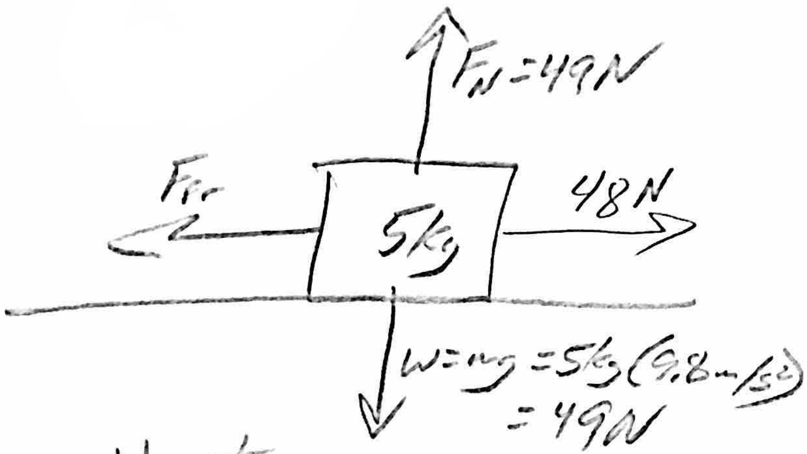
$35kg(0\,m/s^2) = F - 0$

$F = 0$

3.

(3)

a)



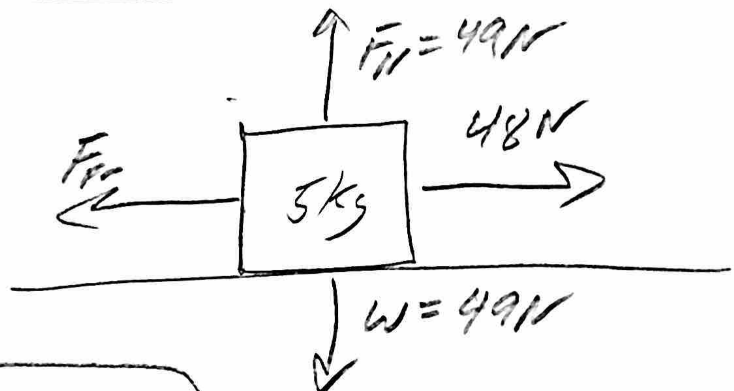
If at least 48N is needed to start moving the box, then F_{Fr} must $= 48N$

$$F_{Fr} = \mu_s F_N = 48N$$

$$\mu_s(49N) = 48N$$

$$\boxed{\mu_s = 0.98}$$

b)



$$\sum F = ma$$

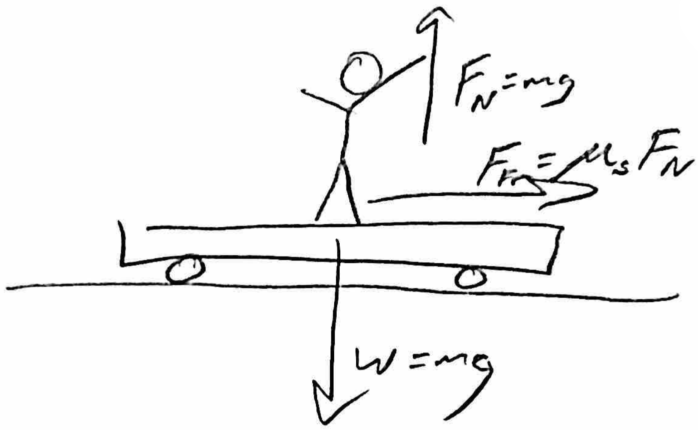
$$\sum F = 48N - F_{Fr}$$

$\Longrightarrow$ $ma = 48N - F_{Fr}$ ($F_{Fr} = \mu_k(F_N)$)

$$5kg(0.7\,m/s^2) = 48N - \mu_k(49N)$$

$$\boxed{\mu_k = 0.91}$$

4. (3)



The only unbalanced force acting on you is Friction!

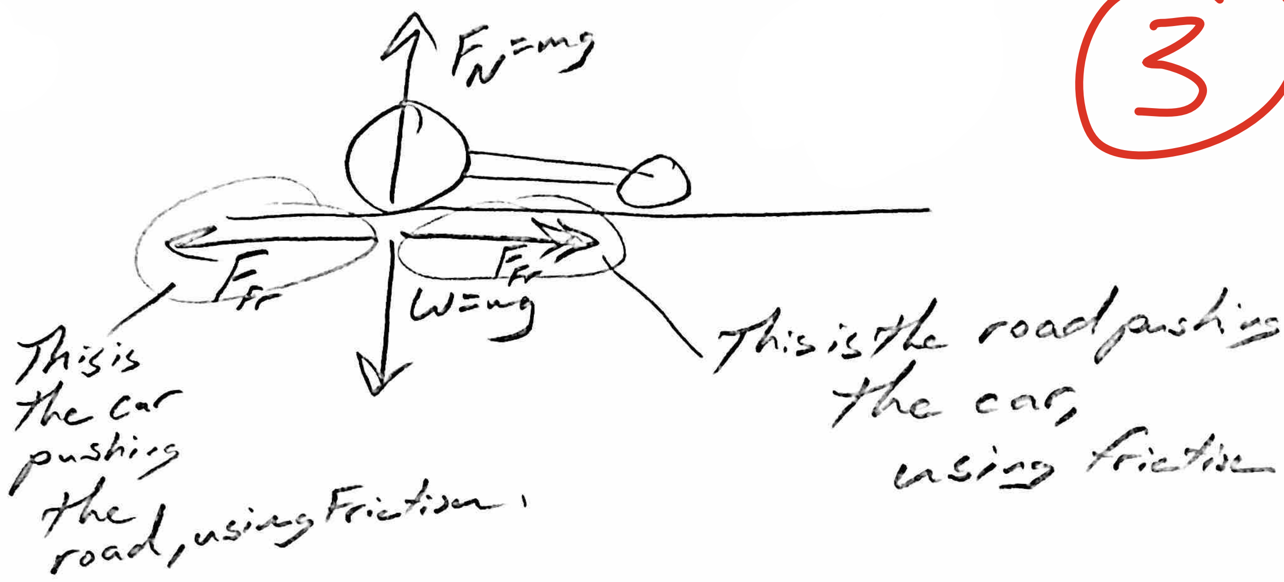
$$\sum F = ma$$
$$\sum F = F_{Fr} = \mu_s F_N = \mu_s mg$$

$\Downarrow$

$$ma = \mu_s mg$$
$$\frac{a}{g} = \mu_s$$
$$\frac{0.2g}{g} = \mu_s$$
$$\boxed{0.2 = \mu_s}$$

5.

3



$$\sum F_{car} = ma$$

$$\sum F_{car} = F_{Fr} = \mu_s F_N = \mu_s mg$$

$$ma = \mu_s mg$$

$$\mu_s = \frac{a}{g}$$ ← we need a...

Using kinematics...

$\Delta x = 1{,}000\,m$

$V_{ox} = 0\,m/s$

$\Delta t = 12\,s$

$$\Delta x = V_0 t + \tfrac{1}{2} a t^2$$

$$1{,}000\,m = 0\,m/s\,(12\,s) + \tfrac{1}{2}\,a\,(12\,s)^2$$

$$a = 13.9\,m/s^2$$

$$\mu_s = \frac{13.9\,m/s^2}{9.8\,m/s^2} = \boxed{1.42}$$

6.

3

kinematics to find Δx

$\Delta x = ?$

$V_0 = 4\,m/s$

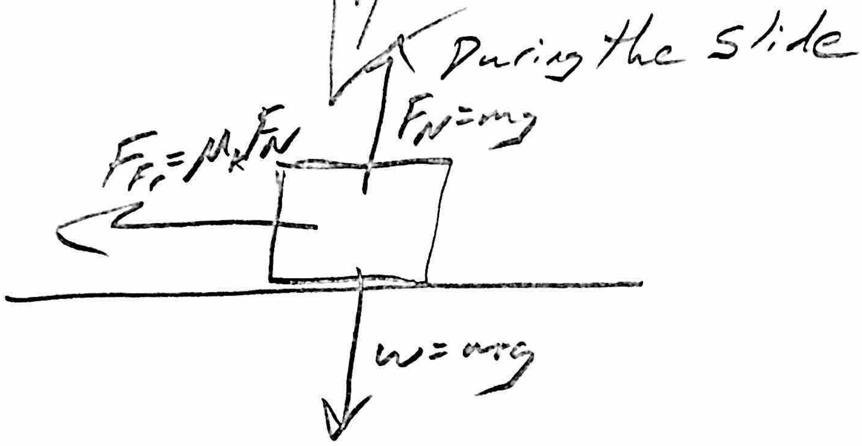
$V = 0\,m/s$

$a =$

$t =$

we need a

$$V^2 = V_0^2 + 2a\Delta x$$



$$\sum F = ma$$

$$\sum F = -F_{Fr} = -\mu_k F_N = -\mu_k mg$$

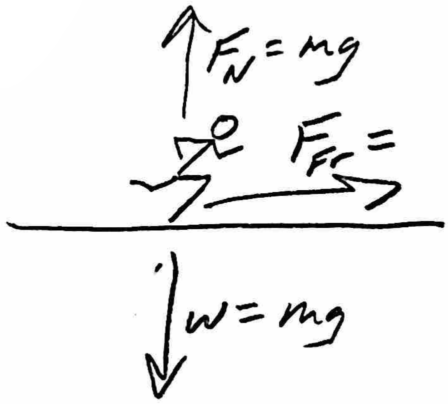
$$\cancel{m}a = -\mu_k \cancel{m}g$$

$$a = -(0.2)(9.8\,m/s^2) = -1.96\,m/s^2 = a$$

$$0\,m/s^2 = 4\,m/s^2 + 2(-1.96\,m/s^2)\Delta x$$

$$\boxed{\Delta x = 4.08\,m}$$

7.



$\sum F = ma$

$\sum F = F_{Fr}$

$F_{Fr} = ma$

$F_{Fr} = \mu_s F_N = \mu_s mg$

$ma = \mu_s mg$

$a = \mu_s g$

$a = 0.015(9.8 m/s^2)$

$a = 0.147 m/s^2$

Kinematics

$V_0 = 0 m/s$

$a = 0.147 m/s^2$

$\Delta x = 10 m$

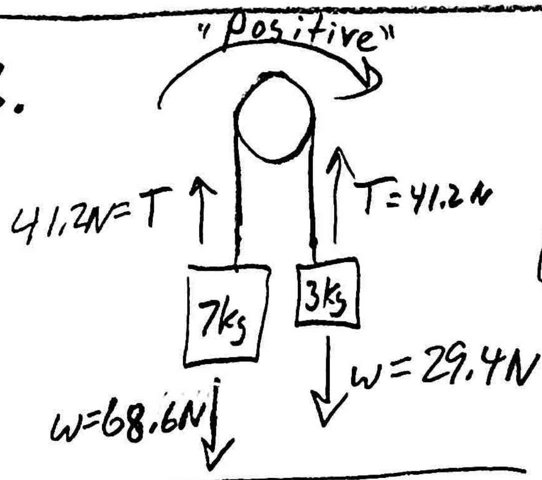
$\Delta t = ?$

$\Delta x = V_0 t + \frac{1}{2} a t^2$

$10 m = 0t + \frac{1}{2}(0.147 m/s^2) t^2$

$t = 11.7 s$

8.



$\sum F_{10} = 10kg(a)$

$\sum F = 29.4N - 68.6N = -39.2N$

$10kg(a) = -39.2 m/s^2$

$a = -3.92 m/s^2$

$a = 3.92 m/s^2$ Counter-clockwise

$\sum F_3 = T - 29.4N$

$\sum F_3 = 3kg(3.92 m/s^2) = 11.76N$

$T - 29.4N = 11.76N$

$T = 41.2N$

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Physics 200
Newton's Laws + Trig.
Bodies on Inclines

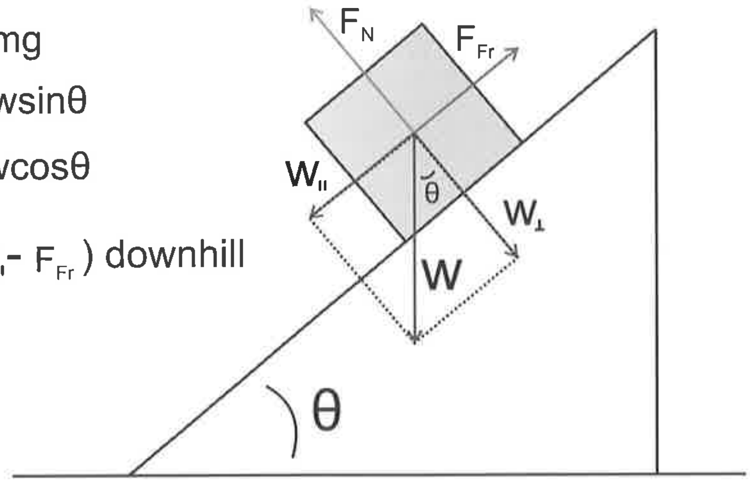
Name: ______________________

$w = mg$

$w_{\parallel} = w\sin\theta$

$w_{\perp} = w\cos\theta$

$\Sigma F = (w_{\parallel} - F_{Fr})$ downhill



- The perpendicular component of weight determines the normal force and, therefore, friction.
- The parallel component of weight contributes to acceleration.
- Unless friction is as strong as the parallel weight component, friction and weight are the only two non-canceling forces contributing to the net force.

Practice Problem: Fill in the remaining cells in the table below.

Item	Direction (When applicable)	Magnitude
coefficient of friction	NA	0.4
θ (degrees)	NA	30
Mass of object (kg)	NA	2
Weight of object (N)	Downward	19.6
Perpendicular Weight Component (N)	Perpendicularly toward incline	16.97409791
Parallel Weight Component (N)	Parallel to incline, downhill	9.8
Normal force (N)	Perpendicularly away from incline	16.97409791
Force of Friction (N)	Parallel to incline, uphill	6.789639166
Net force on object (N)	Parallel to incline, downhill	3.010360834
Acceleration (m/s^2)	Parallel to incline, downhill	1.505180417

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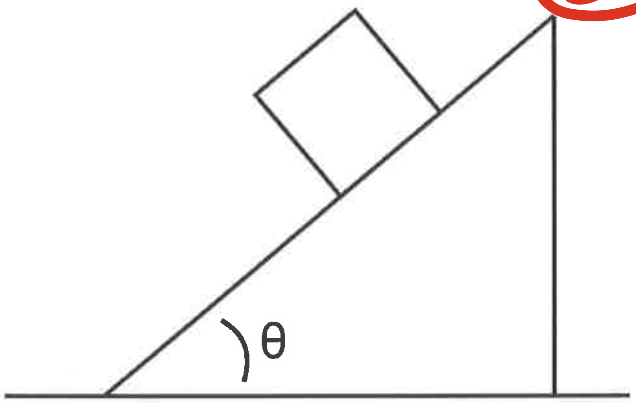
1a. The figure to the right shows a block on an incline. Draw and label the forces acting on the block. Resolve weight into perpendicular and parallel components, relative to the surface.

1b. Fill in the table below for the block on the ramp.



Item	Direction (When applicable)	Magnitude
coefficient of friction	NA	.6
θ (degrees)	NA	60
Mass of object (kg)	NA	2
Weight of object (N)	Downward	19.6
Perpendicular Weight Component (N)	Perpendicularly toward incline	9.8
Parallel Weight Component (N)	Parallel to incline, downhill	16.97409791
Normal force (N)	Perpendicularly away from incline	9.8
Force of Friction (N)	Parallel to incline, uphill	5.88
Net force on object (N)	Parallel to incline, downhill	11.09409791
Acceleration (m/s^2)	Parallel to incline, downhill	5.547048957

6

1. a)

$\Delta t = 1.4s$

$\Delta y = 0$

$$\Delta y = V_0 t + \tfrac{1}{2} a t^2$$

$$0 = V_0(1.4s) + \tfrac{1}{2}(-9.8\,m/s^2)(1.4s)^2$$

$$V_0 = 6.86\,m/s$$

b)

$$V^2 = V_0^2 + 2a\Delta x$$

$$(6.86\,m/s)^2 = 0^2 + 2a(0.3m)$$

$$a = 78.4\,m/s^2$$

c)

$$\Sigma F = ma = 0.3kg(118\,m/s^2)$$

$$\Sigma F = 31.4\,N$$

d)

Band force

$W = 0.4kg(9.8\,m/s^2) = 3.92N$

$$\Sigma F = \text{Band Force} - 3.92N = 31.4N$$

$$\text{Band Force} = 35.3N$$

2.

a) $\Delta y = v_0 t + \frac{1}{2} a t^2$ $-0.92m = 0 + \frac{1}{2}(-9.8 m/s^2) t^2$

$t = 0.433s$

$\bar{V}_x = \frac{\Delta x}{\Delta t}$ $\bar{V}_x = \frac{3.06m}{0.433s}$

$\bar{V}_x = V_0 = 7.07 m/s$

b) $V^2 = V_0^2 + 2a\Delta x$

$(7.07 m/s^2)^2 = 0 + 2a(0.3m)$

$a = 83.3 m/s^2$

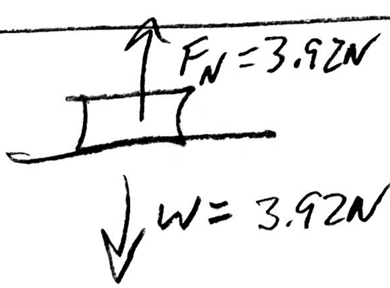
c) $\Sigma F = ma = 0.4kg(83.3 m/s^2) = 33.3N$

d)

$\Sigma F = 33.3N = 35.3N - F_{Fr}$

$F_{Fr} = 2N$

e)

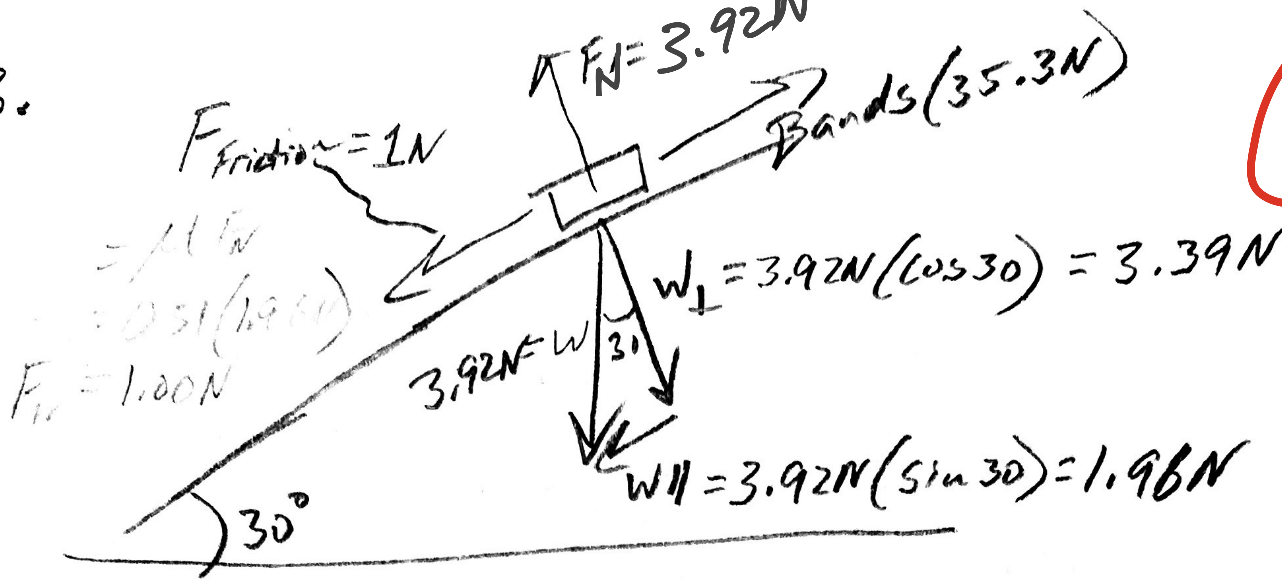


$F_{Fr_K} = \mu_K(3.92N) = 2N$

$\mu_K = 0.51$

6

3.



$F_N = 3.92N$
Bands (35.3N)
$F_{Friction} = 1N$
$= \mu F_N$
$= 0.51(1.96N)$
$F_{fr} = 1.00N$
$W_\perp = 3.92N(\cos 30) = 3.39N$
$3.92N = W$
30
$W_\parallel = 3.92N(\sin 30) = 1.96N$
30°

6

3.

6

a) 3.39 N (Same as $W_\perp$)

b) $F_{Fr} = \mu_k F_N = 0.51(3.39N) = 1.73N$

c) $\Sigma F_{\parallel}$ = Band force − Friction − $W_{\parallel}$

= 35.3N − 1.73N − 1.96N = 31.6N

d) $\Sigma F_{\parallel} = ma$ = 0.4kg (a)

31.6N = 0.4kg (a)

$a = 79.0 m/s^2$

e) $v^2 = v_0^2 + 2a\,\Delta x$

$v^2 = 0 + 2(79.0 m/s^2)(0.3m)$

$v = 6.89 m/s$

f) $\text{range} = \frac{v_0^2 \sin 2\theta}{g} = \frac{(6.89 m/s)^2 \sin(60°)}{9.8}$

Δx = range = 4.20m

g) $\text{range} = \frac{(7.07 m/s)^2 \sin(60°)}{9.8 m/s^2} = 4.42m$