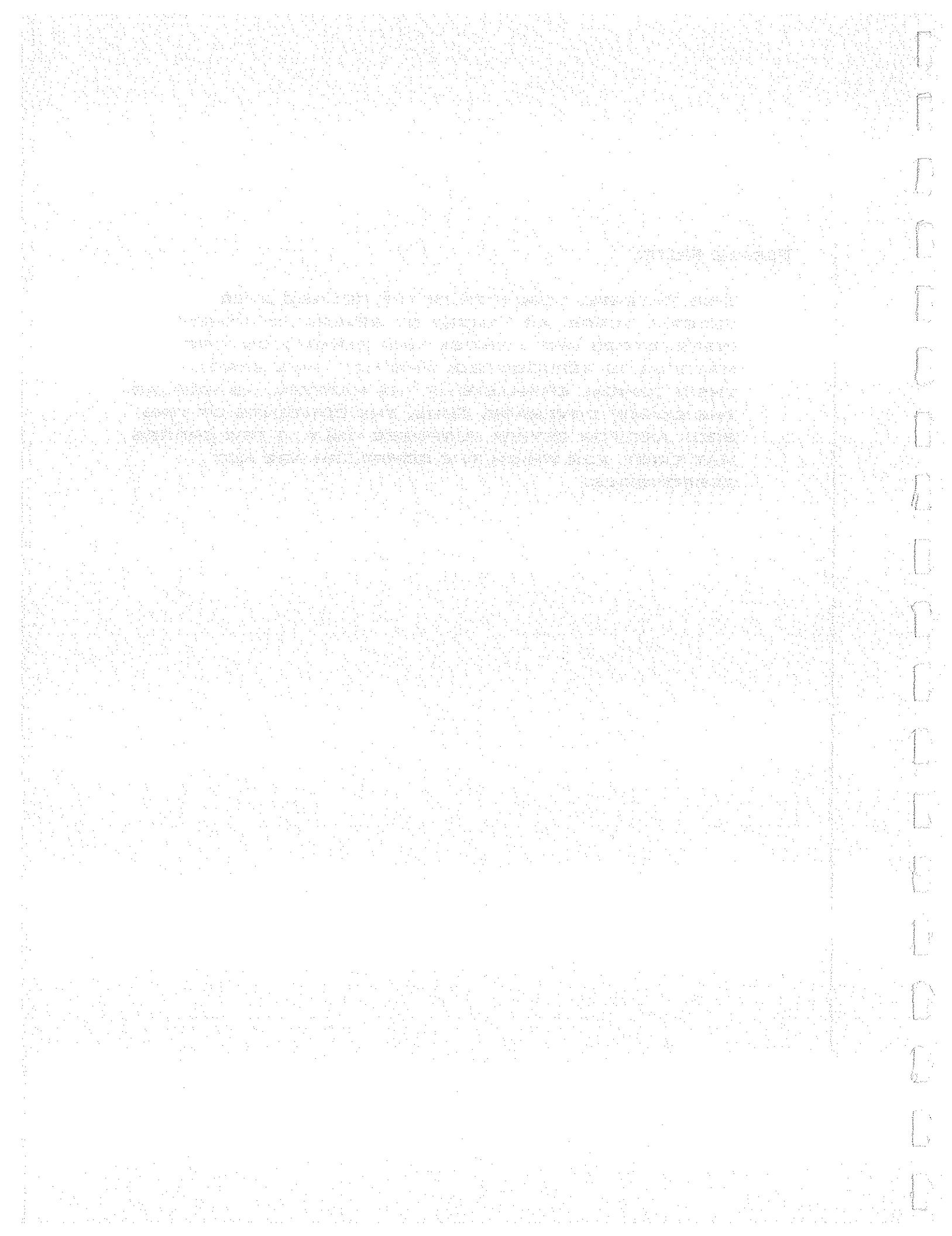


**PLEASE NOTE:**

**THIS MATERIAL COMES FROM THE COURSE OVER  
SEVERAL YEARS, AS TAUGHT BY SEVERAL DIFFERENT  
INSTRUCTORS (WITH WHOSE KIND PERMISSION THIS  
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THEIR TOPICAL EMPHASIS OF THE MATERIAL AS WELL AS  
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BOOK ARE FOR REVIEW PURPOSES ONLY. A FEW ERRORS  
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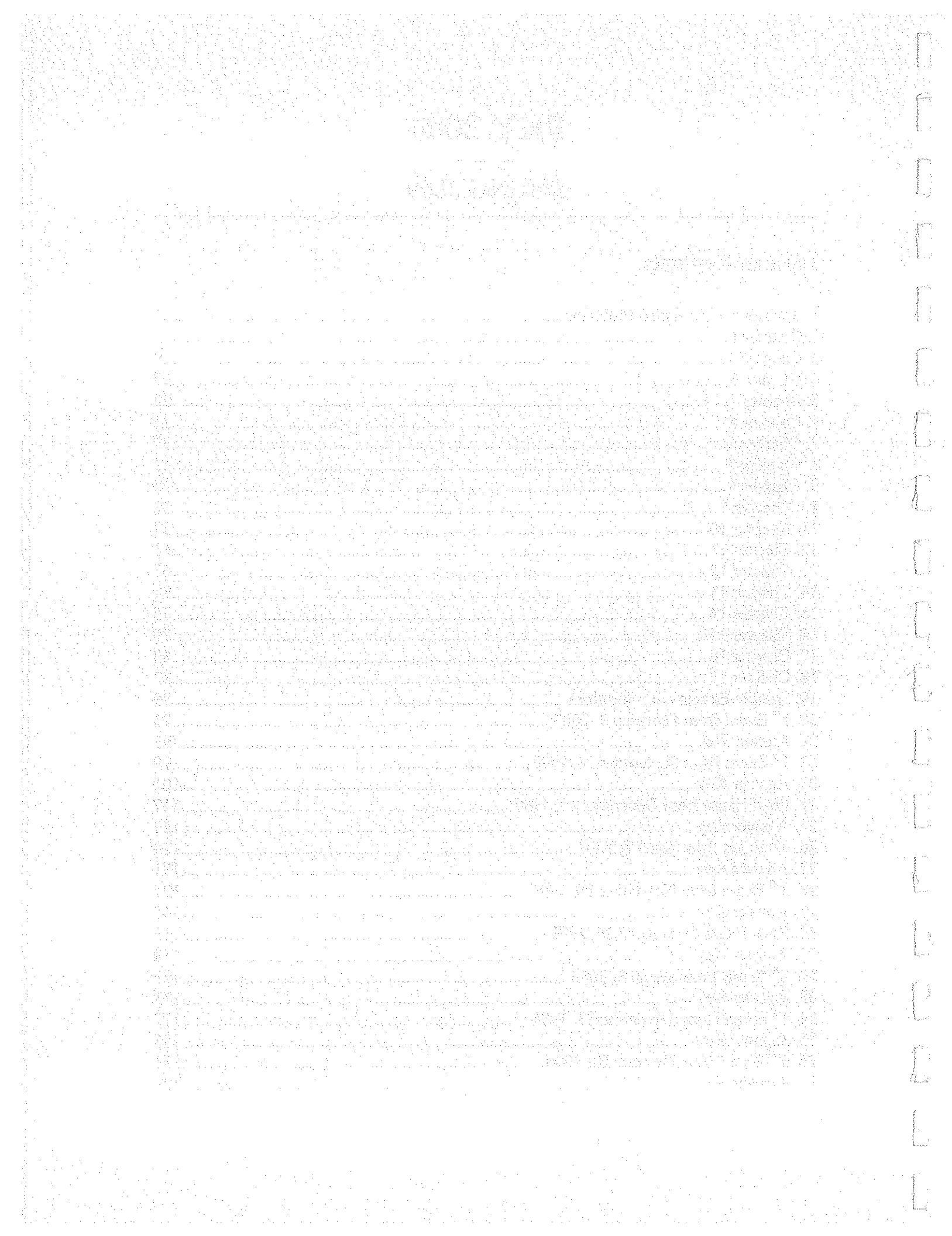
# PHY 2004

## SPRING 2009

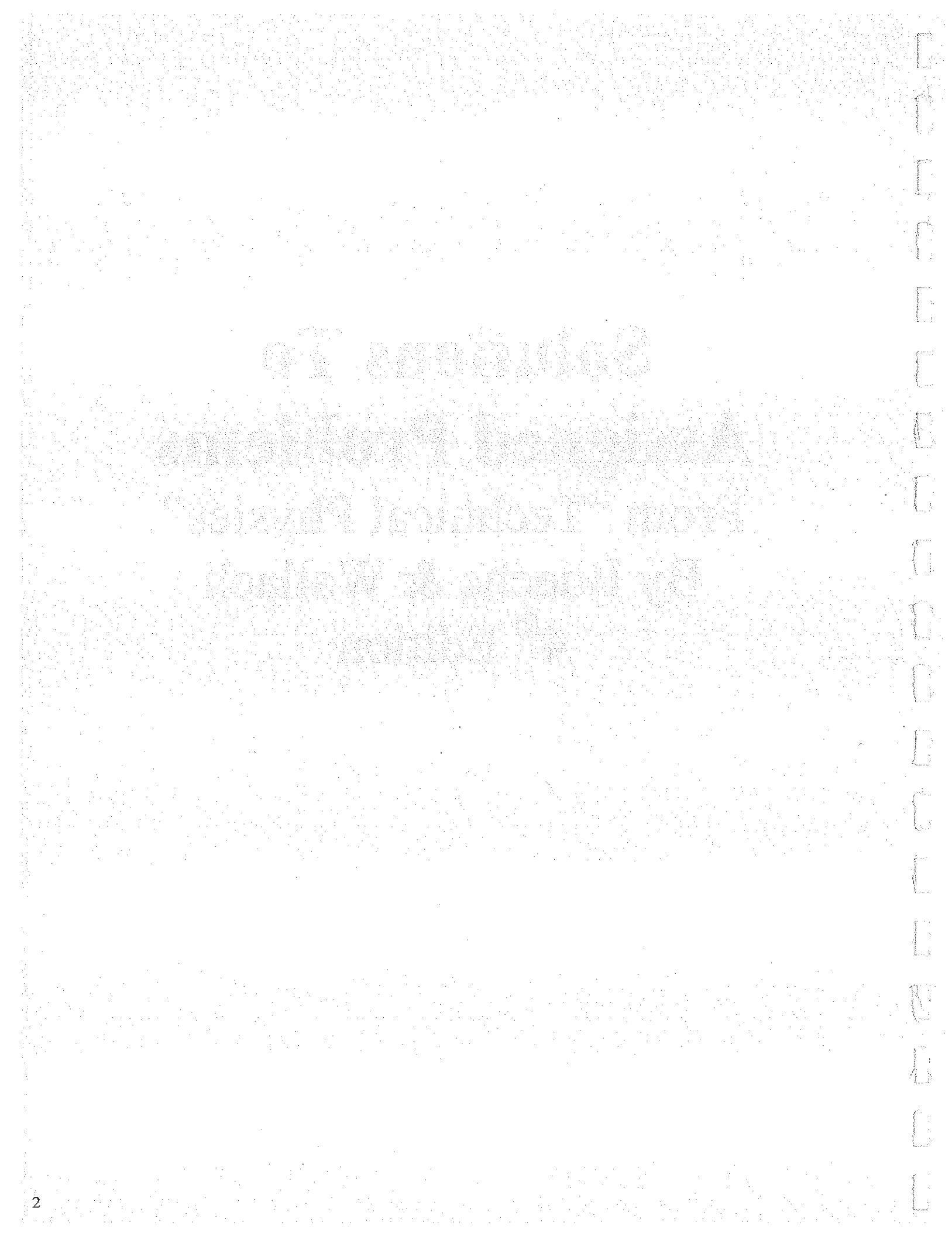
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**Solutions To  
Assigned Problems  
From “Technical Physics”  
By Bueche & Wallach  
4<sup>th</sup> Edition**



PHY 2004 - SOLUTIONS TO ASSIGNED PROBLEMS

Problems from "Technical Physics" by Bueche & Wallach, 4<sup>th</sup> ed.

Chapter 1 (3, 11, 17, 22, 23, 31, 34, 35, 37, 39, 43, 44, 47)

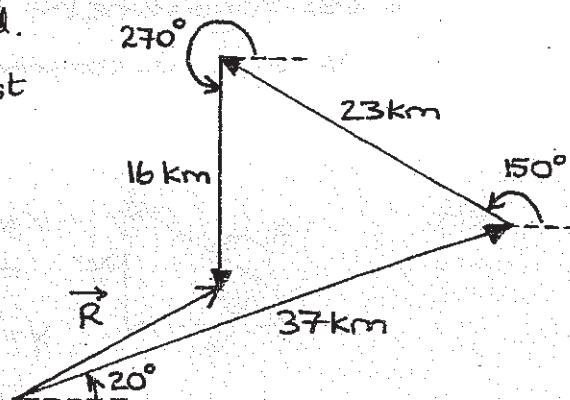
1-3) Method: Lay vectors tail-to-head.

Resultant  $\vec{R}$  connects tail of first vector to head of last vector.  
Here, scale is  $1 \text{ cm} = 10 \text{ km}$ .

Measurement on drawing gives

$$|\vec{R}| = 17 \text{ km}$$

$$\text{angle} = 30^\circ \text{ (rel. to } x\text{-axis)}$$



1-11) Since triangle is a right triangle, we can use the Pythagorean formula to find the length of side C.

$$(a) C = \sqrt{A^2 + B^2} = 2^2 + 3^2 \text{ m} = 3.6 \text{ m} \text{ (to 2 sig. fig.)}$$

$$(b) \sin \theta = A/C = 2/3.6 = 0.56$$

$$(c) \cos \theta = B/C = 3/3.6 = 0.83$$

$$(d) \tan \theta = A/B = 2/3 = 0.67$$

1-17) Note that since we know angle  $\phi$  (not  $\theta$ ), side A becomes the adjacent side and side B the opposite.

$$(a) \sin \phi = B/C \Rightarrow C = B/\sin \phi = 3 \text{ m} / \sin 50^\circ = 3.9 \text{ m} \text{ (to 2 sig. fig.)}$$

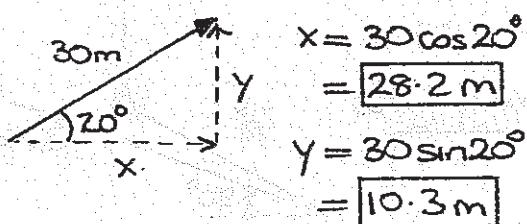
$$(b) \tan \phi = B/A \Rightarrow A = B/\tan \phi = 3 \text{ m} / \tan 50^\circ = 2.5 \text{ m}$$

1-22) Either of two methods can be applied to this problem:

Method I (safer)

- Draw a rough diagram
- Identify a right triangle
- Use trigonometry to find x- and y-components

(a)



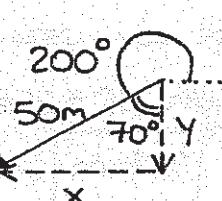
Method II (quicker)

- Identify  $\theta = \text{angle of vector measured CCW rel. to } x\text{-axis}$
- x-component = length  $\times \cos \theta$
- y-component = length  $\times \sin \theta$

$$x = 30 \cos 20^\circ \\ = 28.2 \text{ m}$$

$$y = 30 \sin 20^\circ \\ = 10.3 \text{ m}$$

(b)



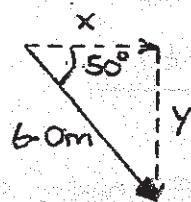
$$x = -50 \sin 70^\circ \\ = -47.0 \text{ m}$$

$$y = -50 \cos 70^\circ \\ = -17.1 \text{ m}$$

$$x = 50 \cos 200^\circ \\ = -47.0 \text{ m}$$

$$y = 50 \sin 200^\circ \\ = -17.1 \text{ m}$$

(c)



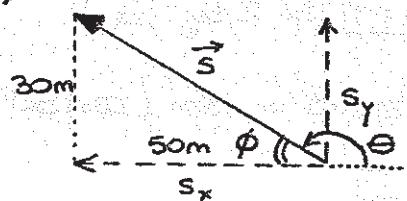
$$x = 6.0 \cos 50^\circ \\ = 3.86 \text{ m}$$

$$y = -6.0 \sin 50^\circ \\ = -4.6 \text{ m}$$

$$x = 6.0 \cos(-50^\circ) \\ = 3.86 \text{ m}$$

$$y = 6.0 \sin(-50^\circ) \\ = -4.6 \text{ m}$$

1-23)



$$\tan \phi = \frac{30}{50} \Rightarrow \phi = 31.0^\circ$$

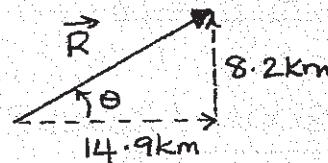
$$\text{magnitude, } |\vec{s}| = \sqrt{s_x^2 + s_y^2} \\ = \sqrt{(-50)^2 + (30)^2} \text{ m} \\ = 58.3 \text{ m}$$

$$\text{angle, } \theta = 180^\circ - \phi$$

$$= 149^\circ$$

1-31) Method : Resolve each vector into components. Add x- and y-components separately. Combine to obtain resultant vector.

vector	x	y	Recall (see 1-22)
37 at $20^\circ$	34.8	12.7	$x = \text{length} \times \cos\theta$
23 at $150^\circ$	-19.9	11.5	$y = \text{length} \times \sin\theta$
16 at $270^\circ$	0.0	-16.0	
resultant, $\vec{R}$	14.9	8.2	



$$\text{magnitude}, |\vec{R}| = \sqrt{14.9^2 + 8.2^2} \text{ km}$$

$$= 17.0 \text{ km}$$

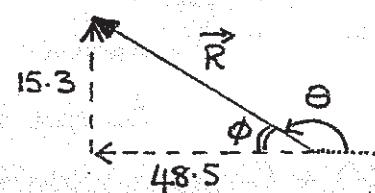
$$\text{angle}, \theta = \tan^{-1}\left(\frac{8.2}{14.9}\right)$$

$$= 28.8^\circ$$

1-34) Apply same method as in 1-31.

vector	x	y
6 at $90^\circ$	0.0	6.0
20 at $180^\circ$	-20.0	0.0
30 at $162^\circ$	-28.5	9.3
resultant	-48.5	15.3

Note: resultant is vector from first office to second.



$$\text{magnitude}, |\vec{R}| = \sqrt{48.5^2 + 15.3^2} \text{ paces}$$

$$= 50.9 \text{ paces}$$

$$\text{angle}, \theta = 180^\circ - \phi$$

$$= 162.5^\circ$$

$$\tan \phi = \frac{15.3}{48.5} \Rightarrow \phi = 17.5^\circ$$

$$\text{Finally, distance between offices} = |\vec{R}| = 50.9 \text{ paces}$$

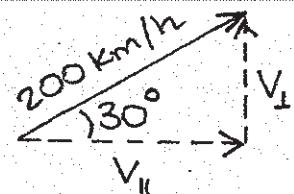
Angle of vector from second office to first

$$= \theta + 180^\circ = 342.5^\circ$$

1-35) Resultant has  $x$  component =  $-5 + 0 + 20 \text{ N} = 15 \text{ N}$ .  
 "  $y$  component =  $-7 + 30 - 16 \text{ N} = 7 \text{ N}$ .  
 " magnitude =  $\sqrt{15^2 + 7^2} \text{ N} = 16.6 \text{ N}$ .  
 " makes angle to  $x$  axis =  $\text{inv tan}(\frac{7}{15}) = 25.0^\circ$ .

1-37) We must resolve the velocity into horizontal and vertical components,  $V_{\parallel}$  and  $V_{\perp}$ :

(a) Plane rises at speed  $V_{\perp} = (200 \text{ km/h}) \sin 30^\circ$   
 $= 100 \text{ km/h.}$



(b) Plane moves over ground at speed

$$V_{\parallel} = (200 \text{ km/h}) \cos 30^\circ$$

$$= 173 \text{ km/h.}$$

1-39) We perform arithmetic operations to "x" and "y" components separately:

$$\begin{aligned} \vec{A} &= (10, 0) \text{ m} \\ \vec{B} &= (15, 0) \text{ m} \end{aligned} \quad \Rightarrow \quad \begin{aligned} \vec{A} + \vec{B} &= (25, 0) \text{ m or } 25 \text{ m due east.} \\ \vec{A} - \vec{B} &= (-5, 0) \text{ m or } 5 \text{ m due west.} \\ 2\vec{A} - \vec{B} &= (5, 0) \text{ m or } 5 \text{ m due east.} \end{aligned}$$

$x = \text{east}$        $y = \text{north}$

1-43) Let  $\vec{v}_{\text{plane/grand}}$  mean "velocity of plane relative to ground".

Then  $\vec{v}_{\text{plane/grand}} = \vec{v}_{\text{plane/air}} + \vec{v}_{\text{air/grand}}$

↑ due to engines    ↑ due to wind

$$= (400, 0) + (-80, 0) \text{ km/h}$$

$$= (320, 0) \text{ km/h or } 320 \text{ km/h due east.}$$

Note: When add relative velocities as above, subscripts multiply like fractions - e.g.,

$$\text{plane/grand} = \text{plane/air} \times \text{air/grand}$$

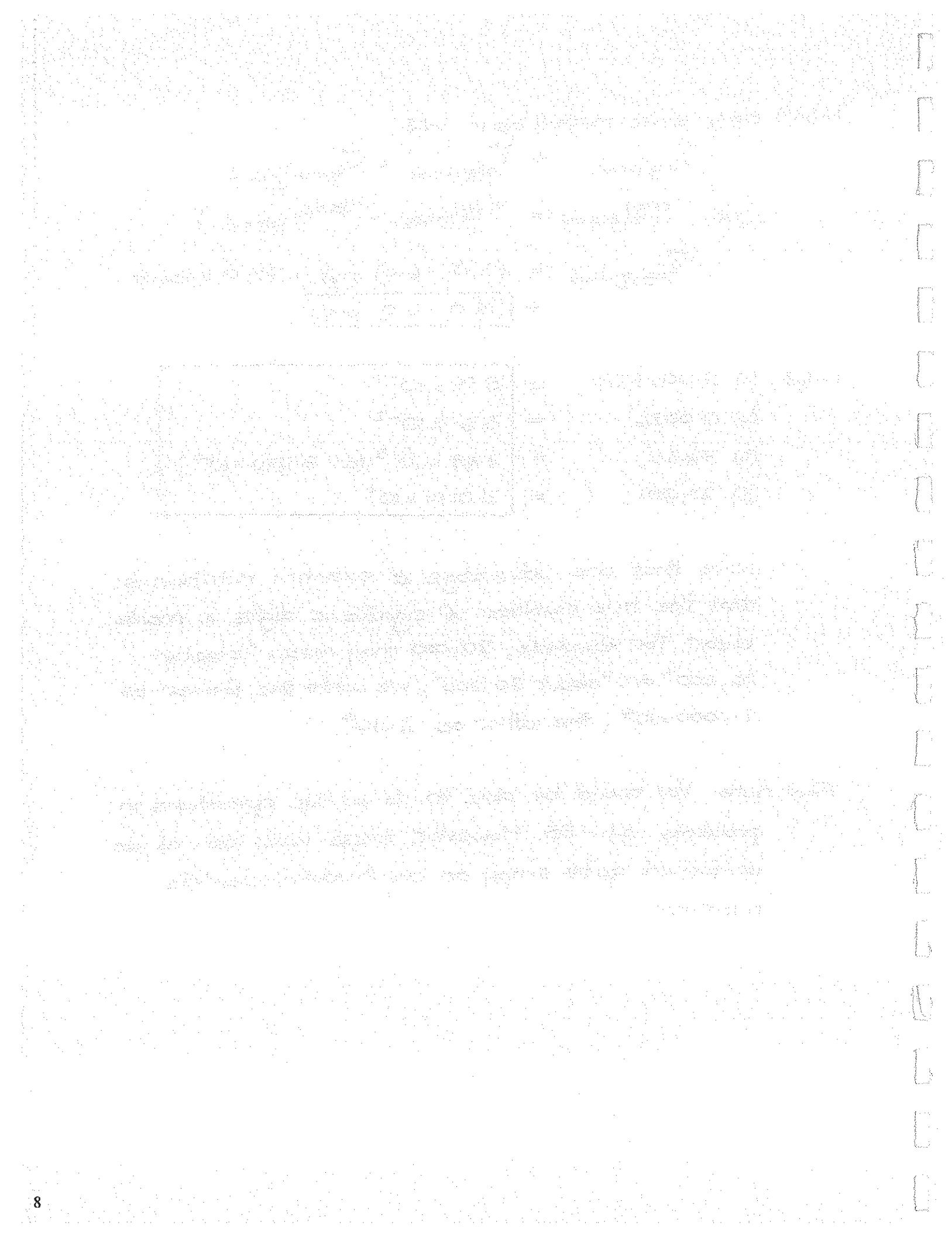
1-44) Apply same method as in 1-43.

$$\begin{aligned}\vec{v}_{\text{bug/grand}} &= \vec{v}_{\text{bug/boat}} + \vec{v}_{\text{boat/grand}} \\ (\text{i.e., } v_{\text{bug/grand}} &= v_{\text{bug/boat}} \times v_{\text{boat/grand}}) \\ \vec{v}_{\text{bug/grand}} &= (3.0, -6.0) \text{ cm/s} + (15.0, 0) \text{ cm/s} \\ &= \boxed{(18.0, -6.0) \text{ cm/s}}\end{aligned}$$

1-47) (a)	$0.000579$	$= 5.79 \times 10^{-4}$
(b)	$0.0036$	$= 3.6 \times 10^{-3}$
(c)	$7490$	$= 7.49 \times 10^{-3}$ (or $7.490 \times 10^{-3}$ )
(d)	$20,001$	$= 2.0001 \times 10^4$

Note that one advantage of scientific notation is that the true number of significant digits is made clear. For example, 20,000 may mean "exactly 20,000" or "about 20,000"; we write the former as  $2.0000 \times 10^4$ , the latter as  $2 \times 10^4$ .

Final note: You should be able to do all the operations in problems 46-55. However, these tasks can all be performed quite simply on any (modern) scientific calculator.



## Chapter 2 (5, 7, 17, 23, 27, 30, 31, 32, 35, 37, 44, 50, 52, 53, 54)

$$2-5) \text{ average speed} = \frac{\text{distance}}{\text{time}} = \frac{500 \text{ miles}}{3 \text{ hours } 13 \text{ mins}} \\ = \frac{500 \text{ miles}}{3 \frac{13}{60} \text{ hours}} = \boxed{155 \text{ miles/hour}}$$

but

$$\text{average velocity} = \frac{\text{vector displacement}}{\text{time}} = \boxed{0 \text{ miles/hour}}$$

(since start and finish are at same place).

$$2-7) 10 \text{ miles} = 10 \text{ miles} \times \left( \frac{5280 \text{ ft}}{1 \text{ mile}} \right) \times \left( \frac{12 \text{ in}}{1 \text{ ft}} \right) \times \left( \frac{2.54 \text{ cm}}{1 \text{ in}} \right) \\ = 10 \times 5280 \times 12 \times 2.54 \text{ cm} \\ = \boxed{1.61 \times 10^6 \text{ cm}}$$

Note that we apply the usual rules of algebra to cancel units that appear in both the top and bottom of fractions.

2-17) (a) To find average speed, we need the total distance.

The object moves from  $x = 2 \text{ m}$  to  $x = 10 \text{ m}$  (a distance of  $8 \text{ m}$ ), then from  $x = 10 \text{ m}$  to  $x = 0 \text{ m}$  (a distance of  $10 \text{ m}$ ).

$$\Rightarrow \text{average speed} = \frac{\text{total distance}}{\text{total time}} = \frac{18 \text{ m}}{10 \text{ s}} = \boxed{1.8 \text{ m/s.}}$$

(b) The average velocity depends on the net displacement,

$$x_f - x_i = 0 \text{ m} - 2 \text{ m} = -2 \text{ m.}$$

$$\Rightarrow \text{average velocity} = \frac{\text{net displacement}}{\text{total time}} = \frac{-2 \text{ m}}{10 \text{ s}} = \boxed{-0.2 \text{ m/s.}}$$

2-23) By definition, average acceleration  $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$ .

We don't know the direction, but  $|\vec{v}_f - \vec{v}_i| = 20 \text{ m/s.}$

$$\Rightarrow \text{magnitude of avg. acceleration, } |\vec{a}| = \frac{20 \text{ m/s}}{8 \text{ s}} = \boxed{2.5 \text{ m/s}^2.}$$

2-27) The minimum stopping time is obtained by braking as

hard as possible, i.e., by achieving the maximum possible deceleration.

$$V_f = V_i + at \Rightarrow t = \frac{V_f - V_i}{a} = \frac{0 - 20 \text{ m/s}}{(-6 \text{ m/s}^2)} = 3.3 \text{ s}$$

(Note that a deceleration of  $6 \text{ m/s}^2$  is an acceleration of  $-6 \text{ m/s}^2$ .)

2-30) We are given  $V_i = 500 \text{ m/s}$ ,  $V_f = 0 \text{ m/s}$ ,  $x = 0.170 \text{ m}$ .

$$\text{Use } V_f^2 = V_i^2 + 2ax \Rightarrow a = \frac{V_f^2 - V_i^2}{2x} = \frac{0^2 - 500^2 \text{ m}^2/\text{s}^2}{2 \times 0.170 \text{ m}} = -7.35 \times 10^5 \text{ m/s}^2$$

$$\text{Use } V_f = V_i + at \Rightarrow t = \frac{V_f - V_i}{a} = \frac{0 - 500 \text{ m/s}}{-7.35 \times 10^5 \text{ m/s}^2} = 6.8 \times 10^{-4} \text{ s.}$$

(Strictly, the deceleration equals  $-a$ , or  $+7.35 \times 10^5 \text{ m/s}^2$ .)

2-31) We are given  $V_i = 6.0 \text{ m/s}$ ,  $x = 100 \text{ m}$ ,  $t = 10.0 \text{ s}$ ,  $a = \text{constant}$ .

$$\text{Use } x = V_i t + \frac{1}{2} a t^2 \Rightarrow a = \frac{2}{t^2} (x - V_i t) = \frac{2}{(10.0 \text{ s})^2} \times (100 \text{ m} - 6.0 \text{ m/s} \times 10.0 \text{ s}) = 0.8 \text{ m/s}^2$$

$$\text{Use } V_f = V_i + at \Rightarrow V_f = 6.0 \text{ m/s} + 0.8 \text{ m/s}^2 \times 10.0 \text{ s} = 14 \text{ m/s.}$$

2-32)(a) avg. acceleration between A and B =  $\frac{V_B - V_A}{t_B - t_A} = \frac{4 - 0 \text{ m/s}}{30 - 0 \text{ s}} = 0.133 \text{ m/s}^2$

(b) avg. acceleration between C and D =  $\frac{V_D - V_C}{t_D - t_C} = \frac{6 - 6 \text{ m/s}}{70 - 45 \text{ s}} = 0 \text{ m/s}^2$

(c) For interval AB we know  $v_i = v_A = 0$ ,  $v_f = v_B = 4 \text{ m/s}$ ,  
 $t = t_B - t_A = 30 \text{ s}$  and  $a = 0.133 \text{ m/s}^2$ .

$$\Rightarrow \text{distance travelled, } x = v_i t + \frac{1}{2} a t^2$$

$$= 0 \text{ m/s} \times 30 \text{ s} + \frac{1}{2} \times 0.133 \text{ m/s}^2 \times (30 \text{ s})^2$$

$$= 60 \text{ m.}$$

(d) For interval CD we know  $v_i = v_c = v_f = v_D = 6 \text{ m/s}$ ,  
 $t = t_D - t_c = 25 \text{ s}$  and  $a = 0 \text{ m/s}^2$ .

$$\Rightarrow \text{distance travelled, } x = v_i t + \frac{1}{2} a t^2$$

$$= 6 \text{ m/s} \times 25 \text{ s} + \frac{1}{2} \times 0 \text{ m/s}^2 \times (25 \text{ s})^2$$

$$= 150 \text{ m.}$$

2-35) Hint: We have two separate objects moving with constant accelerations. What property of the two objects must be the same when the police officer catches the car?

Method: Write separate equations for the displacement of each vehicle from the corner as a function of time.

The police officer catches the car at the time  $t$  when  $x_{\text{police}}(t) = x_{\text{car}}(t)$ .

car: Has constant velocity  $v = 90 \frac{\text{km}}{\text{hr}} \times \left(\frac{1000 \text{ m}}{1 \text{ km}}\right) \times \left(\frac{1 \text{ hr}}{3600 \text{ s}}\right)$

$$= 25 \text{ m/s.}$$

$$\Rightarrow x_{\text{car}}(t) = vt$$

$$= 25t$$

where  $t$  is measured in seconds from the moment the car passes the corner.

police cruiser: until  $t=5s$  has velocity  $v_i = 0$ ; after that has constant acceleration  $a = 5 \text{ m/s}^2$ .

$$x_{\text{police}}(t) = v_i t + \frac{1}{2} a(t-5)^2 = 2.5(t-5)^2.$$

[Here  $(t-5)$  appears instead of  $t$  since acceleration does not start until  $t=5s$ .]

Police cruiser catches car when

$$\begin{aligned} x_{\text{police}}(t) &= x_{\text{car}}(t) \\ 2.5(t-5)^2 &= 25t \\ 2.5t^2 - 25t + 62.5 &= 25t \\ 2.5t^2 - 50t + 62.5 &= 0. \end{aligned}$$

This is a quadratic equation, which has two solutions for  $t$  (see Busche, p. 652)

$$\begin{aligned} t &= \frac{50 \pm \sqrt{50^2 - 4 \times 2.5 \times 62.5}}{2 \times 2.5} \\ &= 1.34s \text{ or } 18.66s. \end{aligned}$$

Although mathematically correct, the solution  $t=1.34s$  is physical nonsense – the police officer didn't give chase until  $t=5s$ .

$\Rightarrow$  The cruiser catches the car at time  $t=18.66s$ .

To find the distance from the corner, substitute  $t=18.66s$  into either  $x_{\text{car}}(t)$  or  $x_{\text{police}}(t)$ :

e.g.,

$$x = 25 \times 18.66 = \boxed{467 \text{ m}}$$

$$\begin{aligned} \text{Velocity of cruiser, } v_{\text{police}} &= v_i + a(t-5s) = 0 + (5 \text{ m/s}^2)(18.66 - 5)s \\ &= \boxed{68.3 \text{ m/s}} \\ &= 246 \text{ km/h or } 152 \text{ miles/h!} \end{aligned}$$

2-37) Choose positive-y direction upwards. Then we know

$$v_i = 0 \text{ m/s}, a = -g = -9.8 \text{ m/s}^2, \text{ and } y = -13.0 \text{ m.}$$

$$\text{Using } y = v_i t + \frac{1}{2} a t^2, \quad t = \sqrt{\frac{2y}{a}} = \sqrt{\frac{2 \times (-13.0 \text{ m})}{(-9.8 \text{ m/s}^2)}} \\ = 1.63 \text{ s.}$$

$$\text{Then } v_f = v_i + at = 0 \text{ m/s} + (-9.8 \text{ m/s}^2) \times 1.63 \text{ s} = -16.0 \text{ m/s.}$$

2-44) Choose positive-y direction upwards. Then we know

$$v_i = +25 \text{ m/s}, a = -g = -9.8 \text{ m/s}^2, \text{ and } y = -30 \text{ m.}$$

Using  $y = v_i t + \frac{1}{2} a t^2$ , have quadratic equation

$$\text{for } t: \frac{1}{2} a t^2 + v_i t - y = 0$$

$$\Rightarrow t = \frac{-v_i \pm \sqrt{v_i^2 - 4 \times \frac{1}{2} a \times (-y)}}{2 \times \frac{1}{2} a} \\ = \frac{-25 \pm \sqrt{25^2 - 4 \times \frac{1}{2} (-9.8) \times 30}}{2 \times \frac{1}{2} (-9.8)} \text{ s} \\ = -1.0 \text{ s or } +6.1 \text{ s.}$$



Just as in 2-35, we have a mathematically correct, but physically nonsensical solution,  $t = -1.0 \text{ s}$ , which we discard.

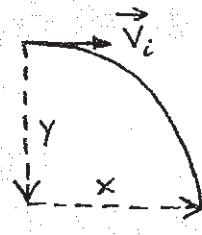
$\Rightarrow$  The ball reaches the water after time  $t = 6.1 \text{ s.}$

$$\text{Now use } v_f^2 = v_i^2 + 2ay = (25 \text{ m/s})^2 + 2 \times (-9.8 \text{ m/s}^2) \times (-30 \text{ m}) \\ = 1213 (\text{m/s})^2$$

$$\text{Velocity just before hits, } v_f = -34.8 \text{ m/s.}$$

2-50) Hint: In problems involving projectile motion, we can write separate equations for the motion in the x- and y-directions, connected only by the time  $t$  appearing in each equation.

Method: Use y-equation to find time ball is in air. Then use time and distance travelled horizontally to deduce initial velocity of ball.



vertical direction: since ball is launched horizontally,

we know  $V_{iy} = 0 \text{ m/s}$ ; also  $a_y = -g = -9.8 \text{ m/s}^2$ ,  $y = -30 \text{ m}$ .

$$\begin{aligned}\text{Using } y &= V_{iy}t + \frac{1}{2}a_y t^2, \quad t = \frac{-V_{iy} \pm \sqrt{V_{iy}^2 - 4 \times \frac{1}{2}a_y \times (-y)}}{2 \times \frac{1}{2}a_y} \\ &= \frac{0 \pm \sqrt{0^2 - 4 \times \frac{1}{2}(-9.8) \times 30}}{2 \times \frac{1}{2}(-9.8)} \text{ s} \\ &= \pm 2.47 \text{ s}.\end{aligned}$$

Once again, the negative solution is unphysical.

$\Rightarrow$  The ball is in the air for a time  $t = 2.47 \text{ s}$ .

[Quicker method: since ball starts with zero vertical velocity, time in air is just that for any object to fall through a height  $h = 30 \text{ m}$ ,

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 30}{9.8}} \text{ s} = 2.47 \text{ s.}]$$

horizontal direction: since  $a_x = 0$ ,  $V_{ix} = \frac{x}{t} = \frac{50 \text{ m}}{2.47 \text{ s}} = 20.2 \text{ m/s}$

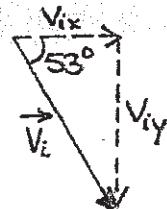
$\Rightarrow$  initial speed of ball =  $20.2 \text{ m/s}$

2-52) Method: Again we treat the x- and y-motion separately.

Here, however, the initial velocity has non-zero components in both x- and y-directions:

$$V_{ix} = V_i \cos 53^\circ = 300 \text{ m/s} \times 0.6 = 180 \text{ m/s}$$

$$V_{iy} = -V_i \sin 53^\circ = -300 \text{ m/s} \times 0.8 = -240 \text{ m/s}$$



y-direction: We know  $v_{iy} = -240 \text{ m/s}$ ,  $a_y = -g = -9.8 \text{ m/s}^2$ , and  $y = -2000 \text{ m}$ .

$$\text{Using } y = v_{iy}t + \frac{1}{2}at^2, t = \frac{-v_{iy} \pm \sqrt{v_{iy}^2 - 4 \times \frac{1}{2}a_y \times (-y)}}{2 \times \frac{1}{2}a_y}$$

$$= \frac{240 \pm \sqrt{(-240)^2 - 4 \times \frac{1}{2}(-9.8) \times 2000}}{2 \times \frac{1}{2}(-9.8)} \text{ s}$$

$$= -56.2 \text{ s or } 7.3 \text{ s.}$$

As usual, we want the positive solution - the bomb hits the ground after 7.3 s.

x-direction: We know  $v_{ix} = 180 \text{ m/s}$ ,  $a_x = 0$ ,  $t = 7.3 \text{ s}$ .

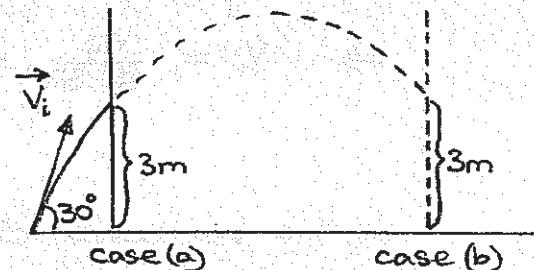
$$\text{Distance travelled horizontally, } x = v_{ix}t + \frac{1}{2}a_x t^2$$

$$= 180 \text{ m/s} \times 7.3 \text{ s}$$

$$= 1310 \text{ m.}$$

2-53) Method: Find the time  $t$  at which  $y = 3 \text{ m}$ . There will be two solutions, corresponding to cases (a) and (b).

Use the time and the horizontal velocity to find the distance from the wall.



$$V_{ix} = 20 \text{ m/s} \times \cos 30^\circ = 17.3 \text{ m/s}$$

$$V_{iy} = 20 \text{ m/s} \times \sin 30^\circ = 10.0 \text{ m/s}$$

y-direction: We know  $v_{iy} = 10.0 \text{ m/s}$ ,  $a_y = -g = -9.8 \text{ m/s}^2$ ,  $y = 3 \text{ m}$ .

$$\text{Using } y = v_{iy}t + \frac{1}{2}a_y t^2, t = \frac{-v_{iy} \pm \sqrt{v_{iy}^2 - 4 \times \frac{1}{2}a_y \times (-y)}}{2 \times \frac{1}{2}a_y}$$

$$= \frac{-10 \pm \sqrt{10^2 - 4 \times \frac{1}{2}(-9.8) \times (-3)}}{2 \times \frac{1}{2}(-9.8)} \text{ s}$$

$$= 0.37 \text{ or } 1.68 \text{ s.}$$

horizontal direction: distance travelled is  $x = v_{ix}t$

Substituting  $t = 0.37$  and  $1.68s$ , find distance from boy to wall is  $6.4m$  or  $29m$

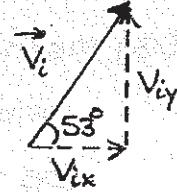
2-54) Method: We can use basically the same method as for the last few problems to relate the time in the air to the vertical component of the initial velocity. However, a quicker method uses the equation

$$v_y = v_{iy} + a_y t \text{ with } a_y = -g = -9.8 \text{ m/s}^2.$$

A total time of  $5.0s$  means  $2.5s$  going up and  $2.5s$  coming down (can you show this?). Therefore, at  $t = 2.5s$ ,  $v_{fy} = 0 \text{ m/s}$ , so  $v_{iy} = gt = 9.8 \text{ m/s}^2 \times 2.5s = 24.5 \text{ m/s}$

$$\text{Now, } v_{iy} = v_i \sin 53^\circ$$

$$\Rightarrow v_i = \frac{v_{iy}}{\sin 53^\circ} = \frac{24.5 \text{ m/s}}{0.8} = 30.7 \text{ m/s}$$



In the horizontal direction we can use

$$x = v_{ix}t$$

$$\text{with } v_{ix} = v_i \cos 53^\circ = 30.7 \text{ m/s} \times 0.6 \\ = 18.5 \text{ m/s}$$

In a total time of  $5.0s$ , the total distance travelled horizontally is

$$x = 18.5 \text{ m/s} \times 5.0s$$

$$= 92 \text{ m}$$

Chapter 3 (2, 5, 10, 18, 22, 25, 27, 30, 31, 36, 38, 39, 43)

3-2) This problem focuses on the relation between mass,  $m$ , and weight,  $w = mg$ .

- (a) To prevent a stationary object accelerating, it must be supported by a net vertical force equal, and opposite, to its weight.

$$\Rightarrow \text{support force} = mg = 800\text{kg} \times 9.8\text{m/s}^2 \\ = 7840\text{N.}$$

- (b) If greatest weight that can be supported is  $w = 50,000\text{N}$ ,  
 largest mass  $= \frac{w}{g} = \frac{50,000\text{N}}{9.8\text{m/s}^2}$   
 $= 5,100\text{ kg.}$

3-5) (a) From Newton's second law,  $m = \frac{F}{a} = \frac{30\text{N}}{5.0\text{m/s}^2} = 6.0\text{kg.}$

(b) Using the same law,  $a' = \frac{F'}{m} = \frac{40\text{N}}{6.0\text{kg}} = 6.67\text{m/s}^2$ .

- 3-10) (a) Mass is an invariant quantity which does not change from location to location.

$$\Rightarrow \text{mass of object on Mars} = \text{mass on earth} = 5.0\text{kg.}$$

(b) Weight of object on Mars  $= mg_{\text{Mars}} = 5.0\text{kg} \times 3.9\text{m/s}^2 \\ = 19.5\text{N}$

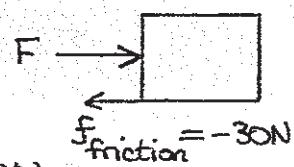
3-18)  $\sum F_x = m a_x \Rightarrow F + f_{\text{friction}} = m a_x$

$$F = m a_x - f_{\text{friction}}$$

$$= 6.0\text{kg} \times 8.0\text{m/s}^2 + 30\text{N}$$

$$= 78\text{N}$$

NB: only need to worry about horizontal forces



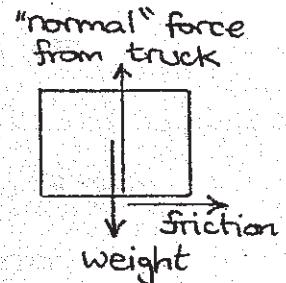
3-22) From the definition in Chapter 2, the average acceleration is  $a = \frac{v_f - v_i}{t} = \frac{0 - 25\text{ m/s}}{0.30\text{ s}} = -83.3 \text{ m/s}^2$ .

⇒ The car's average deceleration is  $83.3 \text{ m/s}^2$ .

Applying Newton's 2<sup>nd</sup> Law, force  $F = ma = 40\text{ kg} \times 83.3 \text{ m/s}^2 = 3300 \text{ N}$ .

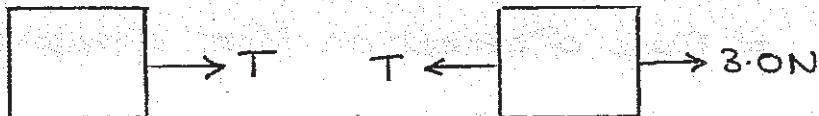
3-25) Consider the box: in order not to slip, it must have the same acceleration as the truck. The only force that can bring about this acceleration is the force of friction. (The other forces acting on the box are vertical.) Thus the maximum acceleration without slipping is related to the maximum frictional force by

$$F_{\max} = m_{\text{box}} a_{\max} \\ \Rightarrow a_{\max} = F_{\max}/m_{\text{box}} = \frac{280\text{ N}}{30\text{ kg}} = 9.3 \text{ m/s}^2.$$



3-27) Draw separate "free-body" diagrams for the two blocks:

(can ignore  
vertical  
forces)



Here  $T$  is the tension in the connecting cord.

Applying Newton's 2<sup>nd</sup> law to each block in turn:

$$\sum F_x = m a_x \Rightarrow T = (0.7\text{ kg}) a \quad (1) \quad (\text{left block})$$

$$3.0\text{ N} - T = (0.7\text{ kg}) a \quad (2) \quad (\text{right "})$$

Solve for acceleration,  $a$ , and tension,  $T$ , using your favorite method for treating simultaneous equations.

For instance, use equation ① to replace  $T$  in equation ②, obtaining

$$3.0N - (0.7\text{kg})a = (0.7\text{kg})a$$

$$(1.4\text{kg})a = 3.0N$$

$$a = \frac{3.0N}{1.4\text{kg}} = 2.1 \text{ m/s}^2.$$

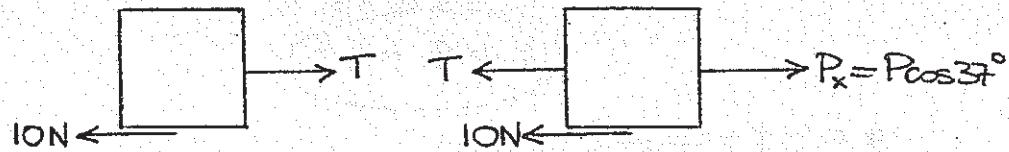
Then, from ①,

$$T = (0.7\text{kg})a$$

$$= 0.7\text{kg} \times 2.1 \text{ m/s}^2 = 1.5N$$

3-30) Again, draw separate free-body diagrams for the two blocks:

(only need horizontal forces)



$$\sum F_x = ma_x \Rightarrow T - 10N = (4.0\text{kg})(0.8\text{m/s}^2) \quad (\text{left})$$

tension in connecting cord,  $T = 10N + 4.0 \times 0.8 \text{ N}$

$$= 13.2 \text{ N}$$

$$P_x - T - 10N = (4.0\text{kg})(0.8\text{m/s}^2) \quad (\text{right})$$

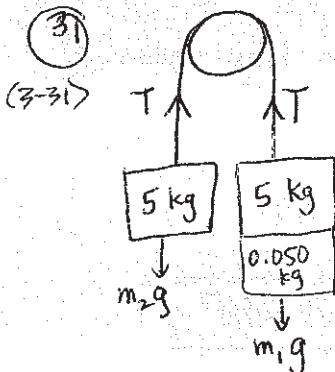
$$P_x = T + 10N + 4.0 \times 0.8 \text{ N}$$

$$= 26.4 \text{ N}$$

$$\text{pulling force, } P = \frac{P_x}{\cos 37^\circ} = 33.1 \text{ N}$$

3-31) Like 3-27 and 3-30, this problem involves coupled motion of two bodies connected by a massless string. Once again, we tackle the problem by writing separate equations for each body. However, the physical arrangement of the objects (see Fig. 3.13) is more complicated than in the previous problems.

### Chp 3



Let  $m_2 = 5 \text{ kg}$   
 $m_1 = 5.05 \text{ kg}$

Choose direction of acceleration so that  $m_1$  goes down and  $m_2$  goes up.

$$\text{For } m_1: m_1 g - T = m_1 a \Rightarrow T = m_1 g - m_1 a$$

$$\text{For } m_2: T - m_2 g = m_2 a$$

$$\Rightarrow (m_1 g - m_1 a) - m_2 g = m_2 a$$

$$\Rightarrow m_1 g - m_2 g = m_1 a + m_2 a$$

$$\Rightarrow a = g \left( \frac{m_1 - m_2}{m_1 + m_2} \right) \quad \leftarrow \text{formula from example 3.8}$$

$$= (9.8) \left( \frac{5.05 - 5}{5.05 + 5} \right)$$

$$= 0.049 \text{ m/s}^2$$

$$y = v_i t + \frac{1}{2} a t^2$$

$$v_i = 0 \quad (\text{initial velocity})$$

$$\Rightarrow y = \frac{1}{2} a t^2$$

$$\Rightarrow t = \sqrt{\frac{2y}{a}} = \sqrt{\frac{2(0.08)}{0.049}} = 1.8 \text{ s}$$

(36)  $F = \frac{G m_1 m_2}{r^2} \quad (\text{Eq 3.4})$

(3-36)

$$= \left( 6.67 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^2} \right) \frac{(6 \times 10^{24} \text{ kg})(7.4 \times 10^{22} \text{ kg})}{(3.84 \times 10^8)^2}$$

$$= 2 \times 10^{20} \text{ N}$$

(38)  $r_N = 4r_E$  Object weighs  $w_E$  on earth.  $w_N = ?$

(3-38)  $m_N = 16m_E$

Let object have mass  $m_1$ .  $\rightarrow w_E = m_1 g_E = \frac{G m_1 m_E}{r_E^2}$

$$w_N = m_1 g_N = \frac{G m_1 m_N}{r_N^2} = \frac{G m_1 (16m_E)}{(4r_E)^2} = \frac{16 G m_1 m_E}{16 r_E^2} = \frac{G m_1 m_E}{r_E^2} = w_E$$

Thus  $w_E = w_N$

Since the object weighs the same on both planets, the acceleration due to gravity on Neptune is about the same as that of Earth  $\approx 9.8 \text{ m/s}^2$

$$(m_1 g_E = m_1 g_N \Rightarrow a_E = a_N)$$

(39)



a) since speed is constant, total force on object must be zero.

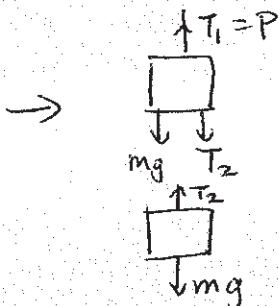
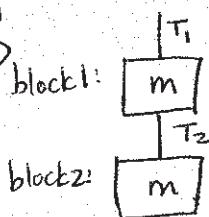
$$\Rightarrow T = mg = (20 \text{ kg})(9.8 \text{ m/s}^2) = 196 \text{ N}$$

b)  $T - mg = ma$

$$\Rightarrow T = mg + ma = m(g+a) = (20)(9.8 + 0.7) = 210 \text{ N}$$

(43)

(3-43)



Write 2 eqns, 1 per block:

block 1:  $ma = T_1 - T_2 - mg$

block 2:  $ma = T_2 - mg$

$$\Rightarrow T_2 = ma + mg = m(a+g)$$

$$\Rightarrow [T_2 = m(a+g)] \quad \{ \text{EQN B}$$

Plug EQN B into the equation for block 1:

$$ma = T_1 - m(a+g) - mg$$

$$\Rightarrow T_1 = 2ma + 2mg$$

$$\Rightarrow [T_1 = 2m(a+g)] \quad \{ \text{EQN A}$$

Use EQN A to solve (a), (b), + (c):

a)  $a=0$  since speed is constant.

$$\Rightarrow T_1 = 2 \cdot \frac{1}{2} (0 + 9.8) = 9.8 \text{ N}$$

b)  $a=1.2 \text{ m/s}^2$

$$\Rightarrow T_1 = 2 \cdot \frac{1}{2} (1.2 + 9.8) = 11 \text{ N}$$

c)  $a=-1.2 \text{ m/s}^2$

$$\Rightarrow T_1 = 2 \cdot \frac{1}{2} (-1.2 + 9.8) = 8.6 \text{ N}$$

d) Use EQN B:

(a)  $T_2 = \frac{1}{2} (0 + 9.8) = 4.9 \text{ N}$

(b)  $T_2 = \frac{1}{2} (1.2 + 9.8) = 5.5 \text{ N}$

(c)  $T_2 = \frac{1}{2} (-1.2 + 9.8) = 4.3 \text{ N}$



## Chp 4

- (3) The normal force on each block equals the vertical component of the force downward on the block.  
 (4-3)

$$(a) i. F_N = mg = (10 \text{ kg})(9.8 \text{ m/s}^2) = 98 \text{ N}$$

$$ii. F_N = mg + P = 98 \text{ N} + 50 \text{ N} = 148 \text{ N}$$

$$iii. F_N = mg - P = 98 \text{ N} - 50 \text{ N} = 48 \text{ N}$$

$$iv. P_{\perp} = P \cos(30^\circ)$$

$$\Rightarrow F_N = mg + P \cos(30^\circ) = 98 \text{ N} + (50 \text{ N})\left(\frac{\sqrt{3}}{2}\right) = 141 \text{ N}$$

$$v. P_{\perp} = P \sin(30^\circ)$$

$$\Rightarrow F_N = mg - P \sin(30^\circ) = 98 \text{ N} - (50 \text{ N})\left(\frac{1}{2}\right) = 73 \text{ N}$$

$$(b) i. F_N = 40 \text{ lb}$$

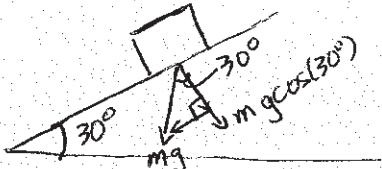
$$ii. F_N = 40 \text{ lb} + 30 \text{ lb} = 70 \text{ lb}$$

$$iii. F_N = 40 \text{ lb} - 30 \text{ lb} = 10 \text{ lb}$$

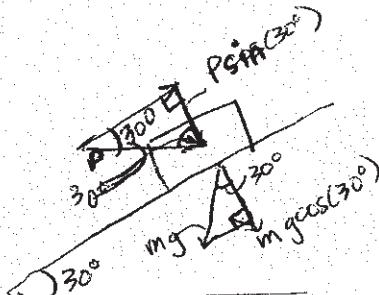
$$iv. F_N = 40 \text{ lb} + 30 \text{ lb} \left(\frac{\sqrt{3}}{2}\right) = 60 \text{ lb}$$

$$v. F_N = 40 \text{ lb} - 30 \text{ lb} \left(\frac{1}{2}\right) = 25 \text{ lb}$$

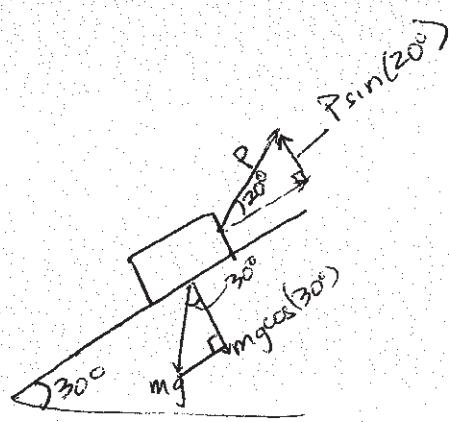
(4)  
 (4-4)



(i)



(iii)



(v)

Diagrams of vertical components of force on block (not including normal force) where "vertical" is taken to be  $\perp$  to the inclined surface.

$$(a) i. F_N = mg \cos(30^\circ) = (10)(9.8)\left(\frac{\sqrt{3}}{2}\right) = 85 \text{ N}$$

$$ii. F_N = mg \cos(30^\circ) - P = 85 \text{ N} - 50 \text{ N} = 35 \text{ N}$$

$$iii. F_N = mg \cos(30^\circ) + P \sin(30^\circ) = 85 \text{ N} + 50 \text{ N} \left(\frac{\sqrt{3}}{2}\right) = 110 \text{ N}$$

$$iv. (P \text{ has no normal component}) \\ \Rightarrow F_N = mg \cos(30^\circ) = 85 \text{ N}$$

$$v. F_N = mg \cos(30^\circ) - P \sin(20^\circ) = 85 \text{ N} - (50 \text{ N})(0.34) = 68 \text{ N}$$

(4-4 cont...)

- (i) i)  $F_N = (40 \text{ lb}) \cos(30^\circ) = 35 \text{ N}$
- ii)  $F_N = (40 \text{ lb}) \cos(30^\circ) - 30 \text{ lb} = 5 \text{ N}$
- iii)  $F_N = (40 \text{ lb}) \cos(30^\circ) + (30 \text{ lb}) \sin(30^\circ) = 50 \text{ N}$
- iv)  $F_N = (40 \text{ lb}) \cos(30^\circ) = 35 \text{ N}$
- v)  $F_N = (40 \text{ lb}) \cos(30^\circ) - (30 \text{ lb}) \sin(20^\circ) = 24 \text{ N}$

4-5) The normal force,  $F_N$ , is again determined from the equation  $\sum F_{\perp} = 0$ . Since the box does not slide parallel to the slope, the frictional force,  $f$ , is calculated from  $\sum F_{\parallel} = 0$ .

$$\sum F_{\perp} = F_N - mg \cos 37^\circ = 0$$

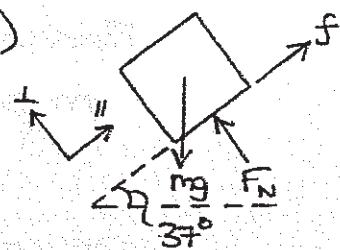
$$F_N = mg \cos 37^\circ = (50 \text{ kg})(9.8 \text{ m/s}^2)(0.8)$$

$$= 392 \text{ N.}$$

$$\sum F_{\parallel} = f - mg \sin 37^\circ = 0$$

$$f = mg \sin 37^\circ = (50 \text{ kg})(9.8 \text{ m/s}^2)(0.6)$$

$$= 294 \text{ N.}$$

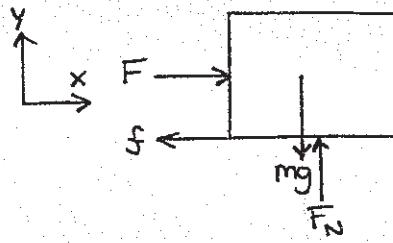


Note:  $f$  is not given by  $\mu_s F_N$   
(that is  $f^{\max}$ , only).

4-9) Since the box does not move vertically,

$$\sum F_y = F_N - mg = 0$$

$$F_N = mg = 800 \text{ N.}$$



To start the box moving, the applied force must just exceed the maximum static friction,

$$f_s^{\max} = \mu_s F_N = 0.8 \times 800 \text{ N} = 640 \text{ N.}$$

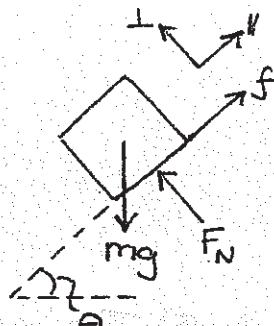
To keep the box moving at constant speed, the applied force must cancel the kinetic friction force,

$$f_k = \mu_k F_N = 0.6 \times 800 \text{ N} = 480 \text{ N.}$$

4-13) Let the angle between the slope and the horizontal be  $\theta$ . Irrespective of whether the box is stationary or moving, we know

$$\sum F_L = F_N - mg \cos \theta = 0$$

$$\Rightarrow F_N = mg \cos \theta$$



(i) stationary box:

$$\sum F_{\parallel} = f_s - m g \sin \theta = 0$$

$$\Rightarrow f_s = m g \sin \theta \quad \text{but} \quad f_s^{\max} = \mu_s F_N = \mu_s m g \cos \theta$$

Therefore the box begins to slip when

$$m g \sin \theta > f_s^{\max} \quad \text{or} \quad m g \sin \theta > \mu_s m g \cos \theta$$

$$\text{or} \quad \tan \theta > \mu_s$$

We are told the box slips when  $\theta$  exceeds  $50^\circ$ .

$$\Rightarrow \mu_s = \tan 50^\circ = 1.19.$$

Note:  $\mu$  does not have to be less than one.

(ii) moving box :

$$\sum F_{\parallel} = f_k - mg \sin \theta = ma \text{ where } f_k = \mu_k F_N = \mu_k mg \cos \theta.$$

$$\Rightarrow a = (\mu_k \cos \theta - \sin \theta) g.$$

The box will continue moving down the slope until the angle  $\theta$  is reduced sufficiently that  $a$  becomes positive (since the velocity is in the negative  $\parallel$  direction).

i.e., stops when

$$0 = (\mu_k \cos \theta - \sin \theta) g \quad \text{or} \quad \tan \theta = \mu_k.$$

We are told the box stops for  $\theta \leq 40^\circ$ .

$$\Rightarrow \mu_k = \tan 40^\circ = 0.84.$$

A-14) The force  $P$  has components

$$P_x = P \cos 37^\circ, P_y = -P \sin 37^\circ.$$

$$\sum F_x = P \cos 37^\circ - f = ma$$

$$\sum F_y = F_N - mg - P \sin 37^\circ = 0$$

$$\Rightarrow F_N = mg + P \sin 37^\circ.$$

(i) Stationary box: when  $P = 190\text{N}$  it just overcomes a friction force  $f = f_s^{\max} = \mu_s F_N$ ; i.e., we can set  $a = 0$

$$\Rightarrow f_s^{\max} = P \cos 37^\circ$$

$$\mu_s = \frac{P \cos 37^\circ}{F_N} = \frac{(190\text{N}) \cos 37^\circ}{300\text{N} + (190\text{N}) \sin 37^\circ} = 0.37.$$

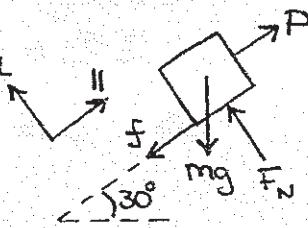
(ii) Moving box: when  $P = 120\text{N}$  it balances a friction force  $f = f_F = \mu_k F_N$  so that  $a = 0$  again.

$$\Rightarrow \mu_k = \frac{P \cos 37^\circ}{F_N} = \frac{(120\text{N}) \cos 37^\circ}{300\text{N} + (120\text{N}) \sin 37^\circ} = 0.26.$$

4-19) As usual, we determine  $F_N$  from

$$\sum F_{\perp} = F_N - mg \cos \theta = 0$$

$$F_N = mg \cos \theta$$



Since the box moves up the slope at constant speed, we know

$$a = 0 \text{ and } f = -\mu_k F_N$$

$$\text{Thus } \sum F_{\parallel} = P - mg \sin \theta - \mu_k F_N = 0$$

$$\begin{aligned} P &= mg \sin \theta + \mu_k F_N = mg (\sin \theta + \mu_k \cos \theta) \\ &= (5.0 \text{ kg})(9.8 \text{ m/s}^2) (\sin 30^\circ + 0.40 \cos 30^\circ) \\ &= 41.5 \text{ N.} \end{aligned}$$

4-25) (a) This part requires the constant acceleration formulae from Chapter 2. We know  $v_i = 80 \text{ cm/s}$ ,  $v_f = 0 \text{ cm/s}$ , and  $x = 60 \text{ cm}$ .

$$\text{Using } v_f^2 = v_i^2 + 2ax, \quad a = \frac{v_f^2 - v_i^2}{2x} = \frac{0^2 - 80^2 (\text{cm/s})^2}{2 \times 60 \text{ cm}} \\ = -53.3 \text{ cm/s}^2 \\ = -0.53 \text{ m/s}^2.$$

(b) This part requires Newton's 2<sup>nd</sup> law from Chapter 3:

$$F = ma = (0.5 \text{ kg})(-0.53 \text{ m/s}^2) = -0.27 \text{ N.}$$

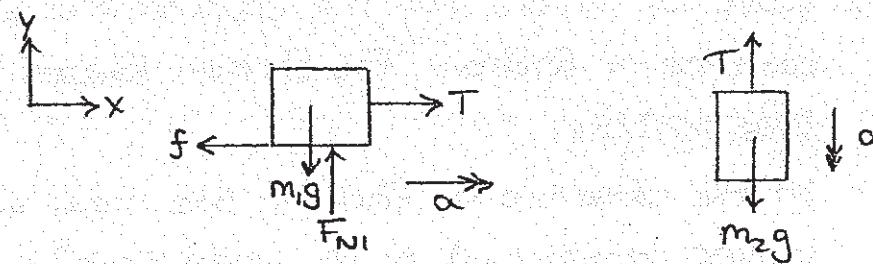
Since the question asks how big the force is, we need its magnitude,  $0.27 \text{ N.}$

(c) For an object resting on a horizontal surface with only gravity and  $F_N$  acting vertically,  $F_N = mg$ .

$$\Rightarrow \mu_k = \frac{\text{frictional force}}{mg} = \frac{0.27 \text{ N}}{(0.5 \text{ kg})(9.8 \text{ m/s}^2)} = 0.054.$$

(Note: mass must be converted to kg to get forces in N.)

4-27) Hint : Just as in Chapter 3, coupled objects require separate free-body diagrams.



We assume that mass  $m_2$  falls with acceleration  $a$ . Since mass  $m_1$  is attached by a string, it has a horizontal acceleration  $a$ . Also, take  $\mu_k = \mu_s = 0.4$  or  $0.8$ .

$$\text{For } m_1: m_1 a = \sum F_x = T - f$$

$$0 = \sum F_y = F_{N1} - m_1 g$$

If  $m_1$  is actually moving,  $f = \mu_k F_{N1}$  and  $m_1 a = T - \mu_k m_1 g$  ①

$$\text{For } m_2: m_2(-a) = \sum F_y = T - m_2 g \quad \text{or} \quad -m_2 a = T - m_2 g \quad ②$$

(a) Solving simultaneous equations ① and ②, with  $\mu_k = 0.4$ :

$$a = \frac{m_2 - \mu_k m_1}{m_2 + m_1} g = \frac{2.0 - 0.4 \times 3.0}{2.0 + 3.0} \times 9.8 \text{ m/s}^2 = 1.57 \text{ m/s}^2$$

$$T = \frac{(1+\mu_k)m_1 m_2 g}{m_1 + m_2} = \frac{(1+0.4)(3.0\text{kg})(2.0\text{kg})(9.8\text{m/s}^2)}{(3.0+2.0)\text{kg}} = 16.5 \text{ N.}$$

(b) In (a), the reason the masses accelerate as shown is that the weight of mass  $m_2$  exceeds the maximum frictional force  $\mu_s m_1 g$  holding back mass  $m_1$ .

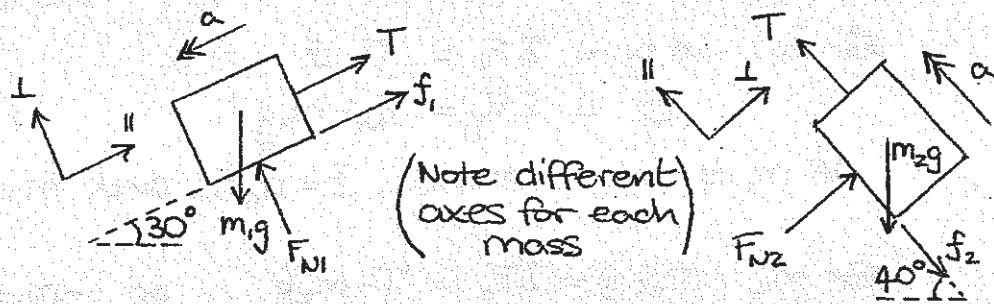
When  $\mu_s$  increases to  $0.8$ ,  $\mu_s m_1 g = 23.5 \text{ N}$  exceeds  $m_2 g = 19.6 \text{ N}$ . Therefore the masses do not move.

$$\Rightarrow a = 0 \text{ m/s}^2, \quad T = m_2 g = 19.6 \text{ N.}$$

4-29) Hint: Think carefully which way friction acts on the masses.

Method: Work out which way the coupled masses move in the absence of friction. The friction forces act to oppose this motion.

In the absence of friction, the mass with the larger component of its weight parallel to its slope will move downwards. Since  $m_1 g \sin 30^\circ = 49.0 \text{ N}$  and  $m_2 g \sin 40^\circ = 18.9 \text{ N}$ , mass  $m_1$  falls,  $m_2$  rises.



$$m_1: m_1(-a) = T - m_1 g \sin 30^\circ + f_1 = T - m_1 g (\sin 30^\circ - \mu_k \cos 30^\circ)$$

$$m_2: m_2 a = T - m_2 g \sin 40^\circ - f_2 = T - m_2 g (\sin 40^\circ + \mu_k \cos 40^\circ)$$

Once again we are left with simultaneous equations for  $T$  and  $a$ . One way to solve is to subtract the 1<sup>st</sup> equation from the second:

$$(m_1 + m_2)a = m_1 g (\sin 30^\circ - \mu_k \cos 30^\circ) - m_2 g (\sin 40^\circ + \mu_k \cos 40^\circ)$$

$$(13.0 \text{ kg})a = (98 \text{ N})(\sin 30^\circ - 0.2 \cos 30^\circ) - (29.4 \text{ N})(\sin 40^\circ + 0.2 \cos 40^\circ)$$

$$= 8.6 \text{ N}$$

$$a = \frac{8.6 \text{ N}}{13.0 \text{ kg}} = \boxed{0.66 \text{ m/s}^2}$$

Substituting for  $a$  into the second equation and rearranging,

$$T = m_2 a + m_2 g (\sin 40^\circ + \mu_k \cos 40^\circ)$$

$$= (3.0 \text{ kg})(0.66 \text{ m/s}^2) + (3.0 \text{ kg})(9.8 \text{ m/s}^2)(\sin 40^\circ + 0.2 \cos 40^\circ)$$

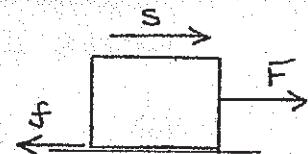
$$= \boxed{25.4 \text{ N}}$$

Chapter 5 (2, 7, 12, 16, 19, 21, 31, 36, 37, 39, 40, 45)

5-2) In each part of this problem we must carefully consider the relative directions of the force,  $F$ , and the displacement,  $s$ , entering the definition of the work done.

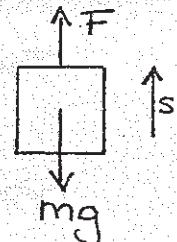
- (a) The force  $F$  is equal in magnitude to the frictional force  $f = 40\text{N}$ , since the object moves at constant speed ( $a = 0$ ).

$$\begin{aligned} \text{work, } W &= Fs \quad (\text{since the vectors point in the same direction}) \\ &= (40\text{N})(0.3\text{m}) \\ &= \boxed{12\text{ J.}} \end{aligned}$$



- (b) If the object is lifted slowly enough that we can take  $a = 0$ , then the force  $F$  is equal in magnitude to the object's weight.

$$\begin{aligned} \text{work, } W &= Fs = mgs \\ &= (5.0\text{kg})(9.8\text{m/s}^2)(0.3\text{m}) \\ &= \boxed{14.7\text{ J.}} \end{aligned}$$

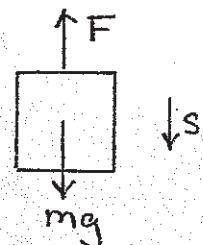


- (c) As in (b),  $W = mgs = (6.0\text{kg})(9.8\text{m/s}^2)(0.6\text{m})$

$$= \boxed{35.3\text{ J.}}$$

- (d) This is the situation in (c) but with  $s$  reversed. Therefore the work has the opposite sign.

$$\text{work, } W = \boxed{-35.3\text{ J.}}$$



- (e) Since the displacement is zero,

$$\text{work, } W = \boxed{0.}$$

5-7) The force acts at an angle of  $37^\circ$  to the displacement, which is parallel to the floor.

$$\Rightarrow \text{work, } W = (90\text{N})(8\text{m}) \cos 37^\circ = 575\text{N.}$$

5-12) Increase in gravitational potential energy is  $\Delta E_p = mg\Delta h$ , where  $\Delta h = \text{increase in object's height (no matter how achieved)}$

(a)  $\Delta E_p = (700\text{kg})(9.8\text{m/s}^2)(20\text{m}) = 140\text{kJ.}$

(b)  $\Delta E_p = 0$  (since  $\Delta h = 0$ ).

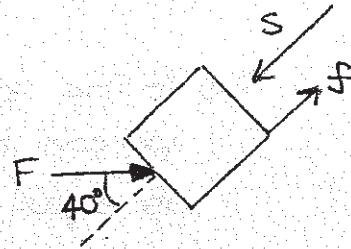
(c)  $\Delta E_p = (700\text{kg})(9.8\text{m/s}^2)(-20\text{m}) = -140\text{kJ.}$

5-16)(a) From the definition, work =  $Fs \cos\theta$ .

The angle between  $F$  and  $s$  is

$$\theta = 180^\circ - 40^\circ = 140^\circ.$$

$$\Rightarrow W = (500\text{N})(2\text{m}) \cos 140^\circ = -766\text{J.}$$



(b) Box is lowered a distance  $(2\text{m}) \sin 40^\circ = 1.29\text{m.}$

(c)  $\Delta E_p = mg\Delta h = (70\text{kg})(9.8\text{m/s}^2)(-1.29\text{m}) = -882\text{J.}$   
↑ lowered

(d) From conservation of mechanical energy

$$\Delta E_k + \Delta E_p = \text{work done by outside forces (F and f)}$$

We assume  $\Delta E_k = 0$  since the box moves "slowly."

Also, we know that work done by friction is  $-fs$ .

Substituting work done by  $F$  and  $\Delta E_p$  from above,

$$-882\text{J} = -766\text{J} - f(2\text{m})$$

$$\Rightarrow \text{friction force, } f = 58\text{ N.}$$

$$5-19) \text{ Power, } P = Fv \cos\theta.$$

Here  $F = mg$  (because lift load at constant speed)

and  $\theta = 0^\circ$  (because  $F$  and  $v$  both point straight up).

$$\Rightarrow P = mgv$$

$$v = \frac{P}{mg} = \frac{(2\text{hp}) \times \left(\frac{746\text{W}}{1\text{hp}}\right)}{(100\text{kg}) \times (9.8\text{m/s}^2)} = 1.5 \text{ m/s}^2$$

$$5-21) \text{ Hint: This is not really a } ** \text{ problem.}$$

Since the car is moving at constant speed on a level road, there is no change in the kinetic energy or the gravitational potential energy. Thus all the work done by the motor goes to overcome friction:

$$\text{friction force} = \text{driving force, } F = \frac{P}{v}$$

$$= \frac{(45\text{hp}) \times \left(\frac{746\text{W}}{1\text{hp}}\right)}{\left(100 \frac{\text{km}}{\text{h}}\right) \times \left(\frac{1000\text{m}}{1\text{km}}\right) \times \left(\frac{1\text{h}}{3600\text{s}}\right)} = 1210 \text{ N.}$$

$$5-31) \text{ Hint: The problem is clearer if you delete the word "nearly".}$$

In the absence of friction, no outside force other than gravity acts on the block as it slides down the incline. Thus, by conservation of energy,

$$E_{kf} + E_{pf} = E_{ki} + E_{pi} + \overset{\circ}{W}_{nc}$$

$$\frac{1}{2}mv_f^2 + 0 = 0 + mgh$$

$$\text{velocity at bottom, } v_f = \sqrt{2gh} = \sqrt{2(9.8\text{m/s}^2)(0.3\text{m})}$$

$$= 2.42 \text{ m/s.}$$

$$5-36) \text{ We are told that the slope in 5-31 was not frictionless after all, so we must allow for a friction force } f \text{ doing work } W_{nc} = -fs \text{ where } s \text{ is the distance slid.}$$

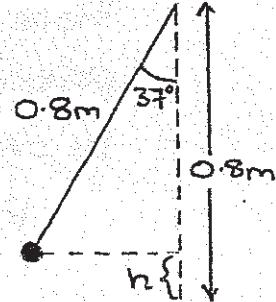
By conservation of mechanical energy,

$$\begin{aligned} E_{kf} + E_{pf} &= E_{ki} + E_{pi} + W_{nc} \\ \frac{1}{2}mv_f^2 + 0 &= 0 + mgh - fs \\ f &= \frac{mgh - \frac{1}{2}mv_f^2}{s} = \frac{m}{s}(gh - \frac{1}{2}V_f^2) \\ &= \frac{3.0\text{kg}}{2.0\text{m}} [(9.8\text{m/s}^2)(0.3\text{m}) - \frac{1}{2}(1.20\text{m/s})^2] = 3.33\text{ N.} \end{aligned}$$

- 5-37) At its initial position, the pendulum ball is a height  $h = (0.8\text{m})(1-\cos 37^\circ) = 0.16\text{m}$  above its lowest point.

The only outside force acting on the ball is the tension in the string. This acts at  $90^\circ$  to the direction of motion, so it does no work ( $\cos 90^\circ = 0$ ).

$$\begin{aligned} \Rightarrow E_{kf} + E_{pf} &= E_{ki} + E_{pi} + \overset{0}{W_{nc}} \\ \frac{1}{2}mv_f^2 + 0 &= 0 + mgh \quad (\text{result independent of } m) \\ V_f &= \sqrt{2gh} = \sqrt{2(9.8\text{m/s}^2)(0.16\text{m})} = 1.77\text{ m/s.} \end{aligned}$$



After passing the lowest point, the ball will carry on until it reaches a height where all its kinetic energy has been converted to gravitational potential energy. Clearly, this is just the height at which it was first released, which was  $0.16\text{m}$  above the lowest point.

- 5-39) By conservation of mechanical energy

$$\begin{aligned} E_{kf} + E_{pf} &= E_{ki} + E_{pi} + W_{nc} \\ 0 + 0 &= 0 + mgh - fs \quad (\text{initial and final velocity} = 0) \\ \text{friction force, } f &= \frac{mgh}{s} = \frac{(2.0\text{kg})(9.8\text{m/s}^2)(1.5\text{m})}{30\text{m}} = 0.98\text{ N.} \end{aligned}$$

5-40) In the absence of friction, the only outside force is at  $90^\circ$  to the direction of motion, and hence does no work.

$$\text{Thus } E_{kf} + E_{pf} = E_{ki} + E_{pi} + \Delta W_{ext}$$

$$\frac{1}{2}mv_f^2 + mgh_f = 0 + mgh_i$$

$$V_f = \sqrt{2g(h_i - h_f)}$$

$$\text{At point C, } V_f = \sqrt{2(9.8\text{m/s}^2)(2.0 - 1.0\text{m})} = 4.4\text{ m/s.}$$

$$\text{At point D, } V_f = \sqrt{2(9.8\text{m/s}^2)(2.0 - 0.5\text{m})} = 5.4\text{ m/s.}$$

5-45) The increase in gravitational potential energy of the water on going from the lake to the tank is

$$\Delta E_p = (mg)(h_f - h_i) = 1000\text{gal} \times \left(\frac{37.1\text{N}}{1\text{gal}}\right) \times 5.0\text{m}$$

$$= 1.86 \times 10^5 \text{J.}$$

In the most favorable situation, the pump has to do just enough work to provide this increase in gravitational energy, i.e., we neglect friction and any increase in the kinetic energy of the water.

$$\Rightarrow \text{minimum work, } W_{min} = \Delta E_p$$

Since work = power  $\times$  time,

$$\Rightarrow \text{minimum time} = \frac{W_{min}}{\text{power}} = \frac{1.86 \times 10^5 \text{J}}{0.5\text{hp} \times \left(\frac{746\text{W}}{1\text{hp}}\right)}$$

$$= 497\text{s.}$$



## Chapter 6 (2, 3, 5, 7, 11, 15, 18, 19, 20, 22, 26, 33)

6-2) We are given  $F_i = 30N$ ,  $F_o = 500N$ ,  $s_i = 12m$ ,  $s_o = 0.5m$ .

$$\text{IMA} = \frac{s_i}{s_o} = \frac{12m}{0.5m} = 24$$

$$\text{AMA} = \frac{F_o}{F_i} = \frac{500N}{30N} = 16.7$$

$$\left. \begin{array}{l} \text{efficiency} = \frac{\text{AMA}}{\text{IMA}} \\ = \frac{16.7}{24} = 0.69. \end{array} \right\}$$

6-3) We are given  $F_i = 50N$ ,  $s_i = 1.50m$ ,  $s_o = 0.042m$ , eff. = 0.40.

$$\text{IMA} = \frac{s_i}{s_o} = \frac{1.50m}{0.042m} = 35.7$$

$$\begin{aligned} \text{load, } F_o &= \text{AMA} \times F_i = (\text{efficiency} \times \text{IMA}) \times F_i \\ &= (0.40 \times 35.7) \times 50N = 714N. \end{aligned}$$

6-5) Since the machines are 100% efficient, we can write

$$\text{AMA} = \text{IMA} \Rightarrow \frac{F_o}{F_i} = \frac{s_i}{s_o} \Rightarrow F_i = \frac{s_i}{s_o} F_o.$$

1<sup>st</sup> kind: When  $F_i$  moves down one unit of distance, w moves up one unit. Thus,

$$\text{IMA} = \frac{1}{1} = 1 \quad \text{and} \quad F_i = w.$$

2<sup>nd</sup> kind: When  $F_i$  moves up one unit, w moves up half a unit.

$$\text{IMA} = \frac{1}{2} = 2 \quad \text{and} \quad F_i = \frac{w}{2}.$$

3<sup>rd</sup> kind: When  $F_i$  moves up one unit, w moves up two units.

$$\text{IMA} = \frac{1}{2} \quad \text{and} \quad F_i = 2w.$$

6-7) Since efficiency =  $\frac{P_o}{P_i}$ ,  $P_o = \text{efficiency} \times P_i$ .

From Chapter 5, we know that in order to lift a weight w,

$$F_o = w \quad \text{and} \quad P_o = F_o V = wV$$

$$\Rightarrow w = \frac{P_o}{V} = \frac{\text{efficiency} \times P_i}{V} = \frac{0.85 \times 140W}{0.08m/s} = 1.5 \text{ kN}.$$

6-11) The wheelbarrow is a lever of the second kind. We are told that the input force is applied at a distance from the fulcrum four times greater than the output force.

$$\Rightarrow \text{IMA} = \frac{s_i}{s_o} = 4.$$

Assuming 100% efficiency,  $\text{AMA} = \text{IMA}$

$$\Rightarrow F_i = \frac{F_o}{\text{IMA}} = \frac{1000\text{N}}{4} = 250\text{N}.$$

6-15) We are given  $F_i = 100\text{N}$ ,  $F_o = 500\text{N}$ ,  $s_i = 24\text{cm}$ ,  $s_o = 3\text{cm}$ .

$$\begin{aligned} \text{IMA} &= \frac{s_i}{s_o} = \frac{24\text{cm}}{3\text{cm}} = 8 \\ \text{AMA} &= \frac{F_o}{F_i} = \frac{500\text{N}}{100\text{N}} = 5 \end{aligned} \quad \left. \begin{array}{l} \text{efficiency} = \frac{\text{AMA}}{\text{IMA}} = 0.625. \end{array} \right\}$$

6-18) Since five ropes support the load, the input force moves a distance five times that moved by the output force.

$$\Rightarrow \text{IMA} = \frac{s_i}{s_o} = 5.$$

$$\begin{aligned} \text{load, } F_o &= \text{AMA} \times F_i = (\text{efficiency} \times \text{IMA}) \times F_i \\ &= (0.90 \times 5) \times 500\text{N} = 2250\text{N}. \end{aligned}$$

6-19) When asked to analyze a pulley system, you should always count the number of separate pieces of rope. If there are two or more ropes, it is a compound machine, rather than a simple machine.

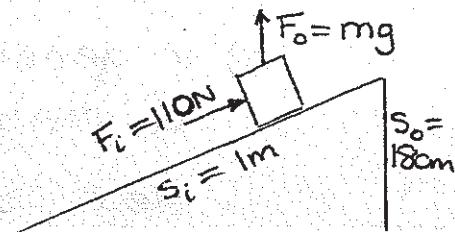
In this problem there are three strings, and hence three simple pulleys, combined into a compound machine. The output force of the top pulley forms the input for the middle pulley, while the output of the middle pulley acts as the input for the bottom pulley.

Suppose the input force is moved a distance  $s_i$ . The top pulley will move  $s_i/2$ , the middle pulley  $s_i/4$ , and the bottom pulley just  $s_i/8$ . Since the load hangs from the bottom pulley,

$$S_o = s_i/8 \\ \Rightarrow IMA = \frac{s_i}{S_o} = 8.$$

$$6-20) IMA = \frac{s_i}{S_o} = \frac{1m}{0.125m} = 8 = 5.6.$$

$$AMA = \frac{F_o}{F_i} = \frac{(30\text{kg})(9.8\text{m/s}^2)}{110\text{N}} = 2.7.$$



$$\text{efficiency} = \frac{AMA}{IMA} = 0.48.$$

$$6-22) \text{In a hydraulic press, } IMA = \frac{A_o}{A_i}.$$

Since the area of a circle is  $A = \frac{\pi}{4}d^2$  ( $d$ =diameter),

$$IMA = \frac{d_o^2}{d_i^2} = \frac{(8.0\text{cm})^2}{(0.375\text{cm})^2} = 455.$$

Assuming 100% efficiency,  $AMA = IMA$ .

$$\Rightarrow F_i = \frac{F_o}{IMA} = \frac{60,000\text{N}}{455} = 132\text{N}.$$

6-26) In an ideal belt-and-gear system,

$$IMA = \frac{\text{torque out}}{\text{torque in}} = \frac{\text{input rotation rate}}{\text{output rotation rate}}$$

$$\text{In this problem, } IMA = \frac{1720 \text{ rev/min} \times \left(\frac{1 \text{ min}}{60 \text{ sec}}\right)}{2.0 \text{ rev/sec}} \\ = 14.3.$$

If friction can be ignored, this is the factor by which the gear system multiplies the torque.

6-33) (a) The object rises 1m when pushed 10m along the incline.

$$\Rightarrow \text{IMA of incline} = \frac{s_i}{s_o} = \frac{1\text{m}}{10\text{m}} = 10.$$

(b) Two strands of rope connect to the moving pulley.

$$\Rightarrow \text{IMA of block and tackle} = 2.$$

(c) In general, IMA of compound machine = product of IMA's of constituent machines.

$$\text{Here, overall IMA} = 10 \times 2 = 20.$$

Note: You should go back and check that you can apply this method for calculating the IMA to the compound machine in 6-19.

## Chapter 7 (2, 5, 11, 17, 21, 22, 26, 29, 30, 36, 39)

7-2) Momentum is a vector:  $\vec{p} = m\vec{v}$ ,

$$\text{i.e., } P_x = MV_x = (1000 \text{ kg})(30 \text{ km/h}) \left( \frac{1000 \text{ m}}{1 \text{ km}} \right) \left( \frac{1 \text{ h}}{3600 \text{ s}} \right) \\ = 8333 \text{ kg} \cdot \text{m/s}$$

$$P_y = MV_y = 0 \text{ kg} \cdot \text{m/s.}$$

7-5)(a) From Chapters 2 and 6 we know that the ball's velocity just before it strikes the floor is

$$V_{iy} = -\sqrt{2gh_1} = -\sqrt{2(9.8 \text{ m/s}^2)(0.8 \text{ m})} = -3.96 \text{ m/s.}$$

$$\Rightarrow P_{iy} = MV_{iy} = (0.02 \text{ kg})(-3.96 \text{ m/s}) = -0.079 \text{ kg} \cdot \text{m/s.}$$

(b) Similarly, the velocity immediately after the rebound is

$$V_{fy} = +\sqrt{2gh_2} = \sqrt{2(9.8 \text{ m/s}^2)(0.6 \text{ m})} = 3.43 \text{ m/s.}$$

$$\Rightarrow P_{fy} = MV_{fy} = (0.02 \text{ kg})(3.43 \text{ m/s}) = 0.069 \text{ kg} \cdot \text{m/s.}$$

$$(c) \Delta P_y = P_{fy} - P_{iy} = -0.079 - 0.069 \text{ kg} \cdot \text{m/s} = 0.148 \text{ kg} \cdot \text{m/s.}$$

7-11) Impulse is a vector:  $(\vec{F}_t) = m(\vec{v}_f - \vec{v}_i)$ ,

$$\text{i.e., } (\vec{F}_t)_x = m(V_{fx} - V_x) = (0.02 \text{ kg})(-2.0 \text{ m/s} - 3.0 \text{ m/s}) \\ = -0.10 \text{ kg} \cdot \text{m/s or } -0.10 \text{ N.s.}$$

$$(\vec{F}_t)_y = m(V_{fy} - V_{iy}) = 0 \text{ N.s.}$$

Thus, the impulse is 0.10 N.s, directed along the  $-x$  direction.

7-17)(a) We can use the constant acceleration formulae from Chapter 2. We know  $v_i = 400 \text{ m/s}$ ,  $v_f = 0 \text{ m/s}$ ,  $x = 0.08 \text{ m}$ .

$$\text{Since } x = \bar{v}t = \frac{1}{2}(v_i + v_f)t \Rightarrow t = \frac{2x}{v_i + v_f} = \frac{2 \times 0.08 \text{ m}}{(400 + 0) \text{ m/s}}$$

$$= 4.0 \times 10^{-4} \text{ s.}$$

$$(b) \text{ Using } \bar{F}t = m(v_f - v_i), \quad \bar{F} = \frac{m(v_f - v_i)}{t}$$

$$= \frac{(0.02 \text{ kg})(0 - 400 \text{ m/s})}{4.0 \times 10^{-4} \text{ s}}$$

$$= -2.0 \times 10^4 \text{ N.}$$

7-21) This is a perfectly inelastic collision in one dimension. The common velocity,  $v$ , after the collision is given by conservation of momentum:

$$m_{\text{boy}} v_{\text{boy}} + m_{\text{girl}} v_{\text{girl}} = (m_{\text{boy}} + m_{\text{girl}}) v$$

$$v = \frac{m_{\text{boy}} v_{\text{boy}} + m_{\text{girl}} v_{\text{girl}}}{m_{\text{boy}} + m_{\text{girl}}}$$

$$= \frac{(70 \text{ kg})(4.0 \text{ m/s}) + (50 \text{ kg})(0 \text{ m/s})}{(70 + 50) \text{ kg}}$$

$$= 2.3 \text{ m/s.}$$

7-22) This is also a one-dimensional momentum conservation problem – this time of the recoil or rocket type, with zero initial momentum:

$$0 = m_{\text{rifle}} v_{\text{rifle}} + m_{\text{bullet}} v_{\text{bullet}}$$

$$v_{\text{rifle}} = -\frac{m_{\text{bullet}}}{m_{\text{rifle}}} v_{\text{bullet}} = -\frac{0.025 \text{ kg}}{1.8 \text{ kg}} \times 500 \text{ m/s}$$

$$= -4.5 \text{ m/s.}$$

7-26) Let the 1200-kg car be mass 1. By momentum conservation,

$$m_1 V_{1i} + m_2 V_{2i} = m_1 V_{1f} + m_2 V_{2f}$$

$$\Rightarrow V_{1f} = \frac{m_1 V_{1i} + m_2 (V_{2i} - V_{2f})}{m_1} = \frac{(1200\text{kg})(4.0\text{m/s}) + (700\text{kg})(0 - 5.0\text{m/s})}{1200\text{kg}}$$
$$= 1.1\text{ m/s.}$$

7-29) By conservation of momentum

$$m_A V_{Ai} + m_B V_{Bi} = m_A V_{Af} + m_B V_{Bf}$$

$$\Rightarrow V_{Bf} = \frac{m_B V_{Bi} + m_A (V_{Ai} - V_{Af})}{m_B} = \frac{-2.0\text{ m/s} + (3.0 - (-1.5))\text{m/s}}{1}$$
$$= 2.5\text{ m/s.}$$

If the collision is perfectly elastic, it must obey the velocity equation

$$\begin{aligned} V_{Af} + V_{Ai} &= V_{Bf} + V_{Bi} \\ -1.5 + 3.0 &\stackrel{?}{=} 2.5 - 2.0 \quad \text{No!} \end{aligned}$$

The collision is not perfectly elastic.

7-30) The final velocities must satisfy both momentum conservation and the velocity equation. For equal masses we obtain

$$V_{Ai} + V_{Bi} = V_{Af} + V_{Bf}$$

and

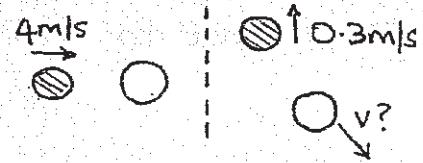
$$V_{Af} + V_{Ai} = V_{Bf} + V_{Bi}.$$

As shown in Example 7.10, the solution is

$$V_{Af} = V_{Bi} = -2.0\text{ m/s}$$

$$V_{Bf} = V_{Ai} = 3.0\text{ m/s.}$$

7-36) Momentum is conserved separately  
in the x- and y-directions



$$x: (1.8 \text{ kg})(4.0 \text{ m/s}) + (3.0 \text{ kg})(0 \text{ m/s}) = (1.8 \text{ kg})(0 \text{ m/s}) + (3.0 \text{ kg}) V_x$$

$$V_x = \frac{1.8 \times 4.0}{3.0} \text{ m/s} = 2.4 \text{ m/s.}$$

$$y: (1.8 \text{ kg})(0 \text{ m/s}) + (3.0 \text{ kg})(0 \text{ m/s}) = (1.8 \text{ kg})(0.3 \text{ m/s}) + (3.0 \text{ kg}) V_y$$

$$V_y = -\frac{1.8 \times 0.3}{3.0} \text{ m/s} = -0.18 \text{ m/s.}$$

7-39) Method: ① We calculate the velocity of ball A just before the collision, using energy conservation. ② We compute the velocity of ball B right after the collision using momentum conservation. ③ We calculate the height reached by ball B using energy conservation again.

① In "falling" through a vertical height  $h_A = 20 \text{ cm}$ , ball A attains a velocity  $V_A = \sqrt{2gh_A} = \sqrt{2(9.8 \text{ m/s}^2)(0.2 \text{ m})} = 1.98 \text{ m/s}$

② After a perfectly elastic collision with a stationary ball B, the velocities  $V_A'$  and  $V_B'$  are given by

$$m_A V_A + 0 = m_A (V_A' + \frac{m_B V_B'}{m_A}) \quad \text{momentum}$$

$$V_A' + V_A = V_B' + 0 \quad \text{velocity equation}$$

$$\text{Adding, } V_A' + 2V_A = V_A' + (1 + \frac{m_B}{m_A}) V_B'$$

$$V_B' = \frac{2m_A}{m_A + m_B} V_A = \frac{2}{3} \times 1.98 \text{ m/s} \\ = 1.32 \text{ m/s.}$$

③ Ball B will rise to a height

$$h_B = \frac{V_B'^2}{2g} = \frac{(1.32 \text{ m/s})^2}{2 \times 9.8 \text{ m/s}^2} = 0.089 \text{ m} = 8.9 \text{ cm.}$$

## Chapter 8 (3, 5, 7, 13, 15, 17, 19, 20, 21, 26, 32, 37, 43)

8-3) The forces balance out when they satisfy

$$\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = \vec{0}.$$

We know

$$\vec{F}_1 = 25\text{N at } 90^\circ = (0, 25) \text{ N}$$

$$\vec{F}_2 = 70\text{N at } 270^\circ = (0, -70) \text{ N}$$

$$\Rightarrow \vec{F}_3 = -\vec{F}_1 - \vec{F}_2 = -(0, 25) \text{ N} - (0, -70) \text{ N}$$

$$= (0, 45) \text{ N or } 45 \text{ N at } 90^\circ.$$

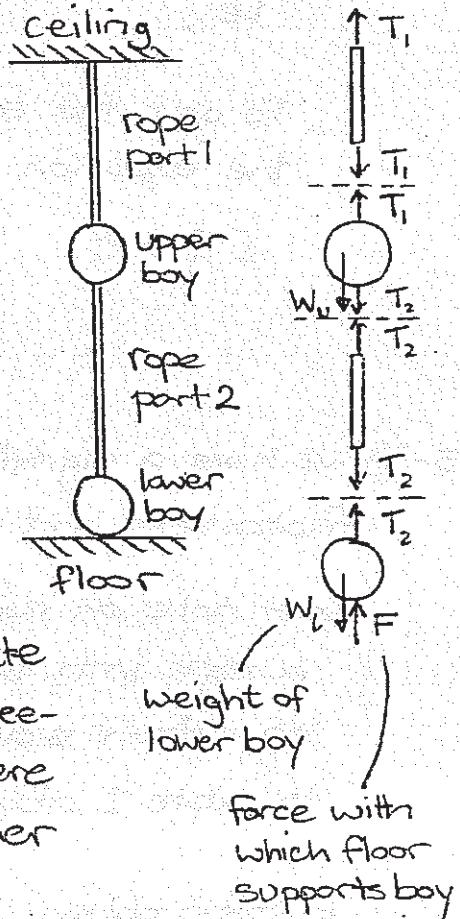
8-5) Although this is a simple problem,

it is instructive to look at the solution in detail because it is important you understand how to treat ropes and strings.

On the far right there are "free-body" diagrams for the things that can move : the two boys, and the different segments of the rope.

Note 1: A rope is broken into separate segments, requiring their own free-body diagrams, at any point where it is held or attached to any other object (including another rope).

Note 2: The free-body diagram for a rope segment is very simple: it just has the tension vector pointing outwards from each end of the segment.



(It is so simple that we don't usually draw it explicitly.)

Note 3: The object connected to the end of a rope segment always experiences a force equal to the tension in the rope, directed away from the object along the direction of the rope.

Looking at the bottom two free-body diagrams, we see that the tension in the lower segment is equal to the force exerted by the lower boy,

i.e.,

$$T_2 = 60\text{lb.}$$

To get the tension in the upper segment, we use the equation for the upper boy to be in equilibrium,

$$\sum F_y = 0: T_1 - T_2 - W_U = 0$$

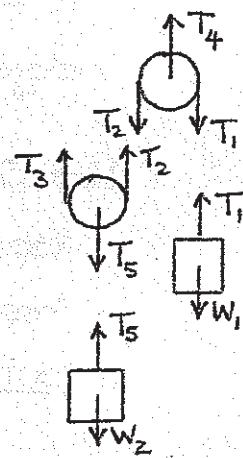
$$T_1 = T_2 + W_U = (60 + 90)\text{lb} = 150\text{lb.}$$

8-7) We have a significant simplification because the pulleys are frictionless and weightless.

Last note on ropes: A frictionless pulley does not break a rope into two segments, so the tension is the same on either side of the pulley. This is the only exception to Note 1 above.

In this problem, we have  $T_1 = T_2 = T_3$ .

We draw a free-body diagram for each weight or pulley. (Note that, as stated in 8-5, we don't really need a free-body diagram for a rope.)



In static equilibrium each object must obey  $\sum F_y = 0$ .

weight 1:  $T_1 - W_1 = 0 \Rightarrow T_1 = T_2 = T_3 = 300\text{N}$ .

weight 2:  $T_5 - W_2 = 0 \Rightarrow T_5 = W_2$ .

left pulley:  $T_2 + T_3 - T_5 = 0 \Rightarrow T_5 = T_2 + T_3$

or  $W_2 = 600\text{ N}$ .

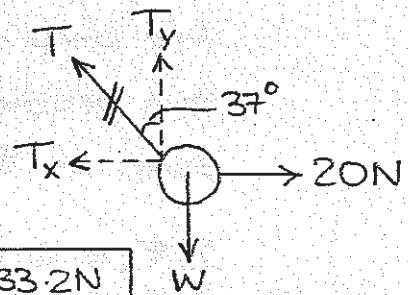
right pulley:  $T_4 - T_1 - T_2 = 0 \Rightarrow T_4 = 600\text{ N}$ .

8-13) The string's tension,  $T$ , must balance

the 20N force and the weight,  $w$ .

Its components are

$$T_x = -T \sin 37^\circ, T_y = T \cos 37^\circ.$$

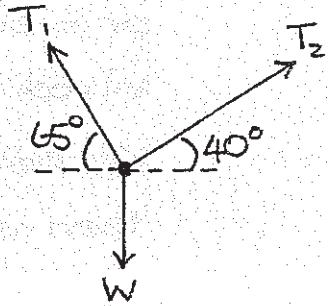


$$\sum F_x = 0 \Rightarrow 20\text{N} - T \sin 37^\circ = 0 \text{ or } T = 33.2\text{N}$$

$$\sum F_y = 0 \Rightarrow T \cos 37^\circ - w = 0 \text{ or } w = 26.5\text{N}$$

8-15) Draw the free-body diagram for the knot where the cords meet.

(We know the weight of the object acts downwards on the knot because the vertical string just transmits the force of gravity from the object to the knot.)



$$\sum F_x = 0 \Rightarrow T_2 \cos 40^\circ - T_1 \cos 65^\circ = 0 \text{ or } T_2 = \frac{\cos 65^\circ}{\cos 40^\circ} T_1$$

$$\sum F_y = 0 \Rightarrow T_2 \sin 40^\circ + T_1 \sin 65^\circ - w = 0$$

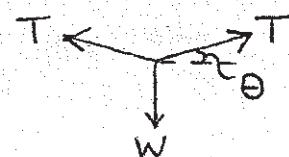
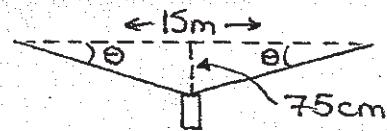
Substitute for  $T_2 \Rightarrow T_1 = \frac{w}{\sin 65^\circ + \frac{\cos 65^\circ \times \sin 40^\circ}{\cos 40^\circ}} = 39.7\text{N}$ .

$$T_2 = \frac{\cos 65^\circ}{\cos 40^\circ} T_1 = 21.9\text{N}.$$

8-17) It is important to get the geometry correct: 15m is the horizontal distance between the poles, not the length of cable.

Angle between cable and horizontal,

$$\theta = \text{inv} \tan\left(\frac{0.75\text{m}}{7.5\text{m}}\right) = 5.7^\circ.$$



Now consider the free-body diagram for the point where the lamp hangs off the cable. Due to the symmetry of the problem, the tension  $T$ , is the same on each side of the suspension point.

$$\sum F_y = 0 \Rightarrow T \sin \theta + T \sin \theta - W = 0$$

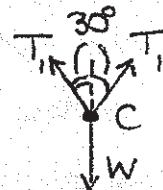
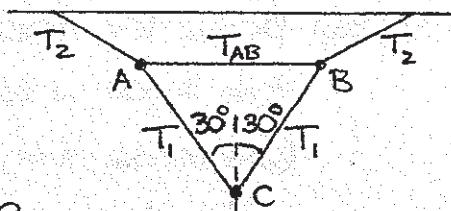
$$T = \frac{W}{2 \sin \theta} = \frac{800\text{N}}{2 \sin 5.7^\circ} = 4030\text{N.}$$

8-19) Again, symmetry simplifies the problem, so we need only introduce 3 unknown tensions.

We obtain  $T_1$  by considering point C, then use this at point A to get  $T_{AB}$ .

$$\text{At } C, \sum F_y = 0 \Rightarrow 2T_1 \cos 30^\circ - W = 0$$

$$T_1 = \frac{W}{2 \cos 30^\circ} = 28.9\text{N.}$$



$$\text{At } A, \sum F_x = 0 \Rightarrow T_{AB} + T_1 \sin 30^\circ - T_2 \cos 40^\circ = 0 \quad T_2$$

$$\sum F_y = 0 \Rightarrow T_2 \sin 40^\circ - T_1 \cos 30^\circ = 0$$

These give  $T_2 = 38.9\text{N}$  and

$$T_{AB} = 15.4\text{N.}$$

