

Physics 121
Midterm Examination #1
October 5, 2006

SOLUTIONS

1. It has been claimed that an insect called the froghopper (*Philaenus spumarius*) is the best jumper in the animal kingdom. This insect can accelerate at $3800 \frac{m}{s^2}$ over a distance of 1.9 mm as it straightens its specially designed "jumping legs."

- (a) (6 pts) Assuming a uniform acceleration, what is the velocity of the insect after it has accelerated through this short distance?

$$v(x = 0.0019) = ? \quad (1)$$

$$v^2 = v_0^2 + 2a(y - y_0) \quad (2)$$

$$v^2 = 0^2 + 2(3800)(0.0019 - 0) \quad (3)$$

$$v^2 = 14.44 \quad (4)$$

$$v = 3.8 \frac{m}{s} \quad (5)$$

- (b) (6 pts) How long did it take to reach that velocity?

$$t(x = 0.0019) = ? \quad (6)$$

$$x = x_0 + v_0t + \frac{1}{2}at^2 \quad (7)$$

$$0.0019 = 0 + 0 + \frac{1}{2}3800t^2 \quad (8)$$

$$t^2 = \frac{2 * 0.0019}{3800} = 0.000001 \quad (9)$$

$$t = 0.0010 \text{ sec} \quad (10)$$

- (c) (8 pts) How high would the insect jump if air resistance could be ignored?

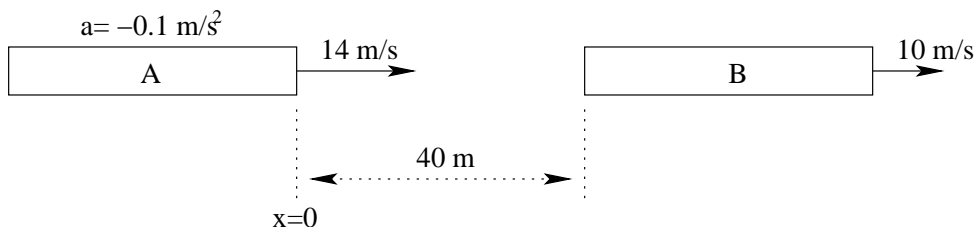
$$y(v_y = 0) = ? \quad (11)$$

$$v_y^2 = v_{0y}^2 - 2g(y - y_0) \quad (12)$$

$$0^2 = 3.8^2 - 19.6(y) \quad (13)$$

$$y = \frac{3.8^2}{19.6} = 0.737 \text{ m} \quad (14)$$

2. Two trains are on the same track as shown in the figure below. The engineer of the rear train spots the trouble and hits the brakes making an acceleration of $-0.1 \frac{m}{s^2}$.



- (a) (10 pts) When do the trains collide?

$$x_A(t = t_c) = x_B(t = t_c) \quad (15)$$

$$x_{0A} + v_{0A}t_c + \frac{1}{2}a_A t_c^2 = x_{0B} + v_{0B}t_c + \frac{1}{2}a_B t_c^2 \quad (16)$$

$$0 + 14t_c + \frac{1}{2}(-0.1)t_c^2 = 40 + 10t_c + \frac{1}{2}0t_c^2 \quad (17)$$

$$0 = 40 - 4t_c + 0.05t_c^2 \quad (18)$$

$$t_c = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad (19)$$

$$t_c = \frac{4 \pm \sqrt{16 - 4(0.05)40}}{0.1} \quad (20)$$

$$t_c = \frac{4 \pm 2.828}{0.1} \quad (21)$$

$$t_c = \frac{4 - 2.282}{0.1} \quad (22)$$

$$t_c = 11.71 \text{ sec} \quad (23)$$

- (b) (10 pts) Where do the trains collide?

$$x_B(t = 11.71) = ? \quad (24)$$

$$x_B = x_{0B} + v_{0B}t_c + \frac{1}{2}a_B t_c^2 \quad (25)$$

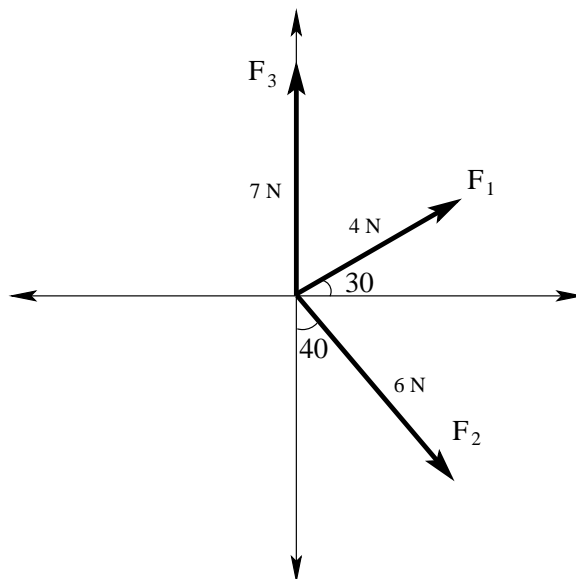
$$x_B = 40 + 10t_c + \frac{1}{2}0t_c^2 \quad (26)$$

$$x_B = 40 + 10(11.71) \quad (27)$$

$$x_B = 157 \text{ m} \quad (28)$$

NOTE: Use $x=0$ as indicated in the figure.

3. In the figure below are three force vectors labelled \vec{F}_1 , \vec{F}_2 , and \vec{F}_3 .



- (a) (6 pts) Calculate the x and y components of \vec{F}_1 , \vec{F}_2 , and \vec{F}_3 .
 (b) (4 pts) Calculate the x and y components of $\vec{F}_1 + \vec{F}_2 - \vec{F}_3$.

	x (m)	y (m)
F_1	$4 \cos 30 = 3.464$	$4 \sin 30 = 2$
F_2	$6 \sin 40 = 3.857$	$-6 \cos 40 = -4.596$
F_3	0	7
$F_1 + F_2 - F_3$	7.321	-9.596

- (c) (5 pts) Calculate the magnitude of the vector from part (b).

$$|A + B - C| = \sqrt{(7.321)^2 + (-9.596)^2} \quad (29)$$

$$|A + B - C| = 12.07 \text{ m} \quad (30)$$

- (d) (5 pts) Calculate the direction of the vector from part (b).

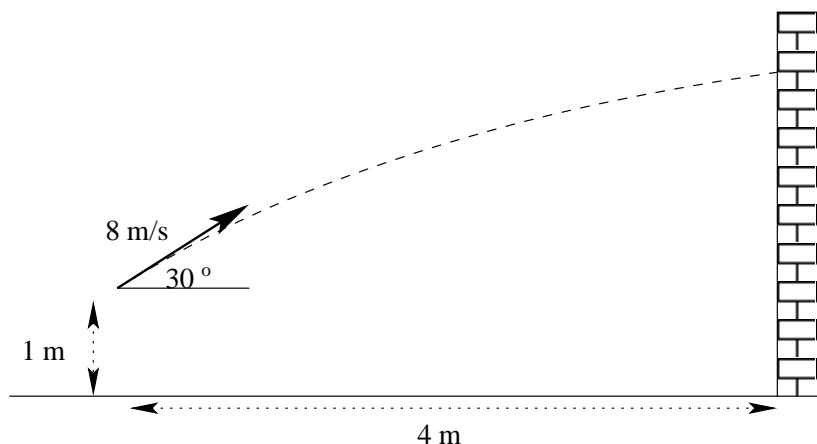
$$\tan \theta = \frac{-9.596}{7.321} \quad (31)$$

$$\theta = \text{atan} \left(\frac{-9.596}{7.321} \right) \quad (32)$$

$$\theta = -52.66^\circ \quad (33)$$

NOTE: Please express your direction answers with respect to the x axis (as a mathematician would).

4. You are playing handball and strike the ball as shown in the figure below.



Find all the following:

(a) (6 pts) The time at which the ball strikes the wall.

$$t(x = 4) = ? \quad (34)$$

$$x = x_0 + v_{0x}t \quad (35)$$

$$4 = 0 + 8 \cos 30t \quad (36)$$

$$t = 0.577 \text{ sec} \quad (37)$$

(b) (6 pts) The height at which the ball strikes the wall.

$$y(t = 0.577) = ? \quad (38)$$

$$y = y_0 + v_{0y}t - \frac{1}{2}gt^2 \quad (39)$$

$$y = 1 + 8 * \sin 30 * 0.577 - 4.9 * 0.577^2 \quad (40)$$

$$y = 1.677 \text{ m} \quad (41)$$

(c) (8 pts) The *magnitude* of the ball's velocity at the wall.

$$v_x(x = 4) = ? = v_{0x} = 8 * \cos 30 = 6.928 \quad (42)$$

$$v_y(t = 0.577) = ? \quad (43)$$

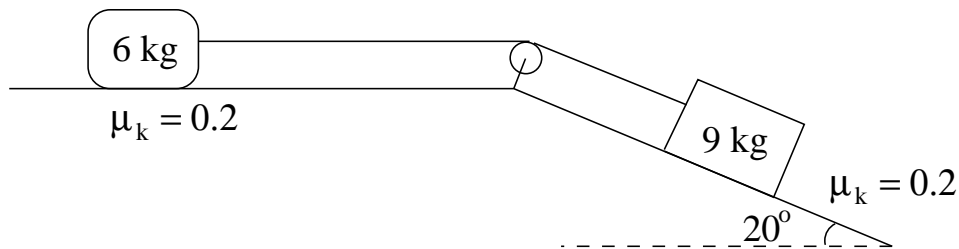
$$v_y = v_{0y} - gt \quad (44)$$

$$v_y = 8 * \sin 30 - 9.8 * 0.577 \quad (45)$$

$$v_y = -1.655 \text{ m} \quad (46)$$

$$|v| = \sqrt{6.928^2 + (-1.655)^2} = 7.123 \frac{\text{m}}{\text{s}} \quad (47)$$

5. The figure below shows two blocks connected by a pulley. Find all the following:



- (a) (6 pts) The normal force on the 6 kg block.

$$N_1 - 6g = 0 \quad (48)$$

$$N_1 = 6g = 58.8 \text{ N} \quad (49)$$

- (b) (7 pts) The normal force on the 9 kg block.

$$N_2 - 9g \cos 20 = 0 \quad (50)$$

$$N_2 = 9g \cos 20 = 82.88 \text{ N} \quad (51)$$

- (c) (7 pts) The acceleration of the system.

$$T - \mu_k N_1 = 6a \quad (52)$$

$$9g \sin 20 - \mu_k N_2 - T = 9a \quad (53)$$

$$9g \sin 20 - \mu_k N_2 - \mu_k N_1 = 15a \quad (54)$$

$$9g \sin 20 - (0.2)58.8 - (0.2)82.88 = 15a \quad (55)$$

$$15a = 1.83 \quad (56)$$

$$a = 0.122 \frac{\text{m}}{\text{s}^2} \quad (57)$$