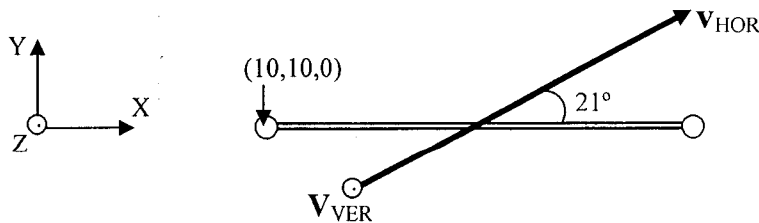


**SPME430**  
**SAMPLE PROBLEMS -- TEST #1**

1. At the instant that he releases the pole, the center of gravity of a pole vaulter has a positive or upward vertical velocity of 5.0 m/s and the magnitude of the horizontal velocity vector of the c.g. is 3.1 m/s. From an overhead view, the horizontal velocity vector makes an angle of  $21^\circ$  with the bar (see sketch). If the position of the c.g. at the peak of his jump is (10.423, 10.012, 5.97) m. Answer the following questions.



- a. What was the vaulter's position at the instant of takeoff (i.e., his X, Y and Z coordinates)?
  - b. What were the values of the velocities in the X and Y directions at the instant of takeoff?
  - c. What was the time between the instant of takeoff and the instant the vaulter's c.g. reached its maximum height?
  - d. What was the time between the instant of takeoff and the instant that the c.g. was directly over the bar?
  - e. If from the peak of his jump the c.g. had to fall 5.5 m before the vaulter landed in the pit how long would it take from the instant of takeoff until the instant the vaulter lands?
  - f. What would the vertical velocity of the vaulter's c.g. be at the instant he contacts the pit?
2. Shown on the following page is a plot of vertical displacement versus time for the c.g. during the hypothetical sports activity.
- a. Make a plot of vertical velocity of the c.g. versus time
  - b. Make a plot of vertical acceleration of the c.g. versus time

# SPME Sample Problems - Solutions

## Test #1

1)  $t_{T0 \rightarrow PK}$

$$0 = 5.0 - 9.81 t$$

$$t = 0.51 \text{ s} \quad \mathbf{C}$$

$$\vec{v}_x = |\vec{v}_H| \cos 21^\circ$$

$$= (3.1) \cos 21^\circ$$

$$= 2.89 \text{ m/s} \quad \mathbf{B}$$

$$\vec{v}_y = |\vec{v}_H| \sin 21^\circ$$

$$= (3.1) \sin 21^\circ$$

$$= 1.11 \text{ m/s} \quad \mathbf{B}$$

$$10.423 = s_{0x} + 2.89(0.51)$$

$$s_{0x} = 8.949 \text{ m} \quad \mathbf{A}$$

$$10.012 = s_{0y} + 1.11(0.51)$$

$$s_{0y} = 9.446 \text{ m} \quad \mathbf{A}$$

$$5.97 = s_{0z} + 5.0(0.51) + \frac{1}{2}(-9.81)(0.51)^2$$

$$s_{0z} = 4.696 \text{ m} \quad \mathbf{A}$$

$t_{T0 \rightarrow BAK}$

$$10.0 = 9.446 + 1.11 t$$

$$t = 0.50 \text{ s} \quad \mathbf{D}$$

$$t_{T0 \rightarrow LWD} = t_{T0 \rightarrow PK} + t_{PK \rightarrow LWD}$$

$$= 0.51 \text{ s} + 1.06 \text{ s}$$

$$= 1.57 \text{ s} \quad \mathbf{E}$$

$$t_{PK \rightarrow LWD}$$

$$5.97 - 5.5 = 5.97 + 0 t + \frac{1}{2}(9.81)t^2$$

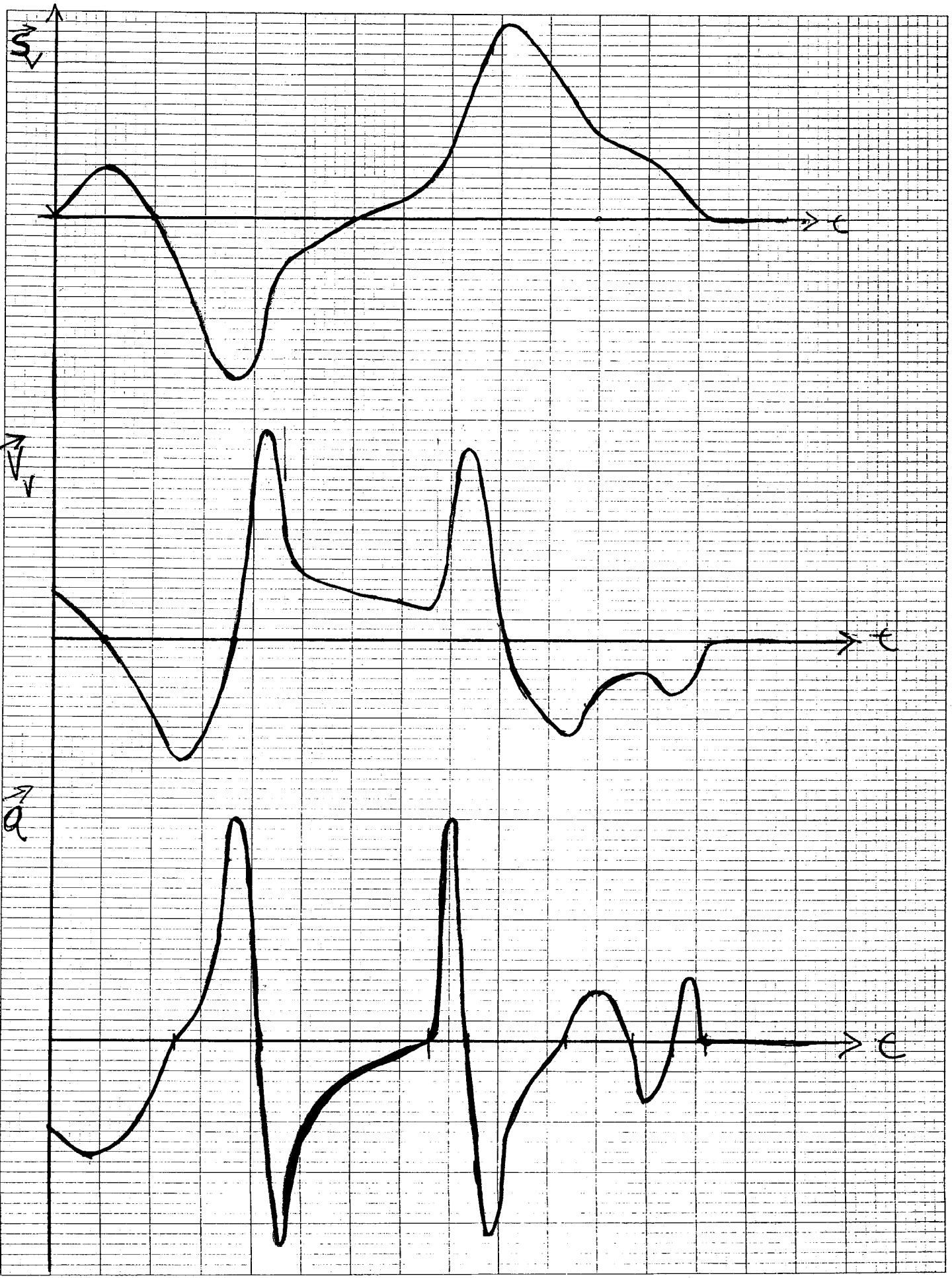
$$t = 1.06 \text{ s}$$

$$v_z^2 = v_0^2 + 2a \Delta s$$

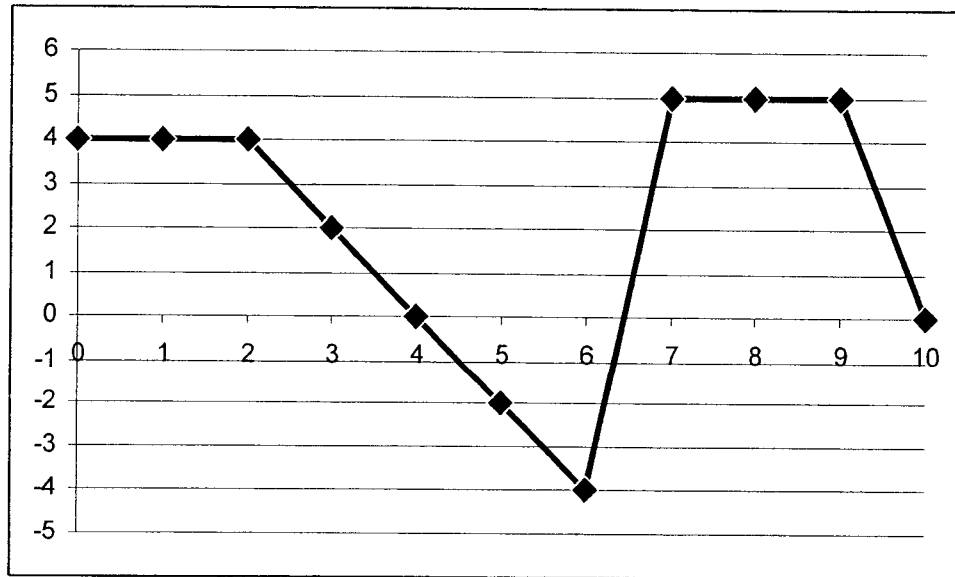
$$v_z^2 = 0^2 + 2(-9.81)(65.5)$$

$$v_z = -10.39 \text{ m/s} \quad (\text{downward}) \quad \mathbf{F}$$

2.



3. The graph below indicates the velocity of a football player in the horizontal direction versus time during a run.



- What were his horizontal accelerations during the intervals: 0-2, 2-4, 4-6, 6-7, 7-9 and 9-10 seconds
- Plot horizontal acceleration versus time.
- What were the changes in his horizontal displacement during the intervals: 0-2, 2-4, 4-6, 6-7, 7-9 and 9-10 seconds
- What was his horizontal displacement at time = 0, 2, 4, 6, 7, 9 and 10 seconds if his displacement at time = 0.0 s was 10 m.
- Plot horizontal displacement versus time.

3) a)  $0-2 \Rightarrow \frac{4-4}{2} = 0 \text{ m/s}^2$

$6-7 \Rightarrow \frac{5-(-4)}{1} = 9 \text{ m/s}^2$

$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$

$2-4 \Rightarrow \frac{0-4}{2} = -2 \text{ m/s}^2$

$7-9 \Rightarrow \frac{5-5}{2} = 0 \text{ m/s}^2$

$4-6 \Rightarrow \frac{-4-0}{2} = -2 \text{ m/s}^2$

$9-10 \Rightarrow \frac{0-5}{2} = -2.5 \text{ m/s}^2$

b) see graph paper

c)

$\Delta \vec{s} = \text{area}$   
under  
 $\vec{v}$  vs  $t$   
curve

$0-2 \Rightarrow 4 \cdot 2 = 8 \text{ m}$

$6-7 \Rightarrow \frac{1}{2}(-4)(0.4) + \frac{1}{2}(5)(0.6) = 0.7 \text{ m}$

$2-4 \Rightarrow \frac{1}{2}(4)(2) = 4 \text{ m}$

$7-9 \Rightarrow 5(2) = 10 \text{ m}$

$4-6 \Rightarrow \frac{1}{2}(-4)(2) = -4 \text{ m}$

$9-10 \Rightarrow \frac{1}{2}(5)(1) = 2.5 \text{ m}$

d)

$0 = 10 \text{ m}$

$2 = 18 \text{ m}$

$4 = 22 \text{ m}$

$6 = 18 \text{ m}$

$7 = 18.7 \text{ m}$

$9 = 28.7 \text{ m}$

$10 = 30.2 \text{ m}$

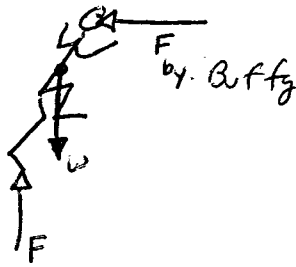
e)

graph paper

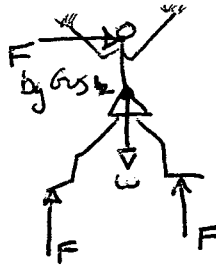


4. A soccer player running across the field (name = Gus, mass = 90 kg, velocity = 7 m/s in the horizontal direction) collides with a cheerleader (name = Buffy, mass = 40 kg) who is standing still on the sidelines. Gus makes a constant force of 800 N in the positive X direction on Buffy for 3 seconds during the course of the collision. (Assume that the linear accelerations of Gus and Buffy in the Y direction are equal to 0 m/s<sup>2</sup> throughout the collision.)
- Make a free-body diagram of Gus at any instant during the collision.
  - Make a free-body diagram of Buffy at any instant during the collision.
  - What was the linear momentum of Gus before the collision?
  - What was the linear momentum of Buffy before the collision?
  - What was the linear momentum of the combined Gus and Buffy system before the collision?
  - What was the net horizontal impulse exerted on Buffy by Gus during the collision?
  - What was the net horizontal impulse exerted on Gus by Buffy during the collision?
  - What was the linear acceleration of Gus during the collision?
  - What was the linear acceleration of Buffy during the collision?
  - If Buffy and Gus stuck together after the collision (i.e., they combined their masses to form 1 body), what is the horizontal velocity of the combined Buffy-plus-Gus system?
  - What is the linear momentum of the Buffy-plus-Gus system before the impact?
  - What is the linear momentum of the Buffy-plus-Gus system after the impact?

4) a)



b)



c)  $mv = 90(7) = 630 \text{ kg m/s}$

d)  $mv = 40(0) = 0 \text{ kg m/s}$

e)  $mv_{\text{Tot}} = mv_{\text{Buffy}} + mv_{\text{Gus}} = 630 + 0 = 630 \text{ kg m/s}$

f)  $F_{\Delta t} = 800(3) = 2400 \text{ N s}$

g)  $F_{\Delta t} = -800(3) = -2400 \text{ N s}$

i)  $a = F/m = \frac{-800}{90} = -8.89 \text{ m/s}^2$

j)  $a = F/m = \frac{800}{40} = 20.0 \text{ m/s}^2$

k)  $v = \frac{mv}{m} = \frac{630}{130} = 4.85 \text{ m/s} \rightarrow$

l)  $630 \text{ kg m/s}$  from e

m)  $630 \text{ kg m/s}$  - impact forces are internal forces  
 $\sum F_{\text{Hoe}} = 0$   
 on the Buffy + Gus system