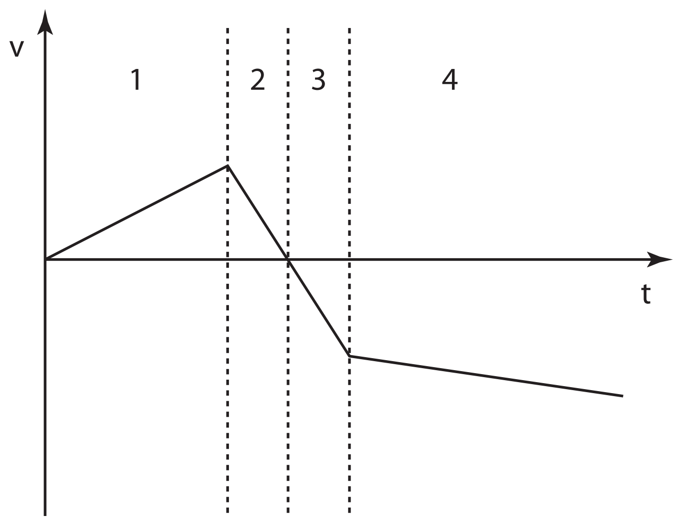
Exam #1: Basic kinematics and dynamics

Name: /30

---

1. Conceptual problems

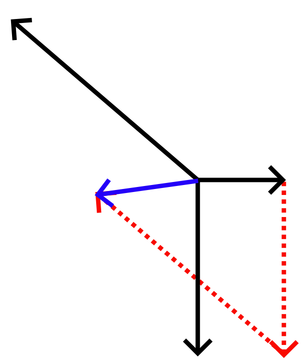
a. The velocity-time graph of a car is shown below. During each of the four time intervals, indicate whether the car is speeding up or slowing down. [4 pts]



Speeding up during periods 1, 3, and 4. In 1 the speed is increasing in the positive direction, and in 3 and 4 the speed is increasing in the negative direction.

Slowing down during period 3. The speed is decreasing in the positive direction.

b. Three forces acting on an object are indicated by the free-body diagram below. Sketch the net force acting on the object. [3 pts]



c. Draw free-body diagrams for each of the following: (i) a projectile in motion in the presence of air resistance, (ii) a rocket leaving the launch pad with its engines operating, and (iii) an athlete running along the end of a horizontal track (i.e., as their direction is changing). [3 pts]

2. A wrecking ball is hanging from a crane when the cable suddenly breaks. It takes the ball 1.2 s for the ball to travel halfway to the ground. Ignore air resistance.

a. How far does the ball fall? [3 pts]

Find the distance that it travels in the first 1.2 s and then multiply by 2.

Given/implied:

$$v_{y,i} = 0$$

$$a_y = -g = -9.81 \text{ m/s}^2$$

$$\Delta t = 1.2 \text{ s}$$

From this we calculate

$$\Delta y = v_{y,i}\Delta t + \frac{1}{2}a_y \Delta t^2 = -7.1 \text{ m},$$

which means that the ball falls

$$\boxed{14.1 \text{ m}}$$

.

b. What is the ball's velocity just before it hits the ground? (3 pts)

To answer this, we now need to recognized that $\Delta y = -14.1$ m. We can use

$$v_{y,f}^2 - v_{y,i}^2 = 2a_y \Delta y$$

$$v_{y,f} = \pm\sqrt{2a_y\Delta_y} = \boxed{-16.6 \text{ m/s}}$$

3. A Ferris wheel carries its riders in a (vertically oriented) circle with a radius of 8.0 m. The Ferris wheel makes one revolution every 9.0 s.

a. Calculate the angular velocity. [2 pts]

$$\omega = 2\pi f = \frac{2\pi}{T} = \boxed{0.70 \text{ rad/s}}$$

b. Calculate the centripetal acceleration and centripetal force acting on a 70-kg person as they travel around in a circle on the Ferris wheel. What direction does the force point? [2 pts]

$$a_c = \omega^2 r = \boxed{3.9 \text{ m/s}^2}$$

$$F_c = ma_c = \boxed{272 \text{ N, directed inward}}$$

c. What is the person's apparent weight (or normal force acting upward on them) as they pass the lowest point of the circle? How does this compare to their weight? [2 pts]

$$\sum F_c = F_n - F_g = ma_c$$

$$F_n = F_g + ma_c = mg + ma_c = m(g + a_c) = \boxed{960 \text{ N}}$$

Their weight is simply

$$F_g = mg = \boxed{687 \text{ N}}$$

4. Chinook salmon are able to move upstream faster by jumping out of the water periodically; this behavior is called porpoising. Suppose a salmon swimming in still water jumps out of the water with a speed of 6.26 m/s at an angle of 45°, sails through the air a distance L before returning to the water, and then swims a distance L at a speed of 3.58 m/s before beginning another porpoising maneuver. Determine the average speed of the fish.

a. How long is the fish in the air during one "jump"? [2 pts]

Given:

$$\Delta y = 0$$
$$v_{y,i} = 6.26\sin(45°)$$
$$a_y = -g = -9.81 \text{ m/s}^2$$

We can solve this using:

$$\Delta y = v_{y,i}\Delta t + \frac{1}{2}a_y\Delta t^2$$

Setting $\Delta y = 0$ and dividing by Δt,

$$0 = v_{y,i} + \frac{1}{2}a_y\Delta t$$

Solving for Δt,

$$\Delta t = \frac{-2v_{y,i}}{a_y} = \boxed{0.9 \text{ s}}$$

b. How far does the fish travel during each "jump"? [2 pts]

$$\Delta x = v_x\Delta t$$
$$v_x = 6.26\cos(45°)$$

Therefore

$$\Delta x = \boxed{4.0 \text{ m}}$$

c. How much time does the fish spend in the water between each "jump"? [2 pts]

Assume constant speed, and note that $\Delta x = L = 4.0$ m and $v = 3.58$ m/s.

$$\Delta x = v\Delta t$$
$$\Delta t = \frac{\Delta x}{v} = \boxed{1.1 \text{ s}}$$

d. What is the average speed of the fish? [2 pts]

Again assume velocity in the x-direction is constant.

$$v = \frac{\Delta x}{\Delta t}$$

Here, $\Delta x = 2L$ and $\Delta t = 2$ s (the total time that passes between "jumps". This gives

$$\boxed{v = 3.96 \text{ m/s}}$$