Name:________________________________

Group:______________________________

Freefall

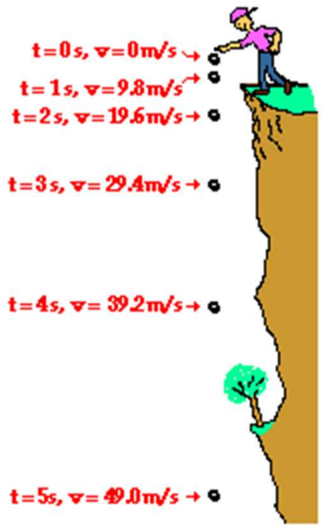
2.4

Freefall

A free falling object is an object that is falling under the sole influence of gravity. Any object that is being acted upon only by the force of gravity is said to be in a state of free fall.

There are **two** important motion characteristics that are true of free-falling objects:

- Free-falling objects do not encounter air resistance.
- All free-falling objects (on Earth) accelerate downwards at a rate of 9.8 m/s/s (often approximated at 10 m/s/s for calculations)



$$a = \frac{\Delta v}{t} = \frac{-9.8\ m/s}{1\ s}$$

A free-falling object has an acceleration of 9.8 m/s/s, downward (on Earth). This numerical value for the acceleration of a free-falling object is such an important value that it is given a special name. It is known as the **acceleration of gravity** - the acceleration for any object moving under the sole influence of gravity. The acceleration of gravity is such an important quantity that physicists have a special symbol to denote it - the symbol **g**.

Recall from an earlier lesson that acceleration is the rate at which an object changes its velocity. It is the ratio of velocity change to time between any two points in an object's path. To accelerate at 9.8 m/s/s means to change the velocity by 9.8 m/s each second.

Falling with Air Resistance

As an object falls through air, it usually encounters some degree of air resistance. Air resistance is the result of collisions of the object's leading surface with air molecules. The actual amount of air resistance encountered by the object is dependent upon a variety of factors. To keep the topic simple, it can be said that the two most common factors that have a direct affect upon the amount of air resistance are the:

1) <u>speed of the object</u> and the
2) <u>cross-sectional area of the object</u>.

Increased speeds result in an increased amount of air resistance.

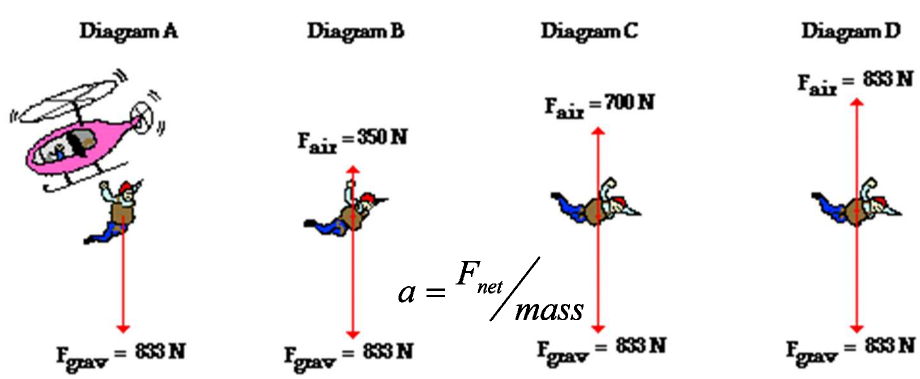
Increased cross-sectional areas result in an increased amount of air resistance.

Terminal Velocity

The fastest something can move because of the resistance it encounters.

Why does an object that encounters air resistance eventually reach a terminal velocity? To answer this questions, Newton's second law will be applied to the motion of a falling skydiver.

In the diagrams to the right, free-body diagrams showing the forces acting upon an 85-kg skydiver (equipment included) are shown. For each case, use the diagrams to determine the net force and acceleration of the skydiver at each instant in time.



$$a = F_{net} / mass$$

$$a = \frac{-833N}{85kg} = -9.8m/s^2$$

$$a = \frac{-833N + 350N}{85kg} = -5.7m/s^2$$

$$a = \frac{-833N + 700N}{85kg} = -1.6m/s^2$$

$$a = \frac{-833N + 833N}{85kg} = 0m/s^2$$

The diagrams illustrate a key principle. As an object falls, it picks up speed. The increase in speed leads to an increase in the amount of air resistance. Eventually, the force of air resistance becomes large enough to balances the force of gravity. At this instant in time, the net force is 0 Newton; the object will stop accelerating. The object is said to have reached a **terminal velocity**. The change in velocity terminates as a result of the balance of forces. The velocity at which this happens is called the terminal velocity.

Falling and Air Resistance

Bronco skydives and parachutes from a stationary helicopter. Various stages of fall are shown in positions *a* through *f*. Using Newton's 2nd law,

$$a = \frac{F_{NET}}{m} = \frac{W - R}{m}$$

find Bronco's acceleration at each position (answer in the blanks to the right). You need to know that Bronco's mass *m* is 100 kg so his weight is a constant 1000 N. Air resistance *R* varies with speed and cross-sectional area as shown.

Circle the correct answers.

1. When Bronco's speed is least, his acceleration is

   (least) (most).

2. In which position(s) does Bronco experience a downward acceleration?

   (a) (b) (c) (d) (e) (f)

3. In which position(s) does Bronco experience an upward acceleration?

   (a) (b) (c) (d) (e) (f)

4. When Bronco experiences an upward acceleration, his velocity is

   (still downward) (upward also).

5. In which position(s) is Bronco's velocity constant?

   (a) (b) (c) (d) (e) (f)

6. In which position(s) does Bronco experience terminal velocity?

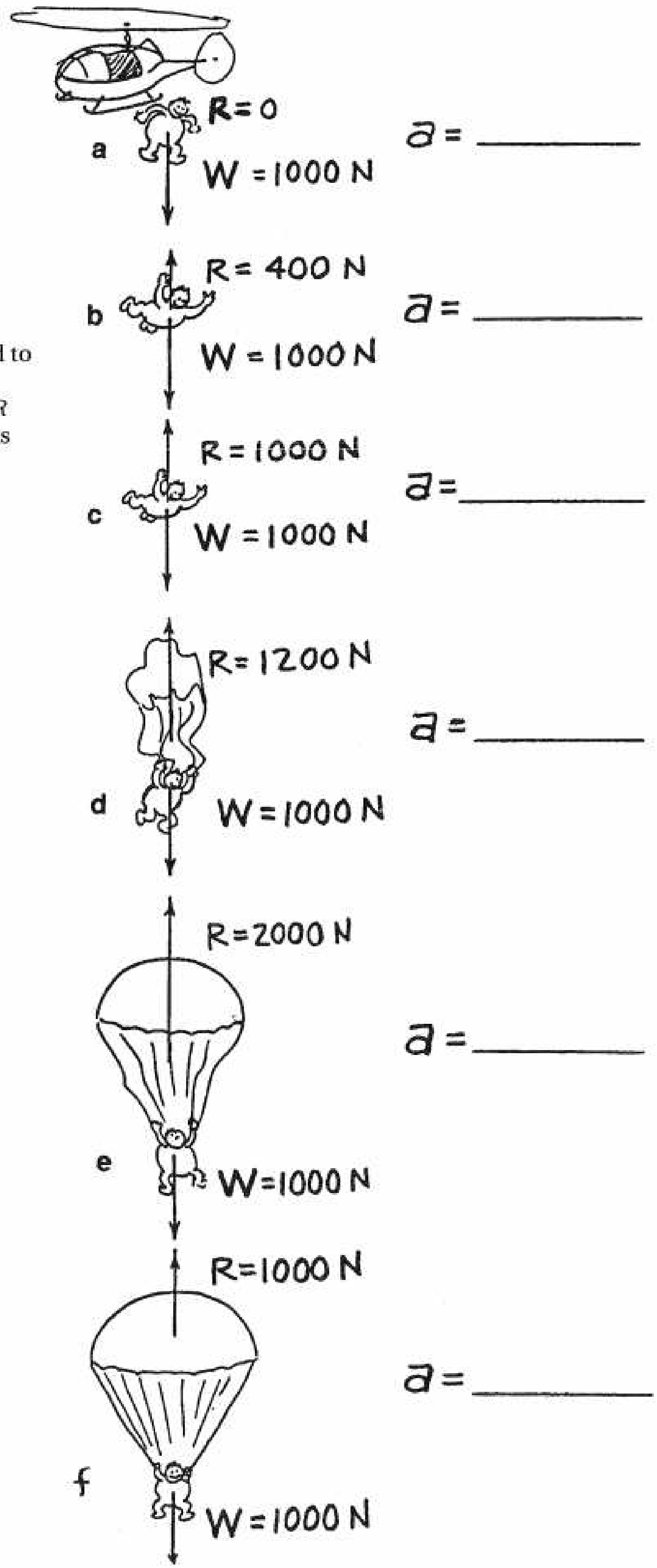
   (a) (b) (c) (d) (e) (f)

7. In which position(s) is terminal velocity greatest?

   (a) (b) (c) (d) (e) (f)

8. If Bronco were heavier, his terminal velocity would be

   (greater) (less) (the same).



conceptual PHYSICS

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