(Taking notes yourself focuses your attention on what I'm saying. So, I've printed some things, like all the sample problems I will go over. But the really important stuff, like how to solve those problems, I have saved for writing on the board.)

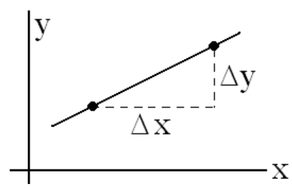
Section 1: Straight Line Motion:

Definitions for:

Displacement

Average velocity

Recall definition of slope:



$$\text{slope} = \frac{\Delta y}{\Delta x}$$

Notice that velocity is the slope of a graph of displacement as a function of time.

Example: A school bus goes 5 miles along a straight road in 15 minutes:

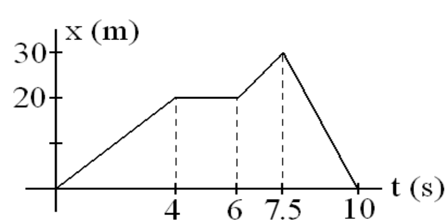
$$v_{av} = \frac{\Delta x}{\Delta t} = \frac{5\ \text{mi}}{.25\ \text{hr}} = \boxed{20\ \text{mi/hr}}$$

Notice: A complete answer (to any kind of problem) includes the appropriate units.

Example 1-1: The bus covers a route 10 miles long, returning to the school in 1/2 hour. Find the average velocity.

Ex. 1-2: Find the instantaneous velocity, v, at t = 7.0 sec.

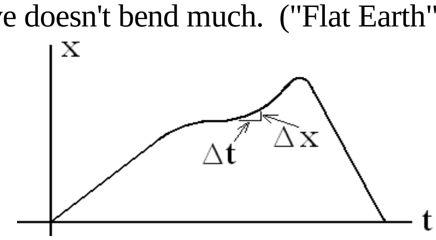
answer: (Find the slope, using a Δt small enough that the slope doesn't change.)



Do the same for non-straight curves: Make Δt very small so curve doesn't bend much. ("Flat Earth" approximation.)

The approximation becomes exact as Δt approaches zero.

Definition, Instantaneous velocity



Mathematical background. (Details to be filled out in a few weeks in Calc 1.):

Derivative:

- gives a function's slope at some point.

- for a polynomial function, is given by:

If $y = ax^n$, then $\frac{dy}{dx} = a(nx^{n-1})$ (a and n are nonzero constants.)

If y = (a constant), then $\frac{dy}{dx} = 0$

Ex. 1-3: An object's position is given by $x = (7t^3 + 4t + 8)$ meters. Find its velocity at t = 2.0 seconds.

Acceleration.

Ex. 1-4: An object is dropped from rest. Two seconds later, its velocity is 19.6 m/s. What is its average acceleration?

Motion With Constant Acceleration:

Δt means $t_f - t_i$. To simplify things, assume the clock was started at t_i, so $t_i = 0$. With nothing to subtract, Δt becomes just plain t.

$$v_{av} = \frac{\Delta x}{t} \Rightarrow \Delta x = v_{av}t$$

$$a = \frac{v_f - v_i}{t} \Rightarrow at = v_f - v_i \Rightarrow v_f = v_i + at$$

(No "av" needed on a because it's constant.)

Because the object steadily picks up speed, $v_{av} = \frac{1}{2}(v_i + v_f)$

These three equations can be substituted into each other and manipulated to obtain:

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$\Delta x = v_i t + \frac{1}{2}at^2$$

These are true for uniform acceleration only.

Ex. 1-5: A certain airplane must reach 30 m/s before leaving the ground. What is its minimum acceleration on a 360 m runway, starting from rest?

Ex. 1-6: You drop a rock off a cliff. It hits bottom exactly six seconds later. How high is the cliff?

"Free fall" = no forces other than gravity.

"Acceleration due to gravity": All freely falling objects near Earth's surface accelerate at a rate of $g = 9.8\ m/s^2$. ($32\ ft/s^2$)

The next page discusses significant figures. This is just for your information, and not something I will test you on.

Ex. 1-7: An object is thrown straight up at 30 m/s. What is its velocity 4.0 s later?

Significant figures:

I used to try to cover this, but eventually decided there wasn't room in the course. All I expect now is that you won't round too far from the correct answer. For example, don't round 3.46 to 3. If you are more than 2% from the correct answer on a test, I will treat it like an arithmetic error. Otherwise, I will treat incorrect rounding like incorrect spelling. Spelling physics "fizzyx" won't cost you credit either. But for those of you who prefer not to look quite that ignorant, here is how you ought to round your numbers:

The basic idea is not to mislead your reader about your accuracy with more decimal places than you actually know. For example, say you measured the width of a piece of paper as 8.0 ± .3 cm. When you then calculate one third of that, your calculator tells you 8.0/3 = 2.666666667. But, using the rules for experimental uncertainty in lab 1A (which I won't go through here) this is only accurate to ± .1 cm. So, most of those figures, or digits, are meaningless. The 7 on the end, for example, might in fact be a 3 or a 9 or anything. The significant figures are the ones about which you have some information. The last of those would be the first 6, because based on the ± .1 it might really be a 5 or a 7, but at least you know it isn't anything else. So, usually you should round after the decimal place which is somewhat, but not completely, uncertain: 2.7 ± .1 cm.

When you don't calculate an uncertainty, like on homework and tests, round using the idea that the answer can't be any more accurate than the least accurate number that went into it. However, exactly how you define "accuracy" depends on what kind of operation you're performing:

If adding or subtracting: Round to the same number of DECIMAL PLACES as the number with the fewest.

Example: 1234.5 + 6.78
6.78 goes to the hundredths place, but 1234.5 only goes to the tenths place. Round 1241.28 on your calculator to 1241.3. The reason: You don't know what is in the hundredths place of 1234.5, so you don't know what to add to the 8, so you don't know the hundredths place of the answer.

If multiplying or dividing: Round to the same number of SIGNIFICANT FIGURES as the number with the fewest.

Example: (1234.5)(6.78)
1234.5 has five significant figures, but 6.78 has only three. Round 8369.91 on your calculator to 8370. (Or, in a case like this, the number of significant figures is clearer written as 8.37×10^3.) The reason: Let ? stand for a figure you don't know. (1234.5)(6.78?) = (1234.5)(6) + (1234.5)(.7) + (1234.5)(.08) + (1234.5)(.00?). The last term might be as big as (1234.5)(.009) ≈ 11 or as small as (1234.5)(.000) = 0. Since you are adding in something that could be anywhere between 0 and 11, you have no idea what's in the last place before the decimal.

Other operations: Rounding by the number of significant figures, like when multiplying, is usually ok.

A couple of final notes:
- Unless specifically told otherwise, assume that all numbers given by the text or me are good to three significant figures. (If I write 7, I'm being lazy and really mean 7.00.)
- When solving a problem involves several steps, wait until the end to round. If you keep rounding along the way, it sometimes adds up to a considerable difference in the answer.

Section 2: Vectors

Vector: has both a magnitude and a direction.

Examples: Force, velocity, etc.

Scalar: has magnitude only.

Examples: Temperature, time, etc.

Vector Addition. (Find the one vector which is equivalent to several acting together.)

Graphical methods: Represent the vectors as arrows on a scale drawing.

Head to tail method: Draw each arrow with its tail on the head of the one you just finished drawing. Then, draw the resultant from the tail of the first to the head of the last. Measure its length and direction to get answer.

Ex. 2-1: A bird flies 6.0 m at 30° above the horizontal, then 4.0 m at 60° above the horizontal, then 9.0 m horizontally back in the direction it came from. Find its resultant displacement by using the head-to-tail method on a scale drawing.

To get them head-to tail: Parallel displacement: Vectors can be moved around the page as long as you maintain the magnitude and direction.

An alternative to the head-to-tail method, when adding just two vectors, is the parallelogram rule. Draw the vectors tail to tail, then complete the parallelogram, then $\vec{R}$ is the diagonal coming from the same point as the two vectors.

Mathematical methods: There are two ways to describe a vector (in the xy plane) with numbers: Assume the tail of the arrow is at the origin. Knowing what point the arrowhead was at would be enough information to draw it. You could tell someone where that point is by giving:

1. The distance and direction from the origin, (r,θ). These are called the vector's magnitude and direction.

2. How far to go horizontally, and how far to go vertically from the origin, (x,y). These are called the x and y components of the vector.

Ex. 2-2: If A_x = 4.00 lb and A_y = 3.00 lb, find A and θ.

Notation:

$\vec{A}$ or **A** means vector A. (Ex: 5.00 lb at 36.9°)

$|\vec{A}|$ or A means the magnitude of $\vec{A}$. (Ex: Just the 5.00 lb.)

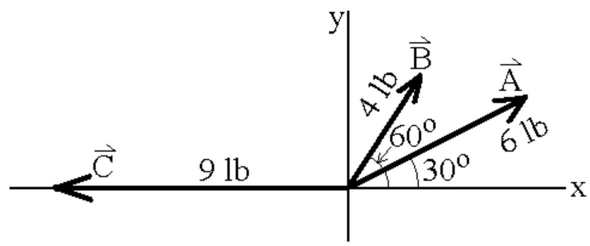
How to find magnitude.

Ex. 2-3: Find the x and y components of $\vec{A}$ = 5.00 lb at 36.9°.

Unit vectors.

Multiplication of a vector by a scalar.

Ex. 2-4: Find the resultant. (Assume the numbers are good to 3 significant figures.)



Vector subtraction: $\vec{A} - \vec{B} = \vec{A} + (-\vec{B})$

As examples of this, I will go over the definitions of velocity and acceleration, generalized to two dimensional motion.

Ex. 2-5: A 5 kg object has a velocity of $5\hat{\imath} + 7\hat{\jmath}$ m/s. Three seconds later, its velocity is $2\hat{\imath} - 2\hat{\jmath}$ m/s. Find

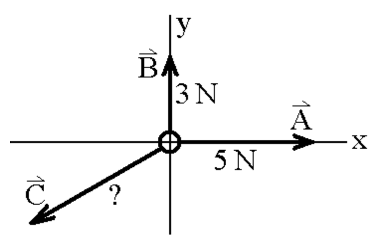
a. its average acceleration.

b. the net force on it, from $\vec{F} = m\vec{a}$.

c. the magnitude of the net force.

Ex. 2-6: If the ring is at rest, what is $\vec{C}$?

(An object can only stay at rest with no net force on it.)



Section 3: Newton's Second Law

$$\Sigma\vec{F} = m\vec{a}$$

Σ is the symbol for a summation.

Force means a push or pull, in pounds or newtons. It is not the same thing as any kind of vector; velocity is not a kind of force, for example.

mass is how you measure a body's inertia - its resistance to acceleration. The SI unit is the kilogram.

a = acceleration.

Newton's first law follows from the second, as a special case.

Units: A newton is equivalent to a $kg \cdot m/s^2$. (So, to get the units to work out right in a calculation, grams must be converted to kg, cm into m, etc.)
Similarly, when working in traditional British units, a pound is equivalent to a $slug \cdot ft/s^2$, where a slug is the unit of mass.

Be sure not to mix up units of force with units of mass.

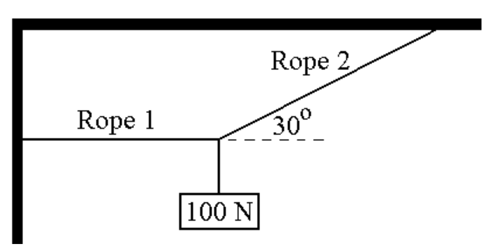
Weight = the force of gravity on an object.

Relationship between weight and mass.

Ex. 3-1: A 3200 lb car goes from 0 to 88 ft/s in 10 s. The forward force from the engine is 1000 lb. How large is the average friction force?

If an object is remaining at rest (static equilibrium) its acceleration is zero. Plugging that into the second law gives $\Sigma F_x = 0$ and $\Sigma F_y = 0$.

Ex. 3-2: Find the tension in each rope. (The force it pulls with at its ends.)



Friction:

f_s = force of static friction. (f_{max} when about to slip. The force is often less than this; whatever is needed to maintain equilibrium.)

f_k = force of kinetic (sliding) friction.

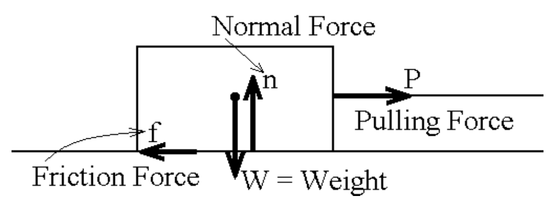
I will explain how these depend on

- the normal force, n = the force ⊥ ("normal") to surfaces which is pushing them together.
- the coefficient of friction, μ (Greek "mu") = a property of the materials (table in handout).

Direction: Friction always opposes motion.

Notice that μ is a dimensionless number.

Ex. 3-3: Given: W = n = 10 N, $\mu_s = .40$ and $\mu_k = .25$,
a. find f when P = 1.0 N and the block is at rest.
b. find P needed to start it moving,
c. find P needed to keep it moving, at constant velocity.

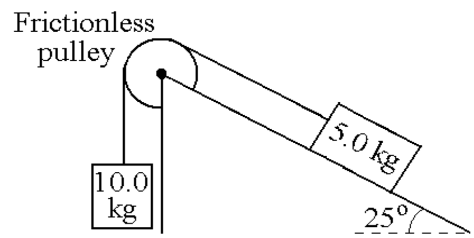


Inclined plane: Have x and y axes parallel and perpendicular to direction of motion, rather than horizontal and vertical.

Ex. 3-4: A 5.00 kg wooden block is pulled at a constant speed up a 25° wooden incline by a rope parallel to the incline. Make a list naming each force on the block along with how many newtons each one is.

System of objects: Write more than one F = ma equation. (Apply F = ma to different parts of the system.)

Ex. 3-5: The blocks are wood, and so is the ramp. Find the acceleration of the blocks, and the tension in the cord.



Section 4: Motion in a Plane

Projectiles (with no air friction):

Two dimensional motion is just the superposition of two one dimensional motions: Think of a ball thrown in a dark room, with a spotlight behind it, and a spotlight above it. The position, velocity and acceleration of the shadow on the floor are the x components of its motion. Likewise, the shadow on the wall represents the y components.

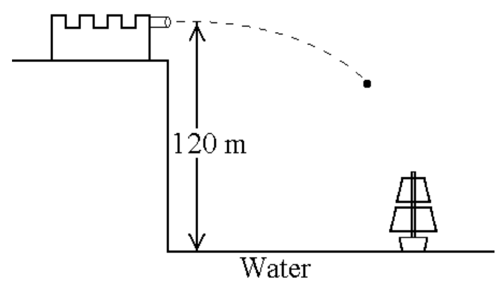
The x component has a constant velocity. ($a_x = 0$.)
y has a constant acceleration. ($a_y = -g$, if down is negative.)

These kinds of one-dimensional motion are described by the equations from section 1.

Ex. 4-1: A projectile is fired at an angle θ_i with initial speed v_i across level land. How far away does it land?

Ex. 4-2: The cannonball is fired horizontally at 100 m/s. How far from the base of the cliff does it land?

Ex. 4-3: With what speed (magnitude of $\vec{v}$) does it hit the water?



Uniform Circular Motion:

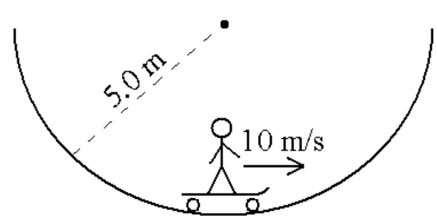
Although the object's speed is constant, it is accelerating, due to the changing direction of $\vec{v}$.

Centripetal acceleration

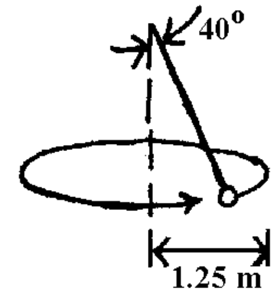
Centripetal force

Ex. 4-4: Without skidding, what is the fastest you can drive around an unbanked curve with a radius of 30 m in the rain?

Ex. 4-5: What is the upward force on the feet of this 70 kg skateboarder?



Ex. 4-6: A 2.30 kg object hung on a string moves at 3.21 m/s in a horizontal circle with a radius of 1.25 m. If the string makes an angle of 40.0° with the vertical, what is the tension in the string?

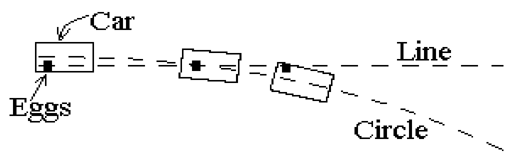


Ex. 4-7: A spaceship moves 7068 m/s in an orbit with an 8.0×10^6 m radius. Find the force of gravity on a 75 kg astronaut inside.

(A "weightless" astronaut is actually in free fall: The ship drops at the same rate you do, so you float relative to the ship. The ship doesn't crash because as it moves to the side, the earth curves out from under it.)

Centrifugal "force": Due to inertia, not a true force. (Such "fictitious forces" or "pseudoforces" come from looking at the world from an accelerating frame of reference.)

Seen from above:



Example: The eggs seem to accelerate at v^2/r relative to the car, giving the appearance of an outward force of mv^2/r. They're actually obeying the first law: In the absence of a force, they follow a straight line. The actual force - friction between the tires and the road - is on the car not the eggs, and toward the center of the curve, not away.)

Ex. 4-8: Assuming the earth to be perfectly spherical, how much difference does its rotation make in the effective value of g between the poles and equator?

Review of Sections 1 - 4:

The exam will have five parts, each worth 25 points. The best four you do will be counted. So, it's best to do all five, and let me drop the worst one.

How to study: Be on intimate terms with your notes. Understand the concepts and how to apply them. Review the sample problems. If you've kept up with the weekly work, just going through the notes to refresh your memory and fill in any gaps is probably all you need. If you haven't been keeping up, you should still focus on the notes, especially on solving problems. If it turns out you can't learn a month of material in one night, do more each week in the future. Don't just memorize quiz solutions without getting a feeling for the concepts. If necessary, work more problems from the text in areas where you feel weak. As always, you can come to my office for help.

Because I'm still trying to teach you things, some of these questions might be a little trickier than on an actual test. Two sample tests are provided. Don't expect the actual test questions to be similar to either one. You need to study everything we covered.

PHY 131 Exam 1

The best 4 of the test's 5 parts will be counted. Work in the bluebook; I will not be looking at this question sheet. Include a clear presentation of how you solved each problem. Include appropriate units with answers. You may refer to a calculator, and the formula sheets provided with this test.

1. A bucket containing 4.0 kg of water is swung in a vertical circle with a 1.1 m radius at 5.0 m/s. What are the magnitude and direction of the force from the bucket on the water as it passes through the top point on the circle?

Ans: 51.7 N down

2. A .75 kg book is given an initial velocity of 4.8 m/s on a horizontal floor. 1.5 s later, it is 4.2 m from its starting point (and still moving, although slower). How large is

a. the force of friction? (Ans: 2.00 N)
b. the coefficient of friction? (Ans: .272)

3. A 6.0 kg box is on a frictionless incline. If you pull uphill on it with 25 N (parallel to the incline), it accelerates uphill at 1.70 m/s^2. You then stop pulling uphill, and instead pull downhill with 25 N. What is its acceleration now?

Ans: 6.63 m/s^2 downhill

4. A rock is thrown from a cliff 25 m above the ground at 42 m/s, 39° below the horizontal. Find the time it takes to reach the ground.

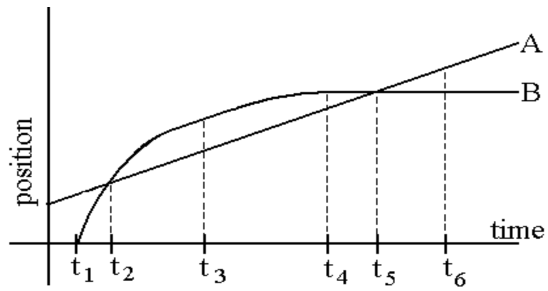
Ans: .820 s

5. Short answer, 5 points each.

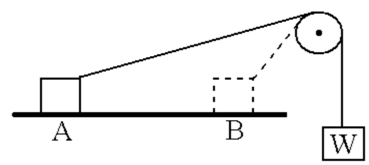
a. A ball is thrown straight up, then returns to the thrower's hand. Taking up as positive, the ball's acceleration is ____as it rises, ____ at the top, and ____ as it falls back down. (State whether "positive," "negative," or "zero" belongs in each blank.)

b. In terms of the three fundamental units; the meter, the kilogram, and the second, what is a newton? (I'm looking for 1 N = 1 s·kg^3/m^2, or something like that.)

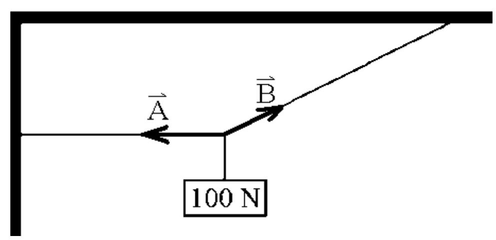
c. Two cars are going down a straight road. As shown, car B first passes car A, then later, A passes B. At which of the indicated times, if any, do the two cars have the same velocity?



d. The weight and frictionless pulley maintain a force of constant magnitude on the block as it slides along. The coefficient of friction is constant along the surface. Is the force of friction more at point A, more at B, or the same both places?



e. Is the magnitude of force $\vec{B}$ more than 100 N, less than 100 N, or equal to 100 N?



PHY 131 Exam 1 (Review)

The best 4 of the test's 5 parts will be counted. Work in the bluebook; I will not be looking at this question sheet. Include a clear presentation of how you solved each problem. Include appropriate units with answers. You may refer to a calculator, and the formula sheets provided with this test.

1. The "Paris gun" used by the Germans in 1918 had a muzzle velocity of 1600 m/s. If fired in a vacuum at 50°, to what maximum height would the shell rise?

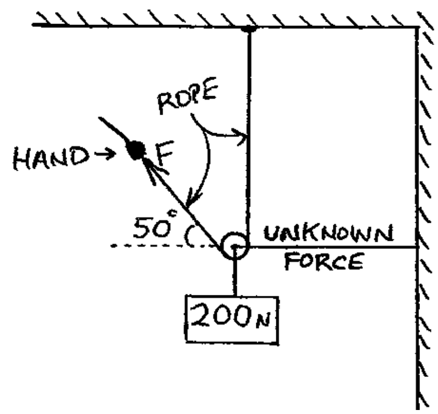
Ans: 7.66×10^4 m (47.6 miles)

2. Two apples fall from a tree at the same time, each from a height of 8.00 m. One falls directly to the ground. The other hits a branch 5.00 m from the ground, which stops it for an instant and then it begins to fall again. How much time passes between the first apple reaching the ground and the second one getting there?

Ans: .515 s

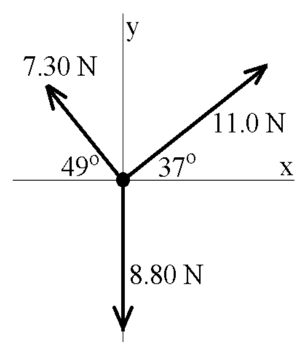
3. One end of the rope is attached to the ceiling. It then passes under a pulley (a wheel) and goes at a 50° angle to your hand. A 200 N weight and a horizontal rope are also attached to the pulley. With what force, F, must you pull the rope to support the 200 N load? (F equals the tension in the rope, which is the same all along it from your hand to the ceiling.) Don't bother finding the horizontal force.

Ans: 113 N



4. Three forces act on a particle as shown. Find the magnitude and direction of their resultant using the head-to-tail method on a scale drawing, not by using components. There are rulers and protractors you can borrow if necessary. (A correct solution using components instead will be worth 15 of the 25 possible points.)

Ans: 5.2 N at 40°



5. Short answer, 5 points each.

a. Vector $\vec{A}$ is shown here.

In your bluebook, make a scale drawing of $-3\vec{A}$.

(Fold the page along the edge of the ruler's picture and use it to measure.)

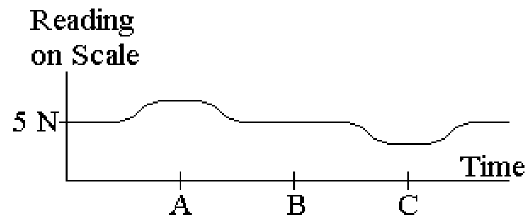
b. Continuing to measure with the ruler above,

i. Draw a picture of the unit vector $\hat{i}$.

ii. Draw a picture of the unit vector $\hat{j}$.

c. i. Does “centripetal force” mean actual force or an inertia effect?
ii. Does “centrifugal force” mean actual force or an inertia effect?

d. A weight is sitting on a scale in an elevator. The scale reads 5.0 N at the start of the graph, when the elevator is at rest. It also reads 5.0 N at time B, when it is moving at a constant speed. Based on what happens elsewhere on the graph, is the elevator moving up or down at B?



e. A car with the cruise control on is moving along a straight, level road at a constant 30 m/s. Sketch a graph of acceleration as a function of time for this car.