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2. The velocity of an object as a function of time is shown in the figure below. Over what intervals is the work done on the object (a) positive, (b) negative, (c) zero? (Hint: make a table showing sign of acceleration (hence sign of net force), sign of displacement, and sign of their product, for each segment.)

(Consider work done by whatever external force is causing the object’s velocity to change.)
A few key ideas from Chapters 8 (force) and 9 (work)

Impulse is momentum change (of system) due to external force exerted on system:

\[
\text{force} = \frac{d(\text{momentum})}{dt} \iff \vec{J} = \int \vec{F}_\text{external} \, dt
\]

Work is energy change (of system) due to external force exerted on system:

\[
\text{force} = \frac{d(\text{work})}{dx} \iff W = \int F_x,\text{external} \, dx
\]

Force exerted BY spring, gravity, etc. (notice the minus sign):

\[
\text{force} = -\frac{d(\text{potential energy})}{dx}
\]

\(\Delta E_{\text{system}}\) = flow of energy into system = work done ON system:

\[
\text{work} = \Delta(\text{energy}) = \Delta K + \Delta U + \Delta E_{\text{source}} + \Delta E_{\text{thermal}}
\]

Notice that work : energy :: impulse : momentum
Work (external, nondissipative, 1D):  
\[ W = \int F_x(x) \, dx \]
which for a constant force is  
\[ W = F_x \Delta x \]

Power is rate of change of energy:  
\[ P = \frac{dE}{dt} \]

G.P.E. near earth’s surface:  
\[ U_{\text{gravity}} = mgh \]

Force of gravity near earth’s surface (force is \(-\frac{dU_{\text{gravity}}}{dx}\)):  
\[ F_x = -mg \]

Potential energy of a spring:  
\[ U_{\text{spring}} = \frac{1}{2} k(x - x_0)^2 \]

Hooke’s Law (force is \(-\frac{dU_{\text{spring}}}{dx}\)):  
\[ F_{\text{by spring ON load}} = -k(x - x_0) \]
A 50 kg woman climbs a 10 m rope in 20 s. What is her average power output? (Use $g \approx 10 \text{ m/s}^2$.)
A spring-loaded toy dart gun is used to shoot a dart straight up in the air, and the dart reaches a maximum height of 8 m. The same dart is shot straight up a second time from the same gun, but this time the spring is compressed only half as far before firing. How far up does the dart go this time (neglecting friction)?

(A) 1 m  
(B) 2 m  
(C) 4 m  
(D) 8 m  
(E) 16 m  
(F) 32 m
Stretching a certain spring 0.10 m from its equilibrium length requires 10 J of work. How much more work does it take to stretch this spring an additional 0.10 m from its equilibrium length? (It may be easier to ask yourself how much total work is needed to stretch the spring 0.20 m from its equilibrium length, then subtract.)

(A) No additional work  
(B) An additional 10 J  
(C) An additional 20 J  
(D) An additional 30 J  
(E) An additional 40 J
A block initially at rest is allowed to slide down a frictionless ramp and attains a speed $v$ at the bottom. To achieve a speed $2v$ at the bottom, how many times as high must a new ramp be?

(A) 1
(B) 1.414
(C) 2
(D) 3
(E) 4
(F) 5
(G) 6
At the bowling alley, the ball-feeder mechanism must exert a force to push the bowling balls up a 1.0 m long ramp. The ramp leads the balls to a chute 0.5 m above the base of the ramp. About how much force must be exerted on a 5.0 kg bowling ball?

(A) 200 N  
(B) 100 N  
(C) 50 N  
(D) 25 N  
(E) 5.0 N  
(F) impossible to determine.
Suppose you drop a 1 kg rock from a height of 5 m above the ground. When it hits, how much force does the rock exert on the ground? (Take $g \approx 10 \text{ m/s}^2$.)

(A) 0.2 N
(B) 5 N
(C) 50 N
(D) 100 N
(E) impossible to determine.
Things to understand before studying architectural structures:

- forces ✓ (but we will continue to use, all term!)
- vectors — (now)
- torques — (chapter 12) — about 1.5 weeks after fall break
A Chapter 10 reading question:

Can an object be accelerated without changing its kinetic energy?
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Answer: Yes. You can change an object’s direction without changing its speed. So its velocity can change without changing its kinetic energy.

Over a finite time interval, this is easy to arrange.

Over an infinitessimal time interval, if the acceleration vector is perpendicular to the velocity vector, then direction changes, but speed does not. This will be important in Chapter 11!
Let’s quickly revisit free-body diagrams in 1D

You push on a crate, and it starts to move but you don’t. Draw a free-body diagram for you and one for the crate. Then use the diagrams and Newton’s third law of motion to explain why the crate moves but you don’t.

(A) The force I exert on the crate is larger than the force the crate exerts on me.

(B) The crate’s force on me is equal and opposite to my force on the crate. The frictional force between my shoes and the floor is equal in magnitude to the crate’s push on me, while the frictional force between the crate and the floor is smaller than my push on the crate.

(C) The crate and I exert equal and opposite forces on each other, but I don’t move because I am much more massive than the crate.
If the crate and I were both standing on an ice rink, then it seems clear that we would both start to move. If the crate and I were both bolted to the floor, then it seems clear that neither one of us would start to move. So the grip of the floor’s friction on my feet must be greater in magnitude than the grip of the floor’s friction on the crate.

Let’s say that I push to the right on the crate with a force $\vec{F}_{\text{me,crate}}$, so the crate pushes to the left on me with a force $\vec{F}_{\text{crate,me}} = -\vec{F}_{\text{me,crate}}$. Meanwhile, the floor pushes to the right on me with a force $\vec{F}_{\text{floor,me}}$, and the floor pushes (by a smaller amount) to the left on the crate with a force $\vec{F}_{\text{floor,crate}}$.

It is reasonable that $|\vec{F}_{\text{floor,crate}}| < |\vec{F}_{\text{floor,me}}|$, because the bottom of the crate is wood, while the soles of my shoes are rubber.
(free-body diagrams in one dimension)
Block sliding down inclined plane: try drawing free-body diagram. Suppose some kinetic friction is present, but block still accelerates downhill. Try drawing this with a neighbor, one step ahead of me.

First: let’s draw $\vec{F}_{E,b}^G$ for gravity.
Add gravity vector

Next decompose $\vec{F}_{E,b}^{G}$ into components $\parallel$ and $\perp$ to surface.
Decompose gravity vector: $\parallel$ and $\perp$ to surface

Next: add contact force “normal” ($\perp$) to surface.
Now add contact force “normal” ($\perp$) to surface

Next: add friction.
Now add friction ($\parallel$ to surface, opposing *relative* motion)
The block shown in this free-body diagram is
(A) at rest.
(B) sliding downhill at constant speed.
(C) sliding downhill and speeding up.
(D) sliding downhill and slowing down.
(E) sliding uphill and speeding up.
(F) sliding uphill and slowing down.
How would I change this free-body diagram . . . if the block were at rest?
How would I change this free-body diagram . . . if the block were sliding downhill at constant speed?
How would I change this free-body diagram . . . 
if the block were sliding downhill and slowing down?
How would I change this free-body diagram . . . if the block were sliding uphill and slowing down?
Another Chapter 10 reading question:

You’ve slammed on the brakes, and your car is skidding to a stop on a steep and slippery winter road. Other things being equal, will the car come to rest more quickly if it is traveling uphill or if it is traveling downhill? Why? (Consider FBD for each case.)
Another Chapter 10 reading question:

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The coefficient of static friction of tires on ice is about 0.10. (a) What is the steepest driveway on which you could park under those circumstances? (b) Draw a free-body diagram for the car when it is parked (successfully) on an icy driveway that is just a tiny bit less steep than this maximum steepness.
A fried egg of inertia $m$ slides (at constant speed) down a Teflon frying pan tipped at an angle $\theta$ above the horizontal. (a) Draw the free-body diagram for the egg. Be sure to include friction. (b) What is the “net force” (i.e. the vector sum of forces) acting on the egg? (c) How do these answers change if the egg is instead speeding up as it slides?
A Ch10 problem that won’t fit into HW5

Calculate $\vec{C} \cdot (\vec{B} - \vec{A})$ if $\vec{A} = 3.0\hat{i} + 2.0\hat{j}$, $\vec{B} = 1.0\hat{i} - 1.0\hat{j}$, and $\vec{C} = 2.0\hat{i} + 2.0\hat{j}$. Remember that there are two ways to compute a dot product—choose the easier method in a given situation: one way is $\vec{P} \cdot \vec{Q} = ||\vec{P}|| \cdot ||\vec{Q}|| \cos \varphi$, where $\varphi$ is the angle between vectors $\vec{P}$ and $\vec{Q}$, and the other way is $\vec{P} \cdot \vec{Q} = P_x Q_x + P_y Q_y$. 
A child rides her bike 1.0 block east and then $\sqrt{3} \approx 1.73$ blocks north to visit a friend. It takes her 10 minutes, and each block is 60 m long. What are (a) the magnitude of her displacement, (b) her average velocity (magnitude and direction), and (c) her average speed?
You are lifting a ball at constant velocity.

(a) When the system is the ball, is work done on the system? If so, by what agent(s)?

(b) Describe the potential energy of this system during the lift.

(c) When the system is ball + Earth, is work done on the system? If so, by what agent(s)?

(d) Describe the potential energy of this system during the lift.
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