Linear to Circular, Part II

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I. Review: Accelerations and Velocities

A. Give an example in which a force is applied to an object but the object does not accelerate. The more specific numbers you can give the better.

B. Give an example (using specific numbers) in which an object accelerates and ***slows down*** without changing its direction. Your example should include the initial velocity, final velocity, and acceleration.

C. Give an example (using specific numbers) in which an object accelerates and ***speeds up*** without changing its direction. Your example should include the initial velocity, final velocity, and acceleration.

D. Give an example in which an object accelerates but its speed does not change. Your example should include the initial velocity of the object, the (approximate) direction of acceleration, and the speed and (approximate) direction of the final velocity.

II. Review: Forces and Work

Recall the following important new pieces of information from lecture:

- If a force acts in the direction of motion, it does positive work.
- If a force acts against the direction of motion, it does negative work.
- If a force acts perpendicular to the direction of motion, it does no work at all.
- If an object is moving in a circle, $\boldsymbol{a}_{\text{cent}} = \boldsymbol{v}^2/\boldsymbol{r}$

A. A force is doing ***positive*** work on an object. There are no other forces on the object. The object will: (a) speed up, (b) slow down, (c) change direction.

B. A force is doing ***negative*** work on an object. There are no other forces on the object. The object will: (a) speed up, (b) slow down, (c) change direction.

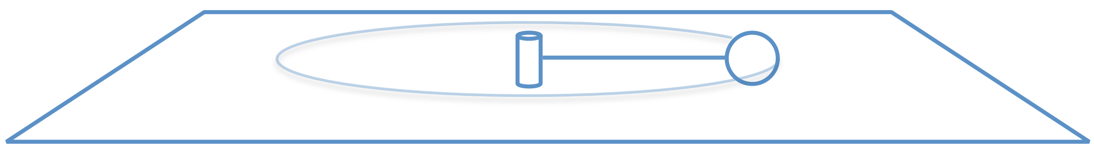
C. A force is doing ***no*** work on an object. There are no other forces on the object. The object will: (a) speed up, (b) slow down, (c) change direction.

III. A Spinning Thing

A toy is constructed of a rod connecting a metal sphere to a stationary base. The sphere has a mass of 1.5 kg. the rod has length .4 meters and negligible mass. (If the rod's mass were not negligible, this would be a rotation problem, involving moment of inertia & torque, so lucky it's massless!)

The toy is positioned on a tabletop. The sphere is given an initial speed of 6 m/s, and the rod causes it to spin in a circle about the base, as shown in the diagram below.

As it spins, it slides across the table. The coefficient of kinetic friction between the tabletop and the sphere is 0.1.



At some particular moment as it spins, the sphere is in the position shown in the diagram above, with the rod extended to the right.

A. Imagine that you are looking ***down*** at the sphere at this moment. Draw a ***bird's-eye-view*** FBD of the sphere at this moment.
   HINT: From this angle, you will only see TWO of the four forces on the sphere.

B. Now imagine that, instead of looking down at the sphere, your eyes are level with the table-top. Draw a ***side-view*** FBD of the sphere, at that same moment.
   HINT: From this angle, you will only see THREE of the four forces on the sphere.
   HINT 2: ONE of the forces in the bird's-eye FBD will ***not*** appear in this FBD. The other one will appear.

C. Is tension doing negative work, positive work, or no work? Explain/justify your answer.

D. What role does tension play in the sphere's motion? What would happen to the sphere if tension suddenly disappeared—i.e. if the rod suddenly broke?

E. Is friction doing negative work, positive work, or no work? Explain/justify your answer.

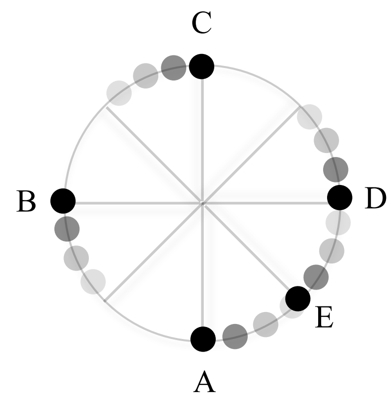
F. What role does friction play in the sphere's motion? What would happen to the sphere if friction did not exist—i.e. if the table and the sphere were perfectly smooth?

G. Is the normal force from the table doing negative work, positive work, or no work? Explain/justify your answer.

H. What role does the normal force play in the sphere's motion? What would happen to the sphere if the normal force suddenly ceased to exist—i.e. if the surface of the table vanished.

IV. A Vertical Circle

A slightly unhinged physics teacher is spinning a set of keys in a circle on the end of a nylon strap, as shown in the diagram to the right. The keys have a mass of 0.4 kg. The nylon strap has a negligible mass. The keys are spinning in the CLOCKWISE direction.



Consider the moment when the keys are at the very bottom of their circular journey (point A in the diagram above).

1. Draw an FBD of the keys at this moment.
2. At this moment, in what direction is the instantaneous velocity of the keys?
3. At this moment, is tension doing positive work, negative work, or no work?
4. At this moment, is gravity doing positive work, negative work, or no work?
5. At this moment, which force(s) are centripetal (i.e. helping to accelerate the keys in towards the center of the circle, in order to keep them moving in a circle)?

Consider the moments when the keys are at points B, C, and D in the diagram above. Redo steps 1 through 5 separately for each of these three moments in time. You can label your work B1, B2…; C1, C2…; D1, D2…

Ok, now consider point E (when the nylon strap forms a 45 degree angle with the verticle).

6. Draw an FBD of the keys at this moment.
7. At this moment, in what direction is the instantaneous velocity of the keys?
8. At this moment, is tension doing positive work, negative work, or no work?
9. At this moment, is gravity doing positive work, negative work, or no work?
   This last question may seem confusing. If it does, that probably means you're thinking. Good. Here's a **HINT:** you may want to consider different components of gravity separately. To do that, you'll need a coordinate system. Think back to the FBDs you did for the pendulum in Lab 6. Think back to question IV above. Think about a radial and a tangential axis.

*** The following problem is EXTRA CREDIT! ***

V. Spinning Thing: Quantitative Approach

This problem is based on the material in section 6-3 in the course textbook. If you are extremely clever ***and*** thoughtful, you may be able to figure them out before reading the textbook. If you want this challenge, go for it—but then please read section 6-3.

Go back to the scenario described in ***problem III*** (not IV) above. Consider the moment in time immediately after the toy begins to rotate, i.e. when the sphere's speed is 6 m/s.

A. Compute the magnitude of the centripetal acceleration at this moment.

B. Consider the birds-eye-view FBD you drew in III.A.

   Apply Newton's Second Law to the sphere on the radial axis (i.e. the axis that is parallel to the radius of the circle, i.e. the axis that contains tension).

   HINT: here is only one force on this axis.

C. What is the acceleration on this axis ($\boldsymbol{a_r}$)?
   HINT: You just calculated it a couple steps ago!

D. Compute the magnitude of the tension force.

E. Apply Newton's Second Law to the sphere on the vertical axis (the y-axis if you like).

F. Compute the magnitude of the normal force. (No tricks here. It comes out pretty simple.)

G. Compute the magnitude of the friction force. (You have normal force, so just compute friction the way you always do.)

H. Apply Newton's Second Law to the ***tangential*** axis (i.e. the axis that runs tangent to the circle; i.e. the axis that is parallel to instantaneous velocity.)

I. Compute the acceleration on this tangential axis.
   HINT 1: Use Newton's Second Law.
   HINT 2: There is only one force on this axis.

J. Which of these forces will change over time? Which of these forces will not change over time?

K. After 2 seconds, how ***fast*** is the sphere moving?

L. At this time (t=2), what will be the magnitude of the tension force?

M. How long will it take the sphere to complete one complete circle.
   HINT 1: What is the distance covered in one complete circle?
   HINT 2: How long would it take the sphere to go this distance if there were no friction?
   HINT 3: Given that there is friction, but friction is constant and thus causes a constant slow down, what kinematics equation can you use to find $\boldsymbol{t}$?