Curves, Work, & Other Components

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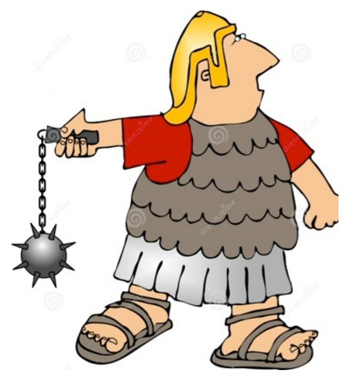
I. Warm Ups with Circles

A) Have you ever met the Space Knight? He's this weird guy who flies around outer space with a giant spiked ball on the end of a chain, beating up asteroids—don't ask me why! Anyway, one night (I guess it's always nighttime in outer space) the Space Knight is swinging his spiked ball in a circle.



The distance from his fist to the ball is 2 meters, and the ball travels at a constant ***speed*** of 10 m/s. The ball has a mass of 20 kg, and the mass of the chain is negligible.

a. Compute the centripetal acceleration of the spiked ball.
b. Compute the tension on the chain.
c. Compute the time for one complete rotation of the ball (i.e. one time around the circle).

B) A moon is orbiting around a strange planet. The moon's orbit is approximately circular, at a distance of 5,000,000 meters from the planet. The moon has a mass of 20,000 kg. The planet exerts a gravitational force of 100,000 N on the moon. This is the ONLY force on the moon.

a. What force must be producing the centripetal acceleration?
b. Compute the magnitude of the moon's centripetal acceleration?
HINT 1: You don't know the moon's speed, so you can't use V^2/r.
HINT 2: Draw an FBD of the moon.
HINT 3: Write out Newton's Second Law and apply it to the radial axis.
HINT 4: Compute the radial acceleration.
c. Compute the magnitude of the moon's velocity.
HINT 1: Use your answer from part b.

II. WORK!

Read section 3-3 from the textbook especially the section called "The Scalar Product."
Read section 7-2 from the textbook.

Recall the direction of velocity & acceleration of an object under constant circular motion
Velocity is tangent to the circle at any point
Acceleration is parallel to the radius at any point

Recall the our preliminary definitions of work done by a force, F:

1. **$W \equiv$ displacement times the component of F that is parallel to displacement.**
2. **$W \equiv$ F times the component of displacement that is parallel to F.**
3. $\boldsymbol{W \equiv \vec{d} \cdot \vec{F} = dF\cos\theta = Fd\cos\theta}$

(Where d is displacement and θ is the angle between the force and the displacement.)

ALL THREE of the above definitions of work are EQUIVALENT—i.e. they come out to the same thing. But sometimes a particular one will be particularly useful.

A) **F parallel to d.**
A child is pushing a cardboard box across a wooden floor. The child pushes due east and the box moves due east. The child pushes with a force of 50 ***n***, and friction pushes with a force of 20 ***n***.

i. Is the child doing negative, positive, or zero work on the box?
ii. Is friction doing negative, positive, or zero work on the box?

The child pushes the box and distance of 12 meters.

iii. Compute the work done by the child on the box.
iv. Compute the work done by friction on the box.

B) **F at an angle to d.**
A child is pushing a cardboard box across a wooden floor. The child is taller than the box, and so she pushes downwards as she pushes it forward. Her push forms a 60 degree angle with the horizontal. She pushes with a strength of 50 ***n***, and friction pushes back with a force of 20 ***n***.

The child pushes the box a distance of 12 meters across the floor.

i. Compute the work done by the child on the box.
ii. Compute the work done by friction on the box.

C) **A special example.**
A 6 kg bowling ball rolls down a ramp. The ramp has a vertical height of 8 meters and forms a 30 degree angle with the horizontal.

i. Compute the work done by gravity on the ball as it rolls down the entire ramp.
HINT 1: Use the SECOND definition of work at the top of this page.
HINT 2: Think hard about that definition. You do ***not*** need ANY trig.
ii. What affect does the angle have on the work done by gravity on the bowling ball?
iii. Say that an object of mass M rolls down a ramp of height H and angle θ, How much work does gravity do as the object rolls down?

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

III. Pendulum

A simple pendulum is constructed by attaching a .5 kg mass to a 2m length of string. The mass is lifted to an angle of 60 degrees and released from rest.

a. Draw a pure FBD of the mass at the moment it is released.
b. Draw a component FBD of the mass at this moment.
c. Compute the centripetal acceleration of the mass at this moment.
   HINT: what is the ***speed*** of the mass at this moment?
d. Write down Newton's Second Law and apply it to the radial axis.
e. Compute the force of tension on the string at this moment.
f. Write down Newton's Second Law and apply it to the tangential axis.
g. Compute the tangential acceleration of the mass at this moment.
h. What kind of work is the tension force doing at this moment (neg, pos, zero)?
i. What kind of work is gravity doing at this moment (neg, pos, zero)?

One second later, the mass has reached the very bottom of its swing. It is now moving at a speed of approximately 3 m/s. For this one instant, the string is perfectly vertical.

a. Draw an FBD of the mass at this moment. (There will be no need for a CFBD.)
b. Compute the centripetal acceleration of the mass at this moment.
c. Write down Newton's Second Law and apply it to the radial axis.
d. Compute the force of tension on the string at this moment.
e. Write down Newton's Second Law and apply it to the tangential axis.
j. Compute the tangential acceleration of the mass at this moment. What kind of work is the tension force doing at this moment (neg, pos, zero)?
k. What kind of work is gravity doing at this moment (neg, pos, zero)?

About half a second later, the mass has swung party way back up. The string is now at an angle 45 degrees away from the vertical, and the mass is moving at a speed of 2 m/s.

a. Draw an FBD of the mass at this moment.
b. Draw a component FBD of the mass at this moment.
c. Compute the centripetal acceleration of the mass at this moment.
d. Write down Newton's Second Law and apply it to the radial axis.
e. Compute the force of tension on the string at this moment.
f. Write down Newton's Second Law and apply it to the tangential axis.
g. Compute the tangential acceleration of the mass at this moment.
h. What kind of work is the tension force doing at this moment (neg, pos, zero)?
i. What kind of work is gravity doing at this moment (neg, pos, zero)?