Chapter 5: Conceptual Review

Chapter 5.1

Work: (the physics definition) \( F(\cos \theta) \Delta x \) (force in the direction of distance times distance)

Will the block move in either case below?

1) \( \Delta x = 0 \)
2) \( \Delta x = \sqrt{\frac{g}{a} + \frac{1}{2}} \quad \text{not } \frac{1}{2} \left( \frac{F}{m} \right) + \theta \)

\[ \varepsilon F_x = F - \frac{1}{2} \text{ net force} = \frac{1}{2} a = \frac{1}{2} \frac{F}{m} \]

3) Which man in a) or b) according to physics worked harder?
   a) second man in a) (not a or b, that's a typo).

4) \( W = (F \cos \theta) \Delta x \)

5) Work is a scalar quantity, it has no direction. The sign depends on the direction of \( F \) relative to \( \Delta x \). For example, suppose the block slides down despite the man's effort to pull it up.

   A) What amount of work is done by the man down the entire distance \( r \)?
   \( (F \cos \alpha) r \)

   B) What is the work done by gravity for the distance \( r \)?
   \( (mg \sin \theta) r \)

6) Work is zero when the direction of force is perpendicular to the direction of motion. For example, suppose a man walks 10m holding a bucket with a constant velocity.

   A) If the bucket weighs \( m \), what is the force used by the man to hold the bucket up?
   \[ F = mg \]

   B) What is the work done by the man?
   \[ \frac{F_{man}}{\Delta x} \rightarrow \quad \varepsilon F_y = F_{man} - mg = 0 \]

7) Important cosines to remember: \( \cos 0^\circ = 1 \); \( \cos 90^\circ = 0 \)

Quick Quiz 5.1: All blocks move a distance \( x \) to the right. Rank from the highest to lowest amount of work done by \( F \): a) b) c) d)
Section 5.2

1) Notes on Energy:
   a) Once again this is not exactly the same concept in physics as in everyday language
   b) Energy is another way to look at things, a new model
   c) Newton used forces as a different way to describe motion.
   d) Just as it’s easier to express certain ideas in one language over another, it’s sometimes easier to
      analyze the motion of an object using Energy.

2) Where does work fit in?
   Work is a “connector” or “bridge” between the energy and force concepts. Somewhat like a translator
   translating between two languages. Here is how the connection works:

3) \( W_{net} = F_{net} \cdot \Delta x = ma \)
   From Ch. 2, \( a = \left( \frac{v_f^2 - v_i^2}{2} \right) \)
   This gives \( W_{net} = m \left( \frac{v_f^2 - v_i^2}{2} \right) = \frac{1}{2}m v_f^2 - \frac{1}{2}m v_i^2 \)

4) Kinetic Energy: (definition) \( K_e = \frac{1}{2}m v^2 \). Hence the net work is the change in kinetic energy. \( W_{net} = \Delta K_e \)

5) a) If \( K_{ef} > K_{ei} \), what can you say about \( v_f \) compared to \( v_i \)?
       \[ |v_f| > |v_i| \]

      b) What about the net work of the object?

6) If a car is coming to a stop, what can you say about the velocities \( v_f \) and \( v_i \)?
   \[ v_i > v_f \]

7) If a car is coming to a stop, what can you say about \( W_{net} \)?

Section 5.3

1) Potential Energy - A “form” of Energy that depends on the position of an object within some system. You will see what
   this means below.

   For example consider the following system from your text: A brick
   starts from rest and falls towards the nail. What is \( \Delta K_e \) of the brick
   \[ V_0 = 0 \]
   \[ V_f = \sqrt{2 \Delta g \Delta x} = g \]
   \[ \text{new} \] \[ m_b = \text{mass of brick} \]
   \[ \Delta K_e = \frac{1}{2} m_b \Delta g \Delta x = m_b g \Delta x \]

   What is the net work done by the brick? \( W = \Delta K_e = \frac{1}{2} m_b \Delta g \Delta x = m_b g \Delta x \)

   *In the case of the brick above, the work is done on the nail. When thinking of things from the
    energy perspective, the nail can be thought of as “absorbing” the brick’s energy. This is only a
    concept. You can also look at this as the force of the brick on the nail and use Newton’s laws.
When the brick is still in the air, before it falls, in this system it can be said that it has a certain "potential energy." It has the potential to fall and "gain" a certain amount of kinetic energy.

2) The potential energy of objects falling towards the earth or any gravitational field is called Gravitational potential:

\[ P_E = mgy \]

This comes from the work equation. \[ W = F \cos \theta \Delta y \]. For an object falling to earth \( \Delta y = h \) (height of object), \( F = mg \), \( \cos \theta = \cos \theta = 1 \). So, \[ W = mg \Delta y = P_E \]

3) Work done on an object by gravity: \( W_g = P_{E_i} - P_{E_f} \)

4) The Potential Energy of an object depends on the system it is in: (this is similar to figure 5.12)

Here:

- System A - Book and table
- System B - Book and floor
- System C - Book and earth

*In which system does the book have the greatest Gravitational Potential?*

*What does this tell you about the distance the potential energy depends on?*

Depend on relative distance between objects

Section 5.4

1) Conservative and Non-conservative forces

a) What can you say about the work done by conservative forces? It is independent of the path the object takes between two points.

b) What about the work done by non-conservative forces? Work depends on path taken by objects.

c) What can you associate with a conservative force only? (i.e., What form of energy?) \( W_c = P_{E_i} - P_{E_f} \) (this time initial minus final)

2) Examples of conservative/non-conservative forces:

- gravity
- friction
*ball falling to earth:

a) $F$ on ball?

$$mg$$

$$
cos\theta = 1$$

$$W_{net} = mg(10.0\text{ m})$$

b) $F_x$ on ball $= 0$

$F_y$ on ball $= mg$

$W_x$ on ball $= 0$

$W_y$ on ball $= mg(10.0\text{ m})$

$$cos\theta_y = 0$$

$W_{net} = mg(10.0\text{ m})$

Hence, what kind of force is gravity? **Conservative**

c) Consider a book on table. There is no friction. A force $F$ is used to push the book to A following two different paths, but it's always along the line of motion. Book has mass $m$.

Path 1

Force $= F$

$cos\theta = 1$

$$W_{net} = FL$$

Path 2 + 3

Force $= F$

$cos\theta = 1$

$$W_{net} = 3FL$$ (the path is twice as long and so the force increases by twice as much.)

What kind of force is $F$? **Non-conservative**

Can you give more examples of these types of forces? *friction, air drag*

Section 5.5

1) Conservation in physics: Even though the form of the quantity may change, it's numeric value remains constant.

2) Total Mechanical Energy: $E = K_E + P_E$

Consider a ball falling to earth. At each point of it's fall, does it have kinetic energy? **Yes**

Does it have potential energy? **Yes**

3) Total Energy is conserved when the only forces acting on an object are conservative. Thus $E_f = E_i$. The initial energy of an object is the same as the final energy.

Thus, $K_{E_i} + P_{E_i} = K_{E_f} + P_{E_f}$
4) Potential Energy stored in a Spring: \( \frac{1}{2} k x^2 \)

Forces exerted by a compressed or a stretched spring: \( F_s = -kx \)

5) Work on a spring: \( F_s \) is not a constant force. It changes with distances. Hence one must use the average forces: \( F_{avg} = (F_{sf} + F_{se}) / 2 = \frac{1}{2} kx \)

Hence \( W_{spring} = F_{avg} \Delta x = \frac{1}{2} kx^2 \)

This is the elastic potential energy "stored" in a spring \( P_{E-spring} = \frac{1}{2} kx^2 \)

How much kinetic energy will the block have in (2) above after the spring's release?

\( (kE_f + P_{Es})_i = (kE_f + P_{Es})_f \Rightarrow \frac{1}{2} kx^2 \)

Spring equation of conservation of energy:

\( (kE_f + P_{Eg} + P_{Es})_i = (kE_f + P_{Eg} + P_{Es})_f \)

Section 5.6

Non-conservative Forces, Non-isolated Systems and Conservation of Energy:

1) How do we account for non-conservative forces in conservation of energy?

- split net work into two components - work done by conservative and work done by non-conservative forces:

\( W_{net} = W_{nc} + W_c = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 \)

What is \( W_c \)? For example, \( W_c = mg \Delta h = \Delta P_g = \Delta K_g \)

Hence \( W_c = P_{Ei} - P_{Ef} \)

And \( W_{nc} = E_f - E_i = \Delta E \)

2) In words: Work done by non-conservative force equals change in mechanical energy.

3) Positive work: energy is transferred to the system

4) Negative work: energy is transferred out of the system

4) Suppose a block sliding on a surface eventually comes to a stop due to friction. Is it's energy conserved? Where no, friction is non-conservative.
does it go?  heat

5) Three types of energy storage in a system:
a) kinetic  
b) potential  
c) internal (heat)  

6) Ways to transfer energy:
a) Work  
b) heat - microscopic collisions of atoms  
c) mechanical waves  
d) electrical transmission  
e) electromagnetic radiation  

7) Conservation of Energy in General: One of the central features of the concept of energy is that: energy is neither created nor destroyed.  

8) How is the energy from the food we eat transferred? Where does it go?  

9) When you light a match what kind of energy transfer occurs from your hand to the fire on the match?  

10) The Hoover Dam-  

11) How does the sun create light?  

Section 5.7

1) Power - rate at which energy transfer occurs.  

2) What is the net work done by this force if it acts in the line of motion? (A force is applied for time \( \Delta t \) over a distance \( \Delta x \))  

\[ W_{net} = F \Delta x \]

3) Average Power is defined as: (can you write it in terms of average velocity?)  

\[ P = \frac{W_{net}}{\Delta t} = \frac{F \Delta x}{\Delta t} = F \bar{v} \]

4) Units of power:  

\[ 1 \text{ Watt} = 1 \text{ J/s} = 1 \text{ kg} \cdot \text{m}^2/\text{s}^2 \]

\[ 1 \text{ hp} = 550 \text{ ft} \cdot \text{lb}/\text{s} = 746 \text{ W} \]