CHAPTER 6 TEST REVIEW
ANSWER KEY

1. State the relationship between force, work/energy, and power.

**ANSWER:** Force is a mass under acceleration. Work and energy are products of force and distance. Power is work/energy per unit time.

2. Define work.

**ANSWER:** Work is the product of the magnitude of the displacement times the component of the force parallel to the displacement.

3. Give the unit for work and the basic SI units that make up the unit for work.

**ANSWER:** The unit for work is the joule (J). \( 1J = 1N \cdot m = 1 \frac{kg \cdot m^2}{s^2} \)

4. What does it mean when it says work is only done by the component of the force parallel to the displacement.

**ANSWER:** The portion of the force that acts in the direction of the displacement is the only part of the force that does work. The magnitude of the force times the cosine of the angle between the force and the direction of displacement will give you the component of the force that does work.

5. Write an equation for work done by the gravitational force.

**ANSWER:** \( W = mgh \)
6. I tie a rope to a 75-kg box so that I can pull it 25 meters across the floor. The angle between the rope and the ground when I am pulling is 30°. If I pull with a force of 500N and friction is negligible,

a. How much work will I do?

**ANSWER:**

\[ W = F \parallel d \]
\[ W = F \cos 30° \times d \]
\[ W = (500N) \cos 30° \times (25m) \]
\[ W = 1.1 \times 10^4 J \]

b. If it takes me 6 seconds to pull the box 25 meters, how much power did I exert?

**ANSWER:**

\[ P = \frac{W}{t} = \frac{1.1 \times 10^4 J}{6s} = 1.8 \times 10^3 W \]

c. What is the normal force acting on the box?

**ANSWER:**

\[ F_N = m g - F_P \sin 30° \]
\[ F_N = (75kg)(9.81) - (500) \sin 30° = 486N \]

d. If the coefficient of friction is 0.60, what is the work done by the friction force on the box?

**ANSWER:**

\[ W_f = F_f \times d \]
\[ F_f = F_N \mu = (486)(0.60) = 291N \]
\[ W_f = (291)(25) = 7.2 \times 10^3 J \]

e. Assuming the box was initially at rest, what will be the velocity of the box at the end of the 25m?

**ANSWER:**

\[ W_p - W_f = KE \]
\[ (1.1 \times 10^4 J) - (7.2 \times 10^3 J) = \frac{1}{2}mv^2 \]
\[ \sqrt{\frac{2(W_p - W_f)}{m}} = v = 10m/s \]
\[ \sqrt{\frac{2(3.8 \times 10^3 J)}{75kg}} = v = 10m/s \]
f. I now climb into the attic and use the rope to pull the box 3m to the attic at a constant rate. How much work did I do?

\[ W_g = mgh = (75kg)(9.81)(3) = 2207J \]

ANSWER: f. \[ W_g = mgh = (75kg)(9.81)(3) = 2207J \]

\[ \text{g. If it takes 8 seconds to pull the box into the attic, how much power did I exert?} \]

\[ P = \frac{W_g}{t} = \frac{2207J}{8s} = 276W \]

ANSWER: g. Power is work divided by time.

7. What is kinetic energy?

ANSWER: The energy of motion

8. Translational kinetic energy is directly proportional to \[ \text{the mass of an object}, \text{and it is proportional to the square of the speed of the object.} \]

9. Explain the work-energy principle.

ANSWER: The net work done on an object is equal to the change in its kinetic energy, \[ W_{net} = \Delta KE = KE_2 - KE_1 = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 \]

10. How much work is done by friction in keeping a 1000-kg box from sliding down a 12° incline if the coefficient of friction is 0.36, the length of the ramp is 1.47m, the temperature is 21°C and the relative humidity is 72%? Oh, and it's an odd-numbered Tuesday.

ANSWER: None. Since the box doesn’t move, there is no displacement and no change in kinetic energy so no work is done.

11. What is potential energy?

ANSWER: The energy associated with forces that depend on the position or configuration of a body (or bodies) and the surroundings.
12. What is the difference between gravitational potential energy and elastic potential energy?

**ANSWER:** Gravitational potential energy is caused by the gravitational attraction of the earth and the body’s position relative to the earth. Elastic potential energy is always associated with a force that does work on the elastic material and is equal and opposite to the work done by that force.

13. Define Hooke’s law (the spring equation) and give the equation for elastic force and elastic potential energy.

**ANSWER:** Hooke’s Law is \( F_s = -kx \), where “k” is the spring constant and the negative sign is because the force is in the opposite direction of the displacement, “x”. \( PE_e = \frac{1}{2}kx^2 \)

14. What is the difference between conservative and non-conservative forces? Give examples of each.

**ANSWER:** Conservative forces, like gravity and springs, do not depend on the path taken but only the starting and ending points. Non-conservative forces like friction are calculated based on the total distance covered and are thus dependent on the path taken.

Lessons Learned for daily lives: For conservatives, the end always justifies the means (and/or path to get there) no matter what you have to start with. Non-conservatives constantly rub you the wrong way no matter how much you try to work around them.

15. Is mechanical energy conserved when friction is present? Why or why not?

**ANSWER:** No. Friction dissipates some of the mechanical energy in the form of heat.

16. State the law of conservation of energy and give the equation when gravity and friction are present.

**ANSWER:** The total energy is neither increased nor decreased in any process. Energy can be transformed from one form to another, and transferred from one body to another, but the total amount remains constant. \( \frac{1}{2}mv_1^2 + mgy_1 = \frac{1}{2}mv_2^2 + mgy_2 + F_fd \)

17. Define power.

**ANSWER:** The rate at which work is done or the rate at which energy is transformed.
18. How much work is required to move a 150-kg box 17 m across a floor at a constant speed when the coefficient of friction is 0.72

**ANSWER:** According to Newton’s Second Law (\(\Sigma F = ma\)), if there is no acceleration (constant speed), the push force must equal the resistance force (friction).

\[
\begin{align*}
\Sigma F &= ma = 0 \\
F_p &= F_f = mg\mu \\
W &= Fd = mg\mu d = 1.8 \times 10^4 \text{J}
\end{align*}
\]

19. How much work would be required to push the same box 17 meters up an 11° incline with the same coefficient of friction again at constant speed.

**ANSWER:** Here the work is equal to the change in potential energy plus the work done by friction to resist the movement.

\[
\begin{align*}
\Sigma F &= ma = 0 \\
F_p - F_g - F_f &= 0 \\
F_p &= F_g + F_f \\
W &= F_p d = F_{gx} d + F_f d \\
F_{gx} &= mg \sin \theta \\
F_f &= F_N\mu \\
F_f &= F_g \cos \theta \mu \\
F_f &= mg \cos \theta \mu \\
W &= mg \sin \theta d + mg \cos \theta \mu d = 2.2 \times 10^4 \text{J}
\end{align*}
\]

Alternatively:

\[
W = mgh + F_f d \\
F_f = mg \cos \theta \mu \\
The \text{box is pushed 17m up the incline (}d\text{) which is the hypotenuse. To find the elevation gain,} \\
h = d \sin \theta \\
W = mgd \sin \theta + mg \cos \theta \mu d = 2.2 \times 10^4 \text{J}
\]

20. An M1/A1 Abrams battle tank fires a 10kg projectile with a muzzle velocity of 1575 m/s. How far will it penetrate armour plating with a resistance force of 2.07x10^7 N? Assume the resistant force is constant and the projectile hits perpendicular to the plating.

**ANSWER:** All of the kinetic energy of the projectile will be absorbed by the resistant force of the plating.

\[
\begin{align*}
F_R d &= \Delta KE \\
d &= \frac{mv^2}{2F_R} = 0.60 m
\end{align*}
\]
21. The 1400-kg rocket Nissan Frontier has coil springs attached to each wheel with a spring constant of 200 kN/m each. While jumping school buses, the Frontier routinely reaches heights of 10m. Assuming it lands evenly on all four wheels (weight evenly distributed), how much does each spring initially compress when it lands?

**ANSWER:** The potential energy of the Frontier at its highest point will be absorbed by the compression of its springs. Each spring will absorb 1/4th of the energy. Note that 200 kN is equal to 2.0 x 10^5 N!!!

\[
\frac{mgh}{4} = \frac{1}{2} kx^2
\]

\[
\sqrt{\frac{2mgh}{4k}} = x
\]

\[
\sqrt{\frac{mg}{2k}} = x = 0.59m
\]

22. A 5000-kg school bus loses its brakes while travelling at 30 m/s going downhill in the mountains. It veers off into a breakaway ramp with a 12° uphill incline filled with loose gravel. It travels 25 m up the incline before coming to a stop.

a. What was the retarding force of the gravel?

**ANSWER:** The work done by the gravity and the retarding force of the gravel absorbed all of the kinetic energy of the school bus.

\[
\Delta KE = W_g + W_{RF}
\]

\[
\frac{1}{2} mv^2 = F_g d + F_{RF} d
\]

\[
\frac{1}{2} mv^2 = mg \sin 12^\circ d + F_{RF} d
\]

\[
mv^2 - 2mg \sin 12^\circ d = 2F_{RF} d
\]

\[
\frac{mv^2 - 2mg \sin 12^\circ d}{2d} = F_{RF} = 7.98 \times 10^4 N
\]

b. What was the retarding force acting on the students in the bus?

**ANSWER:** video games, rap music, CAS reflections and Twitter

*Also accept: non-conservative forces and France*
23. A 2500-kg rollercoaster is travelling at 2.5 m/s at the top of a 45m drop. At the bottom of the drop, the speed is measured to be 27 m/s. If the distance travelled was 65m, what was the average resistant force acting on the roller coaster?

**ANSWER:** At the top of the drop, the roller coaster has PE and KE. At the bottom of the drop, the roller coaster only has KE, but some of the original energy at the top has been dissipated through the work done by resistant forces (friction, sound, air resistance).

\[
\text{PE}_1 + \text{KE}_1 = \text{KE}_2 + W_R \\
\frac{1}{2}mv_1^2 + mg y = \frac{1}{2}mv_2^2 + mg y z + F_R d \\
mv_1^2 + 2mg y - mv_2^2 = 2F_R d \\
\frac{mv_1^2 + 2mg y - mv_2^2}{2d} = F_R = 3.1 \times 10^3 N
\]

24. How much power is required to accelerate the 1400-kg rocket Nissan Frontier from 50 km/hr to 120 km/hr in 6 sec? Give your answer in ft-lb/s.

**ANSWER:** Work is done by the car’s engine to change the car’s kinetic energy. Power is work divided by time. Use SI units to calculate work in watts and then convert to ft-lb/s.

\[
v_f = \left(\frac{120}{3.6}\right) m/s = 33.3 m/s \\
v_i = \left(\frac{50}{3.6}\right) m/s = 13.9 m/s \\
W = \Delta KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 \\
P = \frac{W}{t} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = 1.07 \times 10^5 W \\
P = 1.1 \times 10^5 W \times \frac{0.738 \text{ft-lb/s}}{1 \text{W}} = 7.90 \times 10^4 \text{ft-lb/s}
\]

**Bonus:** Which branch of the federal government constitutes the greatest dissipative force on the nation’s economy? Justify. Give examples