AP Physics C – Work and Energy complete answers

1. a. 346 J
   b. −346 J
   c. 0
2. a. 221 J
   b. −221 J
   c. 442 J
3. a. 3150 J
   b. −3150 J
4. a. 33 steps
   b. 2400 kg
5. a. 0.15 J
   b. 0.15 J
   c. 0.15 J
6. You should find that the totals add up to zero along any path taken. This is a property of what physicists call a "conservative force".
7. a. −0.75 J
   b. −2.1 J
   c. −3.2 J
8. a. Friction does work that depends upon the path. As shown by the numerical values found in the previous problem friction does a different amount of work over the shorter path than over the longer path. Also, unlike gravity, the work done when completing an entire loop is not zero. Because friction always acts in opposition to the motion of the chalk the amount will depend on the length of the path (*i.e.* the distance).
   b. Gravity does work that does not depend upon the distance or length of path. The work done by gravity depends only on the initial and final positions at the beginning and the end regardless of what path is followed between those two points. This is because of the dot product – gravity does zero work for any horizontal motion and in the end the only thing that matters is the vertical component of the *displacement* (*i.e.* change in position).
9. a. 0.025 J
   b. −0.079 J
10. a. −0.250 J
    b. 0.500 J
    c. −0.250 J
    d. 0.960 J
11. a. 583 kJ
    b. 117 m/s
    c. 681 N, up
    d. 84.4 m
12. 3500 N into the tree
13. 2.7 m/s
14. a. 80.6 km
    b. 69.2 km
    c. 52.1 km

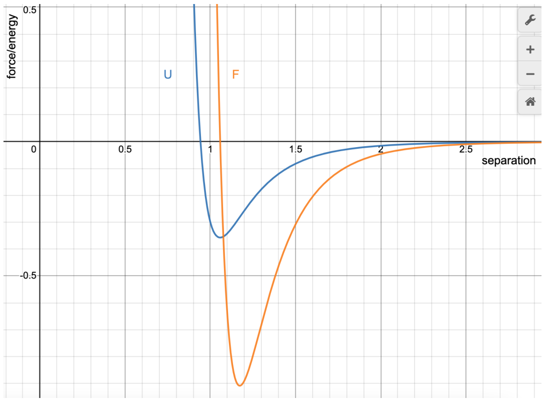
15. a. 414 kJ
    b. 2070 N
    c. 111 times, 22.1 km
16. For any given car driving at highway speeds (*i.e.* "cruising"), the amount of drag is less at lower speeds and therefore the fuel economy is better. So, once you are "up to speed" try driving as slow as reasonably possible – for example you might try actually driving the speed limit :D! Any time you have to accelerate there is additional gas required to account for the increase in the kinetic energy of the car, which depends on mass. So, whenever possible, avoid coming to a complete stop. For both situations, cruising or accelerating, a smaller car requires less gas. A smaller car has less kinetic energy once up to speed due to its smaller mass, and it will have less rolling resistance and less air resistance due to its smaller size.
17. a. 24.4 m/s
    b. No – because energy is a scalar, the result of this calculation is independent of direction.
    c. throw 310 gram rock w/ v = 20.0 m/s (doubling the mass doubles the kinetic energy)
    throw 155 gram rock w/ v = 31.6 m/s (increasing the speed by a factor $\sqrt{2}$ doubles the kinetic energy)
18. a. 88.2 J
    b. 3.70 m/s
    c. 5.42 m/s
    d. No – at any point in time, should the rope break, the total amount of energy, gravitational and kinetic, will be the same because energy is conserved. When the ball hits the floor all of this energy will be transformed into kinetic energy.
19. a. 3.64 m/s, west; 44.1 m/s^2, down
    b. 4.37 m/s down; 64.5 m/s^2, 351.3°
20. $\cos^{-1}(2/3) = 48.2°$
21. a. By assuming that the speed at the top of the loop is $\sqrt{gR}$ it can be shown initial height above top of the loop must be at least $R/2$. This assumes that the initial speed is zero.
    b. For a real-world rollercoaster there will be significant friction. As the coaster travels from the top of the first hill to the top of the loop friction does negative work. This would require the hill to be a greater height so that the coaster has some "extra energy" that it can "afford to lose" and still reach the top of the loop with the required speed. Another factor would be the speed at the top of the initial hill. If the coaster is already in motion at the top of the hill it would help offset the energy that will be lost due to the negative work done by friction.
22. a. 10.6 m/s
    b. The result would be the same. The alternate method would be much more involved. It would be necessary to determine the acceleration and final velocity for the slide down the ramp and then it would be necessary to solve a projectile motion problem for the curving freefall of the block.
23. a. −10.9 J
    b. 3.62 N
    c. 40.9 J; 13.6 N

24. a. 397 J
    b. 235 J
    c. Using the ramp allows the person to perform the task with less "exertion" – requires less force applied to the box, but it requires more work to be done. Simply lifting the box without using the ramp the person actually does less work and expends less energy, but it requires more force applied to the box.
25. a. 515 m/s
    b. altitude 1530 km
    c. would escape Ceres' gravity and fly off into space at 194 m/s
    d. 1300 J/kg good, 1200 J/kg better
26. a. -1.33×10^{10} J
    b. 6694 m/s
    c. 2221 m/s
27. a. $K = \frac{mv^2}{2} \quad U = -mv^2 \quad E = -\frac{mv^2}{2}$
    b. $2r$ (semi-major axis)
    c. $W = \frac{mv^2}{4}$
    d. $v_{\text{min}} = \frac{v}{\sqrt{6}} \quad v_{\text{max}} = \frac{\sqrt{6}}{2}v$
28. a. 65.7 m
    b. 28.9 m/s
    c. Initially the person has a relatively great amount of gravitational potential energy. Until the bungee starts to stretch gravitational potential energy is transforming into kinetic energy as the speed of the person increases. Once the bungee starts to stretch there is a transfer of energy to the bungee in the form of elastic potential energy. As the bungee continues to stretch and gain elastic potential energy, the person is continues to lose gravitational potential energy and also eventually loses all kinetic energy as well.
29. a. $y = \frac{2mg}{k}$
    b. $v = g\sqrt{\frac{m}{k}}$
30. a. 0.785 m/s
    b. 0.226 m
    c. Initially all of the energy is elastic potential energy of the compressed spring. As the block is launched this potential energy is transferred to the block in the form of kinetic energy. As the block slides to a stop its kinetic energy is transformed into both thermal energy of the block and surface and also sound transferred to the surroundings.

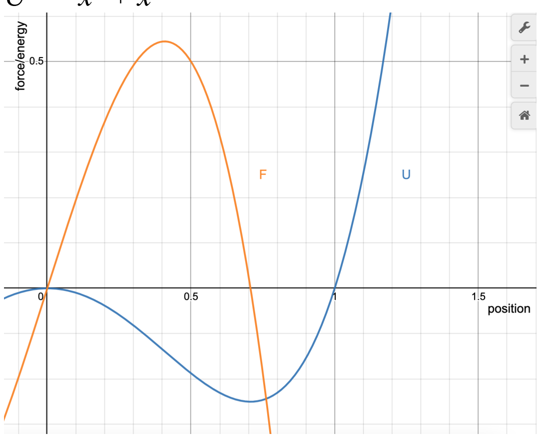
31. a. $F = \frac{12a}{x^{13}} - \frac{6b}{x^7}$

b. $x = \sqrt[6]{\frac{2a}{b}}$

c. $E = \frac{b^2}{4a}$

d. 

32. a. $U = -x^2 + x^4$

b. 

c. The object will accelerate to the left until reaching a position $x = 0.707$ m, and then it will decelerate and come to rest at the origin.

d. 0.667 m/s^2, left

e. 0.408 m/s

f. 2.83 m/s

33. a. $F(r) = \frac{GMm}{R^3} r$

b. $U(r) = \frac{GMm}{2R^3} r^2$

c. $v = \sqrt{\frac{GM}{R}}$

34. 49.0 kW

35. a. 843 kJ

b. −376 kJ

c. 3.1 s

36. a. 672 W
    b. 4.08 s
37. a. 3700 N
    b. 210 hp
38. a. 17 kW
    b. 4.9 km
    c. 23 kW; 7.0 km
39. $P_{\max} = \frac{A^2}{2}\sqrt{\frac{k^3}{m}}$
40. a. 245 N
    b. 75.4%
    c. $-24\underline{0}$ J
41. a. 55 N
    b. 2800 J
    c. 550 J
42. a. 38 kW
    b. 13 kW, 18 hp
    c. 530 N
    d. 26 km/gal