SKILLS NEEDED FOR THE FIRST JAN. PHYSICS TEST (L-H, 2000)

1. Solve a simple equation for its unknown and then plug in given data to determine the numerical value, units, and uncertainty of that unknown quantity, as on every previous test.

2. Name and describe the forces acting on an object which is coasting or being dragged, as on pages 37-40 and many recent tests.

3. Determine the strength of a friction force by the methods in # 16 *or* #18 on RS III.

4. Decide if and how a given change will alter a sliding friction force. (#13-18 on RS III.)

6. Add or subtract vectors and find components of vectors, using #11 on RS III or #1 on RS IV. For example, use the definitions of “total force”, “change in velocity”, and “change in momentum” on RS III & RS V. (See pages 31, 31R, 35, 35R, 41, 53, and and 54.)

7. Given a description of the forces acting on an object, describe the resulting motion. (Use #4 on RS III and #2 on RS V.)

8. Use the relation between weight and mass reviewed in 6-9 on RS III and in 4-5 on RS V.

9. Draw a vector in a given direction, as on p. 34R.

10. Describe the direction of a vector in the manner explained on page 34R.

11. Draw an arrow to describe the instantaneous velocity of an object moving along a curved path, as you did on page 41.

12. Given the lengths of two sides of a right triangle, determine the angle between them with errors no greater than one percent. (#12 on RS III.)

13. Use the definitions of “velocity” and "acceleration" on RS II and RS IV.

14. Use the definitions of “impulse” and “momentum” (on RS V) as on page 53 & 54. Also use the “impulse-momentum law” and the “momentum conservation law” on RS V.

15. Use a graph of force vs time to calculate an impulse. (#12 on RS IV)

16. Use Newton's first and second laws as in the examples on p. 48-52. (#2 on RS IV)

17. Use the definitions of “work”, "energy" and “power” on RS V.

18. Use the kinetic energy formula recorded in #7 on RS VI.

19. Use the “work-energy theorem” and the “energy conservation law” in #8 - 10 on RS VI.

20. Given a propelling force and the speed of the object that is being propelled, calculate the power of the propelling mechanism. (Use #12 on RS VI.)

21. Use the “trajectory principles” in #16 on RS VI.

22. Solve proportion problems (as on every previous test) by using #5 on RS I or #17 on RS II.

23. Round off calculated quantities properly, keeping only one bogus digit.

24. Use Hooke’s equation and the elastic potential energy formula.

First January L-H Test (Y2K) **name_______________**

1. A 6.0-newton horizontal force is used to drag a 1.8-kilogram brick at constant velocity across a level surface. After two seconds that force is suddenly increased to 8.5 newtons. That new force remains constant for two seconds. Then the propelling force suddenly stops acting, and the brick coasts to a stop.
   a. Calculate the total force on the brick just after the *first* sudden change. (skills 3, 4, 6)
   b. Calculate the acceleration of the brick just after the *second* change. (skill 7)
   c. Sketch the brick's speed-time graph. (skill 7)
   d. Sketch a "power vs. time" graph showing how the power of the pulling machine changes during the first four seconds. Make dots at the two points where the propelling force suddenly changed. (skill 20)

2. A particle with mass "M" is shot with velocity "V_o" into a stationary target with mass "RM". ("R" represents a dimensionless mass ratio.) Let "V_f" represent the velocity of the pair of objects just *after* this inelastic collision. You may ignore friction in this example.
   a. One student claims that $V_f = V_o/(1+R)$. Is that claim consistent with momentum conservation? If so, write "yes". If not, correct it. (skill 14)
   b. Sketch a graph of kinetic energy vs time showing how the total kinetic energy of the particle and target is affected by the collision. Label the impact time. (18)
   c. Let "E_o" represent the kinetic energy of the *particle* just before impact, let "E_1" represent the kinetic energy of the *particle* just *after* impact, and let "E_2" represent the kinetic energy of the *target* just after impact. Show with a simple formula how the ratio E_1/E_o can be calculated from R. *Simplify it before writing it into the answer space.*
   d. Sketch a graph showing how that ratio (E_1/E_o) depends on R.
   e. In what way or ways would that graph be different for an *elastic* collision?

3. A 20-kg child on a swing moves along a curved path. Shortly before reaching the midpoint of that path her velocity is 1.10 m/s, 10º down from south. After 0.14 seconds her velocity has the same magnitude but it is 10º *up* from south.
   a. Determine the child's average acceleration in SI units. (skills 6, 13)
   b. Determine the vector sum of the forces acting on the child at the midpoint of the arc. (7)
   c. Calculate the strength of the gravitational force acting on the child at that time. (sk. 8)
   d. Determine the strength of the upward force exerted on the child by the seat. (skill 6)

4. A certain spring's unstretched length is 20 centimeters.
   Stretching it from a length of 44.5 cm. to 45.5 cm. requires 1.57 joules of work.
   a. Calculate the spring's tension when it is stretched to a length of 45 cm. (skill 17)
   b. Reducing its overall stretched length from 45 cm. to 27 cm. will reduce its tension to a fraction of its original value. What is that fraction if this spring is correctly described by Hooke's equation? (skills 22, 24)
   c. Reducing the spring's amount of stretch to 60% of its former value would reduce its elastic potential energy to what fraction of its former value? (skills 22, 24)

5. A projectile is hurled diagonally downward from a high window.
   After 0.45 seconds it is moving at 7.3 m/s in a direction 53º down from east.
   a. Calculate the horizontal component of its initial velocity. (skill 6)
   b. Calculate the vertical component of its initial velocity. (skill 21)

6. A baseball hit by a bat flies through the air for 3.6 seconds. Then it is caught 250 meters away, at the same altitude as the batting point. Let's pretend that air drag can be ignored:
   a. How high did it go? (skill 21)
   b. Calculate the horizontal and vertical components of its velocity just after impact. (21)
   c. Calculate the inclination angle of its initial velocity, just after impact. (skill 12)

7. Was every numerical answer on this test rounded off properly? -If not, please explain. (23)

ANSWER SPACE

1a)

1b)

1c) Bottom margin

1d) Bottom margin

2a)

2b)

2c)

2d)

2e)

3a)

3b)

3c)

3d)

4a)

4b)

4c)

5a)

5b)

6a)

6b)

6c)

7)

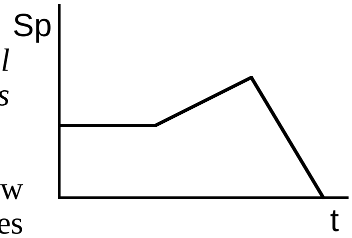
First January Y2K L-H Test Solutions

1. A 6.0-N horizontal force is used to drag a 1.8-kg brick at constant velocity across a level surface. After two seconds that force is suddenly increased to 8.5 N. That new force remains constant for two seconds. Then the propelling force suddenly stops acting, and the brick coasts to a stop.

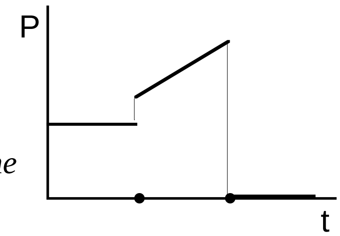
a. Calculate the total force on the brick just after the *first* sudden change.   *(3 points)*
The gravitational and normal forces on the brick cancel. The forward (propelling) force is 8.5 N, and the backward (friction) force is 6.0 N. Therefore the total force on the brick is ***2.5 N forward.***

b. Calculate the acceleration of the brick just after the *second* change.   *(3 points)*
The total force while coasting is equal to the sliding friction force, which is ***6.0 N backward.***

c. Sketch the brick's speed-time graph. *(3 points)*
The speed increases steadily when the total force is forward and constant, and decreases steadily when the TF is backward and constant.



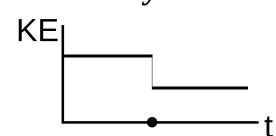
d. Sketch a "power vs. time" graph showing how the power of the pulling machine changes during the first four seconds.   *(2 points)*
Power = propelling force times speed. The force increases suddenly at the two-second point, and the speed increases steadily for the next two seconds.



2. A particle with mass "M" is shot with velocity "V_o" into a stationary target with mass "RM". ("R" represents a dimensionless mass ratio.) Let "V_f" represent the velocity of the pair of objects just *after* this inelastic collision.   You may ignore friction in this example.

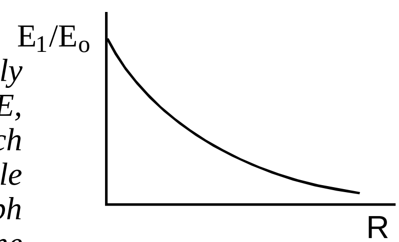
a. One student claims that $V_f = V_o/(1 + R)$. Is that claim consistent with momentum conservation?
The momentum conservation law says $MV_o = (M + RM)V_f$*. Solving for the unknown final velocity, we find that "M" cancels out. The result is the same as the student's equation, so the answer is* ***"yes".***

b. Sketch a graph of kinetic energy vs time showing how the total kinetic energy of the particle and target is affected by the collision. Label the impact time.
The collision is inelastic, so there is a sudden loss of kinetic energy. (2 points)



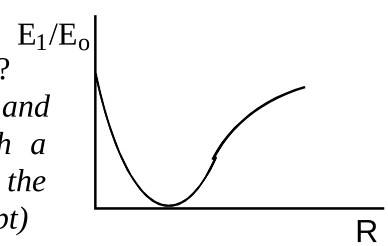
c. Let "E_o" represent the kinetic energy of the *particle* just before impact, let "E_1" represent the kinetic energy of the *particle* just *after* impact, and let "E_2" represent the kinetic energy of the *target* just after impact. Show with a simple formula how the ratio E_1/E_o can be calculated from R.
We know that KE is proportional to speed squared, so $E_1/E_o = (V_f/V_o)^2 = \mathbf{(1 + R)^{-2}}$ *(2 points)*

d. Sketch a graph showing how that ratio (E_1/E_o) depends on R.



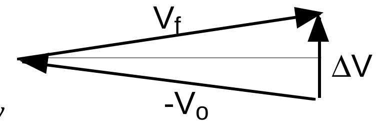
If R is very small, so the target mass is small, then the particle is nearly unaffected by the impact. Its final KE is nearly the same as its original KE, so the ratio is close to 1. If R is made very large the target mass is much greater than the particle mass. In that case the impact brings the particle almost completely to a stop, so the final KE is close to zero. So the graph must have negative slope, but it cannot be linear because it cannot cross the horizontal axis. The equation above agrees with those facts. (2 points)

e. In what way or ways would that graph be different for an *elastic* collision?
If the collision is elastic then the E_1/E_o *ratio will be zero at R = 1, and positive for all other R values. A particle colliding elastically with a stationary target comes to a complete stop if the collision is head-on and the target mass is equal to the particle's mass, as in a "swinging wonder". (2 pt)*



First January Y2K L-H Test Solutions *continued*

3. A 20-kg child on a swing moves along a curved path. Shortly before reaching the midpoint of that path her velocity is 1.10 m/s, 10º down from south. After 0.14 seconds her velocity has the same magnitude but it is 10º *up* from south.



a. Determine the child's average acceleration in SI units. (skills 6, 13)
By definition, average acceleration is $\Delta V/\Delta t$. To calculate the change in velocity we must use vector subtraction; we reverse the original velocity and add it to the final velocity. The resulting isoceles triangle can be split horizontally into two right triangles, from which we find that $\Delta V = 2V\sin(10^o)$. Dividing that result by the given time interval, we get ***2.73 m/s² up.*** *(3 points)*

b. Determine the vector sum of the forces acting on the child at the midpoint of the arc.
Mr. Newton tells us that TF = ma, so we must multiply the acceleration found in 3a by the given mass.

(2.73 m/s² up)(20 kg) = ***54.6 N up*** *(3 points)*

c. Calculate the strength of the gravitational force acting on the child at that time.

mg = *(20 kg)(9.8 N/kg) =* ***196 N*** *(2 points)*

d. Determine the strength of the upward force exerted on the child by the seat.
Total Force = Upward force + Downward force = UF + mg, so UF = TF - mg.
UF = (54.6 N up) - (196 N down) = (54.6 N up) + (196 N up) = ***250 N*** *up. (2 points)*

4. A spring's unstretched length is 20 cm. Stretching it from 44.5 cm. to 45.5 cm. requires 1.57 J.

a. Calculate the spring's tension when it is stretched to a length of 45 cm.
The given work = average force times distance moved, so the average force = work/distance.

1.57 J/0.010m = ***157 N*** *(2 points*

b. Reducing its overall stretched length from 45 cm. to 27 cm. will reduce its tension to a fraction of its original value. What is that fraction if this spring is correctly described by Hooke's equation?
The amount of stretch (called "X") is defined as stretched length - unstretched length.
The original amount of stretch is X_1 = 45 cm - 20 cm = 25 cm. The new one is X_2 = 27 - 20 = 7 cm.
Captain Hooke says that $T_2/T_1 = X_2/X_1$ = ***7/25 = 0.28*** *(one point)*

c. Reducing the spring's stretch to 60% of its former value would reduce its elastic potential energy to what fraction of its former value? *PE is proportional to X^2, so $PE_2/PE_1 = (X_2/X_1)^2 = 0.6^2 =$* ***0.36.***

5. A projectile is hurled diagonally downward. After 0.45 sec it is moving 7.3 m/s, 53º down from east.

a. Calculate the horizontal component of its initial velocity. *The first trajectory principle is that the horizontal velocity does not change. (7.3 m/s)cos(53º) =* ***2.63 m/s eastward.*** *(3 points)*

b. Calculate the vertical component of its initial velocity. *At 0.45 sec. into the trip its vertical velocity is (7.3 m/s) sin 53 = 5.84 m/s down. During that time interval it gained $a\Delta t$ = (9.8 m/s²)(0.45 s) = 4.41 m/s of downward velocity. So it must have started with 5.84 - 4.41 m/s =* ***1.43 m/s downward.*** *(3 pt)*

6. A baseball hit by a bat flies through the air for 3.6 seconds. Then it is caught 250 meters away, at the same altitude as the batting point. a. How high did it go? *It spends 3.6/2 = 1.8 s falling downward.*

$D = at^2/2 = (9.8\ m/s^2)(1.8\ s)^2/2$ = ***15.9 meters*** *(2 points)*

b. Calculate the horizontal and vertical components of its velocity just after impact. *(3 points)*
Horizontal velocity = (250 m)/(3.6 s) = ***69.4 m/s*** *Vertical velocity = (9.8 m/s²)(1.8 s) =* ***17.6 m/s***

c. The inclination angle of its initial velocity = *$\tan^{-1}$(17.6/15.9) =* ***48º*** *up from horizontal. (1 pt)*