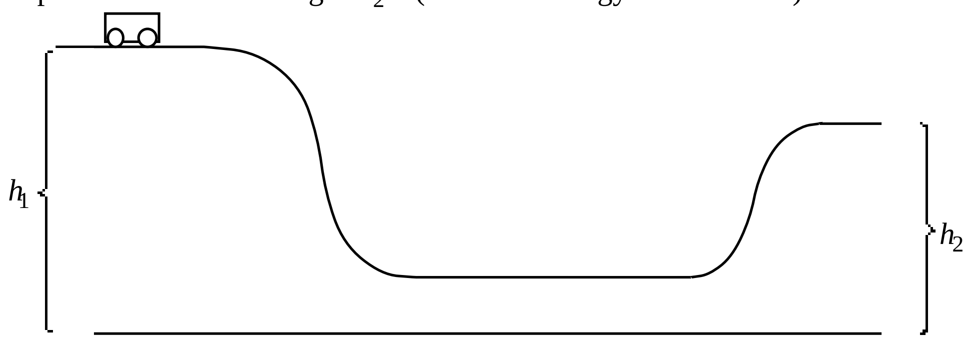
Homework Problems

A mass is slowly raised from the floor to a table top by the force of a human hand (F_H).

1. What is the other force acting on the mass during this motion? Gravity
2. Are the signs of the work done by the two forces the *same* or *opposite*? opposite
3. What is the *net* force acting on the mass during its motion upward? F_{Net} = zero
4. What is the *net* amount of work done by the *net* force on the mass? w_{Net} = zero
5. At the floor the kinetic energy of the mass is, KE = 0 , and at the table, KE = 0.
6. Is the net work done by both forces on the mass equal to the change in the kinetic energy of the mass? yes

7. A cart at a height, h_1, starts rolling down a hill without friction crosses the valley and climbs a hill on the opposite side. What is the speed, v, of the cart when it has reached the top of the hill with a height h_2? (Hint: use energy conservation)



(show work here)

$$PE_1 = mgh_1; \quad KE_1 = 0 \qquad PE_2 = mgh_2; \quad KE_2 = \tfrac{1}{2}mv_2^2$$

$$PE_1 + KE_1 = PE_2 + KE_2$$

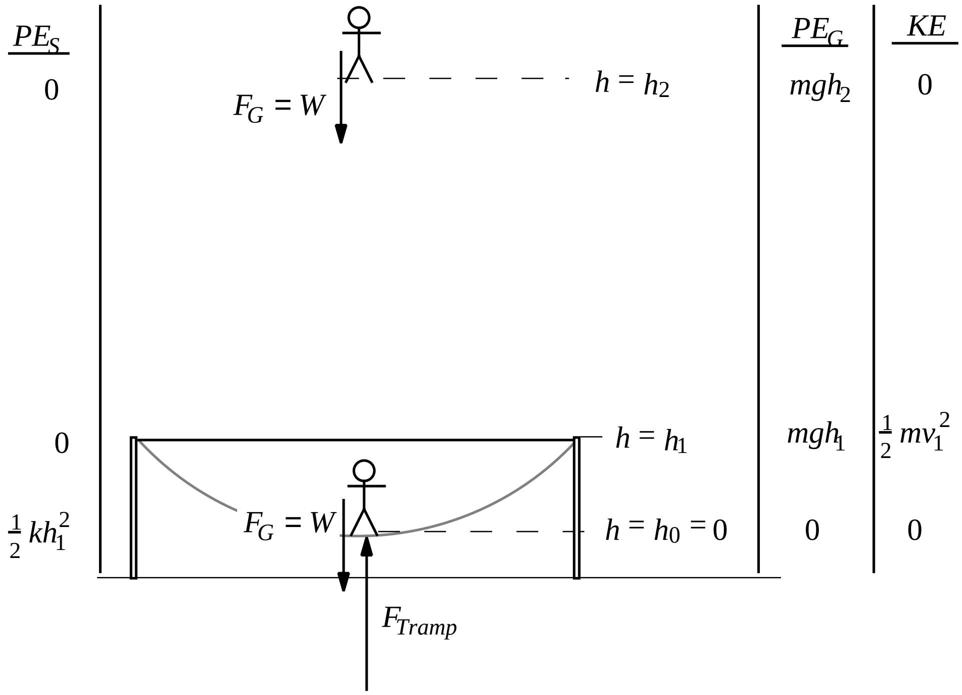
$$\not{m}gh_1 = \not{m}gh_2 + \tfrac{1}{2}\not{m}v_2^2$$

$$v_2^2 = 2g(h_1 - h_2)$$

$$v_2 = \sqrt{2g(h_1 - h_2)}$$

a) $v = \dfrac{(h_1 - h_2)}{g}$ b) $v = \sqrt{\dfrac{2g}{(h_1 + h_2)}}$ c) $v = \sqrt{2g(h_1 - h_2)}$ d) $v = \dfrac{2g}{h_1 h_2}$ e) $v = \sqrt{\dfrac{h_1 h_2}{2g}}$

A person jumping on a trampoline with a weight of 500 N puts 1500 J of potential energy into the trampoline in one of the bounces. The person has a lowest height ($h = h_0 = 0$) and rises to a maximum height, $h = h_2$.



8. Draw the force vectors acting on the person at the highest and and lowest points.

9. The direction of the net force on the person at the highest point is <u>downward</u> , and at the low point is <u>upward</u> .

10. Fill in the table below, with the formula for the spring's potential energy, and person's gravitational potential energy and kinetic energy, at the three heights indicated.

Height	PE(spring)	PE(gravity)	Kinetic Energy
h_0	$\frac{1}{2}k(h_1)^2 = 1500$ J	0	0
h_1	0	mgh_1	$\frac{1}{2}m(v_1)^2$
h_2	0	mgh_2	0

11a. What is the maximum height of the person, assuming the energy stored in the trampoline is fully transferred to the person.

The sum of the potential and kinetic energies of the mass (person) is the same at all heights. Kinetic energy is zero at the top and bottom.

$$\frac{1}{2}k(h_1)^2 = 1500\text{ J} = mgh_2; \qquad mg = 500\text{ N}$$

$$h_2 = \frac{1500\text{ Nm}}{500\text{ N}} = 3\text{ m}$$

12. The maximum distance the person gets below the surface of the trampoline is the value of h_1. If the trampoline spring constant is 10^4 N/m, what is this distance?

$$\tfrac{1}{2}k(h_1)^2 = 1500\text{ J}$$

$$(h_1)^2 = \frac{3000\text{ J}}{k} = \frac{3000\text{ Nm}}{1\times10^4\text{ N/m}} = 0.3\text{ m}^2; \qquad \underline{h_1 = 0.55\text{ m}}$$

13. What is the speed, v, of the person when leaving the surface of the trampoline?

$$1500\text{ J} = mgh_1 + \tfrac{1}{2}m(v_1)^2; \qquad \tfrac{1}{2}m(v_1)^2 = 1500\text{ J} - (500\text{ N})(0.55\text{ m}) = 1225\text{ J}$$

$$(v_1)^2 = \frac{2450\text{ J}}{m} = \frac{2450\text{ J}}{50\text{ kg}} = 49\text{ m}^2/\text{s}^2; \qquad \underline{v_1 = 7\text{ m/s}}$$

14. What is the highest point the person gets above the surface of the trampoline?

(show work here) $\underline{h_2 - h_1 = (3 - 0.55)\text{ m} = 2.45\text{ m}}$

A human with mass m, shoes on a board, starting speed, $v_0 = 0$, falls from a height, h, to the ground. When reaching the ground (just before hitting it) the human has zero gravitational potential energy. Answer the questions using only m, h and g, (ignore air friction).

15. What is gravitational potential energy of the human at the initial height?

$\underline{mgh}$

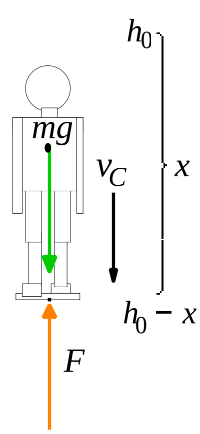
16. Compared to the answer to problem 15, what is the kinetic energy of the human when reaching the ground?

$\underline{mgh}$

17. What is the speed, v, of the human when reaching the ground?

(show work here) $\tfrac{1}{2}mv^2 = mgh; \qquad \underline{v = \sqrt{2gh}}$

When air friction cannot be ignored the frictional force, F, and direction upward, grows with speed and becomes equal to, *and remains at*, the magnitude of the gravitational force at a critical speed v_C.



18. On the diagram to the right, draw and label the two forces acting on the human when reaching the terminal speed v_C.

19. What is the *net* force on the human when reaching speed v_C? zero

After reaching v_C, the human falls an additional distance x.

20. What is the ΔPE_G (final - initial) of the human over the distance, x?

(show work here) $mg(h_0 - x) - mgh_0 = \underline{-mgx}$

21. What is the ΔKE of the human over this distance?

(show work here) $\Delta KE =$ zero

22. What is the sum of kinetic and potential energy changes over this distance? (show work here) $\underline{-mgx}$

23. What is the work done by the frictional force over this distance?
(show work here) $w_{NC} = \Delta KE + \Delta PE = \underline{-mgx}$

24. The frictional force is applied to the bottom of the human's feet. Once reaching v_C describe below, how this person feels compared to standing on the ground.

Forces acting on the person are the same as when standing on the ground, a gravitational force = *mg*, downward, and a compression force = *mg*, upward. Person will feel the same as when standing on the ground.