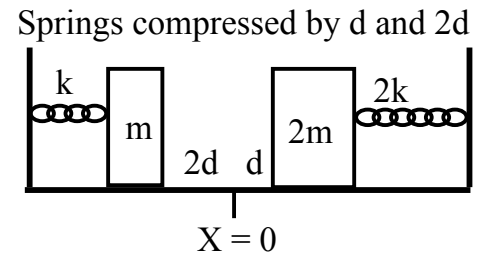
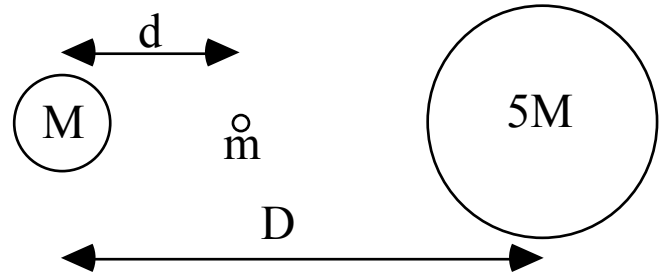


~~2d and the right mass is pulled to the right a distance d. Both masses are released from rest at the same time. Explain why both masses get back to X=0 at the same time.~~



~~B) The diagram shows a binary star system with one star of mass M and the other of mass 5M with the centers of the two stars separated by a distance D as shown. Assume that a third small object of mass m is located a distance d from the center of the left star. The centers of all three objects are on the same line.~~



- ~~i) Is there a value of d for which the total gravitational force on the small mass is zero? If so, write the equation you would solve to find this value of d. Note that you do NOT need to find the value of d. If there is no such value, explain why not.~~
- ~~ii) Using the standard equation for potential energy due to gravity far from the surface, is there a value of d for which the total gravitational potential energy of the small mass is zero? If so, write the equation you would solve to find this value of d. Note that you do NOT need to find the value of d. If there is no such value, explain why not.~~

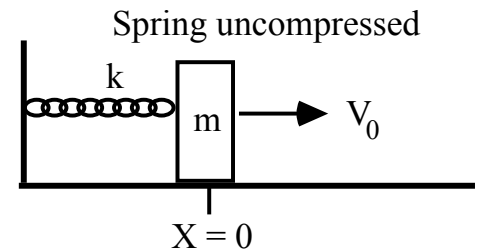
Problem 13

~~Rocket A propels an object of mass m from the surface of the Earth to an altitude 3R_E (R_E is the radius of the Earth) above the surface of the Earth at which point the object stops momentarily before falling back. Rocket B propels an object of the same mass into a circular orbit at an altitude of R_E above the surface. Which rocket does more work? Assume that the initial velocity due to the rotation of the Earth can be ignored. Justify your answer.~~

Problem 14

An object of mass **m** is attached to a spring of spring constant **k** and moves on a frictionless horizontal surface. The mass is at X=0 (where the spring is unstretched) and it has an initial velocity of **V₀** in the positive X direction as shown. The subsequent position and velocity of the object as a function of time are given by:

$$X(t) = A \sin(Ct) \quad \text{and} \quad V(t) = B \cos(Ct)$$



- a) Find the values of A, B, and C in terms of **k**, **m**, and **V₀**.
- b) Since X=0 at t=0, the average velocity between t=0 and a later time can be written simply as

$$V_{\text{avg}}(t) = X(t)/t$$

Find the average velocity between t=0 and t=T/2, where T is the period of oscillation of the mass on the spring. Hint: If you think carefully, you can get the answer with almost no calculations.

- c) Find the average velocity between t=0 and t=T/3, where T is the period of oscillation of the mass on the spring. Express your answer in terms of **V₀** only. Your answer can contain trigonometric functions (like sin, cos, tan, etc.) and numerical constants but no variables other than **V₀**.

Problem 11

a) $E = \frac{1}{2}mv_0^2 - \frac{GmM_E}{R_E}$

b) $\frac{1}{2}mv^2 - \frac{GmM_E}{2R_E} = \frac{1}{2}mv_0^2 - \frac{GM_E m}{R_E}$ $v^2 = v_0^2 - \frac{GM_E}{R_E}$

c) $v = 0$, if $v_{0,min} = \sqrt{\frac{GM_E}{R_E}}$

d) $\frac{mv^2}{2R_E} = \frac{GmM_E}{(2R_E)^2}$, $v = \sqrt{\frac{GM_E}{2R_E}}$

Problem 12

A) $\omega_{left} = \sqrt{\frac{k}{m}}$, $\omega_{right} = \sqrt{\frac{2k}{2m}} = \sqrt{\frac{k}{m}}$

Same $\omega \Rightarrow$ same period \Rightarrow same time to $x = 0$.

B) i) Let right be positive direction: $E_{TOT} = 0 = \frac{G(5M)m}{(D-d)^2} - \frac{G(M)(m)}{d^2}$

Two forces can cancel. Could also write $(D-d)^2 = 5d^2$
(Not required: $d = 0.31D$)

B) ii) $PE_{TOT} = \frac{-G(5M)m}{(D-d)} - \frac{GMm}{d}$, $D > d$ so both terms are negative, so it can NEVER be zero.

Problem 13

Rocket A: $E_I = \frac{-GMm}{R_E}$, $E_F = \frac{-GMm}{4R_E}$, $W_A = \Delta E = \frac{-GMm}{4R_E} - (-\frac{GMm}{R_E}) = \frac{3GMm}{4R_E} = W_A$

Rocket B: $E_I = \frac{-GMm}{R_E}$, $\frac{GMm}{(2R_E)^2} = \frac{mv^2}{2R_E}$, $v^2 = \frac{GM}{2R_E}$, $KE_F = \frac{1}{2} \frac{GMm}{2R_E} = \frac{1}{4} \frac{GMm}{R_E}$

$PE_F = \frac{-GMm}{2R_E}$, $E_F = \frac{1}{4} \frac{GMm}{R_E} - \frac{GMm}{2R_E} = -\frac{GMm}{4R_E}$, $W_B = \Delta E = \frac{3GMm}{4R_E} \Rightarrow$ Same as A.

Problem 14

a) $C = \omega = \sqrt{\frac{k}{m}}$, $B = V_0$, $\frac{1}{2}kA^2 = \frac{1}{2}mV_0^2 \Rightarrow A = \sqrt{\frac{m}{k}}V_0$

b) At $T/2$, block returns to $x = 0$, so $V_{AVG} = 0$ at $t = T/2$

c) $V_{AVG} = \frac{\sqrt{\frac{m}{k}}V_0 \sin(\sqrt{\frac{k}{m}}\frac{T}{3})}{T/3}$. But $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$, so: $V_{AVG} = \frac{3V_0}{2\pi} \sin(\frac{2\pi}{3})$

(Not required: $V_{AVG} = 0.4V_0$)