

$$M\bar{g} + \bar{N} + \bar{T}_1 + \bar{f}_k = M\bar{a}, \quad f_k = \mu N \quad (1)$$

$$\text{OX: } T - f_k = Ma \quad (2)$$

$$\text{OY: } N - Mg = 0 \quad (3) \quad |\bar{T}_1| = |\bar{T}_2| = T$$

1. A mass $M = 5.6 \text{ kg}$ on a horizontal table is pulled by a horizontal string that passes over a frictionless pulley to a free-hanging mass $m = 3.4 \text{ kg}$. The coefficient of friction between M and the table is 0.28 . The acceleration of M is

- a) 3.7 m/s^2
- b) 2.0 m/s^2**
- c) 2.2 m/s^2
- d) 0.20 m/s^2
- e) 0.49 m/s^2

$$m\bar{g} + \bar{T}_2 = m\bar{a}$$

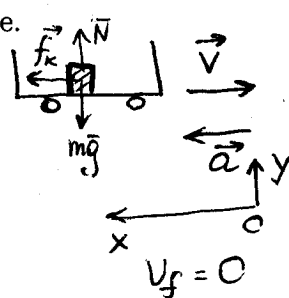
$$\text{OY: } T - mg = -ma \quad (4)$$

$$\text{From (2) and (4): } a(M+m) = mg - f_k \quad (5)$$

$$\text{From (5) and (1): } a = \frac{mg - \mu N}{M+m} = \frac{m - \mu M}{M+m} g$$

2. A 50-kg box is placed in the bed of a truck. The coefficient of friction between the box and the truck bed is 0.54 . If the truck is traveling at 87 km/h ($\approx 54 \text{ mph}$) then calculate the minimum distance the truck can stop in without the box sliding into the cab. Assume that the truck changes its velocity at a constant rate.

- a) $99m$
- b) $1.4 \times 10^3 m$
- c) $55m$**
- d) $1.2 \times 10^2 m$
- e) $2.8 \times 10^2 m$



$$m\bar{g} + \bar{N} + \bar{f}_k = m\bar{a}, \quad f_k = \mu N \quad (1)$$

$$\text{OX: } f_k = ma \quad (2)$$

$$\text{OY: } N - mg = 0 \quad (3)$$

$$\text{From (1)-(3): } a = \mu g$$

$$V_f^2 = V_i^2 + 2a \Delta x \rightarrow \Delta x = \frac{V_i^2}{2a} = \frac{V_i^2}{2\mu g}$$

3. Two skiers start at the top of a hill at the same place (P1) and finish at the bottom of the hill, also at the same place (P2). Skier A takes a straight, smooth route to the finish whereas Skier B takes a curvy, bumpy route to the finish. If you assume that friction is negligible, which of the following statements is true?

- a) Skier A has the same speed as skier B at the finish.**
- b) Skier B has the greater speed at the finish.
- c) Skier A has the greater speed at the finish because the route is straight.
- d) Skier A has the greater speed at the finish because the route is smooth.
- e) Skier A has the greater speed at the finish because the route is both straight and smooth.

4. A Blackhawk helicopter is winching up an injured soldier from a danger zone. The soldier and his kit have a mass of 150 kg and are pulled up 51 m in the air at a steady rate. If it takes 30 s to pull the soldier up, how much power has been used by the helicopter's winch engine (assume no power losses in the engine)?

- a) 1.63 kW
 (b) 2.5 kW
 c) 1.0 kW
 d) 2.7 kW
 e) 2.1 kW



$$W = \Delta U = mg \Delta h$$

$$P = \frac{W}{\Delta t} = \frac{mg \Delta h}{\Delta t} = \frac{(150 \text{ kg})(9.8 \frac{\text{m}}{\text{s}^2})(51 \text{ m})}{30 \text{ s}} = 2.5 \text{ kW}$$

5. A block of mass m is pushed up against a spring, compressing it a distance x , and is then released. The spring projects the block along a frictionless horizontal surface, giving the block a speed v . The same spring projects a second block of mass $4m$, giving it a speed $3v$. What distance was the spring compressed in the second case?

- a) x
 b) $2x$
 c) $3x$
 d) $4x$
 (e) $6x$

$$E_i = E_f$$

$$\frac{kx^2}{2} = \frac{mv^2}{2}$$

$$\frac{k(x')^2}{2} = \frac{(4m)(3v)^2}{2}$$

$$x' = 6x$$

6. See Fig. A below. Release mass m on a string from rest at point A. As it passes the lowest point B, the tension in the string is

- a) impossible to determine; the answer depends on the length of the string.
 b) mg
 (c) $2mg$
 d) $3mg$
 e) None of these is correct.

$$m\bar{a} = \bar{T} + m\bar{g} \quad (\text{at point B})$$

$$\text{OY: } ma = T - mg$$

$$a = a_c = \frac{v^2}{R}$$

$$\rightarrow T = m(a + g) = m\left(\frac{v^2}{R} + g\right) \quad (1)$$

$$\text{From (1)-(2): } T = m \cdot 2g$$

$$E_A = E_B$$

$$E_A = U_A = mg\left(\frac{R}{2}\right)$$

$$E_B = K_B = \frac{mv^2}{2}$$

$$\frac{mv^2}{2} = mg \cdot \frac{R}{2}$$

$$v = \sqrt{gR} \quad (2)$$

7. An astronaut lands on an earthlike planet and drops a small lead ball with a mass of 76.5 g from the top of her spaceship. The point of release is 18 m above the surface of the planet and the ball takes 2.5 s to reach the ground. The astronaut's mass on earth is 68.5 kg. Her weight on the planet is

- a) 69.0 N
 (b) 395 N
 c) 670 N
 d) 990 N
 e) 1.02 kN



$$h = \frac{gt^2}{2}$$

$$g = \frac{2h}{t^2} = \frac{2(18 \text{ m})}{(2.5 \text{ s})^2} = 5.76 \frac{\text{m}}{\text{s}^2}$$

$$mg = \left(5.76 \frac{\text{m}}{\text{s}^2}\right)(68.5 \text{ kg}) \approx 395 \text{ N}$$

8. If the only forces acting on a 2.0-kg mass are $\mathbf{F}_1 = (3\mathbf{i} - 8\mathbf{j})$ N and $\mathbf{F}_2 = (5\mathbf{i} + 3\mathbf{j})$ N, what is the magnitude of the acceleration of the particle?

- a) 1.5 m/s²
 b) 6.5 m/s²
 c) 4.7 m/s²
 d) 9.4 m/s²
 e) 7.2 m/s²

$$m\bar{a} = \bar{F}_1 + \bar{F}_2 = 3\hat{i} - 8\hat{j} + 5\hat{i} + 3\hat{j} = 8\hat{i} - 5\hat{j}$$

$$m = 2 \text{ kg}$$

$$(2)\bar{a} = 8\hat{i} - 5\hat{j} \rightarrow \bar{a} = (4\hat{i} - 2.5\hat{j}) \frac{\text{m}}{\text{s}^2}$$

$$|\bar{a}| = \sqrt{4^2 + (2.5)^2} = 4.7 \frac{\text{m}}{\text{s}^2}$$

9. See Fig. B below. The horizontal surface on which the objects slide is frictionless. If $M = 2.0$ kg, the tension in string 1 is 12 N. Determine F .

- a) 25 N
 b) 20 N
 c) 30 N
 d) 35 N
 e) 40 N

$$m_1: M\bar{a} = \bar{T}_2 \quad \text{OX: } Ma = T_2 \quad (1)$$

$$m_2: (2M)\bar{a} = \bar{T}_1 + \bar{T}_2 \quad \text{OX: } 2Ma = T_1 - T_2 \quad (2)$$

$$m_3: (2M)\bar{a} = \bar{F} + \bar{T}_1 \quad \text{OX: } 2Ma = F - T_1 \quad (3)$$

$$\text{From (1)-(3): } F = \frac{5}{3}T_1 = \frac{5}{3} \cdot 12 \text{ N} = 20 \text{ N}$$

10. See Fig. C below. A roller-coaster car has a mass of 500 kg when fully loaded with passengers. The car passes over a hill of radius 15 m, as shown. At the top of the hill, the car has a speed of 8.0 m/s. What is the force of the track on the car at the top of the hill?

- a) 7.0 kN up
 b) 7.0 kN down
 c) 2.8 kN down
 d) 2.8 kN up
 e) 5.6 kN down

$$\bar{N} + m\bar{g} = m\bar{a}_c \quad a_c = \frac{v^2}{R}$$

$$\text{OY: } mg - N = ma_c$$

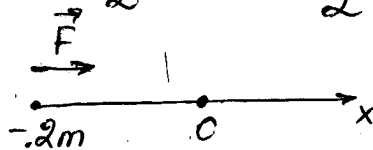
$$N = m(g - a_c) = m\left(g - \frac{v^2}{R}\right) \approx 2.8 \text{ kN (up)}$$

11. When a car goes around a circular curve on a level road,

- a) no frictional force is needed because the car simply follows the road.
 b) the frictional force of the road on the car increases when the car's speed decreases.
 c) the frictional force of the road on the car increases when the car's speed increases.
 d) the frictional force of the road on the car increases when the car moves to the outside of the curve.
 e) there is no net frictional force because the road and the car exert equal and opposite forces on each other.

12. The force an ideal spring exerts on an object is given by $F_x = -kx$, where x measures the displacement of the object from its equilibrium ($x = 0$) position. If $k = 60 \text{ N/m}$, how much work is done by this force as the object moves from $x = -0.20 \text{ m}$ to $x = 0$?

- a) -1.2 J
 ⓑ +1.2 J
 c) +2.4 J
 d) -2.4 J
 e) +3.6 J

$$W = \frac{kx^2}{2} = \frac{(60 \frac{\text{N}}{\text{m}})(0.2\text{m})^2}{2} = 1.2 \text{ J}$$


The diagram shows a horizontal axis labeled x with an equilibrium point 0 . A point is marked at -0.2m . A force vector \vec{F} is shown as an arrow pointing to the right from the -0.2m position.

13. The speed of a 4.0-kg object is given by $v = (2t) \text{ m/s}$, where t is in s. At what rate is the resultant force on this object doing work at $t = 1 \text{ s}$?

- a) 48 W
 b) 40 W
 c) 32 W
 d) 56 W
 ⓐ 16 W

$$W = \int \vec{F} \cdot d\vec{r} \quad dW = \vec{F} \cdot d\vec{r} \quad \vec{v} = \frac{d\vec{r}}{dt} \quad \vec{a} = \frac{d\vec{v}}{dt}$$

$$\text{Rate} = \frac{dW}{dt} = \vec{F} \cdot \frac{d\vec{r}}{dt} = \vec{F} \cdot \vec{v} = (8\text{N})(2.0 \frac{\text{m}}{\text{s}}) = 16\text{W} \quad |\vec{a}| = 2 \frac{\text{m}}{\text{s}^2}$$

$$|\vec{F}| = |m\vec{a}| = (4\text{kg})(2 \frac{\text{m}}{\text{s}^2}) = 8\text{N}$$

14. See Fig. D below. The horizontal surface on which the block slides is frictionless. The speed of the block before it touches the spring is 6.0 m/s . How fast is the block moving at the instant the spring has been compressed 15 cm ? The spring constant k is 2.0 kN/m and the mass of the block is 2.0 kg .

- ⓐ 3.7 m/s
 b) 4.4 m/s
 c) 4.9 m/s
 d) 5.4 m/s
 e) 14 m/s

$$E_i = E_f$$

$$E_i = \frac{mv_i^2}{2}$$

$$E_f = \frac{mv_f^2}{2} + \frac{k(\Delta x)^2}{2}$$

$$v_f^2 = v_i^2 - \frac{k}{m}(\Delta x)^2 = (6 \frac{\text{m}}{\text{s}})^2 - \frac{2000 \frac{\text{N}}{\text{m}}}{2\text{kg}}(0.15\text{m})^2 = 13.5 \frac{\text{m}^2}{\text{s}^2}$$

$$v_f = \sqrt{13.5} = 3.7 \frac{\text{m}}{\text{s}}$$

15. See Fig. E below. A 0.04-kg ball is thrown from the top of a 30-m tall building (point A) at an unknown angle above the horizontal. As shown in the figure, the ball attains a maximum height of 10 m above the top of the building before striking the ground at point B. If air resistance is negligible, what is the value of the kinetic energy of the ball at B minus the kinetic energy of the ball at A ($K_B - K_A$)?

- a) 12 J
- b) -12 J
- c) 20 J
- d) -20 J
- e) 32 J

$$E_A = E_B$$

$$E_A = K_A + U_A$$

$$E_B = K_B + U_B$$

$$K_B - K_A = U_A - U_B = mgH$$

Some possibly useful information:

$$g = 9.80 \text{ m/s}^2$$

$$1 \text{ mile} = 1.609 \text{ km}$$

$$K_B - K_A = (0.04 \text{ kg})(9.8 \frac{\text{m}}{\text{s}^2})(30 \text{ m}) = 12 \text{ J}$$

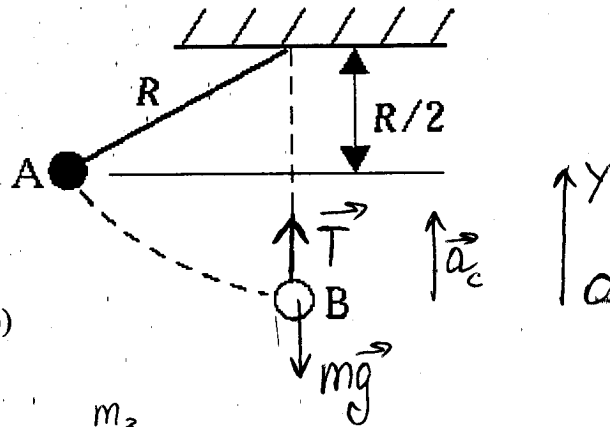


Figure A (Problem 6)

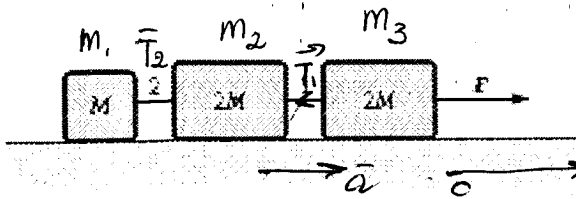


Figure B (Problem 9) (the masses are, from the left, M , $2M$ and $2M$, the strings are labeled "2" and "1", again from the left, and F is the force at the right of the figure)

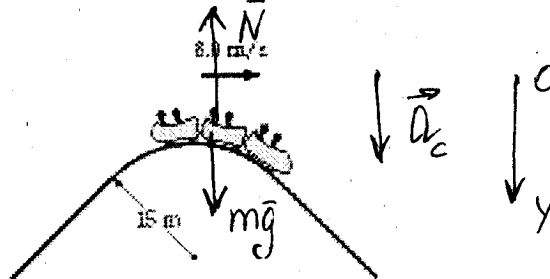


Figure C (Problem 10)

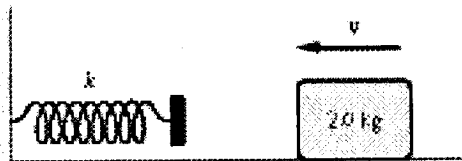


Figure D (Problem 14)

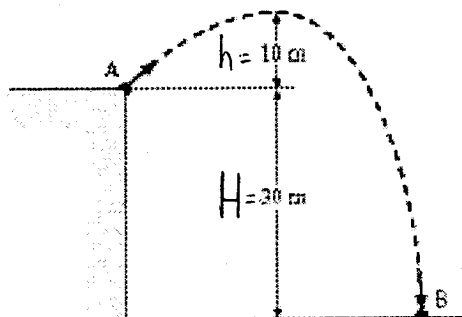


Figure E (Problem 15)