DYNAMICS PROBLEM SOLVING

1. An elevator of mass 800 kg accelerates at 3.0 m/s^2 [down]. What force does the cable exert on the elevator? (5400 N)

$m = 800\ \text{kg}$
$a = -3.0\ \text{m/s}^2$
$\vec{F}_{app} = ?$

$\vec{F}_{net} = m\vec{a} = \vec{F}_{app} - \vec{F}_g$
$\vec{F}_{app} = m\vec{a} + m\vec{g}$
$\vec{F}_{app} = (800\ \text{kg})(-3.0\ \text{m/s}^2) + (800\ \text{kg})(9.8\ \text{m/s}^2)$
$\vec{F}_{app} = 5400\ \text{N}$

2. The engine of a train has a mass of 5.0 x 10^4 kg. It can accelerate six railway cars having a total mass of 3.0 x 10^4 kg at 0.40 m/s^2. What acceleration can it give four railway cars having a total mass of 2.0 x 10^4 kg? (0.46 m/s^2)

$m_E = 5.0 \times 10^4\ \text{kg}$
$m_T = 3.0 \times 10^4\ \text{kg}$
$a = 0.40\ \text{m/s}^2$

$m_T = 2.0 \times 10^4\ \text{kg}$
$a = ?$

Assume no friction so that only force applied to the cars is $\vec{F}_{app}$.

$F_{net} = F_{app}$
$F_{app} = m_T a$
$F_{app} = (3.0 \times 10^4\text{kg})(0.40\ \text{m/s}^2)$
$F_{app} = 1.2 \times 10^4\ \text{N}$

$a = \frac{F_{app}}{m}$
$a = \frac{1.2 \times 10^4\text{N}}{2.0 \times 10^4\text{kg}}$
$a = 0.60\ \text{m/s}^2$

3. A force of 31 N pulls an 8.0 kg steel slider at a constant speed along a horizontal steel rail. What is the coefficient of kinetic friction of steel on steel? (0.40)

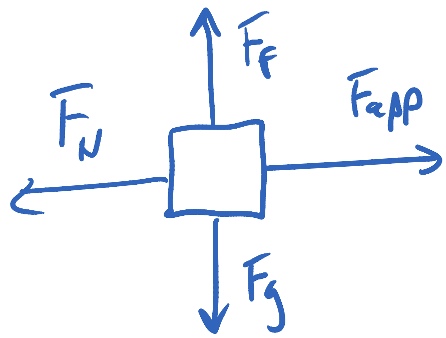
$F_{app} = 31\ \text{N}$
$m = 8.0\ \text{kg}$
$v = \text{constant}$
$a = 0$
$\mu = ?$

Since the slider moves at constant speed,

$F_{app} = F_f$
$F_{app} = \mu F_N$
$F_{app} = \mu mg$
$\mu = \frac{F_{app}}{mg}$
$\mu = \frac{(31\ \text{N})}{8.0\ \text{kg}(9.8\ \text{N/kg})}$
$\mu = 0.40$

4. You are holding a book against a wall. In order to prevent it from falling, you must push with 63 N of force. If the mass of the book is 2.2 kg, what is the coefficient of static friction between the book and the wall? (0.34)

$a = 0$
$F_N = F_{app} = 63\text{ N}$
$m = 2.2\text{ kg}$
$\mu = ?$



$F_f = F_g \quad F_N = F_{app}$

$F_f = F_g$
$\mu F_N = mg$
$\mu F_{app} = mg$
$\mu = \frac{mg}{F_{app}}$
$\mu = 0.34$

5. The coefficient of limiting static friction of a rubber tire on wet concrete is 0.70. What is the mass of a truck that, with its brakes locked, can be dragged by a tow truck exerting a horizontal force of 1.0 x 10^4 N? (1500 kg)

$\mu = 0.70$
$m = ?$
$F_{app} = 1.0 \times 10^4\text{ N}$
$a = 0\text{ (static)}$

$F_{app} = F_f$
$F_{app} = \mu mg$
$m = \frac{F_{app}}{\mu g}$
$m = 1500\text{ kg}$

6. A 240 kg motorcycle and 70. kg rider have a speed of 60. km/h. The air resistance is 1280 N and the rolling friction is 580 N [forward]. If the back wheel pushes on the road with a horizontal force of 1950 N [back], what is the acceleration of the motorcycle? (10 m/s^2)

$m = 310\text{ kg}$
$F_{air} = -1280\text{ N}$
$F_{roll} = 580\text{ N}$
$F_{app} = 1950\text{ N (reaction)}$
$a = ?$

Wheel pushes on the road, so the road pushes on the wheel (F_app).

$F_{net} = ma = F_{air} + F_{roll} + F_{app}$
$a = \frac{F_{air} + F_{roll} + F_{app}}{m}$
$a = \frac{-1280\text{ N} + 580\text{ N} + 1950\text{ N}}{310\text{ kg}}$
$a = 4.0\text{ m/s}^2$

7. Two children wrestle over a toy of mass 1.5-kg. The boy pulls with a force of 6.0 N [W] while the girl pulls with a force of 8.0 N [E]. The toy slides with an acceleration of 1.0 m/s^2.
   a. Draw a free-body diagram of the situation.
   b. Determine the value of the frictional force acting on the toy.

$F_{boy} = -6.0\text{ N}$
$F_{girl} = 8.0\text{ N}$
$a = 1.0\text{ m/s}^2$
$F_f = ?$

$F_{net} = ma = F_{boy} + F_{girl} + F_f$
$F_f = ma - F_{boy} - F_{girl}$
$F_f = (1.5)(1.0) - (-6.0) - (8.0)$
$F_f = -0.5\text{ N}$

8. A hockey puck of mass 3.50 x 10^2 g is sliding along the ice at 6.0 m/s [N] when it hits a rough patch that exerts a frictional force of 0.42 N [S].
    a. Draw a free-body diagram of the puck while it slides on the rough section.
    b. Determine the puck's acceleration.

$m = 3.50 \times 10^{-1}$ kg
$v_i = 6.0$ m/s
$F_f = -0.42$ N
$a = ?$

Only friction acts to oppose its motion.

$$F_{net} = F_f$$
$$ma = -0.42 \text{ N}$$
$$a = \frac{-0.42 \text{ N}}{3.50 \times 10^{-1} \text{ kg}}$$
$$a = -1.2 \text{ m/s}^2$$

9. A 1300 kg car accelerates at 1.6 m/s^2 [E]. A frictional force of 3800 N [W] is acting on the car.
    a. Draw the FBD of the car.
    b. Determine the applied force acting on the car.

$m = 1300$ kg
$a = 1.6$ m/s^2
$F_f = -3800$ N
$F_{app} = ?$

$$F_{net} = F_{app} + F_f$$
$$ma = F_{app} - 3800 \text{ N}$$
$$F_{app} = (1300 \text{ kg})(1.6 \text{ m/s}^2) + 3800 \text{ N}$$
$$F_{app} = 5900 \text{ N}$$

10. A stationary box of mass 4.2-kg is given a push of 8.2 N [S] along a surface where the frictional force acting is 5.8 N [N]. The push lasts for 3.6 s and then the box is allowed to slide on its own until it comes to rest.
    a. Draw free-body diagrams to show the box being pushed and sliding on its own.
    b. Determine the acceleration of the box as it is being pushed.
    c. Calculate the speed of the box just as the push ceases.
    d. Determine the acceleration of the box as it is sliding on its own.

$m = 4.2$ kg
$F_{app} = -8.2$ N
$F_f = 5.8$ N
$\Delta t = 3.6$ s
$v_f = 0$
$a = ?$(during push)
$v_f = ?$(end of push)
$a = ?$(after push)

During the push, there is the applied force and frictional force.

$$F_{net} = F_{app} + F_f$$
$$ma = F_{app} + F_f$$
$$a = \frac{-8.2 \text{ N} + 5.8 \text{ N}}{4.2 \text{ kg}}$$
$$a = -0.57 \text{ m/s}^2$$

The initial speed of the box is zero and it accelerates south while being pushed.

$$v_f = v_i + a\Delta t$$
$$v_f = -0.57 \text{ m/s}^2(3.6 \text{ s})$$
$$v_f = -2.1 \text{ m/s}$$

As it is sliding on its own, it experiences only the frictional force.

$$F_{net} = F_f$$
$$ma = 5.8 \text{ N}$$
$$a = 1.4 \text{ m/s}^2$$

11. An elevator and its contents have a combined mass of 6000-kg. It is suspended by a single cable.
    a. Draw a free-body diagram of the elevator.
    b. What force must the cable exert on the elevator when it is at rest?
    c. What force must the cable exert on the elevator when it is moving upward at 2.0 m/s^2?
    d. What force must the cable exert on the elevator when it is moving downward at 2.0 m/s^2?

$m = 6000\text{ kg}$
$F_{app} = ?(a = 0)$
$F_{app} = ?(a = +2.0\text{ m/s}^2)$
$F_{app} = ?(a = -2.0\text{ m/s}^2)$

$F_{net} = F_{app} - F_g$

$a = 0$
$F_{app} = F_g$
$F_{app} = mg$
$F_{app} = 58800\text{ N}$

$a = +2.0\text{ m/s}^2$
$F_{app} = ma + mg$
$F_{app} = (6000\text{ kg})(2.0\text{ m/s}^2) + (6000\text{ kg})(9.8\text{ m/s}^2)$
$F_{app} = 70800\text{ N}$

$a = -2.0\text{ m/s}^2$
$F_{app} = ma + mg$
$F_{app} = (6000\text{ kg})(-2.0\text{ m/s}^2) + (6000\text{ kg})(9.8\text{ m/s}^2)$
$F_{app} = 46860\text{ N}$

12. A 0.25 kg model rocket accelerates from 15 m/s [up] to 40 m/s [up] in 0.60 s. Calculate the force the escaping gases exert on the rocket. (8.0 N)

$m = 0.25\text{ kg}$
$v_i = 15\text{ m/s}$
$v_f = 40\text{ m/s}$
$\Delta t = 0.60\text{ s}$
$F_{app} = ?$

$F_{net} = F_{app} - F_g$
$ma = F_{app} - mg$
$F_{app} = m(a + g)$
$F_{app} = m\left(\frac{v_f - v_i}{\Delta t} + g\right)$
$F_{app} = (0.25\text{ kg})\left(\frac{40\text{ m/s} - 15\text{ m/s}}{0.60\text{ s}} + 9.8\text{ m/s}^2\right)$
$F_{app} = 13\text{ N}$

13. Two boxes, one with a mass of 60 kg and the other with a mass of 90 kg, are in contact and at rest on a smooth surface. An 800 N force is exerted on the 60 kg box toward the 90 kg box. Calculate:
    a. the acceleration of the boxes. (5 m/s^2)
    b. the magnitude of the action and reaction forces between the boxes. (500 N)

14. A 55 kg girl, Bonnie, facing a 70 kg boy, Gerald, on a frictionless surface pushes Gerald with a force of 250 N for 0. 10 s. Calculate
    a. Bonnie and Gerald's acceleration. (4.5 m/s^2 & -3.6 m/s^2)
    b. Bonnie and Gerald's speed at the end of 0.50 s. (2.3 m/s & -1.8 m/s)

15. Yvonne, a 60 kg skydiver, is falling at 20 m/s when she pulls the rip cord of her parachute. What is her final velocity after 4.0 s if the force of air resistance on her parachute is 768 N [up]? (32 m/s)

16. Two girls, one of mass 40 kg and the other of mass 60 kg, are standing side by side in the middle of a frozen pond. One pushes the other with a force of 360 N for 0.10 s. The ice is essentially frictionless.
    a. What is each girl's acceleration?
    b. What velocity will each girl acquire in the 0.10 s that the force is acting?
    c. How far will each girl move during the same time period?

17. Two crates of mass 12.0 kg and 20.0 kg, respectively, are pushed across a smooth floor together, the 20 kg crate in front of the 12 kg crate. Their acceleration is 1.75 m/s^2. Calculate each of the following.
    a. the force applied to push the crates.
    b. the action-reaction forces between the two crates.

18. Three small children of mass 20.0 kg, 24.0 kg, and 16.0 kg, respectively, hold hands and are pulled across a smooth frozen pond by a larger boy on skates, who pulls a horizontal rope being held by the first child. The skater pulls on the rope with a force of 135 N. Calculate each of the following.
    a. the acceleration of the skater.
    b. the force with which each pair of children must hold hands to ensure that the chain is not broken.