| **2.2 FORCES** | ***HW/Study Packet*** |
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| **SL/HL** | |
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| <u>Required:</u><br>READ Hamper pp 31-43<br>Tsokos (5th Ed), pp 57-75 | <u>Supplemental:</u><br>Cutnell and Johnson, pp 87-95, 99-121, 195-207<br>Do Tsokos (6th Ed)<br>pp 67-68, #1,2,3,8,10; pp 73-75 #2,3,5,8,12,15<br>pp 84-85, #2,3,6,8,11,13,23,24;<br>pp 95-98, #2,3,7,11,12,13,18,19,22,24 |

**REMEMBER TO….**

- ✓ *Work through all of the 'example problems' in the texts as you are reading them*
- ✓ *Refer to the **IB Physics Guide** for details on what you need to know about this topic*
- ✓ *Refer to the **Study Guides** for suggested exercises to do each night*
- ✓ *First try to do these problems using only what is provided to you from the **IB Data Booklet***
- ✓ *Refer to the solutions/key ONLY after you have attempted the problems to the best of your ability*

**UNIT OUTLINE**

**I. FORCES ACTING ON A BODY**
- A. IDENTIFYING FORCES
- B. USING FREE-BODY DIAGRAMS TO DETERMINE RESULTANT FORCES

**II. NEWTON'S FIRST LAW**
- A. INERTIA AND CONSTANT VELOCITY
- B. CONDITIONS FOR EQUILIBRIUM

**III. NEWTON'S SECOND AND THIRD LAWS**
- A. RELATING FORCE AND ACCELERATION
- B. IDENTIFYING PAIRS OF FORCES

**IV. FRICTION**
- A. THE CONCEPT OF FRICTION
- B. STATIC AND DYNAMIC FRICTION

**FROM THE IB DATA BOOKLET**

$F = ma$ $\quad\quad$ $F_{\mathrm{f}} \leq \mu_{\mathrm{s}} R$ $\quad\quad$ $F_{\mathrm{f}} = \mu_{\mathrm{d}} R$

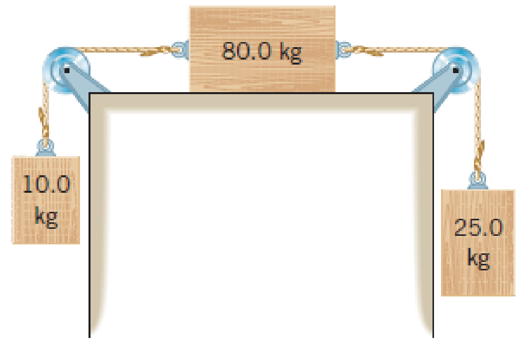
**WHAT YOU SHOULD BE ABLE TO DO AT THE END OF THIS TOPIC**

- □ Understand and state the difference between mass, weight, and gravitational field strength.
- □ Draw vectors representing forces acting on a body (free body diagrams).
- □ Identify situations in which frictional forces act and draw those frictional forces.
- □ Understand and use Hooke's Law.
- □ Describe the consequences of Newton's First Law for translational equilibrium.
- □ Relate situations in which the acceleration is zero to equilibrium situations in which the net force is zero, and solve problems of equilibrium.
- □ Find the net force on a body using free body diagrams, vector addition, and Newton's Second Law.
- □ Recognize that the net force on a body is in the same direction as the acceleration (Newton's Second Law).
- □ Identify pairs of forces that come from Newton's Third Law.
- □ Identify, describe, and quantify solid friction (static and dynamic) by coefficients of friction.

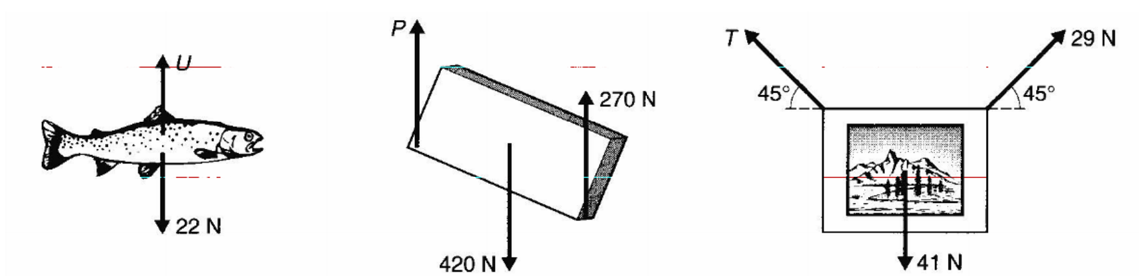
**HOMEWORK PROBLEMS:**

**1.** A man pushes a lawnmower with a force of 80 N directed along the handle which makes an angle of 40° to the vertical. What is the magnitude of the force:
a) in the horizontal direction? **[50 N]** b) in the vertical direction? **[-60 N]**

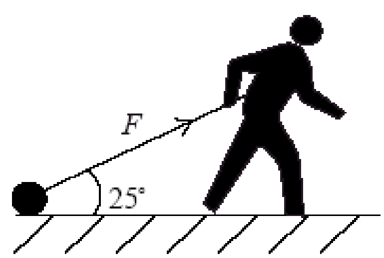
**2.** On the diagram to the right, draw vectors showing all forces.



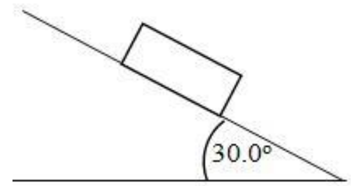

**3.** The body shown in each of the following free-body diagrams is in equilibrium. Write down the value(s) of the unknown force(s) in each case. **[U = 22N, P = 150 N, T = 29 N]**




**4.** An athlete trains by dragging a heavy load across a rough horizontal surface as shown. The athlete exerts a force of magnitude *F* on the load at an angle of 25° to the horizontal. Once the load is moving at a steady speed, the average horizontal frictional force *f* acting on the load is 470 N. Calculate the average value of *F* that will enable the load to move at constant speed.
**[520 N]**



**5.** A block is resting on a rough slope (and not moving) as shown.




a) Label the diagram showing all the forces acting on the block.
b) If the block has a mass of 4 kg and is stationary what is the friction force between the block and the surface? **[20 N]**

**6.** A framed picture of weight 15 N is to be hung on a wall, using a piece of string. The ends of the string are tied to two points, 0.60 m apart on the same horizontal level, on the back of the picture.

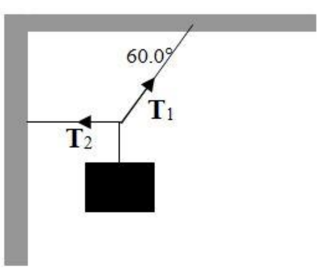
a) Draw a free-body diagram for the picture.

b) find the tension in the string if the string is 1.0 m long. **[9.4 N]**

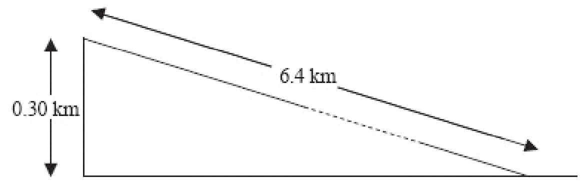
c) find the tension in the string if the string is 0.66 m long. **[18 N]**

**7.** A car engine with weight 1000.0 N hangs from ropes as shown (the car engine is equilibrium so remember the forces must balance.) Find $\mathbf{T}_1$ and $\mathbf{T}_2$, the tensions in the two ropes shown.

**[$T_1$ = 1150 N, $T_2$ = 577 N]**



**8.** From the top of an incline, a road goes downwards in a straight line. At the top of the hill, a driver in a car stops to look at the view. In starting his journey down the hill, the driver decides to save fuel. He switches off the engine and allows the car to move freely down the hill. The car descends a height of 0.30 km in a distance of 6.4 km before levelling out, as shown. The average resistive force acting on the car is $5.0 \times 10^2$ N and the total weight of the car and driver is $1.2 \times 10^4$ N.

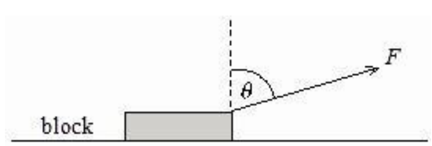



a) What is the acceleration of the car down the incline? **[$5.0 \times 10^{-2}$ ms$^{-2}$]**

b) What is the speed of the car at the bottom of the incline? **[25 ms$^{-1}$]**

c) For the last few hundred meters of its journey down the hill, the car travels at constant speed. Determine the frictional force acting on the car whilst it is moving at constant speed. **[$5.6 \times 10^2$ N]**

**9.** A block of mass m is pulled along a horizontal, frictionless surface by a force of magnitude F. The force makes an angle q with the vertical. Determine an expression for the magnitude of the acceleration of the block in the horizontal direction produced by the force F, in terms of the given variables. **[ $\frac{F\,sin\theta}{m}$ ]**



**10.** A rope with a bucket attached to the end is used to raise water from a well. The mass of the empty bucket is 1.2 kg and it can raise 10.0 kg of water when full. Find the tension in the rope when

a) the empty bucket is lowered with an acceleration of 2.0 $ms^{-2}$ . **[9.4 N]**

b) the full bucket is raised with an acceleration of 0.30 $ms^{-2}$. **[110 N]**

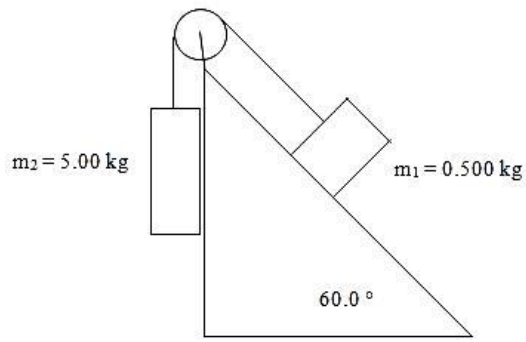
**11.** A 4.80 kg bucket of water is accelerated upward by a cord of negligible mass whose breaking strength is 60.0 N. Find the maximum upward acceleration that can be given to the bucket without breaking the cord. **[2.69 $ms^{-2}$]**

**12.** A sledge loaded with students (sledge and students have a total mass 150.0 kg) slides down a long, snow covered slope. The hill is at a constant angle of 20.0° above the horizontal and the sledge is well waxed so that there is no friction.

a) What is the sledge's acceleration? **[3.42 $ms^{-2}$]**

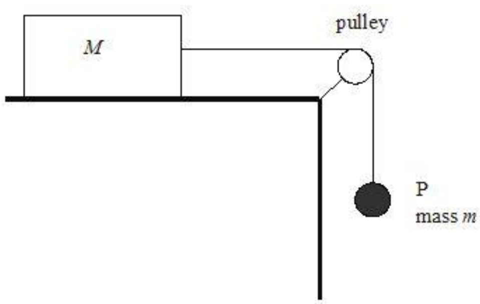
b) Some sand is sprinkled on the slope, and it produces a frictional force of 40.0 N between the sledge and the slope. What is the sledge's acceleration? **[3.09 $ms^{-2}$]**

**13.** Calculate the acceleration of the masses and the tension in the string in the diagram below. You can assume the slope is frictionless and the strings massless. **[a = 8.2 ms$^{-2}$, T = 8.1 N]**




**14.** A block on a frictionless horizontal table is attached by a light, inextensible string to an object P of mass m that hangs vertically as shown. The pulley has zero friction and the acceleration of free fall is g. Determine the acceleration of the block and object P in terms of the given variables.

**[$\frac{m}{m+M}g$]**



**15.** A person has a choice of either pushing or pulling a sled at a constant velocity, as the drawing illustrates. Friction is present. If the angle is the same in both cases, does it require less force to push or to pull the sled? Explain. **[to pull]**


**16.** A box has a weight of 150 N and is being pulled across a horizontal floor by a force that has a magnitude of 110 N. The pulling force can point horizontally, or it can point above the horizontal at an angle θ. When the pulling force points horizontally, the kinetic frictional force acting on the box is twice as large as when the pulling force points at the angle θ. Find θ. **[43°]**

**17.** A 25.0 kg wooden box is pushed across a wooden floor at a constant speed of 1.0 $ms^{-1}$.

a) How much force is exerted on the box? **[74 N]**

b) If the force exerted on the box is doubled, what is the resulting acceleration of the box? **[2.0 $ms^{-2}$]**

c) How long would it take for the velocity of the crate to double to 2.0 $ms^{-1}$? **[0.50 s]**

**18.** A boy exerts 36 N of force horizontally as he pulls a 5.3 kg sled across a cement sidewalk at constant speed. What is the coefficient of kinetic friction between the sled runner and the sidewalk (steel and cement)? **[0.69]**

**19.** Consider the previous problem, but with the sled moving over packed snow. The coefficient of friction (kinetic) is now only 0.12. If a person of mass 66.3 kg sits on the sled, what force is needed to pull the sled across the snow at constant speed? **[84 N]**

**20.** A sled and rider of combined mass 50.0 kg is pulled along a flat, snow-covered ground. The static friction coefficient between the steel runner and the snow is 0.30, and the kinetic friction coefficient is 0.10.

a) How much does the sled weigh? **[491 N]**

b) What force will be needed to start the sled moving? **[147 N]**

c) What force is necessary to keep the sled moving at constant velocity? **[49.1 N]**

d) Once moving, what total force must be applied to the sled to accelerate it at 3.00 $ms^{-2}$? **[199 N]**