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I. **Lecture Multiple Choice [60 pts]. Choose <u>only one</u> answer for each question and fill it out on your bubble sheet.**

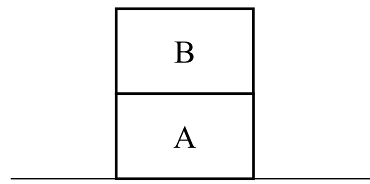
1. [5 pts] A 1200-kg car accelerates at a steady rate from rest to 25 m/s in 4.0 s on a straight horizontal road over a distance of 50 m. Neglecting friction and air resistance, what is the net force acting on the car?

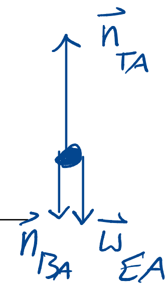
   A. 30000 N
   B. 15000 N
   C. 12000 N
   D. 7500 N
   E. 5000 N

$\vec{F}_{net} = m\vec{a}$; $a = \frac{\Delta v}{\Delta t} = \frac{25\,m/s - 0}{4.0\,s} = 6.25\,\frac{m}{s^2}$

$\Rightarrow F_{net} = (1200\,kg)(6.25\,\frac{m}{s^2}) = \boxed{7500\,N}$

2. [5 pts] Two blocks A and B are placed in a stack over a table, as shown at right. Which one of the following forces would NOT appear on the free-body diagram of block A?





   A. The weight of block A. ✓
   B. The weight of block B. ✗
   C. The normal force by the table on A. ✓
   D. The normal force by B on A. ✓
   E. None of these

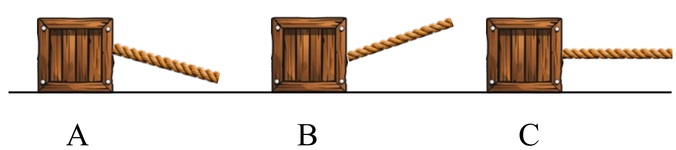
3. [5 pts] A person stands inside an elevator while the elevator is descending and slowing down. Is the normal force by the floor of the elevator onto the person greater than, less than or equal to the person's weight?

$\vec{a}$ points up

   A. Greater than
   B. Less than
   C. Equal to
   D. The answer depends on the value of the elevator's acceleration.
   E. None of the above.

$\vec{F}_{net}$ points up $\Rightarrow$ normal force > weight

4. [5 pts] Three identical crates A, B and C each of mass m are being pulled by ropes over flat horizontal ground, as shown at right. Choose the correct ranking of the normal forces by the ground (G) on the crates.



   A. $n_{GA} > n_{GC} > n_{GB} > mg$
   B. $n_{GA} > n_{GC} = mg > n_{GB}$
   C. $n_{GB} > n_{GC} = mg > n_{GA}$
   D. $n_{GA} = n_{GC} = n_{GB} = mg$
   E. $n_{GC} = mg > n_{GA} = n_{GB}$

In C tension has no vertical component $\Rightarrow n_{GC} = mg$

In A tension pushes down $\Rightarrow n_{GA} > mg$

In B tension pulls up $\Rightarrow n_{GB} < mg$

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5. [5 pts] Consider crate C from the previous question where the rope is horizontal. The mass of the crate is 50 kg, the coefficients of static and kinetic friction with the ground are $\mu_s = 0.4$ and $\mu_k = 0.3$ and the tension in the rope is 250 N. What is the force of friction acting on the crate?
Hint: Is the applied tension big enough to overcome maximum static friction?

A. 100 N
B. 250 N
C. 200 N
D. 150 N
E. 50 N

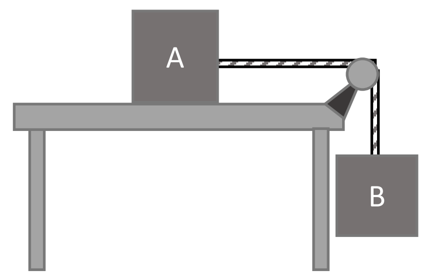
Did we exceed $f_{s,max}$? $f_{s,max} = \mu_s n = \mu_s mg$
$= (0.4)(50\,kg)(9.8\,\frac{m}{s^2})$
$= 196\,N$

Tension $= 250\,N > 196\,N$

$\Rightarrow f = f_k = \mu_k n = \mu_k mg = (0.3)(50\,kg)(9.8\,\frac{m}{s^2})$
$= 150\,N$

Use the following situation to answer the next two questions.

Two blocks, A and B, are connected by a massless inextensible string running over a frictionless pully with block A placed on the table, and block B hanging over the edge of a table.



6. [5 pts] The surface of the table is rough so that the force of static friction prevents block A from moving. Is the magnitude of that force of friction by the table on block A greater than, less than or equal to the weight of the hanging block B?

A. Greater than
B. Less than
C. Equal to
D. Not possible to answer without knowing the masses.

No motion $\Rightarrow \vec{F}_{net,A} = \vec{F}_{net,B} = 0$

$F_{net,A} = T - f_s = 0 \Rightarrow T = f_s$; $F_{net,B} = T - w_{EB} = 0$

$\Rightarrow T = f_s = w_{EB}$

7. [5 pts] We now repeat the same experiment in the previous question but replace the rough table with a frictionless one. Choose the expression representing Newton's second law applied to block B, where T is the magnitude of tension in the string and a is the magnitude of acceleration of the system.

A. $T = m_B a$
B. $T = m_A g + m_B g$
C. $m_B g - T = m_B a$
D. $m_B g + T = m_B a$
E. $m_B a = m_B g$

No friction $\Rightarrow \vec{a}$ points down for B

$\Rightarrow T - w_{EB} = m_B(-a)$; $w_{EB} = m_B g$

$\Rightarrow T - m_B g = -m_B a$

$\Rightarrow -T + m_B g = m_B a$

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Use the following situation to answer the next two questions.
A microscopic spherical particle of smoke drops from rest to the ground through air.

8. [5 pts] Which one of the following correctly describes this problem? Do NOT neglect air resistance.

   A. This is a high Reynold's number problem where inertial forces dominate viscous forces.

   B. The particle accelerates for a long time before reaching its terminal speed.

   C. The particle moves at free-fall acceleration throughout its drop.

   D. The drag force on the particle is proportional to the density of air.

   E. The drag force acting on the particle is proportional with the particle's speed.

9. [5 pts] The smoke particle has a radius of $2.0 \times 10^{-8} m$ and a mass of $5.0 \times 10^{-16} kg$. At what terminal speed does that particle fall through air?
   You may need some of these values: density of air is $\rho = 1.2\ \mathrm{kg/m^3}$, viscosity of air is $\eta = 1.8 \times 10^{-5}\mathrm{Pa \cdot s}$, drag coefficient for a spherical object is $C_D = 0.5$.

   A. $7.2 \times 10^{-4}\mathrm{m/s}$

   B. $4.8 \times 10^{-3}\mathrm{m/s}$

   C. $3.1 \times 10^{-4}\mathrm{m/s}$

   D. $5.5 \times 10^{-3}\mathrm{m/s}$

   E. $3.6\ \mathrm{m/s}$

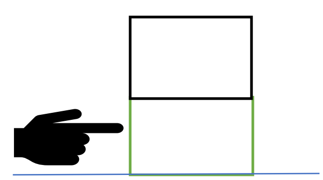
$v = v_{term} \Rightarrow \sum F_y = 0 \Rightarrow D = mg$

$D = 6\pi\eta r v$ (low Re)

$\Rightarrow 6\pi\eta r v_{term} = mg \Rightarrow v_{term} = \frac{mg}{6\pi\eta r}$

$$\Rightarrow v_{term} = \frac{(5.0\times10^{-16})(9.8)}{6\pi(1.8\times10^{-5})(2.0\times10^{-8})} = 7.2\times10^{-4}\ \mathrm{m/s}$$

10. [5 pts] Two blocks are stacked on top of each other and placed on the floor. There is friction between the blocks and friction with the floor. The bottom block is pushed with a force and accelerates, as does the top block with it. What force is accelerating the top block? Both blocks move together.



   A. The force from the hand acts on both the top and bottom blocks

   B. the normal force from the bottom block acts on the top block and pushes it forward

   C. kinetic friction from the bottom block acts on the top block and pushes it forward

   D. static friction from the bottom block acts on the top block and pushes it forward

   E. none of these properly describe the situation.

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11. [5 pts] Two cars take a turn on the freeway at constant speed. Car A is on the inside and car B is on the outside of the turn, and they both complete the turn in the same time. Which car had the greatest tangential speed?
    - A. Same speed
    - B. Car A was faster
    - C. $\boxed{\text{Car B was faster}}$
    - D. would need to the actual radii to make a comparison

$v_t = \frac{2\pi r}{T}$; $T_A = T_B$ $\Rightarrow v_{t,A} < v_{t,B}$

$r_A < r_B$

12. [5 pts] You round a turn in your car with a radius of $\underbrace{15.0\text{ m}}^{r}$ moving with a speed of 7.5 m/s (v_t) on flat ground. What force is required to allow you to complete the turn? The car's mass is 1,200 kg (m).
    - A. $\boxed{4.5\text{ kN}}$
    - B. 9 kN
    - C. 700 N
    - D. 450 N
    - E. Not enough information

$$F_{net} = ma$$
$$= \frac{m v_t^2}{r} = \frac{(1200\text{ kg})(7.5\text{ m/s})^2}{15.0\text{ m}}$$
$$= 4500\text{ N} = 4.5\text{ kN}$$

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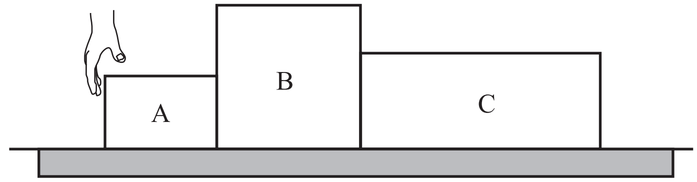
III. Tutorial Free Response [20 pts] Explain your answer where required.

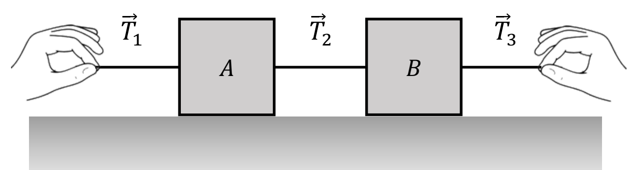
A hand pushes three blocks with masses $m_A < m_B < m_C$ over a rough table. The blocks move at constant velocity.



17. [4 pts] Is the net force on block A greater than, less than or equal to the net force on block C? Explain briefly.
The net force on block A is equal to the net force on C. Since the whole system is moving at constant velocity, the acceleration is zero and hence the net force on the system and each of its constituents is zero, therefore it is equal for all blocks.

18. [6 pts] Consider the following statement: "The force by block B on block C is greater than the force by block A on block B". Do you agree or disagree? Explain your answer briefly.
I disagree. Since the net force is zero on each block, the force by B on C, n_{BC}, is equal to the friction by the table on C, f_{TC}. For block B, the force by A, n_{AB}, is balanced by friction by table on A and force by C, $f_{TB} + n_{CB}$. And since $n_{CB} = n_{BC}$, we conclude that n_{AB} must be greater than n_{BC}.

19. [4 pts] Two identical blocks, A and B, each of mass m are connected via a massless string. The blocks are on a frictionless horizontal surface. Two hands pull on two other massless strings connected to the two blocks, as shown.
If the two-block system is accelerating to the left, rank the magnitudes of the tension forces $\vec{T}_1$, $\vec{T}_2$ and $\vec{T}_3$ from the smallest to greatest. No need to provide explanation.

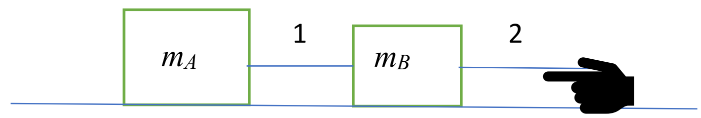


Answer: $T_1 > T_2 > T_3$

20. [6 pts] Suppose now the massless string connecting the two blocks is replaced by a rope of mass $m_R > 0$. If the hands are still pulling on the other strings causing the two-block system to accelerate to the left, is the horizontal component of the tension force by block B on the rope *greater than*, *less than*, or *equal to* the horizontal component of the tension force by block A on the rope? Explain your answer briefly.
Less than. According to Newton's second law, the net force on the rope will be proportional to its mass and points left, since the acceleration is to the left. This means that the sum of forces in the horizontal direction acting on the rope must point to the left. The forces that have horizontal components are the tension by block A on rope 2, $T_{A2,x}$ pointing left, and the tension by block B on rope 2, $T_{B2,x}$ pointing right. Since the net force points left, we conclude that the horizontal component of the tension to the right by block B on the rope must be less than the horizontal component of tension by A on the rope.

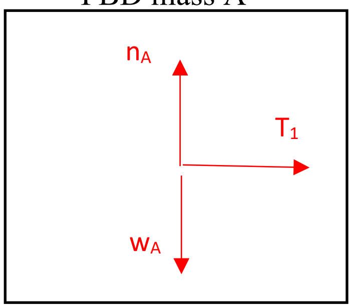
II. Lecture Free response [20 pts]: Show work or explain reasoning where requested.

Two blocks are connected by a massless string and pulled by another massless string as shown. A hand pulls on the string to the right. There is no friction or air resistance.

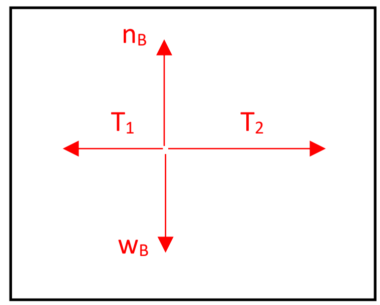


13. [8 pts] Draw free body diagrams for mass A and mass B. Use notation from the text and class.

FBD mass A

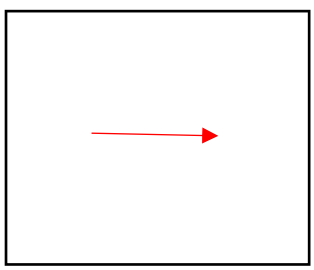


FBD mass B

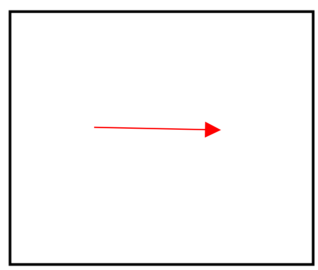


14. [3 pts] Draw the direction of the net force on A and B in the boxes below:

F net on A

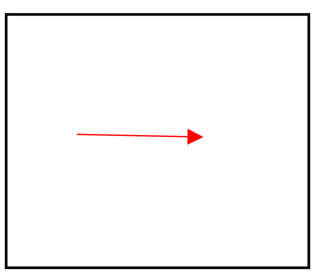


F net on B

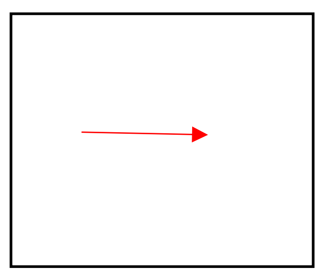


15. [3 pts] Draw the direction of the acceleration of A and B in the boxes below:

acceleration of A



acceleration of B



16. [6 pts] It is found that the mass is moving to the *left* and slowing down. If the acceleration is 2.7 m/s^2 what is the tension in string 1 and string 2? Let m_B=1.6 kg and m_A=1.5 m_B.

Combine system A and B, so $F_{net}=T_2=(m_A+m_B)\ a$ = 2.5 (1.6 kg) 2.7 m/s^2 = 10.8 N

For B: $F_{net}=T_1=m_A\ a$ =1.5 (1.6 kg) 2.7 m/s^2 = 6.48 N

T_1= 6.5 N	T_2= 10.8 N