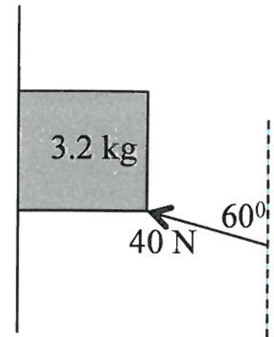
Exam 2, PHY 191B 10/25/16, **100pts**

Name ______________________________

The use of a calculator and *provided* cheat-sheet is allowed.
Put your cellphone, laptop, and Apple Watch in your backpack and place the backpack at the front of the hall.
Anyone found in possession of these items, or any written information other than the provided cheat-sheet, will be expelled from the exam.

Part A (50 points) : 10 *multiple-choice numerical questions*. Each question is worth 5 points.
SHOW REASONING CLEARLY! Correct answer w/o **clear** reasoning = ZERO credit!

1. A 3.2 kg wood block is pressed against a vertical wood wall by the 40N force shown in the figure.
If the block is initially at rest, will
a) the block move downward?
b) the block move upward?
c) the block stay at rest?
The coefficients of static and kinetic friction for wood on wood are 0.2 and 0.1 respectively.



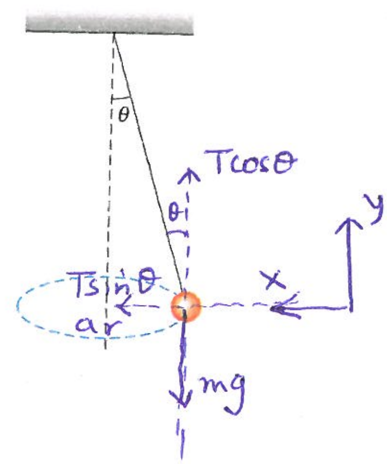
Force up $= 40\cos 60 = 20N$, Force down $= 3.2(9.8) = 31.4N$

$\Rightarrow$ net force is $\downarrow$ $\therefore f_s$ is $\uparrow$ and $f_{s\,max}$ is $\mu_s n = 0.2(40\sin 60) = 6.9N$

So... total maximum force $\uparrow$ is $20 + 6.9 = 26.9N$ which is LESS THAN the force $\downarrow$ (31.4N)

$\Rightarrow$ BLOCK MOVES DOWNWARD

2. Consider a conical pendulum with a bob of mass 80 kg on a 10.0 m wire making an unknown angle with the vertical and moving in a horizontal circle, as shown below, with a radial acceleration toward the center of the circle of 8.2 m/s^2. What is the tension in the wire? (Pick the closest answer)
a) 690 N
b) 800 N
c) 910 N
d) 1020 N
e) 1130 N



$T\sin\theta = ma_r$ from $F_{net_x} = ma_x$

$T\cos\theta = mg$ from $F_{net_y} = m\overset{\nearrow 0}{a_y}$

Solve for 'T' from bottom eqn. & plonk into top eqn:

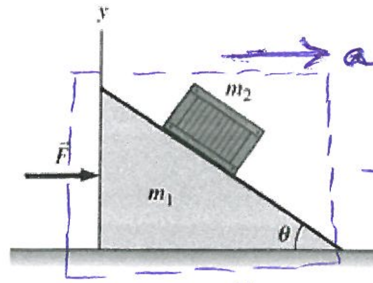
$\frac{mg}{\cos\theta} \cdot \sin\theta = ma_r \Rightarrow a_r = g\tan\theta$

$\Rightarrow \tan\theta = a_r/g = 8.2/9.8 \Rightarrow \theta = 40^\circ$

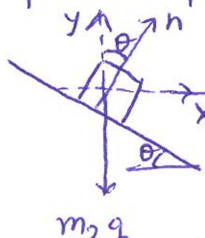
PLONK BACK in any of the 2 eqns. for 'T' above to find, for example from eqn. (ii), $T = \frac{mg}{\cos\theta} = \frac{80(9.8)}{\cos 40^\circ} = 1023N$

3. In the diagram on the right, a block of mass $m_2 = 2$kg is placed on a wedge of mass $m_1 = 3$kg, and a horizontal force $F = 53$N is applied to m_1 as shown. It is observed that m_2 does not slip either up or down along the wedge, as the wedge + block system moves forward. The contact force between the wedge and the block is (all surfaces are frictionless)

a) 33N b) 29N c) 25N d) 23N
e) 20N



To find 'n' between m_1 & m_2, need f.b.d. for one ... let's do m_2:



$\rightarrow 10.6\,m/s^2$

$F_{net_x} = ma_x$

$\Rightarrow n\sin\theta = 2a = 2(10.6)$ —(ii)

$F_{net_y} = ma_y$

$\Rightarrow n\cos\theta - 2g = 0$ —(iii)

f.b.d. for "$m_1 + m_2$" system:

$F_{net} = ma$ in x-direction

$\Rightarrow F = (m_1 + m_2)a$

$\Rightarrow a = \frac{53}{2+3} = 10.6\,m/s^2$ —(i)

Solve for n from Eq (ii) & plonk into Eqn. (iii); $\frac{2g}{\cos\theta} \cdot \sin\theta = 2(10.6)$

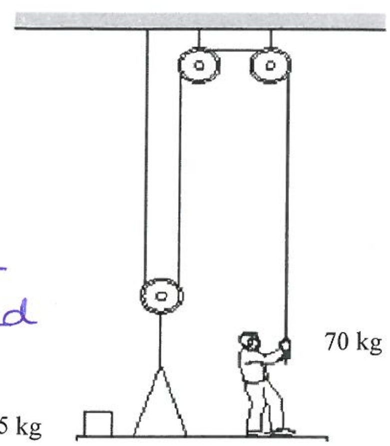
$\Rightarrow \theta = \tan^{-1}(10.6/9.8) = 47°$

PLONK INTO Eqn. (ii) or (iii) to find let's say this!

$n = \frac{2(9.8)}{\cos 47°} = 29\,N$

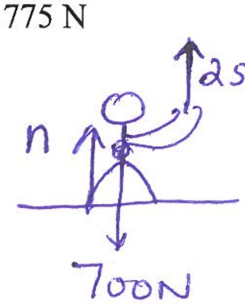
4. A 70 kg person stands on a 15 kg platform. He pulls on the rope that is attached to the platform via the frictionless system shown, with a force of 250N. If he pulls the platform (and therefore himself too) up at a steady acceleration of 2.5 m/s^2, what is the contact force between him and the platform? Ignore friction, and pick the closest answer (assume $g = 10$ m/s^2 for this question).

a) 575 N
b) 625 N
c) 675 N
d) 725 N
e) 775 N



Since question asks for contact force between man & platform, need f.b.d. for one of them

let's say, man



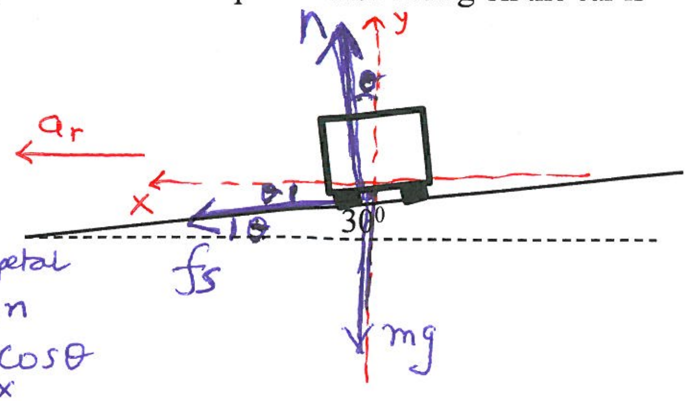
$F_{net_y} = ma_y$ yields

$n + 250 - 700 = 70(2.5)$

$\Rightarrow n = 625\,N$

5. A car of unknown mass rounds a curve of unknown radius on a road banked at 30^0 to the horizontal, turning leftward as shown, with the maximum permissible speed before it begins to skid outward. The coefficient of static friction between the car and the road is 0.8, and the magnitude of the normal force between the car and the road is 24,672 N. The centripetal force acting on the car is

a) 18,927 N   b) 21,029 N
c) 23,133 N   d) 25,236 N
e) 29,429 N



Look @ x-direction:

$F_{net\,x} = ma_x$

yields $n\sin\theta + f_s\cos\theta = \frac{mv^2}{r} = F_{centripetal}$

$\Rightarrow F_{centripetal} = n\sin\theta + (f_s)_{max}\cos\theta$, with $(f_s)_{max} = \mu_s n$

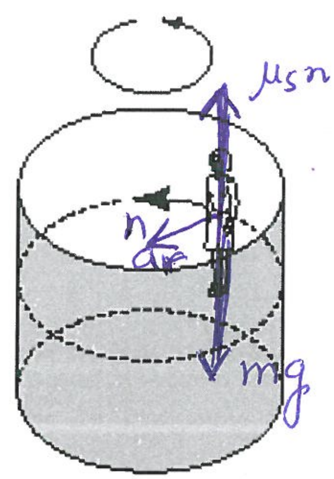
$= 24{,}672\sin 30 + (0.8)(24{,}672)\cos 30$

$= 24{,}672(\sin 30 + 0.8\cos 30)$

$= 29{,}429$ N

6. A person of mass 80 kg rides the "Human Centrifuge" as shown, with a uniform speed of 7 m/s. The coefficient of static friction is 0.6. The minimum normal force between the rider and the wall is

a) 1310 N   b) 1568 N   c) 1724 N
d) 1960 N   e) 2613 N



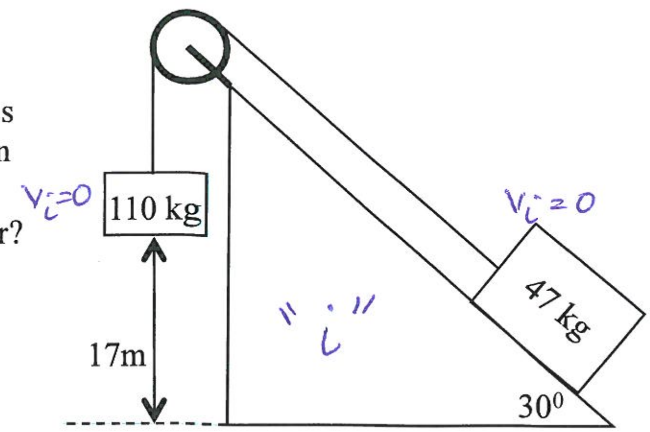
RADIUS IS UNKNOWN. But we do know:

$F_{net\,y} = ma_y$

yields $\mu_s n = mg$

$\Rightarrow n = \frac{mg}{\mu_s} = \frac{80(9.8)}{0.6} = 1310$ N

16. A 47 kg block and a 110 kg block are initially at rest, connected by a string as shown. The pulley is frictionless and of negligible mass. The coefficient of kinetic friction between the 47 kg block and incline is 0.2. What is the speed of the 110 kg block just before hitting the floor? (12pts)



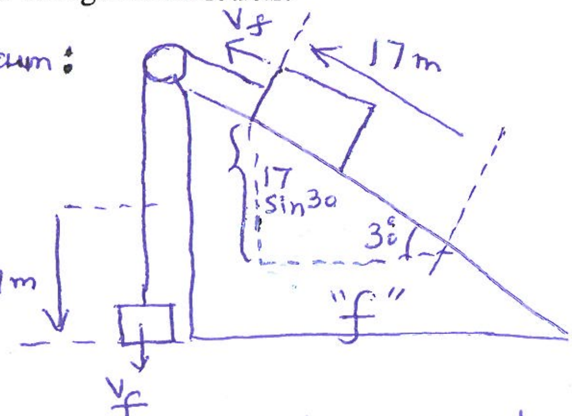
a) 7 m/s
b) 9 m/s
c) 11 m/s
d) 13 m/s
e) 15 m/s

ANSWER____ (1pt)

SHOW WORK CLEARLY BELOW. (11 pts)

"The C. O. M. E. …young Jedi… the C. O. M. E! And don't forget the friction!"

Look @ the "i" & "f" situations drawn:



Now apply C.O.M.E.

$\Delta K + \Delta U = W_{NC}$

$KE_f - KE_i$

$= \frac{1}{2}(47)v_f^2 + \frac{1}{2}(110)v_f^2 - 0$

Workdone by friction $= -\mu_k n\, d$

$= -0.2(47)(9.8)\cos 30^\circ\,(17)$

$= -1356.2\,J$

$\Delta U_g + \Delta U_s \to 0$

$= -110(9.8)(17) + 47(9.8)\underbrace{(17\sin 30)}_{\text{ht. that 110kg mass "rises"}}$

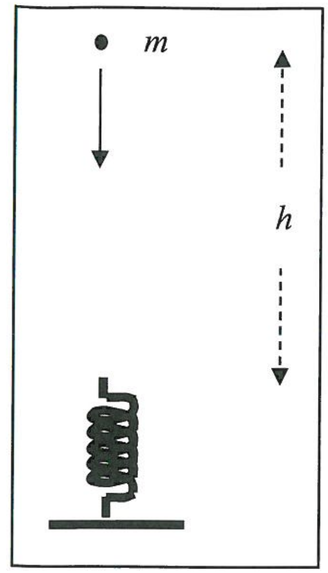
b/c 47kg mass "dropped"

$= -14410.9\,J$

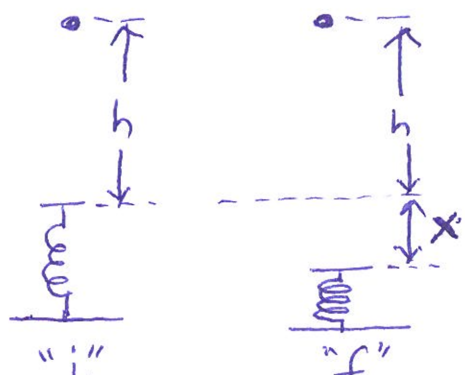
$\therefore\ \frac{1}{2}(47)v_f^2 + \frac{1}{2}(110)v_f^2 - 14410.9 = -1356.2$

i.e. $v_f = \sqrt{(-1356.2 + 14410.9)\left(\frac{2}{47+110}\right)} = 12.9\,m/s$

7. A ball of mass $m = 0.1$ kg drops from a height of $h = 0.5$ m on to a vertical spring of force constant $k = 5$ N/m. What is the maximum compression of the spring? Caution! Don't ignore the potential energy lost by the ball even while it is compressing the spring!



a) 0.7 m b) 0.5 m
c) 0.3 m d) 0.2 m
e) 0.1 m



$\Delta K + \Delta U = W_{NC} \rightarrow 0$

$\Delta K \rightarrow 0$

$\Delta U \rightarrow \Delta U_g + \Delta U_s$

$-mg(h+x) + \underbrace{\frac{1}{2}kx^2}_{\text{"gained"}} = 0$

b/c "lost"

$\Rightarrow -0.1(9.8)(0.5+x)+\frac{1}{2}(5)x^2=0$

or, $2.5x^2 - 0.98x - 0.49 = 0$

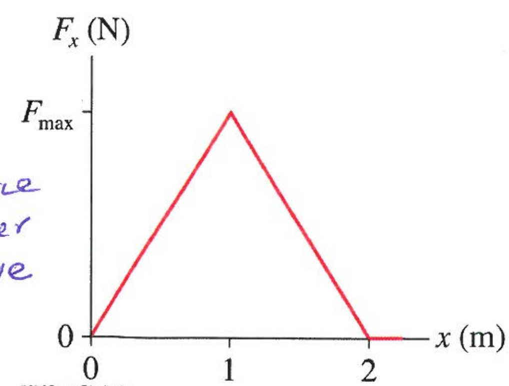
$\Rightarrow x = \frac{0.98 \pm \sqrt{0.98^2+4(2.5)(0.49)}}{2(2.5)}$

ignore!

$\Rightarrow x = 0.7\,m$

8. A particle of mass 1.5 kg moving along the x-axis is subjected to a contact force shown in the figure. The particle goes from velocity 4 m/s at $x = 0$ to a velocity 6 m/s at $x = 2$m. Find the value of F_{max}.

a) 5 N b) 8 N
c) 15 N d) 20 N
e) 36 N



$\Delta K + \Delta U = W_{NC}$, $\Delta U \rightarrow 0$

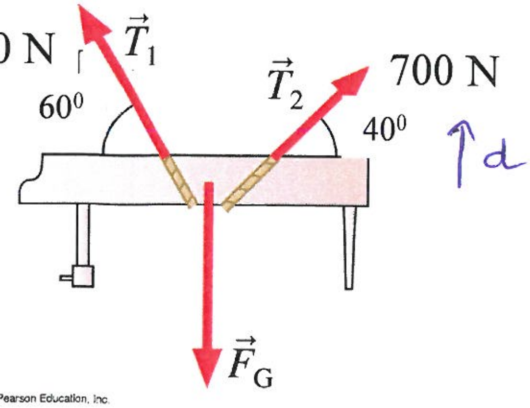
W_{NC} → work by contact force = area under F–x curve

$KE_f - KE_i = \frac{1}{2}(1.5)(6^2-4^2) = \frac{1}{2}(2)F_{max}$

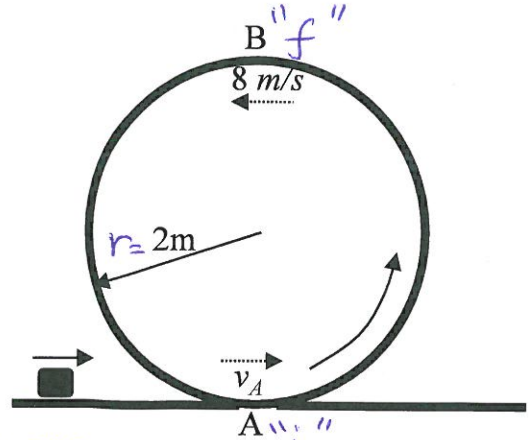
$\Rightarrow F_{max} = 15\,N$

9. The two ropes seen in the figure are used to raise a 143 kg piano vertically by 7 m from the ground. What is the total work done by the non-conservative forces acting on the piano?
   a) 10 kJ
   b) 12 kJ
   c) 15 kJ
   d) 18 kJ
   e) 20 kJ

$$W_{NC} = (T_1 \sin 60^\circ + T_2 \sin 40^\circ) d$$
$$= (1100 \sin 60^\circ + 700 \sin 40^\circ) 7$$
$$= 9{,}818 \text{ J}$$



10. A block of mass 2 kg slides toward a "loop-the-loop" arrangement and slides on the inside of the (frictionless) vertical circle of radius 2 m. The block has a velocity v_A as it whizzes past the bottom of the loop, and a velocity 8 m/s at the top of the circle..
The normal force by the track on the block *at the bottom* is
[Hint: First use C. O. M. E. to find v_A]
   a) 132 N
   b) 142 N
   c) 152 N
   d) 162 N
   e) 172 N



APPLY C.O.M.E between A & B:

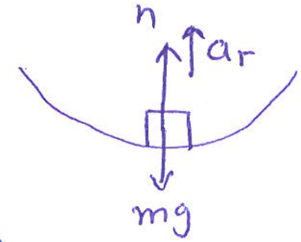
$$\Delta KE + \Delta PE = W_{NC} \to 0$$

$$\left(\frac{1}{2} m v_{top}^2 - \frac{1}{2} m v_{bottom}^2\right) + mg(2r) = 0$$

$$\Rightarrow \frac{1}{2}(2)8^2 - \frac{1}{2}(2)v_{bottom}^2 + 2(9.8)(4) = 0$$

$$\text{or, } v_{bottom} = \sqrt{64 + 78.4} = 11.93 \text{ m/s}^2$$

Now, use f.b.d. & Newton's law @ bottom:



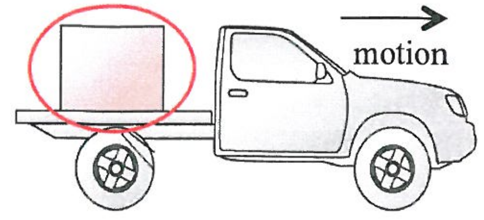
$$F_{net_y} = ma_y \Rightarrow n - mg = \frac{m v_{bottom}^2}{r} \Rightarrow n = mg + \frac{m v_{bottom}^2}{r}$$

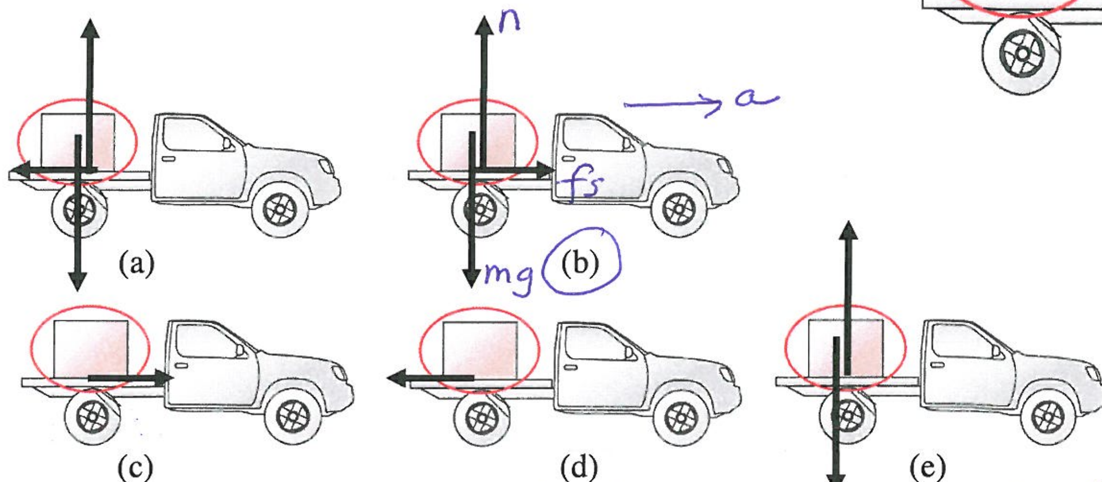
$$= 2(9.8) + \frac{2(11.93^2)}{2}$$

$$= 162 \text{ N}$$

Part B (12 points) 3 *conceptual questions* (11 – 13): Each question is worth 4 points. SHOW BRIEF REASONING! Correct answer w/o **clear** reasoning = ZERO credit!

11. Consider a crate riding along without slipping in a flatbed truck which is **speeding up** in the direction shown. Which of the below represents the correct free body diagram for the crate?





REASON: The force accelerating the crate forward is the force of static friction which prevents the crate from slipping backward.

12. The work done by a centripetal force of magnitude F as a particle moves once around a circle of radius R is

a) Not enough info, can't tell b) $F\pi R$ c) $2F\pi r$ d) 0

REASON: There's no displacement in the direction of the centripetal force! In other words, the centripetal force is ALWAYS perpendicular to the direction of motion! So the dot product of force & displacement is zero b/c $\cos 90° = 0$.

13. Which statement below is true?

A stone is thrown with initial speed v_0 from the top of a cliff of height h, landing in the ocean below. Neglecting air resistance,

a) if it is thrown nearly straight upward, so that it rises to a great height before descending to the ocean, its speed when it strikes the ocean will be greater than if it is thrown horizontally.

b) if it is thrown nearly straight downward, so that it descends as rapidly as possible, its speed when it strikes the ocean will be greater than if it is thrown horizontally.

c) if it is thrown at an elevation angle of 45^0 its speed when it strikes the ocean will be greater than if it is thrown horizontally.

d) the speed when it strikes the ocean is the same regardless of the initial elevation angle.

REASON: APPLY C.O.M.E. between top & bottom.

At top: $KE+PE = \frac{1}{2}mv_0^2 + mgh$
At bottom: $KE+PE = \frac{1}{2}mv_{bottom}^2 + 0$

This is true irrespective of launch angle!

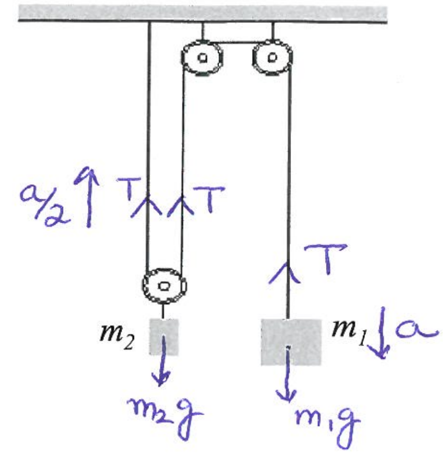
Since $\Delta KE + \Delta PE = 0$,

$\frac{1}{2}mv_{bottom}^2 = \frac{1}{2}mv_0^2 + mgh$ ALWAYS!

i.e. V_{bottom} is the SAME IN ALL CASES!

Part C (38 points) Questions 14 – 16 : 3 *Numerical Problems.*
SHOW WORK CLEARLY.
Correct answer w/o **clear show of** work = ZERO credit!

14. The mass $m_1 = 5.0$ kg and the mass $m_2 = 3.0$ kg are suspended as shown by frictionless pulleys and strings of negligible mass. Note that the pulley from which m_2 is suspended is movable.
Initially m_1 is held at rest. After m_1 is released what is the tension in the string? (12pts)
(Hint: Mind the acceleration constraint! For every 1 meter that m_1 descends, how much does m_2 ascend?) A : 0.5m $\Rightarrow a_2 = \frac{a_1}{2}$



a) 20 N b) 25 N c) 27 N d) 29 N
e) 43 N
ANSWER:________________________________ (1pt)
SHOW WORK CLEARLY BELOW.
Note! Since the problem's not asking about speed or about height that any mass rises or falls (and neither is this information provided) using C. O. M. E. is probably not a great idea. Alrighty then… good old Newton's Laws it is…
TIPS: 1) Start by drawing a f. b. d. for each mass (4 pts)
2) Write down the F_{net} = ma equation for each mass (4 pts)
3) You should have 2 equations and 2 unknowns. Find the tension. (4pts)

Since the question asks for the tension, we should draw f.b.d.'s for each mass. The f.b.d.'s are indicated on the figure.

For m_1, $F_{net} = ma$ yields $m_1 g - T = m_1 a$ — (i)

For m_2, $F_{net} = ma$ yields $2T - m_2 g = m_2 \frac{a}{2}$ —(ii)

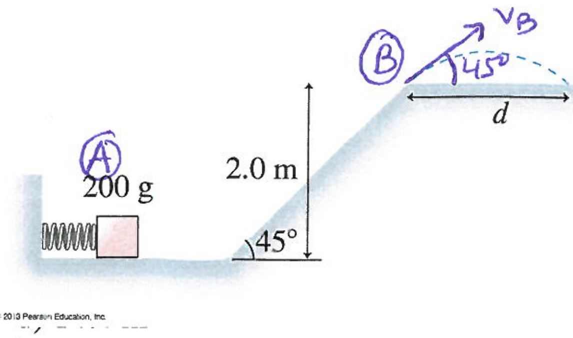
(i) → $5g - T = 5a$ & (ii) → $2T - 3g = \frac{3a}{2}$

Solve for 'a' from (i) & plonk in (ii): $2T - 3g = \frac{3}{2}\left(\frac{5g - T}{5}\right)$

$\Rightarrow T\left(2 + \frac{3}{10}\right) = \left(\frac{3}{2} + 3\right)g$

$\Rightarrow T = \frac{4.5(9.8)}{2.3} = 19.2$ N

15. The spring in the figure below has a spring constant 1400 N/m. It is compressed 15 cm, then launches a 200 g block over a horizontal frictionless surface. The block climbs a frictionless ramp, then sails a horizontal distance *d* through the air. Find the value of *d*



a) 7.5 m   b) 9.8 m   c) 12.1 m

ANSWER_________________________________ (1pt)

SHOW WORK CLEARLY BELOW. (12 pts)

When JediMaster Samir is gone, slain by a Sith Lord, always remember his voice from the clouds "Who needs The Force…Use C. O. M. E. if you can. May the C. O. M. E. be with you!"

APPLY C.O.M.E. between A & B to find the launch velocity @ B:

$$\Delta K + \Delta U = \cancel{W_{NC}}^{\,0}$$

$$\Delta K = \frac{1}{2}mv_B^2 - 0$$

$$\Delta U = \Delta U_g + \Delta U_s$$

$$\Delta U_g = +(0.2)(9.8)(2)$$

$$\Delta U_s = 0 - \frac{1}{2}(1400)(0.15)^2$$

$$\frac{1}{2}mv_B^2 - 0 + (0.2)(9.8)(2) + 0 - \frac{1}{2}(1400)(0.15)^2 = 0$$

$$\Rightarrow \quad v_B = 10.9 \text{ m/s}$$

Now it's a standard projectile problem.

HOR: $d = (v_B \cos\theta)\Delta t \Rightarrow d = (10.9\cos 45^\circ)\Delta t$

VERT: $\Delta y = 0 = (v_B \sin 45)\Delta t - \frac{1}{2}(9.8)(\Delta t)^2 \Rightarrow (10.9\sin 45)\cancel{\Delta t} = 4.9(\Delta t)^{\cancel{2}}$

$\Rightarrow \Delta t = 1.57 \text{ s}$

PLONK!

We find $d = 12.1 \text{ m}$