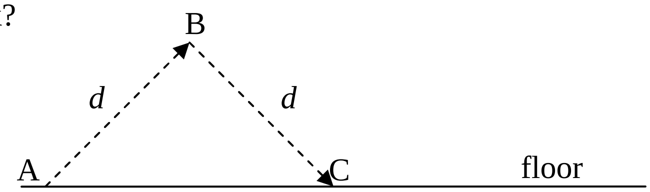
(MC1) You take a book, of mass m, from the floor and move it along the path AB (of length d) (see figure) and return it back to the floor along path BC (also of length d). What is the total work done by gravity on the book?

(A) $mg \times 2d$ (B) $mg \times d$

(C) zero (D) $mg \times 2^{1/2}d$



Answer (C): $\Delta PE = -W_{gravity}$*. Since initial and final vertical positions are the same (ground) then* $\Delta PE = 0$*, so* $W_{gravity} = 0$*.*

(MC2) A cup is on the edge of a horizontal table rotating initially in uniform circular motion (constant speed). The table suddenly stops turning. What will happen to the cup?

(A) It will continue in a straight line with the same speed.

(B) It will stop suddenly with the table.

(C) It will continue rotating in a circle with the same speed.

(D) It will just fall from the table.

Answer (A): By Newton's first law, an object moving in a straight line will continue in a straight line with the same velocity as long as there is no force acting on it. In circular motion, the velocity vector is along the tangent to the circle. So once the force disappears, the object will fly off along the tangent.

(MC3) A ball of mass m is thrown to the right with speed $2v$. It hits a wall and then bounces back of the wall to the left with speed v. The impulse the wall gives the ball is

(A) mv to the right (B) mv to the left (C) $3mv$ to the right (D) $3mv$ to the left

Answer (D): If we choose the right direction to be positive, then the initial momentum = $p_i = m(2v)$*. Final momentum is* $p_f = -m(v)$*. Impulse =* $\Delta p = p_f - p_i = -mv - 2mv = -3mv$*, where the negative sign means to the left.*

(MC4) An object has inertia. What does this mean?

(A) If initially at rest, the object cannot make itself move.

(B) If initially moving, the object cannot make itself stop.

(C) If initially moving in a straight line, it cannot change the direction of its motion.

(D) All of the above.

Answer (D).

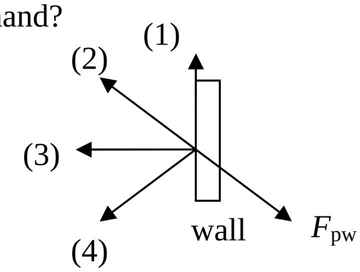
(MC5) A person is pushing a wall by a force F_{pw} using his hand. Which arrow in the figure below gives the direction of the force of the wall on the person's hand?

(A) Arrow (1)

(B) Arrow (2)

(C) Arrow (3)

(D) Arrow (4)



Answer (B): By Newton's third law.

(MC6) You add 22.362 and 1055.85, the result with correct number of significant figures is
(A) 1078.21 (B) 1078.212 (C) 1078.2 (D) 1078

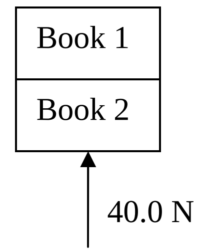
Answer (A): In addition you count the least number of decimal places. The least number is 2 in 1055.85.

(MC7) A car accelerates from rest. In doing so, the magnitude of the car's momentum changes by a certain amount, *p*. The magnitude of Earth's momentum changes by
(A) a larger amount than *p* because the mass of Earth is very large.
(B) the same amount as *p* but we are unable to feel it.
(C) zero, because Earth does not move.
(D) smaller amount than *p* because Earth moves with a very small velocity.

Answer (B): the car-Earth system is isolated so the momentum of the system is conserved. The initial momentum of the car is zero, so is that of Earth. The final momentum of the car is p. Since momentum is conserved and is zero, then the final momentum of Earth is also p but in the opposite direction. The change in Earth's momentum is the same is that of the car.

(P1) Book 1 of mass 1.0 kg is sitting on Book 2 of mass 1.0 kg. A force of 40.0 N is applied to Book 2 and both books accelerate up (see figure).

(A) Calculate the magnitude of the acceleration of the books. Show your work. **(2 pts)**



Total force = $F = 40 - (m_1 + m_2)g = 40 - (1 + 1)(9.8) = 20.4$ N
So $a = F / m = 20.2/ (1 + 1) = 10.2$ m/s^2 = 10 m/s^2.

(B) Calculate the force of Book 1 on Book 2. Show your work. **(2 pts)**

Total force on Book 1 is force due to Book 2 (up) and force of gravity (down). So we have F (total on 1) = F (of 2 on 1) – m_1g. So F (of 2 on 1) = F (total on 1) + m_1g = $m_1a + m_1g$ = $m_1(a + g)$ = (1)(10.2 + 9.8) = 20N. Therefore, F (of 1 on 2) = 20 N down (Newton's third law).

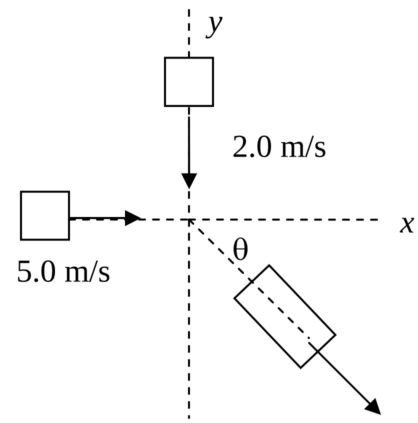
Another way: F (total on 2) = m_2a = 40.0 – m_2g – F (of 1 on 2). So F (of 1 on 2) = 40.0 – m_2g – m_2a = 40.0 – $m_2(g + a)$ = 40.0 – 20 = 20 N.

(C) Calculate the net force on Book 2. Show your work. **(2 pts)**

$F = m_2a = (1)(10.2) = 10.2$ N = 10 N.

(P2) The figure shows two objects of the same mass, one moving in the $+x$ direction with velocity 5.0 m/s and one moving in the $-y$ direction with velocity magnitude 2.0 m/s. The objects collide, stick to each other, and move at angle θ, in the direction shown in the figure.

(A) Calculate the magnitude of the velocity of the objects after collision. Show your work. **(3 pts)**



For the x-component we have $m_1 v_1 = (m_1 + m_2)\, v \cos\theta$
For the y-component we have $m_2 v_2 = (m_1 + m_2)\, v \sin\theta$

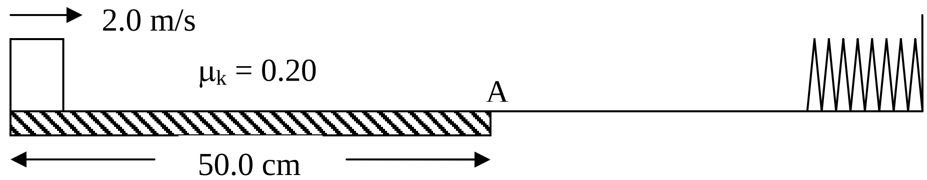
Using numbers the equations are $5m = (2m)\, v \cos\theta$
and $2m = (2m)\, v \sin\theta$. *Divide the two equations and you get*
$5/2 = \cos\theta / \sin\theta$, *so* $\tan\theta = 2/5$, $\theta = 21.8^o = 22^o$.

You can use either equation to get v. Using $2m = 2m\, v \sin\theta$ *we get*
$v = 1 / \sin\theta = 2.5$ *m/s.*

(B) Calculate the angle θ, after collision. Show your work. **(3 pts)**

From above we see $\theta = 21.8^o = 22^o$

(P3) A box of mass 1.0 kg moves in a straight line on a horizontal surface with coefficient of kinetic friction $\mu_k = 0.20$. The initial speed of the box is 2.0 m/s to the right. See figure below.



(A) If the length of the surface is 50.0 cm, what is the speed of the box when it reaches the end of the surface at point A? Show your work. **(3 pts)**

Easiest to use work-energy theorem: $W_{non\text{-}conservative} = \Delta KE + \Delta PE$. *Since the surface is horizontal, then* $\Delta PE = 0$. *We also have* $W_{non\text{-}conservative} = F_{friction}\, d \cos\theta$. $\theta = 180^o$, $d = 0.50$ m *and* $F_{friction} = \mu_k F_N = \mu_k mg$. *Also,* $\Delta KE = mv_f^2/2 - mv_i^2/2$. *Putting all together we have*

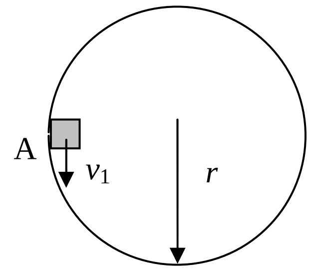
$-\mu_k mg = mv_f^2/2 - mv_i^2/2$. *So,* $v_f^2 = v_i^2 - 2\mu_k mg = 2^2 - (0.2)(1.0)(9.8) = 2.04$. *So* $v_f = 1.4$ m/s.

(B) **After leaving the surface**, the box moves on a horizontal, frictionless surface until it hits a spring whose spring constant is k = 100.0 N/m. How much does the box compress the spring by? Show your work. **(2.6 pts)**

Energy is conserved, so $mv^2/2 = kx^2/2$. *Therefore,* $x = (mv^2/k)^{1/2} = (1 \times 2.04 / 100)^{1/2} = 0.14$ m $= 14$ cm.

(P4) In the figure, the track is a circle and is frictionless. The radius of the circle is r = 10.0 cm. A block of mass 1.0 kg is at point A, as shown in the figure.

(A) What is the minimum speed the block must have at the top of the track so that the block continues moving in a circle? Show your work. **(2 pts)**

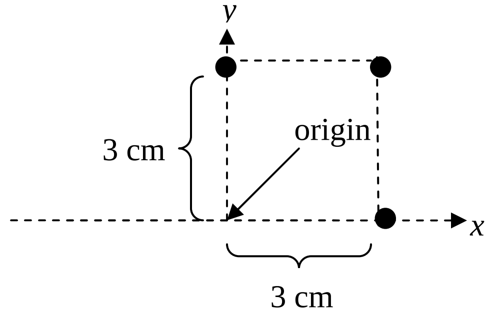


At the top the total force is F_N + mg (both down). By Newton's second law we have $F_N + mg = ma$. The minimum speed is when $F_N = 0$ (barely touching the surface from the inside). So $mg = ma = mv^2/r$. Solving for v we get $v = v_{min} = (rg)^{1/2} = (0.1 \times 9.8)^{1/2} = 0.999$ m/s = 1.0 m/s.

(b) Suppose the block is given velocity v_1 at point A as shown in the figure. What is the minimum value of v_1 so that the block continues moving in a circle? Show your work. **(2 pts)**

Use conservation of energy. Choosing the origin at point A, then we have $E_A = mv_A^2/2$ and $E_{top} = mv^2_{min}/2 + mgr$. From $E_A = E_B$ we get $v_A^2 = v^2_{min} + 2gr = 1 + (2)(9.8)(0.1) = 2.96$. So $v_A = 1.7$ m/s.

(P5) A system is made of three objects, which are located as shown below. All have the same mass m. Find the location of the center of mass of the system **with respect to the origin shown in the figure.** Show your work. **(3 pts)**



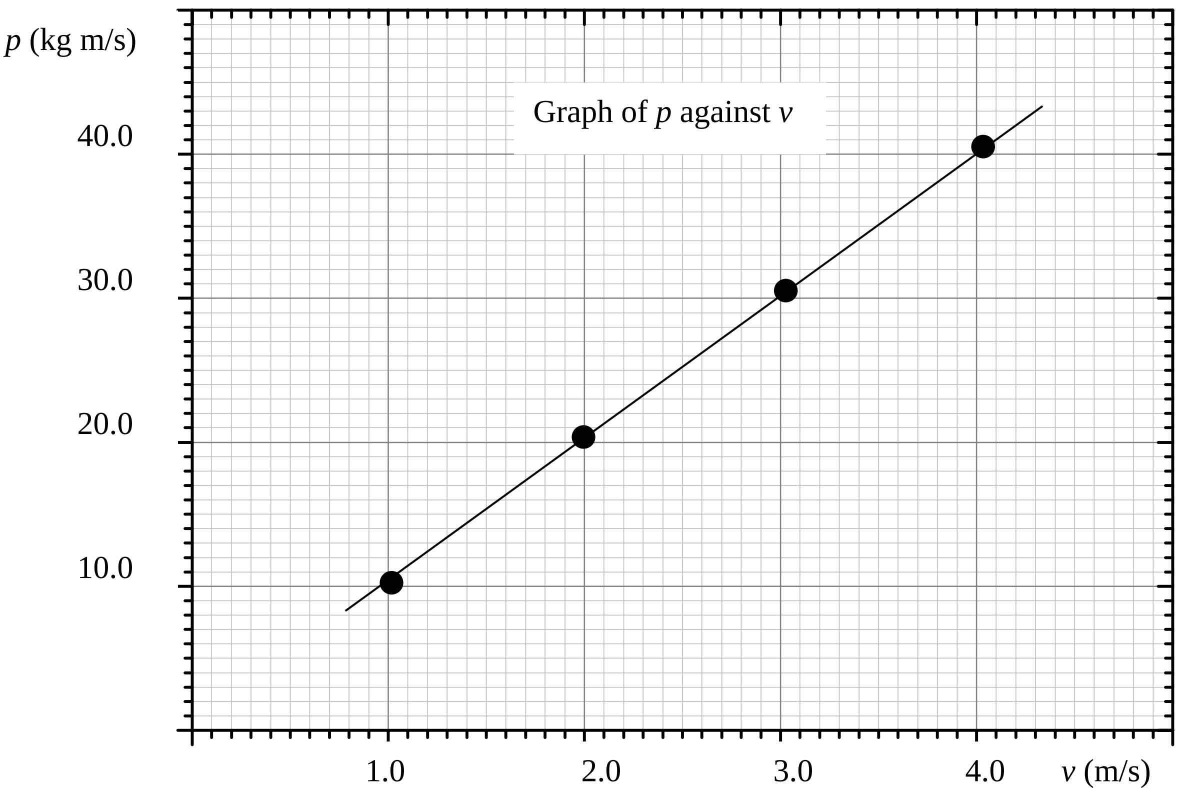
$x_{cm} = [(0)m + 3m + 3m]/(m + m + m) = 2$ cm

$y_{cm} = [(0)m + 3m + 3m]/(m + m + m) = 2$ cm

(P6) In an experiment you make an object move at different velocities. You then measure the object's momentum. You obtain the following table (in the table, v is velocity and p is momentum).

v **(m/s)**	p **(kg m/s)**
1.0	10.0
2.0	20.0
3.0	30.0
4.0	40.0

(A) Make a graph of p against v in the graph area below. Make the graph in the same way you learned in the labs. **You do not have to draw the average point. (4 pts)**



(B) Use the graph to find the mass of the object. *Hint*: $p = mv$. **Make sure your final answer has the correct number of significant figures.** Show your work. **(3 pts)**

m = slope = (40.0 – 10.0) / (4.0 – 1.0) = 10. kg (2 significant figures only. Note that 10.0 is 3 significant figures and 10 is 1 significant figure. The answer must have a decimal point after the number 10 to make it 2 significant figures).