UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 115.3
MIDTERM EXAM

October 17, 2019 Time: 90 minutes

NAME: ______________SOLUTIONS______________________ STUDENT NO.: ____________
(Last) **Please Print** (Given)

LECTURE SECTION (please check):

- ❑ 01 Dr. M. Ratzlaff
- ❑ 02 A. Qamar
- ❑ 03 B. Zulkoskey
- ❑ 97 Dr. A. Farahani
- ❑ C15 Dr. A. Farahani

INSTRUCTIONS:

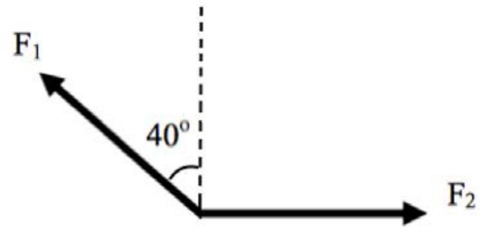
1. This is a closed book exam.
2. The test package includes a test paper (this document), an exam booklet, a formula sheet, a scratch card and an OMR sheet. The test paper consists of 8 pages, including this cover page. **It is the responsibility of the student to check that the test paper is complete**.
3. Only a basic scientific calculator may be used. Graphing or programmable calculators, or calculators with communication capability, or calculators in smart phones are **not** allowed.
4. Enter your name and student number on the cover of the test paper and check the appropriate box for your lecture section. Also enter your name on the exam booklet and scratch card.
5. Enter your name and NSID on the OMR sheet.
6. The test paper, the exam booklet, the formula sheet, the scratch card, and the OMR sheet must all be submitted.
7. No test materials will be returned.

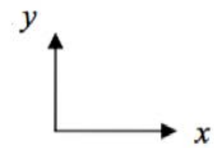
QUESTION NUMBER	MAXIMUM MARKS	MARKS OBTAINED
A1-12	12	
B1-4	8	
B5-8	8	
B9-12	8	
B13-16	8	
MARK	out of 36:	

PART A

FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET.

A1. Forces F_1 and F_2 act on an object, with force F_2 acting in the positive x direction. From the free body diagram and coordinate system shown, which one of the following is the correct expression for the y component of $\vec{F}_1 + \vec{F}_2$?





(A) $F_1 \cos 40°$ (B) $-F_1 + F_2 \cos 40°$ (C) $F_1 \sin 40° + F_2 \cos 40°$
(D) $-F_1 \sin 40°$ (E) $F_1 \sin 40°$

> Since $\vec{F}_2$ does not have a y-component, the y-component of $\vec{F}_1 + \vec{F}_2$ is the y-component of $\vec{F}_1$. Since the angle that is given is with respect to the y-axis, the y-component is $+F_1 \cos(40^\circ)$ (A)

A2. Which one of the following choices is correct for the units of α in the expression $\alpha = \sqrt{\frac{Fx}{4m}}$, where F is force in Newtons, x is displacement in meters, and m is mass in kilograms

(A) m/s^2 (B) m/s (C) m^2/s (D) m^2/s^2 (E) kg m/s

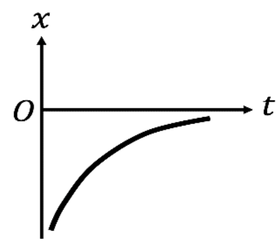
$$[\alpha] = \sqrt{\frac{Nm}{kg}} = \sqrt{\frac{(\cancel{kg} \cdot m/s^2)m}{\cancel{kg}}} = \sqrt{m^2/s^2} = m/s \quad \text{(B)}$$

A3. Which one of the following values is a reasonable order-of-magnitude estimate of the volume of a medium-sized orange?

(A) 1 cm^3 (B) 10 cm^3 (C) 100 cm^3 (D) 10 m^3 (E) 100 m^3

> Approximate an orange as a sphere. The volume of a sphere is $\frac{4}{3}\pi r^3 \approx 4r^3 = 4\left(\frac{d}{2}\right)^3 = \frac{4}{8}d^3 = \frac{1}{2}d^3$
> where r is radius and d is diameter. A medium-sized orange will easily fit in the palm of your hand, so approximate its diameter as 7 to 8 cm. Therefore the volume is approximately 170 cm^3 to 250 cm^3. (C)

A4. The position versus time graph of an object moving in one dimension is shown below.



Which one of the following statements about the motion of this object is correct?

(A) The object is moving with constant velocity in the positive direction.
(B) The object is moving with constant velocity in the negative direction.
(C) The object is moving in the positive direction and speeding up.
(D) The object is moving in the negative direction and slowing down.
(E) The object is moving in the positive direction and slowing down.

The position of the object is on the negative side of the *x*-axis, and the object is moving toward the origin. Therefore, the object is moving in the positive direction. The rate of change of position of the object (the slope of the position vs. time graph) is decreasing, so the object is slowing down. (E)

A5. A package is released by a plane flying with a constant horizontal velocity. A truck is directly below the plane at this time. The truck is driving on a flat road in the same direction as the plane is flying. Assume there is no wind or air resistance. Which one of the following statements is correct?

(A) Whether or not the package lands on the truck depends on the mass of the package.
(B) If the truck initially has the same velocity as the plane and an acceleration in the same direction as its velocity, the package will land on the truck.
(C) Whether or not the package lands on the truck depends on the altitude of the plane.
(D) If the truck has the same constant velocity as the plane, the package will land on the truck.
(E) If the truck initially has the same velocity as the plane and an acceleration in the opposite direction to its velocity, the package will land on the truck.

With no wind or air resistance, the package will continue to move with the same constant horizontal velocity as the plane, but will also have a vertical component of motion due to its weight. Therefore, if the truck has the same constant velocity as the plane, the package will land on the truck. (D)

A6. A moving walkway at an airport has a speed υ and a length L. A woman stands on the walkway as it moves from one end to the other, while a man in a hurry to reach his flight walks on the walkway with a speed of 2υ relative to the moving walkway. Compared to the woman's time, how much sooner does the man reach the end of the walkway?

(A) $\frac{L}{\upsilon}$ (B) $\frac{L}{3\upsilon}$ (C) $\frac{2L}{3\upsilon}$ (D) $\frac{4L}{3\upsilon}$ (E) $\frac{L}{2\upsilon}$

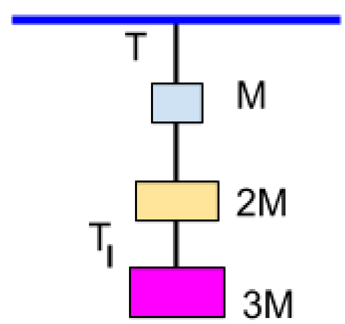
From $\Delta x = \upsilon t$, the woman, standing with the walkway, will move the distance L in a time of $\frac{L}{\upsilon}$. The man, moving with a speed of 2υ relative to the walkway, is moving at a speed of 3υ relative to the building. Therefore, the man will move the distance L in a time of $\frac{L}{3\upsilon}$. The difference in these times, which is how much sooner than the woman that the man reaches the end of the walkway, is $\frac{L}{\upsilon} - \frac{L}{3\upsilon} = \frac{3L - L}{3\upsilon} = \frac{2L}{3\upsilon}$ (C)

A7. If an object is in equilibrium, which one of the following statements is FALSE?

(A) The object must be at rest.
(B) The acceleration of the object is zero.
(C) The net force acting on the object is zero.
(D) The speed of the object is constant.
(E) The velocity of the object is constant.

For an object in equilibrium, the net force acting on it, and therefore its acceleration, are zero. This means that the object is either at rest and remaining at rest, **or** is moving at constant velocity. The statement that the object **must** be at rest is false. (A)

A8. Three blocks are suspended from the ceiling by strings as shown. The top block has mass M, the middle block has mass 2M, and the bottom block has mass 3M. The tension in the string between the top block and the ceiling is T. What is the tension, T_1, in the string connecting the bottom block and middle block?



(A) 3 T (B) $\frac{3}{5}$T (C) $\frac{1}{2}$T
(D) $\frac{2}{3}$T (E) 6 T

The external forces acting on the system of three blocks are T and the total weight of the three blocks. Since the three blocks are in equilibrium, the tension T must be equal in magnitude to $M_{tot}g = (M + 2M + 3M)g = 6Mg$. Since the bottom block is in equilibrium, the net force on it must be zero. Therefore, $+T_1 - 3Mg = 0$, so $T_1 = 3\,Mg = \frac{1}{2}T$. (C)

A9. A painter holds a paint brush, of mass *m*, against the ceiling by applying a vertical force of magnitude *F*. The magnitude of the normal force of the ceiling on the brush is

(A) $F + m$ (B) $F - m$ (C) $F - mg$
(D) $F + mg$ (E) 0

The net force on the paint brush in the vertical direction is zero. Choosing up to be the positive vertical direction, the forces on the paint brush are $+F$, $-mg$ and $-n$. $+F - mg - n = 0$, so $n = F - mg$. (C)

A10. A person is holding a stone of mass *m* in her hand. The stone is initially at rest. She then throws the stone straight up with a velocity υ. What is the net work done on the stone from the moment when she starts accelerating it to throw it upward until it reaches maximum height *h*?

(A) $+mgh$ (B) 0 (C) $-mgh$ (D) $-\frac{1}{2}m\upsilon^2$ (E) $+\frac{1}{2}m\upsilon^2$

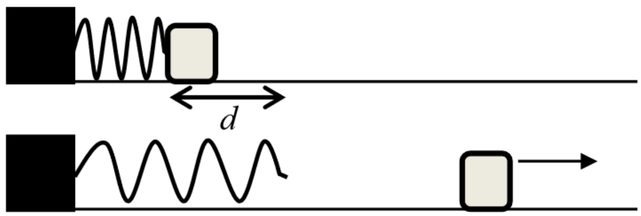
The stone is initially at rest in the person`s hand, and is again at rest when it reaches maximum height. Therefore, there is no change in the kinetic energy of the stone, and therefore no net work is done on it. (B)

A11. A mass tied to the end of a string swings from its highest point down to its lowest point along a semi-circular trajectory. Let W_g, W_T and W_a represent work done by gravity, tension, and air resistance, respectively. Which one of the following statements is correct?

(A) $W_g > 0, W_T = 0, W_a > 0$ (B) $W_g > 0, W_T > 0, W_a < 0$
(C) $W_g = 0, W_T = 0, W_a < 0$ (D) $W_g < 0, W_T = 0, W_a < 0$
(E) $W_g > 0, W_T = 0, W_a < 0$

As the mass swings from high to low, its height above an arbitrary reference is decreasing, and therefore its gravitational potential energy is decreasing. Therefore, the gravitational force is doing positive work on the mass. Since the mass is moving along a semi-circular trajectory, the tension in the string is perpendicular to the motion, and therefore does no work. The air resistance force opposes the motion of the mass, so it does negative work. (E)

A12. An object on a frictionless surface is pushed against a horizontal ideal spring, so that the spring is compressed a distance d. The object is released, and it has a kinetic energy of KE_1 when it loses contact with the spring. The object is then pushed against the spring so that it is now compressed a distance of $2d$. Which one of the following expressions is correct for the kinetic energy, KE_2, of the object when it loses contact with the spring?



(A) $KE_2 = 2KE_1$ (B) $KE_2 = 4KE_1$ (C) $KE_2 = KE_1$ (D) $KE_2 = 8KE_1$ (E) $KE_2 = 1.41KE_1$

Since the object is moving along a horizontal frictionless surface, mechanical energy is conserved and there is no change in the object`s gravitational potential energy. Therefore, $KE_i + PE_{spring,i} = KE_f + PE_{spring,f}$. So, $0 + \frac{1}{2}kd^2 = KE_1 + 0 \Rightarrow KE_1 = \frac{1}{2}kd^2$ When the spring is compressed a distance of $2d$, $0 + \frac{1}{2}k(2d)^2 = KE_2 + 0 \Rightarrow KE_2 = 4(\frac{1}{2}kd^2) = 4KE_1$ (B)

PART B

WORK OUT THE ANSWERS TO THE FOLLOWING PART B QUESTIONS.

BEFORE SCRATCHING ANY OPTIONS, BE SURE TO DOUBLE-CHECK YOUR LOGIC AND CALCULATIONS.

YOU MAY FIND IT ADVANTAGEOUS TO DO AS MANY OF THE PARTS OF A QUESTION AS YOU CAN BEFORE SCRATCHING ANY OPTIONS.

WHEN YOU HAVE AN ANSWER THAT IS ONE OF THE OPTIONS AND ARE CONFIDENT THAT YOUR METHOD IS CORRECT, SCRATCH THAT OPTION ON THE SCRATCH CARD. IF YOU REVEAL A STAR ON THE SCRATCH CARD THEN YOUR ANSWER IS CORRECT (FULL MARKS, 2/2).

IF YOU DO NOT REVEAL A STAR WITH YOUR FIRST SCRATCH, TRY TO FIND THE ERROR IN YOUR SOLUTION. IF YOU REVEAL A STAR WITH YOUR SECOND SCRATCH, YOU RECEIVE 1.2 MARKS OUT OF 2.

REVEALING THE STAR WITH YOUR THIRD, FOURTH, OR FIFTH SCRATCHES DOES NOT EARN YOU ANY MARKS, BUT IT DOES GIVE YOU THE CORRECT ANSWER.

YOU MAY ANSWER ALL FOUR PART B QUESTION GROUPINGS (1-4, 5-8, 9-12, AND 13-16) AND YOU WILL RECEIVE THE MARKS FOR YOUR BEST 3 GROUPINGS.

USE THE PROVIDED EXAM BOOKLET FOR YOUR ROUGH WORK.

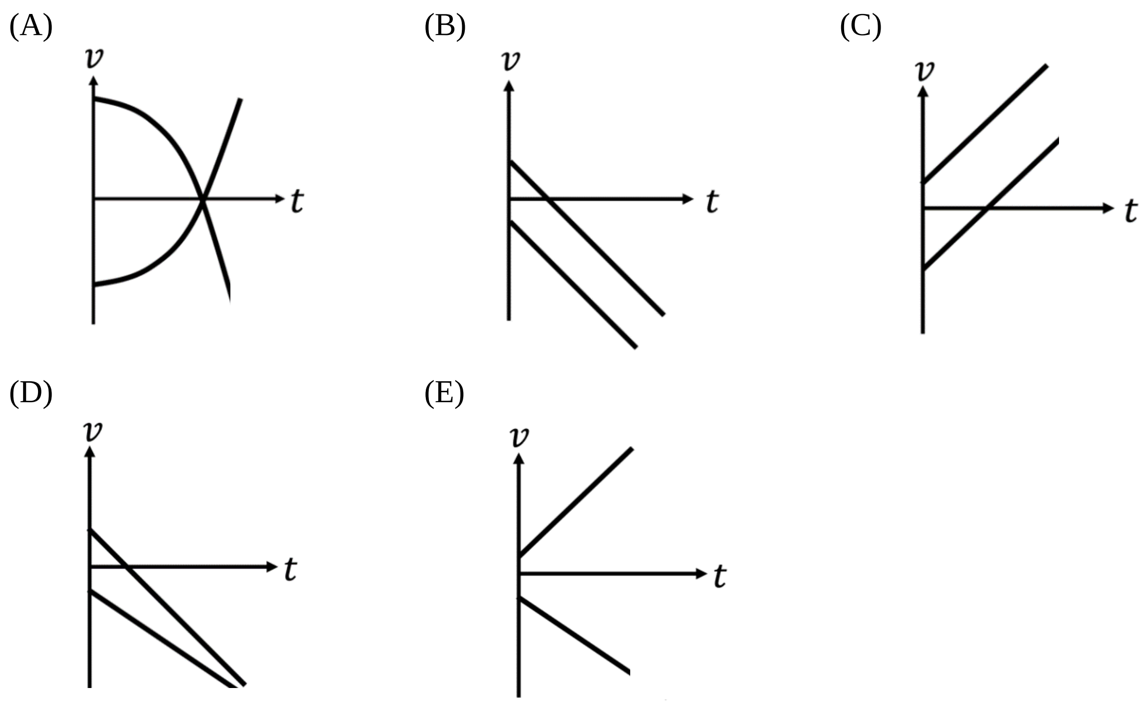
Grouping B1-B4

A person throws ball A straight up from the base of a tower with a speed of 30.0 m/s. At the same instant, a friend who is standing on the tower at a height of 275 m directly above the person on the ground throws ball B directly downward with a speed of 25.0 m/s. Assume up to be the positive direction and ignore any effects due to air resistance.

B1. At the instant when the two balls strike each other in the air, which one of the following expressions is correct for the relationship between their displacements?

The displacement of ball A, Δy_A, is positive (up) and the displacement of ball B, Δy_B, is negative (down). The sum of the magnitudes of the two displacements is 275 m. Therefore,
$\Delta y_A - \Delta y_B = 275 \text{ m}$

B2. Which figure best represents v vs. t plots for the two balls during the time interval before they strike each other?



Both balls are in free fall, so they both have the same acceleration of magnitude g directed downward. Therefore, their v vs. t graphs will be parallel with the same negative slope. The initial velocity for ball A will be positive and the initial velocity for ball B will be negative.

B3. Calculate the time it takes the balls to strike each other (assume the balls have negligible size).

$$\Delta y_A - \Delta y_B = 275 \text{ m}$$
$$\upsilon_{oA}t + \tfrac{1}{2}a_A t^2 - (\upsilon_{oB}t + \tfrac{1}{2}a_B t^2) = 275 \text{ m}$$
$$\upsilon_{oA}t + \tfrac{1}{2}(-g)t^2 - \upsilon_{oB}t - \tfrac{1}{2}(-g)t^2 = 275 \text{ m}$$
$$\upsilon_{oA}t - \tfrac{1}{2}gt^2 - \upsilon_{oB}t + \tfrac{1}{2}gt^2 = 275 \text{ m}$$
$$\upsilon_{oA}t - \upsilon_{oB}t = 275 \text{ m}$$
$$t = \frac{275 \text{ m}}{\upsilon_{oA} - \upsilon_{oB}} = \frac{275 \text{ m}}{(+30.0 \text{ m/s} - (-25.0 \text{ m/s}))}$$
$$t = 5.00 \text{ s}$$

B4. How high above the ground do the two balls strike each other?

$$\Delta y_A = \upsilon_{oA}t + \tfrac{1}{2}a_A t^2$$
$$\Delta y_A = (+30.0 \text{ m/s})(5.00 \text{ s}) + \tfrac{1}{2}(-9.80 \text{ m/s}^2)(5.00 \text{ s})^2$$
$$\Delta y_A = +27.5 \text{ m}$$

Grouping B5-B8

An archer on top of a cliff fires an arrow at a target painted on the ground. The arrow has a velocity of 75.0 m/s and is released at an angle of $\theta = 35.0°$ below the horizontal. Assume air resistance is negligible. The arrow hits the target 1.05 s after it is released.

B5. Calculate the horizontal distance from the arrow's release point to the target.

$$\Delta x = \upsilon_{ox} t = (\upsilon_o \cos\theta)t = (75.0 \text{ m/s})\cos(35.0^\circ)(1.05 \text{ s})$$
$$\Delta x = 64.5 \text{ m}$$

B6. Calculate the height above the ground of the arrow's release point.

Choose UP as the +ve vertical direction

$$\Delta y = \upsilon_{oy} t + \tfrac{1}{2} a_y t^2 = -(\upsilon_o \sin\theta)t + \tfrac{1}{2} a_y t^2$$
$$\Delta y = -(75.0 \text{ m/s})\sin(35.0^\circ)(1.05 \text{ s}) + \tfrac{1}{2}(-9.80 \text{ m/s}^2)(1.05 \text{ s})^2$$
$$\Delta y = -50.57 \text{ m} = -50.6 \text{ m}$$

B7. Calculate the time for the arrow to reach a point 20.0 m below its release point.

$$\Delta y = \upsilon_{oy}t + \tfrac{1}{2}a_y t^2 = -(\upsilon_o \sin\theta)t + \tfrac{1}{2}a_y t^2$$
$$-\tfrac{1}{2}a_y t^2 + (\upsilon_o \sin\theta)t + \Delta y = 0$$
$$(4.90 \text{ m/s}^2)t^2 + (43.02 \text{ m/s})t + (-20.0 \text{ m}) = 0$$
$$t = \frac{-43.02 \text{ m/s} \pm \sqrt{(43.02 \text{ m/s})^2 - 4(4.90 \text{ m/s}^2)(-20.0 \text{ m})}}{2(4.90 \text{ m/s}^2)}$$
$$t = 0.443 \text{ s}, \ -9.22 \text{ s}$$
$$t = 0.443 \text{ s}$$

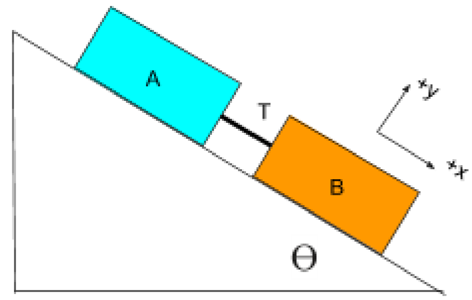
B8. Calculate the velocity of the arrow when it hits the target.

$$\upsilon_x = \upsilon_{ox} = \upsilon_o \cos\theta = (75.0 \text{ m/s})\cos(35.0^\circ) = 61.44 \text{ m/s}$$
$$\upsilon_y = \upsilon_{oy} + a_y t = -\upsilon_o \sin\theta + a_y t$$
$$\upsilon_y = -(75.0 \text{ m/s})\sin(35.0^\circ) + (-9.80 \text{ m/s}^2)(1.05 \text{ s})$$
$$\upsilon_y = -53.31 \text{ m/s}$$
$$\upsilon = \sqrt{\upsilon_x{}^2 + \upsilon_y{}^2} = \sqrt{(61.44 \text{ m/s})^2 + (-53.31 \text{ m/s})^2}$$
$$\upsilon = 81.3 \text{ m/s}$$
$$\phi = \arctan\left(\left|\frac{-53.31 \text{ m/s}}{61.44 \text{ m/s}}\right|\right) = 40.9^\circ$$

Since the arrow is moving down and to the right, the velocity is directed 40.9° below the horizontal

Grouping B9-B12

Two blocks, each of mass m = 2.00 kg, are made of different materials. The blocks are tied together, placed on an inclined plane of angle Θ = 22.0°, and released from rest. Assume the string connecting the blocks has negligible mass. The coefficient of kinetic friction between block A and the incline is 0.246 and the coefficient of kinetic friction between block B and the incline is 0.123.

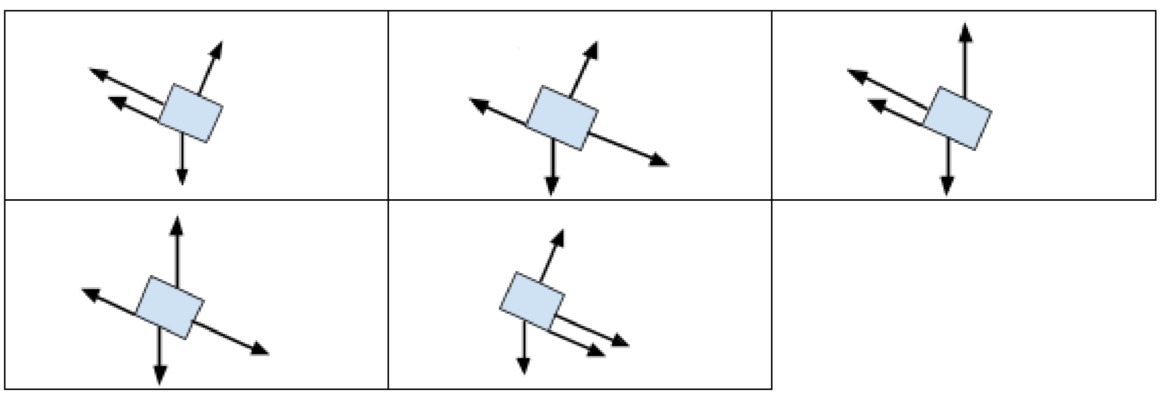


B9. Given the choice of axes shown in the diagram, which one of the following is the correct expression for the magnitude of the normal force, n_A, on block A?

(A) $n_A = mg \sin\Theta$ (B) $n_A = mg \cos\Theta$ (C) $n_A = mg$
(D) $n_A = mg + T \cos\Theta$ (E) $n_A = mg - T \sin\Theta$

Since the net force on block A in the *y*-direction is zero, the magnitude of the normal force equals the magnitude of the *y*-component of the block's weight. $n_A = mg \cos\Theta$

B10. Which one of the following free-body diagrams best represents the forces acting on block A?



The forces acting on block A are the normal force, perpendicular to the inclined plane, the weight force, vertically down, the frictional force, parallel to the inclined plane and directed up the plane, and the tension force, parallel to the inclined plane and directed down the plane.

B11. Calculate the magnitude of the tension in the string.

Apply Newton's Second Law separately to each of the blocks:

Block A:

$$\sum F_y = 0 \;\Rightarrow\; n_A - m_A g\cos\Theta = 0 \;\Rightarrow\; n_A = m_A g\cos\Theta$$

$$\sum F_x = m_A a \;\Rightarrow\; m_A g\sin\Theta + T - f_{kA} = m_A a$$

$$m_A g\sin\Theta + T - \mu_{kA} m_A g\cos\Theta = m_A a$$

$$g\sin\Theta + \frac{T}{m_A} - \mu_{kA} g\cos\Theta = a$$

Block B:

$$\sum F_y = 0 \;\Rightarrow\; n_B - m_B g\cos\Theta = 0 \;\Rightarrow\; n_B = m_B g\cos\Theta$$

$$\sum F_x = m_B a \;\Rightarrow\; m_B g\sin\Theta - T - f_{kB} = m_B a$$

$$m_B g\sin\Theta - T - \mu_{kB} m_B g\cos\Theta = m_B a$$

$$g\sin\Theta - \frac{T}{m_B} - \mu_{kB} g\cos\Theta = a$$

Equating the two expressions for a:

$$g\sin\Theta + \frac{T}{m_A} - \mu_{kA} g\cos\Theta = g\sin\Theta - \frac{T}{m_B} - \mu_{kB} g\cos\Theta$$

$$\frac{T}{m_A} + \frac{T}{m_B} = \mu_{kA} g\cos\Theta - \mu_{kB} g\cos\Theta$$

$$m_A = m_B,\ \text{so let } m = m_A = m_B$$

$$\frac{T}{m} + \frac{T}{m} = \frac{2T}{m} = \mu_{kA} g\cos\Theta - \mu_{kB} g\cos\Theta$$

$$T = \tfrac{1}{2}(mg\cos\Theta)(\mu_{kA} - \mu_{kB})$$

$$T = 1.12\ \text{N}$$

B12. Calculate the magnitude of the acceleration of the blocks down the incline.

$$a = g\sin\Theta + \frac{T}{m_A} - \mu_{kA} g\cos\Theta = 2.00\ \text{m/s}^2$$

Grouping B13-B16

A 75.0 kg skier starts from rest and slides down a 41.5 m long slope, which is inclined at 25.0° to the horizontal. The slope is not frictionless, and the final velocity of the skier is 12.5 m/s. You can neglect air resistance.

B13. Calculate the work done on the skier by gravity as she skis from the top to the bottom of the slope.

$$W_{grav} = -\Delta PE_{grav} = -(mgy_f - mgy_i) = mgy_i - mgy_f = mg(y_i - y_f)$$

Let x be the length of the slope, then $(y_i - y_f) = x\sin\theta$ where θ is the incline of the slope.

$$W_{grav} = mgx\sin\theta = (75.0\text{ kg})(9.80\text{ m/s}^2)(41.5\text{ m})\sin(25.0^\circ)$$

$$W_{grav} = 1.29\times10^4\text{ J}$$

B14. Calculate the work done on the skier by friction as she skis from the top to the bottom of the slope.

$$E_i + W_{nc} = E_f \quad \Rightarrow \quad KE_i + PE_i + W_{nc} = KE_f + PE_f$$

where $W_{nc} = W_{fric}$

$$W_{fric} = KE_f + PE_f - KE_i - PE_i$$

$$W_{fric} = \tfrac{1}{2}m\upsilon_f^2 + 0 - 0 - mgx\sin\theta$$

$$W_{fric} = \tfrac{1}{2}(75.0\text{ kg})(12.5\text{ m/s})^2 - (75.0\text{ kg})(9.80\text{ m/s}^2)(41.5\text{ m})\sin(25.0^\circ)$$

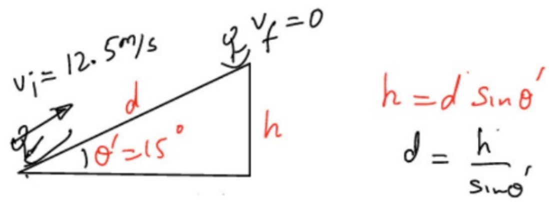
$$W_{fric} = -7.03\times10^3\text{ J}$$

B15. Calculate the coefficient of kinetic friction between the skier and the slope.

$$W_{fric} = f_k(\cos180^\circ)x = -\mu_k nx = -\mu_k(mg\cos\theta)x$$

$$\mu_k = -\frac{W_{fric}}{(mg\cos\theta)x} = -\frac{-7.03\times10^3\text{ J}}{(75.0\text{ kg})(9.80\text{ m/s}^2)(41.5\text{ m})\cos(25.0^\circ)} = 0.254$$

B16. Once the skier reaches the bottom of the slope, she encounters an uphill slope inclined at 15.0° to the horizontal. Assuming that the coefficient of kinetic friction stays the same, find the vertical height the skier reaches before coming to rest.



Apply $E_i + W_{nc} = E_f$ between the bottom of the slope and the height on the uphill slope at which the skier comes to rest.

$$KE_i + PE_i + W_{fric} = KE_f + PE_f$$

$$\tfrac{1}{2} m\upsilon_i^2 + 0 - \mu_k mg\cos\theta' \frac{h}{\sin\theta'} = 0 + mgh$$

where θ' is the angle of the uphill slope and h is the height up the slope that the skier reaches

$$\tfrac{1}{2} m\upsilon_i^2 = mgh + \mu_k mg\cos\theta' \frac{h}{\sin\theta'} = mg(1+\mu_k\cot\theta')h$$

$$h = \frac{\upsilon_i^2}{2g(1+\mu_k\cot\theta')} = \frac{(12.5\text{ m/s})^2}{2(9.80\text{ m/s}^2)(1+0.254\cot(15.0^\circ))} = 4.09\text{ m}$$

END OF EXAMINATION