

UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

Physics 115.3

FINAL EXAMINATION

December 20, 2018

Time: 3 hours

NAME: _____ **SOLUTIONS MASTER** _____ STUDENT NO.: _____
(Last) **Please Print** (Given)

LECTURE SECTION (please check):

- | | | | |
|-----------------------------|---------------|------------------------------|-----------------|
| <input type="checkbox"/> 01 | A. Zulkoskey | <input type="checkbox"/> 97 | Dr. A. Farahani |
| <input type="checkbox"/> 02 | Dr. R. Pywell | <input type="checkbox"/> C15 | Dr. A. Farahani |
| <input type="checkbox"/> 03 | B. Zulkoskey | | |

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 (OpScan / bubble) sheet. The test paper consists of 12 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 (e.g. Texas Instruments TI-30X series, Hewlett-Packard HP 10s or 30S) may be used. Graphing or programmable calculators, or calculators with communication capability, 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 (OpScan / bubble) sheet.
6. The test paper, the exam booklet, the formula sheet, the scratch card, and the OMR (OpScan / bubble) sheet must all be submitted.
7. No test materials will be returned.

| QUESTION # | MAX. MARKS | MARKS |
|------------|------------|-------|
| A1-20 | 20 | |
| B21-24 | 8 | |
| B25-28 | 8 | |
| B29-32 | 8 | |
| B33-36 | 8 | |
| B37-40 | 8 | |
| B41-44 | 8 | |
| MARK | out of 60: | |

PART A

For each of the following questions in Part A, enter the most appropriate response on the OMR (OpScan / bubble) sheet. Use the exam booklet for your rough work.

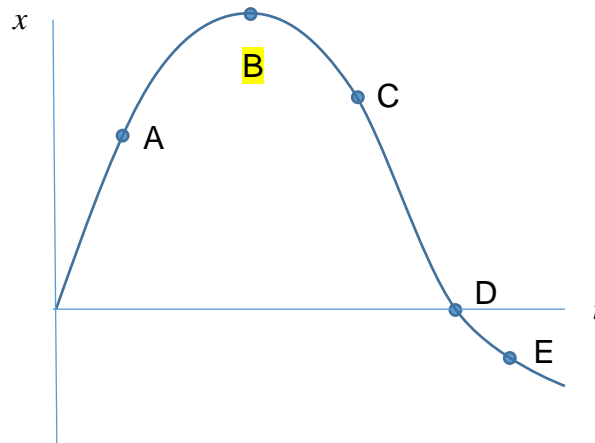
A1. Which one of the following relationships is dimensionally consistent with an expression for the magnitude of an acceleration? In these expressions, x is distance, t is time, and v is speed.

- (A) $\frac{v}{t^2}$ (B) $\frac{v}{x^2}$ (C) $\frac{v^2}{t}$ **(D) $\frac{v}{t}$** (E) $\frac{v^2}{x^2}$

A2. Two cars are at rest at a stop light. When the light turns green at time $t = 0$, car 1 travels with constant acceleration a , and car 2 travels with constant acceleration $3a$. After a time interval Δt , which one of the following expressions correctly relates the distance travelled by each car?

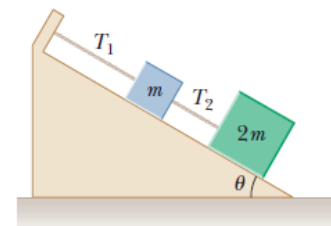
- (A) $\Delta x_2 = 6\Delta x_1$ **(B) $\Delta x_2 = 3\Delta x_1$** (C) $\Delta x_2 = 9\Delta x_1$ (D) $\Delta x_2 = 1.5\Delta x_1$
(E) cannot be determined without knowing the value of Δt

A3. The figure shows a position versus time graph for a moving object. At which lettered point is the object moving the slowest?



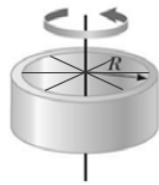
A4. Two blocks of masses m and $2m$ are held in equilibrium on a frictionless incline as shown in the figure. What is the tension T_2 in the lower cord connecting the two blocks?

- (A) $3 mg \sin \theta$ **(B) $2 mg \sin \theta$** (C) $mg \sin \theta$
(D) $3 mg$ (E) $2 mg$

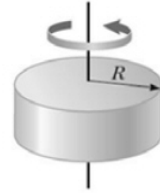


- A5. Consider a block being pushed across a horizontal, frictional surface at a constant velocity. Which statement best describes the block-surface system?
- (A) The pushing force must be larger than the kinetic friction force to keep the block moving with constant velocity.
 - (B) The work done by the pushing force is equal to the work done by kinetic friction.
 - (C)** The work done by the net force is zero.
 - (D) The work done by kinetic friction is independent of the mass of the block.
 - (E) If the pushing force is removed from the block, the block will immediately come to rest.
- A6. A ball is dropped from rest from a window at a height h above the ground. Just before it reaches the ground it has a speed v_1 . If the same ball is dropped from rest at a height $3h$ above the ground, how does the speed of the ball just before it reaches the ground, v_2 , compare to v_1 ?
- (A) $v_2 = 3v_1$
 - (B) $v_2 = 6v_1$
 - (C)** $v_2 = \sqrt{3}v_1$
 - (D) $v_2 = v_1/3$
 - (E) $v_2 = v_1/\sqrt{3}$
- A7. An object of mass $2m$ moving with speed $2v$ in the $+x$ direction strikes an object of mass m that is initially at rest. Following the collision, the object of mass m moves with speed $2v$ in the $+x$ direction. The velocity of the object of mass $2m$ after the collision is
- (A) zero.
 - (B) $\frac{1}{2}v$ in the $+x$ direction
 - (C) $\frac{1}{2}v$ in the $-x$ direction
 - (D)** v in the $+x$ direction
 - (E) v in the $-x$ direction
- A8. Todd and Susan are standing on a rotating circular platform. Todd is standing on the edge of the platform and Susan is standing halfway between the centre of the platform and its edge. Which one of the following statements is correct concerning the relationship between Todd's tangential speed and Susan's tangential speed?
- (A) Todd's tangential speed is exactly half of Susan's.
 - (B) Todd's tangential speed is exactly one-quarter of Susan's.
 - (C) Todd's tangential speed is the same as Susan's.
 - (D)** Todd's tangential speed is exactly twice as large as Susan's.
 - (E) Todd's tangential speed is exactly four times as large as Susan's.
- A9. An object at the end of a string is swung in a circular path so that it initially moves with a constant period T . If the period is shortened to $\frac{1}{3}T$ without changing the radius of the circle, what is the new centripetal acceleration in terms of the original centripetal acceleration a_c ?
- (A)** $9a_c$
 - (B) $3a_c$
 - (C) a_c
 - (D) $a_c/3$
 - (E) $a_c/9$
- A10. The speed of a satellite of mass m , orbiting the Earth in a stable circular orbit of radius R , is V . The speed of a satellite of mass $2m$, in a stable circular Earth orbit of radius $4R$, is
- (A) $\frac{1}{4}V$
 - (B)** $\frac{1}{2}V$
 - (C) V
 - (D) $2V$
 - (E) $4V$

- A11. A hoop with spokes of negligible mass and a solid disk each have the same mass M and radius R . Both objects start from rest and are accelerated by the same force of constant magnitude F acting tangentially to the rim of the object so that they rotate as shown in the diagrams below. After a time t , how does the angular acceleration of the hoop α_h compare to the angular acceleration of the disk α_d ?



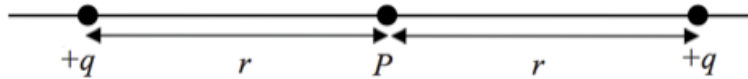
Hoop



Disk

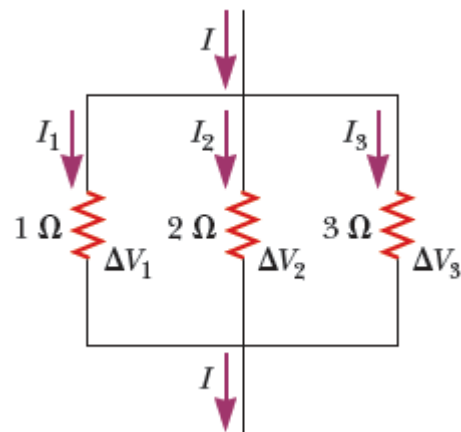
- (A) $\alpha_h = 2\alpha_d$ (B) $\alpha_h = 4\alpha_d$ **(C)** $\alpha_h = \alpha_d/2$ (D) $\alpha_h = \alpha_d/4$ (E) $\alpha_h = \alpha_d$
- A12. How would a spinning disk's kinetic energy change if its moment of inertia were five times larger but its angular speed were five times smaller?
- (A) 0.1 times as large as before. **(B)** 0.2 times as large as before.
(C) same as before. (D) 5 times as large as before.
(E) 10 times as large as before.
- A13. While a diver is moving through the air (after leaving the board and before hitting the water), which one of the following quantities must remain constant for the diver? You may ignore any effects due to air resistance.
- (A) position (B) velocity (C) momentum
(D) angular velocity **(E)** angular momentum about the diver's centre of mass
- A14. If two isolated, uncharged objects are rubbed together and one of them acquires a negative charge, then the other object...
- (A) remains uncharged.
(B) also acquires a negative charge.
(C) acquires a positive charge.
(D) acquires a positive charge equal to twice the magnitude of the negative charge.
(E) acquires a positive charge equal to half the magnitude of the negative charge.
- A15. If a negative charge is released from rest in a uniform electric field, it will move...
- (A) in the direction of the electric field.
(B) from high potential to low potential.
(C) from low potential to high potential.
(D) in a direction perpendicular to the electric field.
(E) in circular motion.

- A16. Two identical charges, each of magnitude q , are held a distance $2r$ apart on the x -axis. What is the magnitude of the electric field at point P midway between the charges?



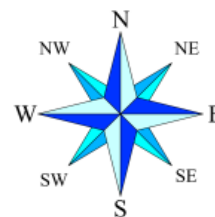
- (A) Zero (B) $\frac{k_e q}{r}$ (C) $\frac{2k_e q}{r^2}$ (D) $\frac{4k_e q}{r^2}$ (E) $\frac{8k_e q}{r^2}$
- A17. A wire with resistance R is cut into three pieces of equal length and then the three pieces are connected in parallel. What is the resistance of the parallel wiring?
- (A) $9R$ (B) $3R$ (C) R (D) $R/3$ (E) $R/9$

- A18. Given the circuit diagram shown to the right, which statement below concerning the current in each resistor or potential difference across each resistor is correct?



- (A) $I_1 = I$ and $I_2 = I_3 = 0$
 (B) $I_1 < I_2$ and $I_2 > I_3$
 (C) $\Delta V_1 < \Delta V_2 < \Delta V_3$
 (D) $I_1 > I_2 > I_3 > 0$
 (E) $I_1 + 2I_2 + 3I_3 = I$
- A19. Consider a battery with an emf of ε and internal resistance of r . The battery is initially connected to a resistor circuit that has an equivalent resistance of R . If the equivalent resistance of the resistor circuit increases, what happens to the terminal voltage and the current drawn from the battery? You may assume that the internal resistance does not change.
- (A) The current decreases and the terminal voltage also decreases.
 (B) The current decreases and the terminal voltage increases.
 (C) The current decreases and the terminal voltage does not change.
 (D) The current increases and the terminal voltage decreases.
 (E) The current increases and the terminal voltage also increases.

A20. An electron initially travelling North enters a region with a uniform magnetic field directed toward the center of the Earth. Which statement best describes the trajectory of the electron just as it enters the magnetic field? (image: <http://cliparts.co/clipart/3775881>)



- (A) The electron feels a magnetic force East and begins circular motion.
- (B) The electron feels a magnetic force West and begins circular motion.
- (C) The electron feels no magnetic force and continues in a straight path North.
- (D) The electron feels a magnetic force away from the surface of the Earth and begins circular motion.
- (E) The electron feels a magnetic force toward the center of the Earth and begins circular motion.

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.

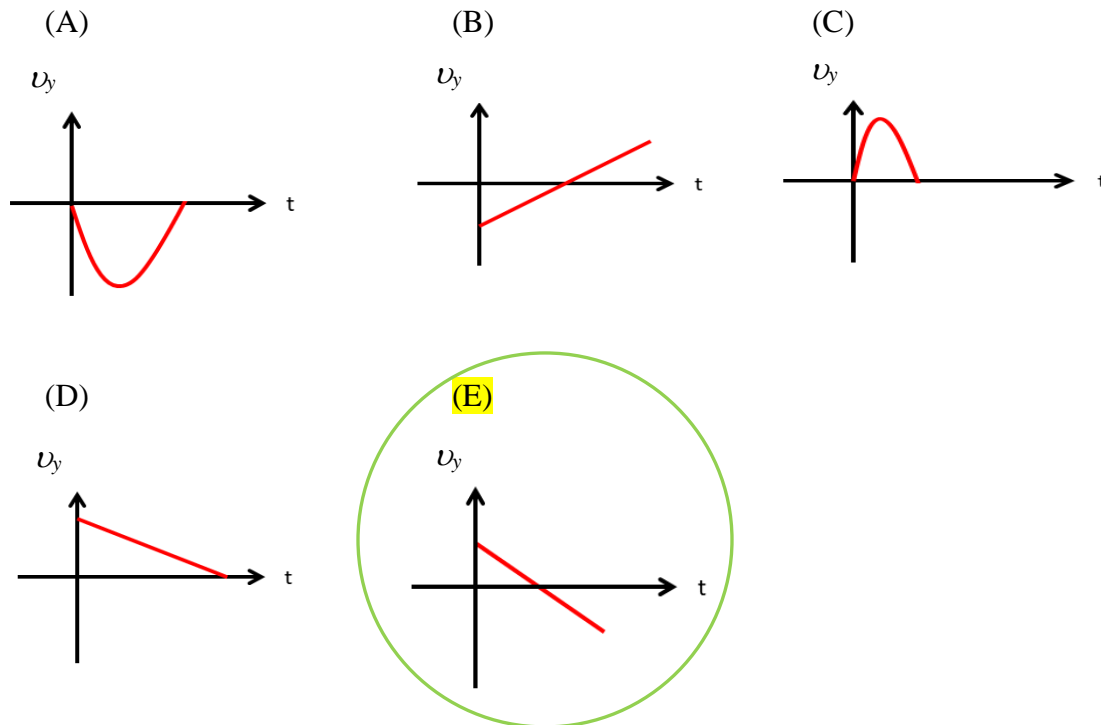
You may answer all six Part B question groupings (B21-24, B25-28, B29-32, B33-36, B37-40, and B41-44) and you will receive the marks for your best 5 groupings.

Use the provided exam booklet for your rough work.

Grouping B21 to B24:

A transport truck is travelling eastward with a constant speed of 55.0 km/h along a level road. At time $t = 0$ a person standing in the enclosed back of the truck throws an apple core vertically upward with an initial speed of 7.00 m/s. Ignore the effects of air resistance.

B21. Which one of the following velocity versus time graphs best describes the motion of the apple core in the vertical direction from the time it was released until it has returned to its original height?



B22. Calculate the time for the apple core to reach maximum height.

Choose the positive x and y directions to be horizontal to the right and vertically upward. Assume that the truck is moving horizontally to the right.

$$v_y = v_{oy} + a_y t \Rightarrow t = \frac{v_y - v_{oy}}{a_y} = \frac{0 - 7.00 \text{ m/s}}{-9.80 \text{ m/s}^2} = 0.7143 \text{ s}$$

B23. Calculate the horizontal displacement of the apple core, relative to the ground, from the time it was thrown until it has returned to the same height from which it was released.

The time for the apple core to return to its initial height can be calculated by noting that the vertical displacement is zero from release until return to initial height.

$$\Delta y = v_{oy}t + \frac{1}{2}a_y t^2 \Rightarrow 0 = v_{oy}t + \frac{1}{2}a_y t^2 \Rightarrow 0 = v_{oy} + \frac{1}{2}a_y t$$

$$t = \frac{-v_{oy}}{\frac{1}{2}a_y} = \frac{-(7.00 \text{ m/s})}{\frac{1}{2}(-9.80 \text{ m/s}^2)} = 1.429 \text{ s}$$

(Note that this total time of flight is exactly twice the time for the apple core to reach maximum height.)

$$\Delta x = v_x t = (55.0 \text{ km/h})(1000 \text{ m/km})(1 \text{ h}/3600 \text{ s})(1.429 \text{ s}) = 21.8 \text{ m}$$

B24. Calculate the velocity of the apple core, relative to the ground, when it reaches the same height from which it was released.

Relative to the ground, the apple core has a constant horizontal velocity of $(55.0 \text{ km/h})(1000 \text{ m/km})(1 \text{ h}/3600 \text{ s}) = 15.28 \text{ m/s}$. When it returns to the height from which it was thrown, the apple core has a vertical velocity of -7.00 m/s . The magnitude of the final velocity is calculated using the Pythagorean theorem and the direction of the final velocity is calculated using inverse tangent:

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{(15.28 \text{ m/s})^2 + (-7.00 \text{ m/s})^2} = 16.8 \text{ m/s}$$

$$\theta_v = \text{inv tan} \left| \frac{v_y}{v_x} \right| = \text{inv tan} \left| \frac{-7.00 \text{ m/s}}{15.28 \text{ m/s}} \right| = 24.6^\circ \text{ below the horizontal}$$

Grouping B25 to B28:

A block of wood of mass 1.64 kg is at rest on a frictionless horizontal surface. A bullet of mass 0.0192 kg is fired at the block of wood. The bullet is moving horizontally with a speed of 325 m/s when it strikes the block of wood. The bullet passes through the block of wood, emerging with a speed of 127 m/s.



B25. Which one of the following statements is correct concerning the effect of the collision on the momentum of the block and the momentum of the bullet?

- (A) The momentum of the bullet is unchanged and the momentum of the block is unchanged.
- (B) The magnitude of the change in momentum of the bullet is less than the magnitude of the change in momentum of the block.
- (C) The magnitude of the change in momentum of the bullet is greater than the magnitude of the change in momentum of the block.
- (D) The change in the momentum of the bullet equals the change in the momentum of the block.
- (E)** The change in the momentum of the bullet equals the negative of the change in the momentum of the block.

B26. Calculate the speed of the block of wood after the bullet has passed through it.

Momentum is conserved during the collision of the bullet and block of wood

$$\vec{P}_{tot,i} = \vec{P}_{tot,f} \Rightarrow m v_i = M V + m v_f \Rightarrow V = \frac{m(v_i - v_f)}{M}$$

$$V = \frac{(0.0192 \text{ kg})(325 \text{ m/s} - 127 \text{ m/s})}{1.64 \text{ kg}} = 2.318 \text{ m/s}$$

B27. Calculate the mechanical energy that is dissipated in the bullet-block interaction.

$$\Delta KE = KE_f - KE_i = \left(\frac{1}{2} M V^2 + \frac{1}{2} m v_f^2 \right) - \frac{1}{2} m v_i^2$$

$$\Delta KE = \left[\frac{1}{2} (1.64 \text{ kg})(2.318 \text{ m/s})^2 + \frac{1}{2} (0.0192 \text{ kg})(127 \text{ m/s})^2 \right] - \frac{1}{2} (0.0192 \text{ kg})(325 \text{ m/s})^2$$

$$\Delta KE = -855 \text{ J, so } |\Delta KE| = 855 \text{ J}$$

- B28. As the block slides across the horizontal surface, it encounters an area where the coefficient of kinetic friction between the block and the area is 0.111. Calculate the distance that the block slides in this area before coming to rest.

Since the surface is horizontal, the normal force is vertically upward with a magnitude equal to the weight of the block. The only force doing work on the block is the force of kinetic friction. The stopping distance can be calculated using the Work-Energy theorem.

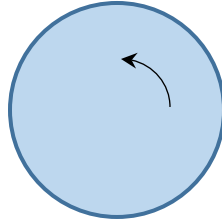
$$W_{net} = \Delta KE$$

$$f_k \Delta x \cos(180^\circ) = KE_{M,f} - KE_{M,i} \Rightarrow -\mu_k Mg \Delta x = -KE_{M,i} \Rightarrow \Delta x = \frac{-KE_{M,i}}{-\mu_k Mg} = \frac{\frac{1}{2} MV^2}{\mu_k Mg}$$

$$\Delta x = \frac{V^2}{2\mu_k g} = \frac{(2.318)^2}{2(0.111)(9.80 \text{ m/s}^2)} = 2.47 \text{ m}$$

Grouping B29 to B32:

A merry-go-round with a radius of 2.60 m is initially at rest. Starting at $t = 0$, a constant net torque is applied to the merry-go-round, resulting in a constant angular acceleration of 0.370 rad/s^2 .



B29. Calculate the number of revolutions of the merry-go-round in the first 3.40 s of angular acceleration.

$$\Delta\theta = \omega_o t + \frac{1}{2} \alpha t^2 = 0 + \frac{1}{2} (0.370 \text{ rad/s}^2)(3.40 \text{ s})^2 = 2.139 \text{ rad}$$
$$\Delta\theta = 2.139 \text{ rad} \times \frac{1 \text{ rev}}{2\pi \text{ rad}} = 0.3404 \text{ rev}$$

B30. At $t = 3.40 \text{ s}$, determine the tangential speed of a child located 1.35 m from the axis of rotation.

$$v_t = r\omega = r(\omega_o + \alpha t) = (1.35 \text{ m})(0.370 \text{ rad/s}^2)(3.40 \text{ s}) = 1.6983 \text{ m/s}$$

B31. At $t = 3.40 \text{ s}$, determine the magnitude of the total acceleration of the child.

The child has a tangential acceleration due to the angular acceleration of the merry-go-round and a radial acceleration due to the circular motion. These two accelerations are perpendicular to each other.

$$a_{tot} = \sqrt{a_t^2 + a_c^2} = \sqrt{(r\alpha)^2 + \left(\frac{v_t^2}{r}\right)^2}$$
$$a_{tot} = \sqrt{\left((1.35 \text{ m})(0.370 \text{ rad/s}^2)\right)^2 + \left(\frac{(1.6983 \text{ m/s})^2}{1.35 \text{ m}}\right)^2} = 2.194 \text{ m/s}^2$$

- B32. At $t = 3.40$ s, determine the direction of the total acceleration of the child. Specify the direction as the angle from the radially inward direction.

The angle of the total acceleration with respect to the radial direction is given by

$$\theta = \text{inv tan} \left(\frac{a_t}{a_c} \right) = \text{inv tan} \left(\frac{0.4995 \text{ m/s}^2}{2.136 \text{ m/s}^2} \right) = 13.2^\circ$$

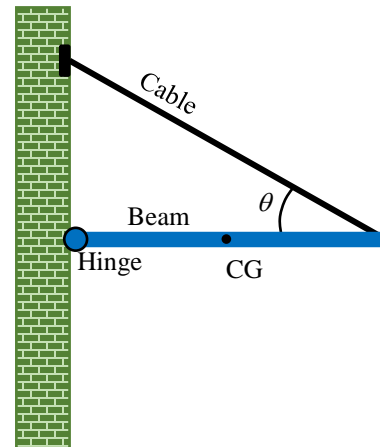
Check:

$$\theta = \text{inv tan} \left(\frac{r\alpha}{r\omega^2} \right) = \text{inv tan} \left(\frac{\alpha}{\omega^2} \right) = \text{inv tan} \left(\frac{\alpha}{(\alpha t)^2} \right) = \text{inv tan} \left(\frac{1}{\alpha t^2} \right)$$

$$\theta = \text{inv tan} \left(\frac{1}{\alpha t^2} \right) = \text{inv tan} \left(\frac{1}{(0.370 \text{ rad/s}^2)(3.40 \text{ s})^2} \right) = 13.2^\circ$$

Grouping B33 to B36:

A uniform horizontal beam 7.50 m long and weighing 355 N is attached to a vertical wall by a frictionless hinge so that it is free to rotate. A cable attaches the far end of the beam with the wall, and makes an angle of $\theta = 45.3^\circ$ with respect to the horizontal.



B33. Which one of the following statements best describes a system that is in mechanical equilibrium?

- (A) The net torque on the system must be zero, but the net force does not need to be zero.
- (B) The net force on the system must be zero, but the net torque does not need to be zero.
- (C) A system with only two forces acting on it that are equal in magnitude but opposite in direction always has a net torque of zero and therefore is in mechanical equilibrium.
- (D) The sum of the magnitudes of the forces on the system must be zero without consideration of the directions of the forces.

(E) The net force and the net torque on the system must each be zero.

B34. Calculate the magnitude of the tension in the cable.

To calculate the tension in the cable, apply torque equilibrium with respect to the hinge.

$$\sum \tau = 0 \Rightarrow +\tau_{cable} - \tau_{weight} = 0 \Rightarrow TL \sin \theta = mg \frac{1}{2} L$$

$$T = \frac{mg}{2 \sin \theta} = \frac{355 \text{ N}}{2(\sin(45.3^\circ))} = 249.7 \text{ N}$$

B35. Calculate the vertical component of the force exerted by the hinge on the beam.

To calculate the vertical component of the force exerted by the hinge, apply force equilibrium in the vertical direction.

$$\sum F_y = +F_{y,hinge} - mg + T \sin \theta$$

$$F_{y,hinge} = mg - T \sin \theta = 355 \text{ N} - (249.7 \text{ N})\sin(45.3^\circ) = 177 \text{ N}$$

B36. The maximum tension force that the cable can withstand before breaking is $4.00 \times 10^2 \text{ N}$. Calculate the maximum distance a 35.6 kg block can be placed on the beam, as measured from the hinge, without breaking the cable.

Set the tension to the maximum value and apply torque equilibrium with respect to the hinge.

$$\sum \tau = 0 \Rightarrow +\tau_{cable} - \tau_{weight} - \tau_{block} = 0 \Rightarrow T_{\max} L \sin \theta - m_{beam} g \frac{1}{2} L - m_{block} g \ell = 0$$

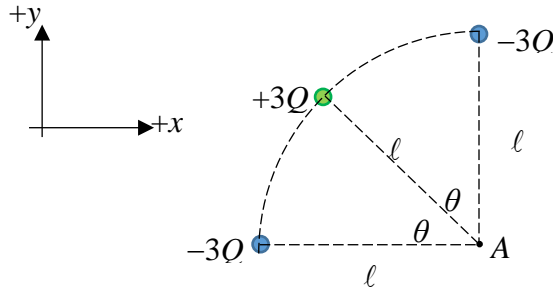
$$m_{block} g \ell = T_{\max} L \sin \theta - m_{beam} g \frac{1}{2} L$$

$$\ell = \frac{T_{\max} L \sin \theta - m_{beam} g \frac{1}{2} L}{m_{block} g} = \frac{L(T_{\max} \sin \theta - \frac{1}{2} w_{beam})}{m_{block} g}$$

$$\ell = \frac{(7.50 \text{ m}) \left[(400 \text{ N}) \sin(45.3^\circ) - \frac{1}{2} (355 \text{ N}) \right]}{(35.6 \text{ kg})(9.80 \text{ m/s}^2)} = 2.30 \text{ m}$$

Grouping B37 to B40:

Three point charges are fixed in place at points on a circular arc of radius ℓ as shown in the diagram. Angle θ is 45.0°



B37. Which one of the following expressions is correct for the electric potential at point A?

- (A) $3k_e \frac{Q}{\ell}$ (B) $-3k_e \frac{Q}{\ell}$ (C) $9k_e \frac{Q}{\ell}$ (D) $-6k_e \frac{Q}{\ell}$
(E) Since there is no charge at A, the electric potential at A is zero.

The electric potential at A is the sum of the potentials due to each of the charges.

$$V_A = k_e \frac{-3Q}{\ell} + k_e \frac{-3Q}{\ell} + k_e \frac{3Q}{\ell} = -3k_e \frac{Q}{\ell}$$

B38. Given that $Q = 1.00 \times 10^{-9} \text{ C}$ and $\ell = 0.155 \text{ m}$, calculate the electric potential energy of a proton placed at A.

$$PE_{el} = qV_A = (q) \left(-3k_e \frac{Q}{\ell} \right) = e \left(-3(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2) \frac{1.00 \times 10^{-9} \text{ C}}{0.155 \text{ m}} \right)$$

$$PE_{el} = e(-174 \text{ V}) = -174 \text{ eV}$$

B39. Which one of the following statements is correct for the direction of the electric field at point A?

- (A) The electric field at A is directed toward the $+3Q$ charge.
- (B) The electric field at A is in the $+x$ direction.
- (C) Since there is no charge at A, the electric field at A is zero.
- (D) The electric field at A is in the $-x$ direction.
- (E) The electric field at A is in the $+y$ direction.

Note that the magnitudes of the electric fields at A due to the two $-3Q$ charges are equal and the directions are perpendicular. Therefore, the net electric field at A due to the two $-3Q$ charges is directed at 45° above the $-x$ axis (toward the $+3Q$ charge). The electric field at A due to the $+3Q$ charge is directed away from the $+3Q$ charge. Therefore, the net electric field at A (due to all 3 charges) is directed either away from or toward the $+3Q$ charge.

B40. Which one of the following expressions is correct for the magnitude of the electric field at point A?

- (A) $9k_e \frac{Q}{\ell^2}$
- (B) $3k_e \frac{Q}{\ell^2}$
- (C) $1.24k_e \frac{Q}{\ell^2}$
- (D) $7.24k_e \frac{Q}{\ell^2}$
- (E) Since there is no charge at A, the electric field at A is zero.

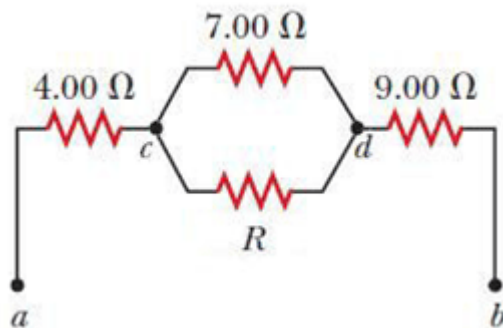
Note that the magnitudes of the electric fields at A due to the two $-3Q$ charges are equal and the directions are perpendicular. Therefore, the net electric field at A due to the two $-3Q$ charges is

$\sqrt{\left(k_e \frac{3Q}{\ell^2}\right)^2 + \left(k_e \frac{3Q}{\ell^2}\right)^2} = \sqrt{18} \left(k_e \frac{Q}{\ell^2}\right) = 4.243 \left(k_e \frac{Q}{\ell^2}\right)$, directed at 45° above the $-x$ axis (toward the $+3Q$ charge).

The electric field at A due to the $+3Q$ charge is $k_e \frac{3Q}{\ell^2}$, directed away from the $+3Q$ charge. Therefore, the net electric field at A (due to all 3 charges) is $4.243 \left(k_e \frac{Q}{\ell^2}\right) - 3 \left(k_e \frac{Q}{\ell^2}\right) = 1.24 \left(k_e \frac{Q}{\ell^2}\right)$ directed toward the $+3Q$ charge.

Grouping B41 to B44:

Consider the following circuit:



B41. Calculate the value of R given that the equivalent resistance between points c and d is 4.50Ω .

$$\frac{1}{R_{par}} = \frac{1}{R} + \frac{1}{7.00 \Omega} \Rightarrow \frac{1}{R} = \frac{1}{R_{par}} - \frac{1}{7.00 \Omega} \Rightarrow R = \left(\frac{1}{R_{par}} - \frac{1}{7.00 \Omega} \right)^{-1}$$

$$R = \left(\frac{1}{4.50 \Omega} - \frac{1}{7.00 \Omega} \right)^{-1} = 12.6 \Omega$$

B42. The potential difference between points a and b is 54.0 V . Calculate the current through the 9.00Ω resistor.

The 9.00Ω resistor carries the total current – the current that is drawn from the source of the potential difference.

$$I_{tot} = \frac{V_{ab}}{R_{tot}} = \frac{54.0 \text{ V}}{(4.00 \Omega + 4.50 \Omega + 9.00 \Omega)} = 3.086 \text{ A}$$

B43. Calculate the potential difference across resistor R .

The potential difference across R is the potential difference across points c and d . This equals the potential difference across points a and b minus the voltage drop across the 4.00Ω resistor and the voltage drop across the 9.00Ω resistor

$$V_{cd} = V_{ab} - V_{4\Omega} - V_{9\Omega} = V_{ab} - I_{tot}(4.00 \Omega + 9.00 \Omega) = 54.0 \text{ V} - (3.086 \text{ A})(13.0 \Omega) = 13.9 \text{ V}$$

B44. Calculate the current through resistor R .

Apply Ohm's Law

$$I_R = \frac{V_R}{R} = \frac{13.88 \text{ V}}{12.6 \Omega} = 1.10 \text{ A}$$

END OF EXAMINATION