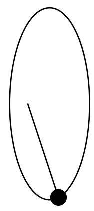


7. An object weighing 10.0 N is swung in a vertical circle of diameter 2.0 m. The object's critical velocity at sea level is most nearly

(A) 1 m/s
(B) 3 m/s
(C) 5 m/s
(D) 7 m/s
(E) 9 m/s

8. A waterfall is 100 m high. The increase in water temperature at the base is most nearly

(A) 0.2° C
(B) 0.8° C
(C) 1.2° C
(D) 2.0° C
(E) 2.8° C

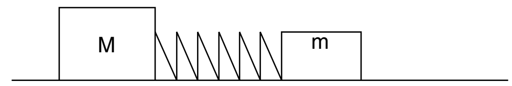
9. A pendulum with a period of 2 sec at sea level is observed in a spacecraft at an altitude above the earth, which is equal to the earth's radius. The pendulum at that altitude has a period of

(A) 2 sec
(B) 4 sec
(C) 6 sec
(D) 8 sec
(E) 10 sec

10. The number of Coulombs of charge contained in an alpha particle ${}^{4}_{2}\alpha$ is

(A) 1.6×10^{-19} C
(B) 2.4×10^{-19} C
(C) 3.2×10^{-19} C
(D) 4.8×10^{-19} C
(E) 5.2×10^{-19} C

Questions 11–13 refer to the following figure.



11. Two masses, M and m, rest on a frictionless horizontal surface as shown. They are attached by a compressed spring of negligible mass, M = 2 m. The spring is released, and the masses move apart. Compared with the total momentum of the masses before release, after release, the total momentum is

(A) half as much.
(B) unchanged.
(C) twice as much.
(D) four times as much.
(E) sixteen times as much.

12. The magnitude of the final momentum of mass M compared with that of mass m is

(A) half as much.
(B) the same.
(C) twice as much.
(D) four times as much.
(E) sixteen times as much.

13. The final kinetic energy of mass m, as compared to that of mass M, is

(A) $\frac{1}{4}$ as great.
(B) $\frac{1}{2}$ as great.
(C) zero.
(D) twice as great.
(E) four times as great.

14. A 20 kg box is pushed along a floor with constant speed and constant force of 40 N. The coefficient of friction between the box and the floor is

(A) 0.02
(B) 0.2
(C) 0.4
(D) 0.8
(E) 2

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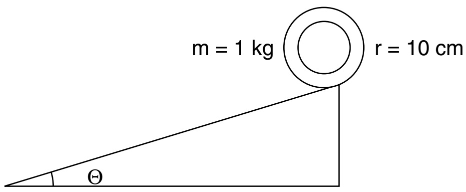
Questions 15–17 refer to the following figure.



15. A 1 kg hoop of radius 10 cm rolls from rest down a ramp and makes 1.5 rev. in 1 second. Its angular acceleration is

(A) 0.2π rad/s^2
(B) 2π rad/s^2
(C) 4π rad/s^2
(D) 6π rad/s^2
(E) 20π rad/s^2

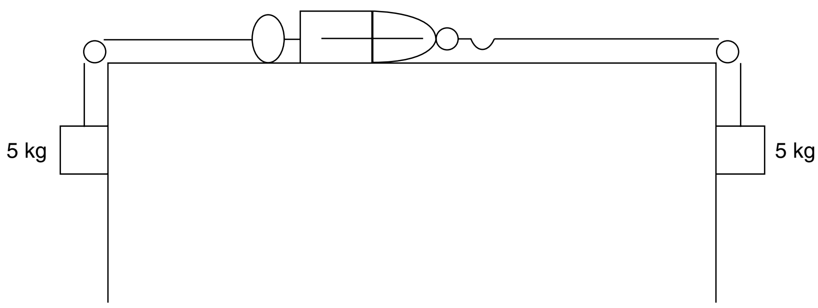
16. If I for the hoop equals mr^2, the net force acting on the hoop is closest to

(A) 2 N
(B) 4 N
(C) 6 N
(D) 8 N
(E) 10 N

17. The angle Θ of the ramp is nearest to

(A) 0°
(B) 15°
(C) 30°
(D) 45°
(E) 60°

Question 18 refers to the following figure.



18. Two 5 kg masses are attached to a spring scale by strings that pass over frictionless pulleys at the edge of a lab table as shown here. The spring scale reads

(A) 0 N
(B) 10 N
(C) 20 N
(D) 50 N
(E) 100 N

19. A 1500 kg car is being driven over a hill of radius 40 m. What is the greatest speed that the car may attain and still maintain contact with the road?

(A) 5 m/s
(B) 10 m/s
(C) 15 m/s
(D) 20 m/s
(E) 25 m/s

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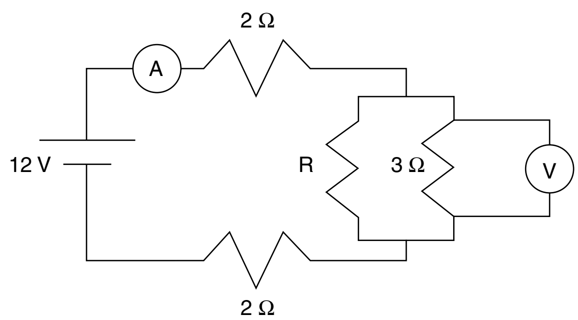
Questions 20–21 refer to the following figure.



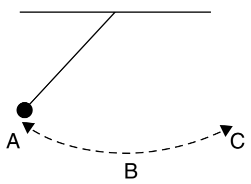
20. If the ammeter in the above illustration reads 2 A, resistor R has a value of

(A) 2 Ω
(B) 4 Ω
(C) 6 Ω
(D) 8 Ω
(E) 10 Ω

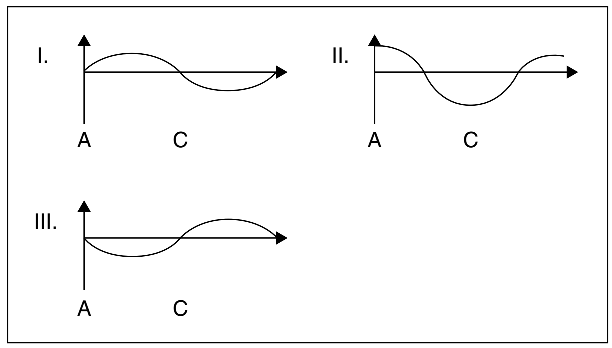
21. The current through the 3 Ω resistor is

(A) $\frac{1}{5}$ A
(B) $\frac{1}{3}$ A
(C) $\frac{2}{3}$ A
(D) $\frac{4}{5}$ A
(E) $\frac{4}{3}$ A

Questions 22–23 refer to the following figure.



22. The above illustration shows a pendulum in simple harmonic motion. Of the following, which represent the pendulum's velocity versus time and the acceleration vs time graphs?



(A) I and II
(B) I and III
(C) II and III
(D) III and I
(E) III and II

23. Which are the graphs most closely representative of potential energy E_P vs time and kinetic energy E_K versus time?

(A) I and II
(B) I and III
(C) II and I
(D) III and I
(E) III and II

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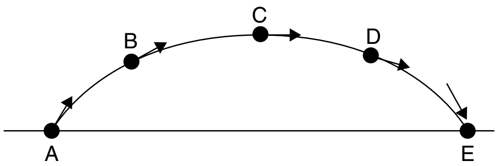
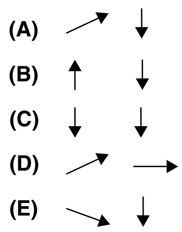
Questions 24–26 refer to the following figure.

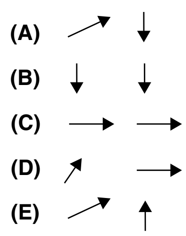


A soccer ball is kicked into the air and reaches its maximum height at point C. Points B and D are equidistant from the ground. Neglect air friction.

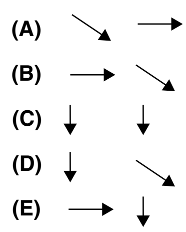
24. The arrows best showing the ball's instantaneous acceleration at points B and C are



25. The arrows best showing the ball's instantaneous velocity at points A and C are



26. The horizontal and vertical components of the velocity at point D are



27. A tea-heater coil of resistance R and current I is placed in a cup of water of mass m, to heat the water from room temperature to boiling at temperature T in t seconds. The heat needed for this process is

(A) IR/m
(B) I^2Rmt
(C) I^2Rm / t
(D) I^2Rt
(E) I^2R / t

Questions 28–30

A projectile is fired from a cannon at an angle of 30° with the horizontal and with an initial velocity of 40 m/s.

28. The time it spends in the air is

(A) 2 seconds.
(B) 4 seconds.
(C) 6 seconds.
(D) 8 seconds.
(E) 10 seconds.

29. The horizontal distance it will travel is

(A) < 100 m
(B) between 100 and 200 m
(C) between 200 and 400 m
(D) between 400 and 500 m
(E) > 500 m

30. It reaches a maximum height of

(A) 20 m
(B) 75 m
(C) 100 m
(D) 125 m
(E) 150 m

31. An X-Ray photon having a wavelength of 3 Å has an energy equivalent closest to

(A) 10^{-16} J
(B) 10^{-15} J
(C) 10^{-14} J
(D) 10^{-13} J
(E) 10^{-12} J

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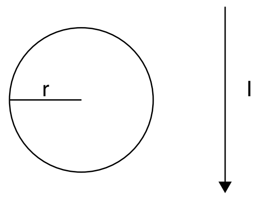

32. A circle of wire of radius r is brought near a straight wire carrying a current I, which is increasing in value. The wires are both on a flat, horizontal table, as seen from above. The false statement is

(A) The magnetic field inside the wire circle resulting from its induced current is directed out of the paper.
(B) The induced current in the circle flows counterclockwise.
(C) The current in the circle depends on the changing current in the straight wire.
(D) There is a constant magnetic flux through the circle.
(E) The magnetic flux inside the circle depends on the current in the straight wire.

33. A construction worker on a 20 m high scaffolding throws an object sideways with a speed of 9 m/s. A trash container is 20 m from the base of the scaffolding. How far from the container does the object land?

(A) 2 m
(B) 3 m
(C) 4 m
(D) 5 m
(E) 6 m

34. (3 Volts) × (3 seconds) × (3 Amperes) equals

(A) 27 N
(B) 27 Ω
(C) 27 W
(D) 27 J
(E) 27 C

35. A spring with spring constant k decompresses through a distance **x** and pushes a block of mass m out along a frictionless surface with velocity **v** =

(A) $\mathbf{x}k/m$
(B) $\mathbf{x}(m/k)^{\frac{1}{2}}$
(C) $\left(\frac{1}{2}\right)mk^2$
(D) $(k\mathbf{x})^{\frac{1}{2}}$
(E) $\mathbf{x}(k/m)^{\frac{1}{2}}$

36. A kilowatt-hour is a unit of

(A) force.
(B) current.
(C) capacitance.
(D) energy.
(E) power.

37. Each is a vector quantity except

(A) velocity.
(B) momentum.
(C) torque.
(D) energy.
(E) impulse.

38. A number of forces act on an object which is in rotational equilibrium. Which are true statements about the state of the object?

(A) There is no net force.
(B) There is no torque.
(C) There is no net torque.
(D) There is no acceleration.
(E) There is no momentum.

39. Total internal reflection occurs when

(A) $\sin i > \sin r$
(B) $i < r$
(C) $n < 1$
(D) $i > I_C$
(E) $c > n$

40. In order for a mass to accelerate, which is true?

(A) There must be no friction acting on it.
(B) There must be a force acting on it.
(C) There must be a net force acting on it.
(D) There must be no normal force acting on it.
(E) There must be a normal force acting on it.

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Physics B
Section II, Free Response Questions

Time — 90 Minutes, 7 questions of equal weight

Percent of total grade — 50

Instructions: When you are instructed to begin, carefully tear out the green insert and start working. The questions in the green insert are duplicates of the questions in this booklet. A helpful table of information and lists of equations that may be helpful to you are found on pages 1–3 of this booklet. NO CREDIT WILL BE GIVEN FOR ANYTHING WRITTEN IN THE GREEN INSERT. It is provided for reference only as you answer the free response questions.

Show all of your work. You are to write your answer to each question in the pink booklet. Additional answer pages follow each question. Credit for your answers depends on your demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Credit for your answers also depends on the quality of your solutions and explanations. Be sure to write CLEARLY and LEGIBLY. If you make an error, cross it out rather than erasing it. This may save you valuable time.

Advanced Placement Physics B Equations

Newtonian Mechanics		***Electricity and Magnetism***	
$\mathbf{v} = \mathbf{v}_0 + \mathbf{a}t$	**a** = acceleration	$\mathbf{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{\mathbf{r}^2}$	A = area
$\mathbf{x} = \mathbf{x}_0 + \mathbf{v}_0 t + \frac{1}{2}at^2$	**F** = force	$\mathbf{E} = \frac{\mathbf{F}}{q}$	**B** = magnetic field
$\mathbf{v}^2 = \mathbf{v}_0^2 + 2\mathbf{a}(\mathbf{x}-\mathbf{x}_0)$	f = frequency	$U_E = qV = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{\mathbf{r}}$	C = capacitance
$\Sigma\mathbf{F} = \mathbf{F}_{NET} = m\mathbf{a}$	h = height	$\mathbf{E}_{AVE} = -\frac{V}{\mathbf{d}}$	**d** = distance
$\mathbf{F}_{fric} \leq \mu\mathbf{N}$	**J** = impulse	$V = \frac{1}{4\pi\varepsilon_0}\Sigma(q)$	**E** = electric field
$\mathbf{a}_c = \frac{\mathbf{v}^2}{\mathbf{r}}$	K = kinetic energy	$C = \frac{Q}{V}$	**ε** = emf
$\tau = \mathbf{rF}\sin\Theta$	k = spring constant	$C = \frac{\varepsilon_0 A}{\mathbf{d}}$	**F** = force
$\mathbf{p} = m\mathbf{v}$	l = length	$U_c = \frac{1}{2}QV = \frac{1}{2}CV^2$	**I** = current
$\mathbf{J} = \mathbf{F}\Delta t = \Delta\mathbf{p}$	m = mass	$I_{AVE} = \frac{\Delta Q}{\Delta t}$	l = length
$K = \frac{1}{2}m\mathbf{v}^2$	**N** = normal force	$R = \rho(l/A)$	P = power
$\Delta U_g = m\mathbf{gh}$	P = power	$V = IR$	Q = charge
$\mathbf{W} = \mathbf{Fr}\cos\Theta$	**p** = momentum	$C_{PAR} = C_1 + C_2 + \ldots C_n$	q = point charge
$P_{AVE} = \frac{\mathbf{W}}{\Delta t}$	r = radius, distance	$\frac{1}{C_{SER}} = \frac{1}{C_1} + \frac{1}{C_2} = \ldots \frac{1}{C_n}$	R = resistance
$P = \mathbf{Fv}\cos\Theta$	**r** = position vector	$R_{SER} = R_1 + R_2 + \ldots R_n$	r = distance
$\mathbf{F}_s = -k\mathbf{x}$	T = period	$\frac{1}{R_{PAR}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots \frac{1}{R_n}$	t = time
$U_s = \frac{1}{2}k\mathbf{x}^2$	t = time	$\mathbf{F}_B = q\mathbf{vB}\sin\Theta$	U = potential (stored) energy
$T_P = 2\pi(1/\mathbf{g})^{\frac{1}{2}}$	U = potential energy	$\mathbf{F}_B = \mathbf{B}\,l\,\mathbf{I}\sin\Theta$	V = electric potential or potential difference
$T_S = 2\pi(m/k)^{\frac{1}{2}}$	**v** = velocity, (v) speed	$\mathbf{B} = \frac{\mu_0 I}{2\pi\mathbf{r}}$	**v** = velocity
$T = \frac{1}{f}$	**W** = work done on a system	$\phi_M = \mathbf{B}\cdot A = \mathbf{B}A\cos\Theta$	v = speed
$\mathbf{F}_G = -\frac{Gm_1 m_2}{r^2}$	**x** = position	$\varepsilon_{AVE} = \frac{\Delta\phi_M}{\Delta\tau}$	ρ = resistivity
$U_G = -\frac{Gm_1 m_2}{r}$	μ = coefficient of friction	$\varepsilon = \mathbf{Blv}$	ϕ_M = magnetic flux
	Θ = angle		
	τ = torque		

29. **(B)** First, find the horizontal component of the initial velocity: $\mathbf{v_{O\ H} = v_O}$ cos 30°

$$\mathbf{v_{O\ H} =} (40\text{ m/s})\frac{(3)^{\frac{1}{2}}}{2} = (20)(3)^{\frac{1}{2}}\text{ m/s}$$

Now, using $\mathbf{d_H = (v_H)(t)}$ = $(20)(3)^{\frac{1}{2}}$ m/s(4 sec) = $(80)(3)^{\frac{1}{2}}$ m or **between 100 and 200 m**.

30. **(D)** Using $\mathbf{d = v_O t + \left(\frac{1}{2}\right) a\ t^2}$,

$$\mathbf{d_V = (v_{O\ V})(t) + \left(\frac{1}{2}\right)(g)(t^2)} \text{ It takes 2 sec to reach the highest point.}$$

$$= (20\text{ m/s})(2\text{ sec}) - (5\text{ m/s}^2)(4\text{s}^2) = 40\text{ m} - 20\text{ m} = \mathbf{20\text{ m}}$$

31. **(B)** Using **f = v /λ** and **E = hf**,

$$E = h\mathbf{v} / \lambda = (6.63 \times 10^{-34}\text{J} \cdot \text{s})(3 \times 10^8\text{ m/s}) / (3 \times 10^{-10}\text{ m}) = 6.63 \times 10^{-16}\text{ J}$$

Rounding to the nearest power of 10: $\mathbf{10^{-15}}$ **J**

32. **(D)** The current is changing in the straight wire; therefore, the induced current in the circle is changing, as is the magnetic flux inside the circle, which is directed out of the paper. The induced current flows counterclockwise in the circle.

33. **(A)** Using $\mathbf{d = v_O t + \left(\frac{1}{2}\right)at^2}$, to find the time the object is in the air:

(Position formula for vertical displacement)

$$-20\text{ m} = -5\text{ m/s}^2\ (t^2)$$

$$t = 2\text{ sec in the air.}$$

For the horizontal displacement: (Position formula for horizontal displacement)

$$\mathbf{d = v_O t + \left(\frac{1}{2}\right)at^2}$$

$$\mathbf{d} = (9\text{ m/s})(2\text{ sec}) = 18\text{ m.}$$

The object lands **2 m away from the container.**

34. **(D)** (3 Volts) × (3 seconds) × (3 Amperes) = (3 J / C)(3 sec)(3 C / s) = **27 J**

35. **(E)** Setting the energy in the compressed spring $\mathbf{E_P = \left(\frac{1}{2}\right)kx^2}$ equal to the kinetic energy of the sliding mass $\mathbf{E_K = \left(\frac{1}{2}\right)mv^2}$, $\left(\frac{1}{2}\right)\text{k}\mathbf{x}^2 = \left(\frac{1}{2}\right)\text{m}\mathbf{v}^2$

$$\mathbf{v}^2 = \text{k}\mathbf{x}^2/\text{ m and } \mathbf{v = x\ (k / m)^{\frac{1}{2}}}$$

36. **(D)** A kilowatt-hour equals 1 kW times 1 hr:

(1000 W)(3600 sec) = (1000 J / s)(3600 sec) = $\mathbf{3.6 \times 10^6}$ **J of energy.**

37. **(D)** Velocity is defined as speed with direction. Momentum is velocity times mass in a particular direction. Torque is a turning force and is either clockwise or counterclockwise in direction. Impulse is force over a certain amount of time in a particular direction. **Energy is not a vector.** (For instance, energy stored in a spring or a battery has a magnitude but no direction.)

38. **(C)** Although the object may be in rotational equilibrium, it may still be moving in a straight line, possibly accelerating, and possibly possessing momentum. The torques on the object are balanced, therefore there is **no net torque.**

57. **(B)** Decreasing temperature extracts energy, decreasing the kinetic energy of molecular vibrations, which decreases the number of electron collisions encountered in current flow.

58. **(C)** The rock travels 2 m in the first second. Its average **speed** for the first second is 2 m/s. 2m/s is the average of (0 + 4m/s) /2. The rock picks up speed at the rate of **4 m/s/s.**

59. **(D)** Using Hooke's Law, $\mathbf{F = -kx}$,

$$-k = \frac{(\mathbf{F/x}) = (2\,\text{kg})(10\,\text{m/s}^2)}{(0.5\,\text{m})} = \mathbf{40\ N/m}$$

60. **(E)** Using $\mathbf{F_G} = \frac{\text{G M1 M2}}{\mathbf{r}^2}$,

$$\mathbf{F_G} = \frac{\text{G M1 M2}}{\mathbf{d}^2}$$

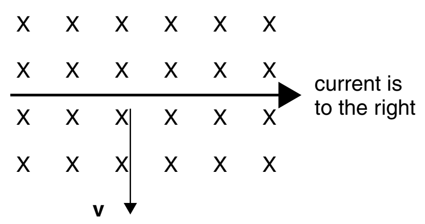
61. **(E)** At point P, the marble's velocity is directed toward the right. At P, its acceleration is centripetal due to its circular path and is directed toward the center.

62. **(B)** Using the right hand, pointing the thumb in the direction of the current flow, the fingers curl in the direction of the magnetic field.

63. **(A)** Using $\varepsilon = \mathbf{Blv}$,

$$\varepsilon = (0.5\ \text{T})(0.2\ \text{m})(0.2\ \text{m/s}) = \mathbf{0.02\ V}$$

64. **(D)** Using **F = qvXB,** fingers swing from **v** to **B** and the thumb points in the direction of **F**.



65. **(B)** Since $\varepsilon = \mathbf{Blv}$, the emf is directly related to wire speed.

66. **(D)** Since one half-life is 60 years, 60 years / half-life × 1 half-life = $\frac{1}{2}$ sample remains

120 years	$\frac{1}{4}$
180 years	$\frac{1}{8}$
240 years	$\mathbf{\frac{1}{16}}$

67. **(E)** Thinner wire increases resistance, resulting in decreased current.

68. **(D)** Using the Law Of Conservation of Momentum:

$$m\mathbf{v} + M(0) = (m + M)\,\mathbf{V}$$

$$\frac{m\mathbf{v}}{(m + M)} = \mathbf{V}$$

69. **(B)** Using $\mathbf{P} = \frac{\mathbf{W}}{t} = \frac{\mathbf{Fd}}{t} = \frac{\text{MgH}}{t}$

70. **(C)** Using $P = \frac{\text{MgH}}{t}$,

$$P = (3.0\ \text{kg})(10\ \text{m/s}^2)(0.5\ \text{m})/(1.0\ \text{s}) = \mathbf{15\ W}$$

Sample B Exam #1 Answers and Comments

Free Response

1. **(a)** $\mathbf{F_{WT} = F_N =}$ 500 N and the mass of the crate is 500 N / 9.8 m/s^2 = 51 kg.

$\mathbf{V_O} =$ 10 m/s, $\mathbf{V_F} = 0$, $\mathbf{d} = 12$m Using $\mathbf{V_F^2 = V_O^2 + 2ad}$, $\mathbf{a} = (-100\ m^2/s^2)/24\ m$ $\mathbf{= -4.2\ m/s^2}$

(b) Using $\mu = \mathbf{F_F} / \mathbf{F_N}$, $\mu = \frac{m\mathbf{a}}{m\mathbf{g}} = \mathbf{a/g} = \frac{-4.2\ m/s^2}{-9.8\ m/s^2} = \mathbf{0.43}$

(c) Using $\mathbf{W = Fd = (ma)d}$, $\mathbf{W} = \frac{(500\ N)}{(9.8\ m/s^2)}(-4.2\ m/s^2)\ (12\ m) = \mathbf{2600\ J}$

(d) The kinetic energy of the crate when it begins sliding is completely turned into heat by the work done in stopping it. Its kinetic energy was also **2600 J.**

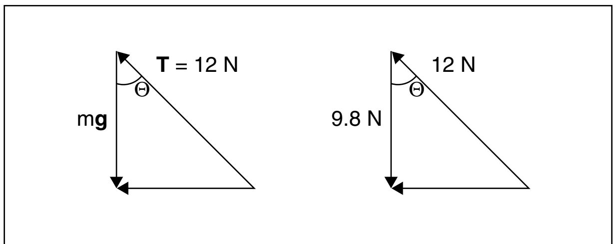
(e) Halving the original coefficient of friction would make the crate slide farther before stopping but the **same amount of work would still be done**, just spread over a larger distance: 2600 J.

(f) Using $\mathbf{V_F^2 = V_O^2 + 2ad}$, $0 = (10\ m/s^2)^2 + (2)(\mathbf{a})(20\ m)$

$$\mathbf{a_{WET}} = -2.5\ m/s^2$$

Using $\boldsymbol{\mu} = \frac{\mathbf{F_F}}{\mathbf{F_N}}$, $\mu = \frac{(m\mathbf{a})}{(m\mathbf{g})} = \frac{\mathbf{a}}{\mathbf{g}} = \frac{-2.5\ m/s^2}{-9.8\ m/s^2} = \mathbf{0.26}$

2.



(a) $\cos \Theta = \frac{m\mathbf{g}}{\mathbf{T}} = \frac{9.8\ N}{12\ N} = 0.8166$ and $\mathbf{\Theta = 35.2°}$

(b) Since the velocity will be determined from the centripetal force,

$$\mathbf{F_C} = \frac{m\mathbf{v}^2}{r}$$

$$\mathbf{F_C} = (12\ N)(\sin \Theta) = (12\ N)(\sin 35.2°) = 6.9\ N \qquad \frac{(1\ kg)(\mathbf{v}^2)}{(0.58\ m)}$$

$$\mathbf{v} = \left[\frac{(6.9\ N)(0.58\ m)}{(1\ kg)}\right]^{\frac{1}{2}} = \mathbf{2.0\ m / s}$$

(c) i. With the new mass: $\cos \Theta = \frac{m\mathbf{g}}{\mathbf{T}} = \frac{(1.2\ kg)(9.8\ m/s^2)}{12\ N} = 0.98$ and $\Theta = \mathbf{11.5°}$

ii. Again using centripetal force:

$$\mathbf{F_C} = \frac{m\mathbf{v}^2}{r}$$

$$\mathbf{F_C} = (12\ N)(\sin \Theta) = (12\ N)(\sin 11.5°) = 2.39\ N \qquad \frac{(1\ kg)(v^2)}{(0.20\ m)}$$

$$\mathbf{v} = \left[\frac{(2.39\ N)(0.20\ m)}{(1.2\ kg)}\right]^{\frac{1}{2}} = \mathbf{0.63\ m / s}$$

(d) Part (a) will now be **half** as much since only **half the mass is being lifted**.

Part (b) will be **unchanged** since **the water's mass does not affect the calculation in** $\Delta \mathbf{T} = \frac{2gy}{c}$.

Part (c)will be **unchanged**, again since **mass does not affect the calculation in** $\Delta \mathbf{T} = \frac{2gy}{c}$.

(e) Using **Eff =** $\frac{\text{Work Out}}{\text{Work In}} = \frac{\text{Energy Out}}{\text{Energy In}}$

or $\frac{\Delta T.\text{Observed}}{\Delta T.\text{Predicted}}$

$$\text{Efficiency} = \frac{(0.41^\circ C)}{(0.7^\circ C)} = 0.59 \text{ or } \mathbf{59\%}$$

5. **(a)** Using $\mathbf{mgh}_{BOFFO} = \mathbf{mgh}_{BEPPO}$

$$(314\text{ N})(1.8\text{ m}) = (225\text{ N})(\mathbf{h_{BEPPO}})$$

$$\mathbf{h_{BEPPO} = 2.5\ m}$$

(b) Using $\mathbf{mgh}_{BOFFO} = \mathbf{mgh}_{BEPPO+COCO}$

$$(314\text{ N})(\mathbf{h_{BOFFO}}) = (225\text{ N} + 45.5\text{ N})(2.5\text{ M})$$

$$\mathbf{h_{BOFFO} = 2.2\ m}$$

(c) Using $\mathbf{mgh}_{BOFFO} = \mathbf{mgh}_{BEPPO}$

$$(314\text{ N})(2.2\text{ m}) = (225\text{ N})(\mathbf{h_{BEPPO}})$$

$$\mathbf{h_{BEPPO} = 3.1\ m}$$

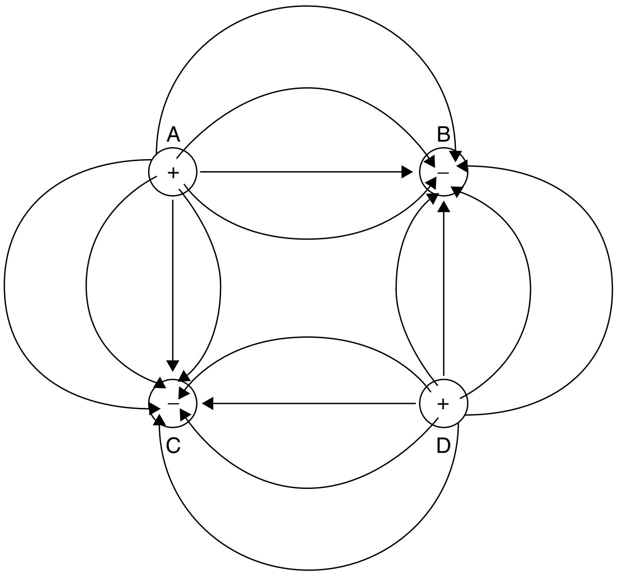
(d) Using Boffo's potential energy converted to kinetic energy:

$$\mathbf{mgh}_{BOFFO} = \left(\frac{1}{2}\right)\mathbf{mv^2}$$

$$\mathbf{v}_{BOFFO} = \sqrt{2gh}$$

$$\mathbf{v}_{BOFFO} = \mathbf{6.6\ m/s}$$

6. **(a)**



(b) The total electric force on charge B is equal to the sum of the forces of the other three charges on charge B: (k has been substituted for $\frac{1}{4\pi\varepsilon_0}$)

$$\mathbf{F_{TOTB} = F_{AB} + F_{BD} + F_{BC} = F_{BC} - F_{AB} - F_{BD}}$$

$$\mathbf{F_{BC}} = \frac{(k)(-3.0\,nC)(-3.0\,nC)}{\left[(0.02\,m)^2(0.02\,m)^2\right]} = \frac{(9.0\times10^9\,Nm^2/C^2)(9.0\times10^{-18}\,C^2)}{(8.0\times10^{-4}\,m^2)} = 1.0\times10^{-4}\,N$$

$$\mathbf{F_{AB}} = \frac{(k)(+3.0\,nC)(-3.0\,nC)}{(0.02\,m)^2} = \frac{(9.0\times10^9\,Nm/C^2)(-9.0\times10^{-18}\,C^2)}{4.0\times10^{-4}\,m^2} = -2.0\times10^{-4}\,N$$

$$\mathbf{F_{BD} = F_{AB}} = -2.0\times10^{-4}\,N$$

The vector sum of the attractive forces due to charges A and D is the Pythagorean of F_{AB} and F_{BD}, which equals -2.8 × 10^{-4}N directed toward the charge of C. Therefore:

$$\mathbf{F_{TOTB}} = 1.0\times10^{-4}\,N - 2.8\times10^{-4}\,N = \mathbf{-1.8\times10^{-4}\,N\ directed\ toward\ charge\ at\ 225°\ C}.$$

(c) Using $\mathbf{V = \Sigma\frac{kq}{r}}$,

$$\mathbf{V} = \frac{(9\times10^9\,Nm^2/C^2)}{(0.028/2\,m)}[+3\,nC +3\,nC -3\,nC -3\,nC] = \mathbf{0}$$

(d) Using $\mathbf{E} = \Sigma\frac{\mathbf{F}}{q} = \Sigma\frac{kq}{\mathbf{r}} = \frac{(9\times10^9\,Nm^2/C^2)}{(0.028\,m)^2}[+3\,nC +3\,nC -3\,nC -3\,nC] = \mathbf{0}$

There are two pairs of vectors that are anitparallel and thus add up to zero.

7. **(a)** Using $\mathbf{F_{BUOY} = V\rho g}$,

$$\mathbf{F_{BUOY}} = \left(\frac{4}{3}\right)(\pi)(0.04\,m)^3(1000\,kg/m^3)(9.8\,m/s^2) = \mathbf{2.6\,N}$$

(b) $\mathbf{F_{TENSION} = F_{BUOY} - F_{WT}} = 2.6\,N - (0.01\,kg)(9.8\,m/s^2) = \mathbf{2.5\,N}$

(c) $\mathbf{F_{TENSION} = F_{BUOY} - F_{WT}}$

$$= \left(\frac{4}{3}\right)(\pi)(0.08\,m)^3(1000\,kg/m^3)(9.8\,m/s^2) - (0.01\,kg)(9.8\,m/s^2)$$
$$= 21.0\,N - 0.098\,N \cong \mathbf{21.0\,N}$$