General Physics: Final Exam (version 2)

11 December 2019

Name: Solution **Total:** /150

Instructions

- There are 15 questions on 10 pages.
- Show your reasoning and calculations and always explain your answers.

Physical constants and useful formulae

$$g = 9.80\,\text{m/s}^2 \qquad G = 6.67 \times 10^{-11}\,\text{Nm}^2/\text{kg}^2$$

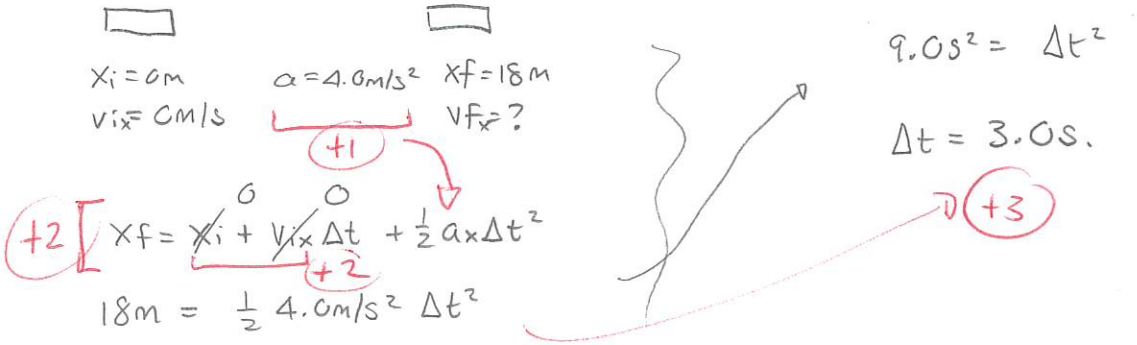
$$\text{Cylinder/disk: } I = \frac{1}{2}mr^2 \qquad \text{Hoop: } I = mr^2 \qquad \text{Solid sphere: } I = \frac{2}{5}mr^2$$

$$R = 8.314\,\text{J/mol K} \qquad N_\text{A} = 6.02 \times 10^{23}\,\text{/mol} \qquad T_K = T_C + 273.15 \qquad T_F = \frac{9}{5}T_C + 32$$

$$P_\text{atmos} = 1.01 \times 10^5\,\text{Pa} \qquad \rho_\text{water} = 1.0 \times 10^3\,\text{kg/m}^3$$

Question 1

A cart is at rest on a horizontal surface at the moment that a constant force starts to act on it. While the force acts on the cart it has a constant acceleration of $4.0\,\text{m/s}^2$ to the right and it reaches a point 18.0 m from its starting location. Determine how long it takes the cart to travel a distance of 18.0 m from its starting location.



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Question 2

A 0.145 kg baseball is struck with speed 30 m/s at an angle of 70° from the horizontal. Ignoring air resistance, determine the maximum height that the baseball reaches.

$v_{ix} = v_i \cos 70°$ ← not needed here.

$v_{iy} = v_i \sin 70°$

$= 30\,m/s \sin 70°$

$= 28\,m/s$

$t_i = 0s$ $t_f =$

$x_i = 0m$ $x_f = ?$

$y_i = 0m$ $y_f = ?$

$v_{ix} =$

$v_{iy} =$ $v_{fy} = 0m/s$

$a_x = 0m/s^2$

$a_y = -9.8m/s^2$

must be all y...

otherwise only +1

$v_{fy}^2 = v_{iy}^2 + 2 a_y \Delta y$

$(0m/s)^2 = (28m/s)^2 + 2 \times (-9.8m/s^2)\,\Delta y$

$\Rightarrow -795m^2/s^2 = -19.6m/s^2\,\Delta y$

$\Rightarrow \Delta y = \dfrac{-795m^2/s^2}{-19.6m/s^2}$

$= 41m$

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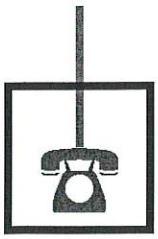
Question 3

A phone with mass m is suspended in an elevator as illustrated. The elevator moves up with a decreasing speed. The rope suspending the phone has no slack throughout the motion. Which of the following (choose one) is true regarding the tension in the rope that suspends the phone?



i) $T = 0\,N$.

ii) $T = mg$.

iii) T is larger than mg.

iv) T is smaller than mg but larger than $0\,N$

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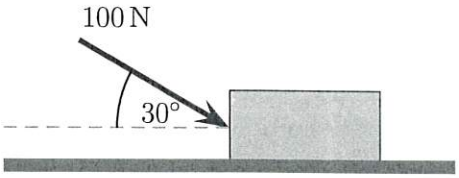
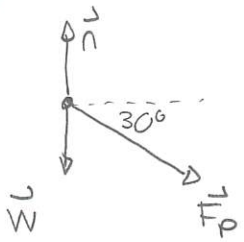
Question 4

A person pushes with a force of magnitude 100 N on a 10 kg block at an angle of 30° above the horizontal as illustrated. The block moves along a horizontal frictionless surface.



a) Determine the magnitude of the acceleration of the block.



+3

$\Sigma F_x = ma_x$] +1

$\Sigma F_y = ma_y = 0$

$W = mg = 10\,kg \times 9.8\,m/s^2 = 98\,N$ +1

Components

	x	y
n	0	n
W	0	−98 N
F_P	87 N	neg...

+3

$F_{Px} = F_P \cos 30°$

$= 100N \cos 30° = 87\,N$ +4.5

So $\Sigma F_x = ma_x$

$\Rightarrow 87N = 10\,kg\ a_x$

$\Rightarrow a_x = 8.7\,m/s^2$

+5

+2

b) Which of the following (choose one) is true regarding the magnitude of the normal force, n, exerted by the floor on the block?

i) $n = mg$
ii) $n > mg$
iii) $n < mg$

$\Sigma F_y = 0$

$n - 98N + F_{Py} = 0$

$n = 98N - F_{Py}$

this is negative

So $n > 98N$

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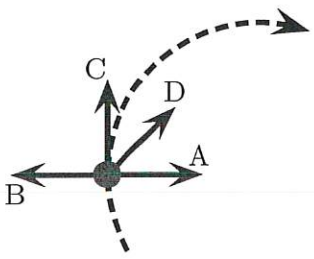
Question 5

A bug walks at a constant speed clockwise along a circular path on a horizontal surface. Which vector best illustrates the net force on the bug at the illustrated moment? Explain your choice.



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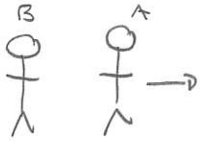
Question 6

Two ice skaters, Alice and Bob, are initially at rest on a frictionless horizontal ice sheet. Alice has mass 50 kg and Bob 100 kg. Alice pushes off of Bob and she then slides straight east with speed 5.0 m/s. Determine the velocity (including direction) with which Bob moves after they are separated.



East

initial

$v_{iA} = 0$ m/s

$v_{iB} = 0$ m/s

after

$v_{fA} = 5.0$ m/s

$v_{fB} = ??$

No net external force $\Rightarrow$ momentum conserved.

$p_{tot\,f} = p_{tot\,i}$

$m_A v_{fA} + m_B v_{fB} = m_A v_{Ai} + m_B v_{Bi} = 0$ kg m/s.

$50\text{kg} \times 5.0\text{m/s} + 100\text{kg}\, v_{fB} = 0$

$100\text{kg}\, v_{fB} = -250\text{kg m/s}$

$v_{fB} = -2.5$ m/s

← west.

+1

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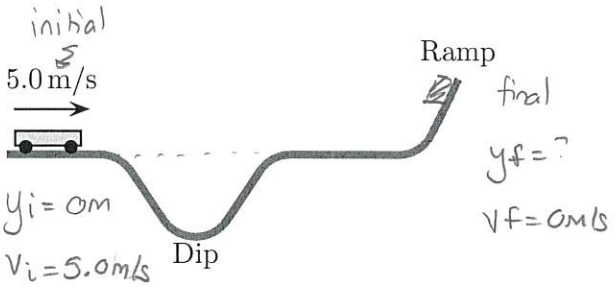
Question 7

A 0.250 kg cart approaches a dip on the illustrated frictionless track. While the cart moves along the horizontal surface on the left, its speed is 5.0 m/s. The bottom of the dip is 0.80 m below the horizontal.



a) Determine the maximum height that the cart reaches on the ramp at the right.

Work done by non-conservative forces = 0. Energy conserved

$E_f = E_i$

$K_f + U_{gf} = K_i + U_{gi}$ (+3)

$\frac{1}{2}mv_f^2 + mgy_f = \frac{1}{2}mv_i^2 + mgy_i$ (0 m/s, 0m)

(+2) (+2) (+2)

$mgy_f = \frac{1}{2}mv_i^2$

$= \frac{1}{2}\, 0.250kg\, (5.0m/s)^2 = 3.125J$ (+2)

$0.250kg \times 9.8 m/s^2\, y_f = 3.125J$

$y_f = \frac{3.125J}{0.250kg \times 9.8 m/s^2}$ (+4) (+3)

$= 1.3m$

b) The track is replaced by another but with a shallower dip (depth 0.40 m). Which of the following (choose one) is true?

(+4)

i) The cart reaches a higher point on the ramp than it did with a deeper ramp.

ii) The cart reaches a lower point on the ramp than it did with a deeper ramp.

iii) The cart reaches the same on the ramp as it did with a deeper ramp.

The dip does not change the total energy which remains the same. So U_g at end is same ⇒ same height.

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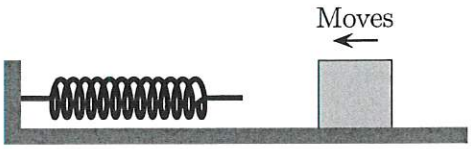
Question 8

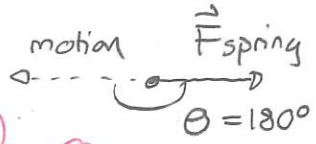
A box slides along a rough horizontal surface toward a spring. The box hits the spring and compresses it. *While the spring is being compressed by the block*, let W_{spring}, be the work done by the spring and W_{f} the work done by friction.



a) Which of the following (choose one) is true *while the spring is being compressed?*

i) $W_{\text{spring}} = 0$
ii) $W_{\text{spring}} > 0$
iii) $W_{\text{spring}} < 0$

Explain your answer.



$W_{spring} = F_{spring}\, d \cos\theta$ (+2) (4!) (+2)

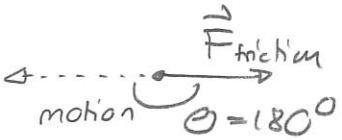
$= F_{spring}\, d \cos 180°$ (+2) $= -1$

so negative. (4!) (+2)

b) Which of the following (choose one) is true *while the spring is being compressed?*

i) $W_{\text{f}} = 0$
ii) $W_{\text{f}} > 0$
iii) $W_{\text{f}} < 0$

Explain your answer.



By same reasoning as above $\theta = 180° \Rightarrow$ W_f negative (+2) (+2)

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Question 9

Two moving objects have the same masses. The kinetic energy of object A is 4 times the kinetic energy of object B. Which of the following (choose one) is true?

i) The speed of A is the same as the speed of B.
ii) The speed of A is twice the speed of B. (+2)
iii) The speed of A is four times the speed of B.
iv) The speed of A is 16 times the speed of B.

Explain your answer.

$K_A = \frac{1}{2} m_A v_A^2$ (+2)

$K_B = \frac{1}{2} m_B v_B^2$

$K_A = 4 K_B$ (+3)

$\Rightarrow \frac{1}{2} m_A v_A^2 = 4\left(\frac{1}{2} m_B v_B^2\right)$

$v_A^2 = 4 v_B^2 \Rightarrow v_A = 2 v_B$

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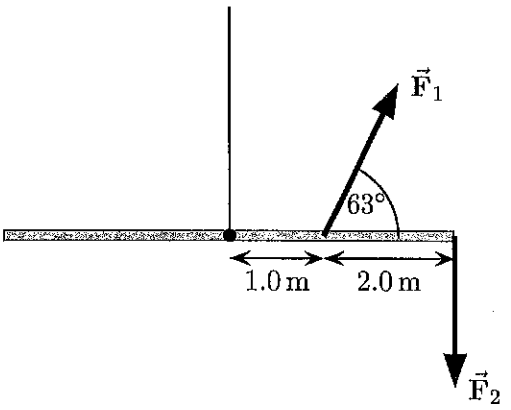
Question 10

A 6.0 m rod with mass 10 kg is suspended from its midpoint as illustrated. Two forces are applied to the rod at the indicated points and the rod remains at rest horizontally. The magnitude of $\vec{F}_1$ is 50 N. The other force $\vec{F}_2$ acts vertically downward. Determine the magnitude of $\vec{F}_2$.



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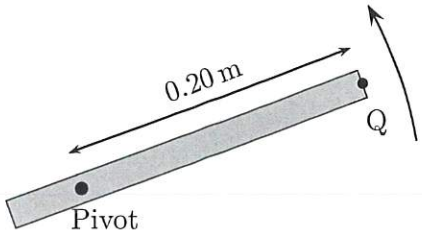
Question 11

A solid rod of length 0.25 m rotates about the illustrated pivot. It does four complete revolutions every second. Determine the angular velocity and the tangential velocity (speed) of the point Q at the end of the rod.



$\omega = \frac{\Delta\theta}{\Delta t}$ +1

$\Delta\theta = 4 \times 2\pi \text{ rad} = 8\pi \text{ rad}$ +2

$\Delta t = 1.0 \text{ s}$

$\Rightarrow \omega = \frac{8\pi \text{ rad}}{\text{s}} = 25 \text{ rad/s}$ +2

$v = \omega r = 8\pi \text{ rad/s} \times 0.20 \text{ m}$ +1

$= 1.6\pi \text{ rad/s}$

$\Rightarrow v = 5.0 \text{ m/s}$ +2

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Question 12

An ideal gas is kept at room temperature in a container with constant volume. The container is connected to a pump which can remove or add gas molecules. Initially there is 1 mol of gas in the container at atmospheric pressure $P_{\text{atm}} = 1.01 \times 10^5$ Pa. The pump then operates, reducing the pressure to $\frac{1}{4}P_{\text{atm}}$ while keeping the volume and temperature constant. Which of the following (choose one) is true?

i) The number of moles of gas at the end of the process is $\frac{1}{4}$ mol.

ii) The number of moles of gas at the end of the process is $\frac{1}{2}$ mol.

iii) The number of moles of gas at the end of the process is 1 mol.

iv) The number of moles of gas at the end of the process is 2 mol.

v) The number of moles of gas at the end of the process is 4 mol.

$PV = nRT$

$P = n\left(\frac{RT}{V}\right)$ ($\frac{RT}{V}$ constant)

$n = \left(\frac{V}{RT}\right)P$

If P is reduced to $\frac{1}{4}$ then n is reduced to $\frac{1}{4}$

/5

Question 13

A 1.5 kg block of copper is dropped into 10 kg of water. The copper is initially cooler than the water but during a initial period its temperature increases by 5.0° C. Determine the change in temperature of the water during this period.

	c	L_f	L_v
Water	4.18×10^3 J/kg·°C	3.33×10^5 J/kg	2.26×10^6 J/kg
Copper	3.85×10^2 J/kg·°C	2.09×10^5 J/kg	4.73×10^6 J/kg

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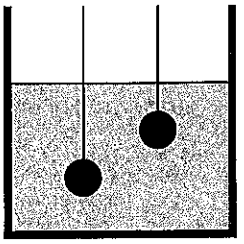
Question 14

Two balls are suspended at rest in a fluid. The balls have the same volume but the density of the ball on the right is twice that of the density of the ball on the left. The ball on the left is at twice the depth beneath the surface as that on the right. Let $F_{\text{B left}}$ be the buoyant force on the ball on the left and $F_{\text{B right}}$ be the buoyant force on the ball on the right. Which of the following (choose one) is true?



i) $F_{\text{B left}} = \frac{1}{4}F_{\text{B right}}$

ii) $F_{\text{B left}} = \frac{1}{2}F_{\text{B right}}$

iii) $F_{\text{B left}} = F_{\text{B right}}$

iv) $F_{\text{B left}} = 2F_{\text{B right}}$

v) $F_{\text{B left}} = 4F_{\text{B right}}$

Volumes are same

$F_B = \rho_{fluid}\, g\, V_{disp}$

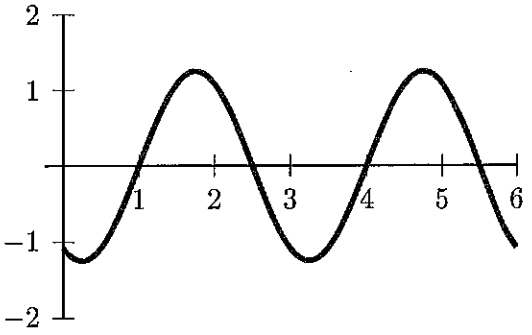
same same.

so F_B same.

/5

Question 15

A snapshot of a wave on a string is illustrated. The units of the axes are meters. The wave is observed as time passes and it is found that 750 crests pass the 4 m mark in 5.0 s. Determine the wavelength and the speed of this wave.



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