Phys 111
Fall 2019

General Physics: Final Exam (version 1)

9 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

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

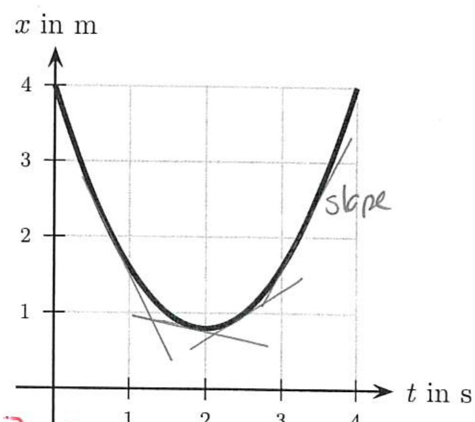
$$\text{Cylinder/disk: } I = \frac{1}{2}mr^2 \qquad \text{Hoop: } I = mr^2 \qquad \text{Solid sphere: } I = \frac{2}{5}mr^2$$

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

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

Question 1

An ant walks along a straight stick. The graph illustrates the ant's position vs time. During the period from 0 s to 4 s does the velocity of the ant remain constant? During the period from 0 s to 4 s is the acceleration of the ant zero or not?
Explain your answers.



* Velocity = slope of position vs time] +1
Slope is always changing] ~~+3~~ +2
⇒ velocity always changing (not constant)] +1

* Acceleration = rate of change of velocity] +1
$\underbrace{\text{Velocity always changing}}_{+2}$ ⇒ $\underbrace{\text{accel} \neq 0.}_{+1}$

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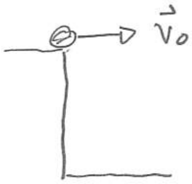
Question 2

A rock is thrown with speed 20 m/s horizontally from a bridge, at height 3.0 m above the water. Determine the horizontal distance that the ball travels until it hits the water.



$x_f = \cancel{x_i}^{0} + V_{ix}\,\Delta t + \frac{1}{2}\cancel{a_x}^{0}\,\Delta t^2$ (+1)

$x_f = V_{ix}\,\Delta t$] (+1)

$\Rightarrow$ $x_f = 20\,m/s\,\Delta t$

or $V_{fy}^2 = V_{iy}^2 + 2a_y\,\Delta y$ to get V_{fy} then $V_{fy} = V_{iy} + a\Delta t$ to get Δt (+2)

$t_i = 0s$	$t_f = ?$
$x_i = 0m$	$x_f = ?$
$y_i = 3.0m$	$y_f = 0m$
(+1) [$V_{ix} = 20m/s$	$V_{fx} = ?$
(+2) [$V_{iy} = 0m/s$	$V_{fy} = ?$
(+2) [$a_x = 0m/s^2$	
$a_y = -9.8m/s^2$	

Need Δt from vertical

$y_f = y_i + \cancel{v_{iy}}^{0}\Delta t + \frac{1}{2}a_y\,\Delta t^2$]

$0m = 3m - \frac{1}{2}\,9.8m/s^2\,\Delta t^2$

$4.9m/s^2\,\Delta t^2 = 3m$

$\Delta t^2 = \frac{3m}{4.9m/s^2} = 0.61s^2$ (+3)

$\Delta t = \sqrt{0.61s^2} = 0.78s$

$x_f = 20m/s \times 0.78s$
$= 15.6m$] (+2)

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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

$\uparrow \vec{T}$
$\downarrow \vec{F}_g\ (= mg)$ (+1)

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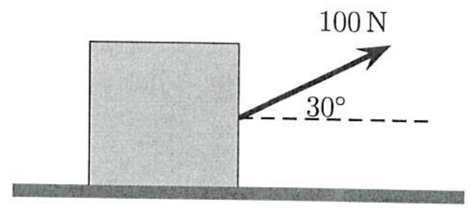
$\vec{v}_i \uparrow\ \uparrow \vec{v}_f \Rightarrow$ accel is $\downarrow$ $\Rightarrow$ F_{net} is $\downarrow$ $\Rightarrow$ $mg > T$.
(+2) (+2)

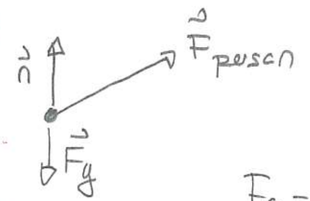
Question 4

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



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

+2



$\sum F_x = ma_x$ +1

$\sum F_y = ma_y = 0$ +1 (stays along horizontal)

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

Components:

+3 $F_{px} = F_p \cos 30°$
$= 100N \cos 30° = 86\,N$

+3 $F_{py} = F_p \sin 30°$
$= 100N \sin 30° = 50\,N$

	x	y
$\vec{F}_g$	0	$-98N$
$\vec{n}$	0	n
$\vec{F}_p$	86N	50N

+2

+2 ~~+3~~

$\sum F_x = ma_x \Rightarrow 86N = 10kg\, a$

$\Rightarrow a = 8.6\,m/s^2$

b) Determine the magnitude of the normal force acting on the block.

$\underbrace{\sum F_y = 0 \Rightarrow -98N}_{+1} + n + 50N = 0$

$\Rightarrow n - 48N = 0$

$\Rightarrow n = 48N$

~~+2~~ ~~+3~~ +4

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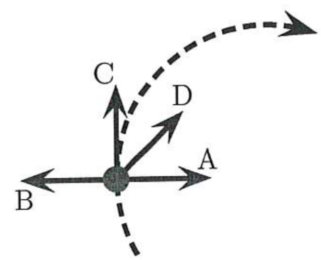
Question 5

A bug walks at a constant speed counterclockwise 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.



+3 Acceleration points radially inward →

+1 $\vec{F}_{net} = m\vec{a}$, means $\vec{F}_{net}$ points →

+1 so option $\boxed{A}$

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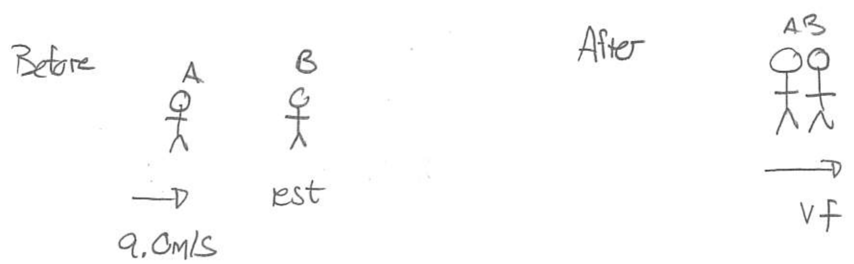
Question 6

initially at rest

Two ice skaters, Alice and Bob, are on a frictionless horizontal ice sheet. Alice has mass 50 kg and Bob 100 kg. Alice slides straight east with speed 9.0 m/s toward Bob. They collide and hold on to each other. Determine the velocity (including direction) with which Alice and Bob move after they have collided.

No net external force ⇒ total momentum conserved.



$p_{tot\,f} = p_{tot\,i}$ +2

+1

$m_B v_f + m_A v_f = m_B \cancel{v_{Bi}} + m_A v_{Ai}$ (0)

$(m_B + m_A) v_f = m_A v_{Ai}$

$150\,kg\ v_f = 50\,kg \times 9.0\,m/s = 450\,kg\,m/s$

$\Rightarrow v_f = \frac{450\,kg\,m/s}{150\,kg} = 3.0\,m/s$ +5

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positive so moves →

+1

Question 7

A 0.250 kg cart approaches a bump on the illustrated frictionless track, whose base lies on the Earth. The top of the bump is 0.80 m above the Earth. While the cart moves along the horizontal surface on left, it's speed is 5.0 m/s. Does the cart reach the top of the bump? If you say it does, determine its speed at the top of the bump. If you say it does not, determine how high it reaches.

$v_i = 5.0\,m/s$

$y_i = 0\,m$

Total energy conserved

either +3

$E_f = E_i$

$K_f + U_{gf} = K_i + U_{gi}$

$\frac{1}{2} m v_f^2 + \underbrace{mgy_f}_{+2} = \underbrace{\frac{1}{2} m v_i^2}_{+2} + \cancel{mgy_i}$

$\frac{1}{2}\, 0.250\,kg\; v_f^2 + 0.250\,kg \times 9.8\,m/s^2\; y_f = \frac{1}{2}\, 0.250\,kg \times \overbrace{(5.0\,m/s)^2}^{+2}$

$= 3.125\,J$

+2

If it reaches the top $y_f = 0.80\,m$ and

$0.125\,kg\; v_f^2 + \underbrace{0.250\,kg \times 9.8\,m/s^2 \times 0.80\,m}_{1.96\,J} = 3.125\,J$

This is possible. It $\overbrace{\text{does reach top}}^{+2}$. To get speed

+5

$0.125\,kg\; v_f^2 = 3.125\,J - 1.96\,J = 1.165\,J$

$v_f^2 = \frac{1.165\,J}{0.125\,kg} = 9.32\,m^2/s^2$

$v_f = 3.05\,m/s$.

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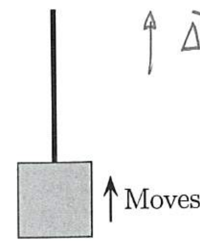
Question 8

A box is raised with decreasing speed by a rope, which remains taut while it does this. The box moves upward by a distance of 0.5 m. Let W_{rope} be the work done by the rope and W_{grav} be the work done by gravity during this process. Which of the following (choose one) is true?



$\uparrow \Delta\vec{x}$ $\quad \uparrow \vec{F}_{rope}$ $\quad \downarrow \vec{F}_{grav}$

i) W_{rope} is positive, W_{grav} is positive.

ii) W_{rope} is positive, W_{grav} is negative.

iii) W_{rope} is negative, W_{grav} is positive.

iv) W_{rope} is negative, W_{grav} is negative.

$W = \underbrace{F \Delta x \cos\theta}_{+1}$

Angle between rope and Δx $= 0° \Rightarrow W > 0$ +1

" " grav " Δx $= 180° \Rightarrow W < 0$ +1

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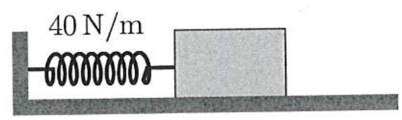
Question 9

A 2.0 kg box is on a frictionless horizontal surface and is compressed against a spring, with spring constant 40 N/m. The box is held at rest against the spring, with is compressed by 0.20 m. The block is released and eventually leaves the spring. Determine the speed of the block after it has left the spring.



$v_i = 0\,m/s$ $\quad V_f = ?$

$x_i = 0.20\,m$ $\quad x_f = 0\,m$

$y_i = 0\,m$ $\quad y_f = 0\,m$

Energy is conserved

$E_f = E_i$

+3 $K_f + U_{gf} + U_{spf} = K_i + U_{gi} + U_{spi}$

$\underbrace{\tfrac{1}{2} m v_f^2}_{+2} + mg\cancel{y_f} + \tfrac{1}{2}k\cancel{x_f}^2 = \cancel{\tfrac{1}{2} m v_i^2} + \cancel{mg y_i} + \underbrace{\tfrac{1}{2} k x_i^2}_{+2}$

$\tfrac{1}{2} \times 2.0\,kg\; v_f^2 = \tfrac{1}{2}\, 40\,N/m\, (0.20\,m)^2 = 0.80\,J$

$1.0\,kg\; v_f^2 = 0.80\,J$

$v_f^2 = 0.80\,m^2/s^2$

$v_f = 0.89\,m/s$

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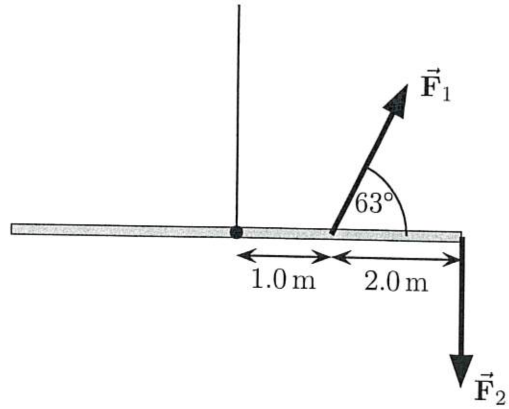
Question 10

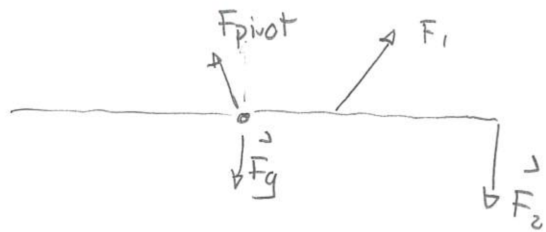
A 6.0 m rod with mass 10 kg is suspended from its midpoint as illustrated. Two forces are applied to the rod at the indicated points and the rod remains at rest horizontally. The magnitude of $\vec{\mathbf{F}}_1$ is 50 N. The other force $\vec{\mathbf{F}}_2$ acts vertically downward. Determine the magnitude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



(+1) $\tau_{net} = 0$

Take the midpoint as pivot

(+1) $\tau_{pivot} + \tau_{grav} + \tau_1 + \tau_2 = 0$



In all cases

(+2) $\tau = rF\sin\phi$

For pivot, gravity $r = 0 \Rightarrow \tau_{pivot} = 0\ \text{N·m}$ (+1)

$\tau_{grav} = 0\ \text{Nm}$ (+1)

For 1 $\quad \tau_1 = 1.0\,\text{m} \times 50\,\text{N} \sin 63° = 45\ \text{N·m}$ (+2) (+1)

For 2 $\quad \tau_2 = 2.0\,\text{m} \times F_2 \sin 270° = -3.0\,\text{m}\ F_2$ (+2) (+1)

So

$$0\,\text{N·m} + 0\,\text{N·m} + 45\,\text{N·m} - 3.0\,\text{m}\,F_2 = 0$$

$$\Rightarrow F_2 = \frac{45\,\text{N·m}}{3.0} = 15\,\text{N}$$ (+3)

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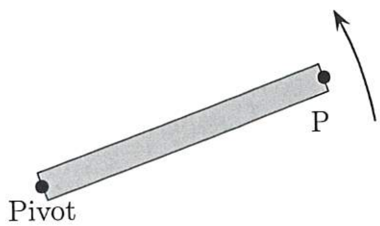
Question 11

A solid rod of length 0.25 m rotates about one end at a constant rate. It does four complete revolutions every second. Determine the angular velocity and the tangential velocity (speed) of the point P at the end of the rod.



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

In 1s $\Delta\theta = 4\,\text{rev} \times 2\pi\,\text{rad/rev} = 8\pi\,\text{rad}$ (+2)

$\omega = \frac{8\pi\,\text{rad}}{1\,\text{s}} = 25\,\text{rad/s} \Rightarrow \boxed{\omega = 25\,\text{rad/s}}$ (+2)

$\underbrace{V = \omega r}_{+1} = 25\,\text{rad/s} \times 0.25\,\text{m} = 6.3\,\text{m/s} \Rightarrow \boxed{V = 6.3\,\text{m/s}}$ (+2)

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Question 12

An ideal gas is inside a sealed container whose volume is kept constant. The gas is initially at atmospheric pressure, $P_{\text{atm}} = 1.01 \times 10^5$ Pa and temperature 20° C. The gas is then heated at constant volume so that its pressure reaches three times atmospheric pressure, i.e. $3P_{\text{atm}}$. Which of the following (choose one) is true regarding the temperature of the gas when it reaches pressure $3P_{\text{atm}}$?

i) Temperature is less than 20° C.

ii) Temperature between 20° C and 60° C.

iii) Temperature is exactly 60° C.

iv) Temperature greater than 60° C.

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3 times as large

$PV = nRT \Rightarrow T = P\left(\frac{V}{nR}\right)$

$\Rightarrow T_{final} = 3T_i$

$\Rightarrow T_{final} = 3(20+273) = 879\,\text{K}$

$= 606°\text{C}$ $(879\,\text{K} - 273\,\text{K})$

get T = 3 times but not Kelvin (+3)

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

$\underbrace{Q_{cu} + Q_{water} = 0}$ +2 $\underbrace{Q_{water} = -Q_{cu}}$

$\Rightarrow \underbrace{m_w c_w \Delta T_w}_{+3} = -\underbrace{m_c c_c \Delta T_c}$

$\Rightarrow 10\,\text{kg} \times \underbrace{4.18 \times 10^3\,\text{J/kg·C°}}_{+2}\,\Delta T_w$

$= -1.5\,\text{kg} \times \underbrace{3.85 \times 10^2\,\text{J/kg·°C}}_{+2} \times 5.0\,°\text{C}$

$\Rightarrow 41800\,\text{J/°C}\,\Delta T_w = -2890\,\text{J}$

$\Rightarrow \Delta T_w = \dfrac{-2890\,\text{J}}{41800\,\text{J/°C}} = -0.069\,°\text{C}$ +3

missing - sign $\boxed{-1}$

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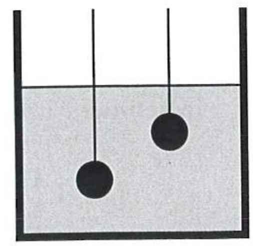
Question 14



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

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

ii) $F_{B\text{ right}} < F_{B\text{ left}} < 2F_{B\text{ right}}$

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

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

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

same   identical ⇒ same volume.

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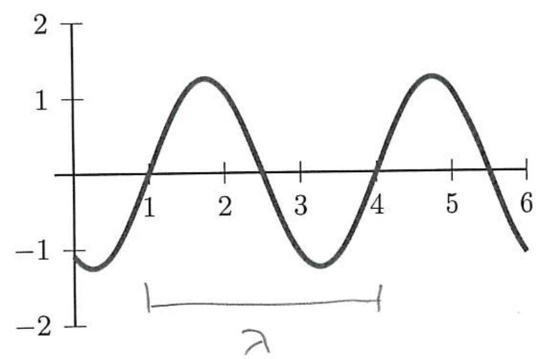
Question 15

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.



+2 [$\lambda = 3.0\,\text{m}$ by inspection.

+2 [$v = \lambda f$

Then $f = \dfrac{750\text{ crests}}{5.0\,\text{s}} = 150\,\text{Hz}$] +2

$v = 3.0\,\text{m} \times 150\,\text{Hz} = 450\,\text{m/s}$.] +2

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