Solutions

Fall 2013
Physics 105, sections 1, 2 and 3
Exam 2
Colton

RED

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Please write your CID_____

No time limit. No notes. No books. Student calculators only. All problems equal weight, 100 points total.

Constants/Materials parameters:

$g = 9.8$ m/s^2
$G = 6.67 \times 10^{-11}$ N·m^2/kg^2
$k_B = 1.381 \times 10^{-23}$ J/K
$N_A = 6.022 \times 10^{23}$
$R = k_B \cdot N_A = 8.314$ J/mol·K
$\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4
Mass of Sun = 1.991×10^{30} kg
Mass of Earth = 5.98×10^{24} kg

Radius of Earth = 6.38×10^6 m
Radius of Earth's orbit = 1.496×10^{11} m
Density of water: 1000 kg/m^3
Density of air: 1.29 kg/m^3
Linear exp. coeff. of copper: 17×10^{-6} /°C
Linear exp. coeff. of steel: 11×10^{-6} /°C
Specific heat of water: 4186 J/kg·°C
Specific heat of ice: 2090 J/kg·°C

Specific heat of steam: 2010 J/kg·°C
Specific heat of alum.: 900 J/kg·°C
Latent heat of melting (water): 3.33×10^5 J/kg
Latent heat of boiling (water): 2.26×10^6 J/kg
Thermal conduct. of alum.: 238 J/s·m·°C
$v_{sound} = 343$ m/s at 20°C

Conversion factors

1 inch = 2.54 cm
1 mile = 1.609 km
1 m^3 = 1000 L

1 hp = 745.7 W
1 gallon = 3.785 L
1 atm = 1.013×10^5 Pa = 14.7 psi

$T_F = \frac{9}{5}T_C + 32$
$T_K = T_C + 273.15$

Other equations

$x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
Surface area of sphere = $4\pi r^2$
Volume of sphere = $(4/3)\pi r^3$
$v_{ave} = \dfrac{v_i + v_f}{2}$
$v = v_0 + at$
$x = x_0 + v_0 t + \frac{1}{2}at^2$
$v_f^2 = v_0^2 + 2a\Delta x$
$w = mg$, $PE_g = mgy$
$F = -kx$, $PE_s = ½ kx^2$
$f = \mu_k N$ (or $f \le \mu_s N$)
$P = F_{//}v = Fv\cos\theta$
$\vec{F}\Delta t = \Delta\vec{p}$
Elastic: $(v_1 - v_2)_{bef} = (v_2 - v_1)_{after}$
arc length: $s = r\theta$
$v = r\omega$
$a_{tan} = r\alpha$
$a_c = v^2/r$
$F_g = \dfrac{GMm}{r^2}$, $PE_g = -\dfrac{GMm}{r}$
$I_{pt\ mass} = mR^2$
$I_{sphere} = (2/5)\ mR^2$
$I_{hoop} = mR^2$

$I_{disk} = (1/2)\ mR^2$
$I_{rod}\ (center) = (1/12)\ mL^2$
$I_{rod}\ (end) = (1/3)\ mL^2$
$L = r_\perp p = rp_\perp = rp\sin\theta$
$P = P_0 + \rho gh$
$VFR = A_1 v_1 = A_2 v_2$
$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$
$\Delta L = \alpha L_0 \Delta T$
$\Delta V = \beta V_0 \Delta T$; $\beta = 3\alpha$
transl. $KE_{ave} = \frac{1}{2}mv_{ave}^2 = \frac{3}{2}k_B T$
$Q = mc\Delta T$; $Q = mL$
$\dfrac{\Delta Q}{\Delta t} = kA\dfrac{T_2 - T_1}{L}$
$P = e\sigma AT^4$
$|W_{on\ gas}|$ = area under P-V curve
= $|P\Delta V|$ (constant pressure)
= $|nRT\ln(V_2/V_1)|$ (isothermal)
= $|\Delta U|$ (adiabatic)
$U = \frac{3}{2}Nk_B T = \frac{3}{2}nRT$ (monatomic)

$U = \frac{5}{2}Nk_B T = \frac{5}{2}nRT$ (diatomic, around 300K)
$Q_h = |W_{net}| + Q_c$
$e = \dfrac{|W_{net}|}{Q_{added}} = 1 - \dfrac{Q_c}{Q_h}$
$e_{max} = 1 - \dfrac{T_c}{T_h}$
$\omega = \sqrt{\dfrac{k}{m}}$, $T = 2\pi\sqrt{\dfrac{m}{k}}$
$\omega = \sqrt{\dfrac{g}{L}}$, $T = 2\pi\sqrt{\dfrac{L}{g}}$
$v = \sqrt{\dfrac{T}{\mu}}$, $\mu = m/L$
$\beta = 10\log\left(\dfrac{I}{I_0}\right)$ $I_0 = 10^{-12}$ W/m^2
$f' = f\dfrac{v \pm v_0}{v \pm v_S}$
$\sin\theta = v/v_s$
o-o/c-c: $f_n = nf_1$; $n = 1,2,3,...$
o-c: $f_n = nf_1$; $n = 1,3,5,...$

Instructions:

- Write your CID at the top of the first page, otherwise you will not get this exam booklet back.
- Circle your answers in this booklet if you wish, but be sure to **record your answers on the bubble sheet.**
- Unless otherwise specified, **ignore air resistance** in all problems.
- Use g = 9.8 m/s^2.

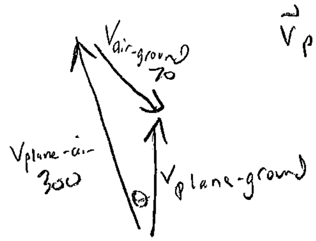
1. Fritz drives in a straight line, first for 500 m at 10 m/s, then for 200 m at 30 m/s. What was his average velocity?
    a. Less than 10.0 m/s
    b. 10.0 – 10.5
    c. 10.5 – 11.0
    d. 11.0 – 11.5
    e. 11.5 – 12.0
    f. 12.0 – 12.5
    g. 12.5 – 13.0
    h. More than 13.0 m/s

50m @10 m/s = 50sec

200m @ 30 m/s = 6.67 sec

$V_{ave} = \frac{\Delta x}{\Delta t} = \frac{700m}{56.67 sec} = 12.35 m/s$

2. Victor wishes to fly an airplane due north in a 70 km/h wind blowing due south-east. The airspeed of the airplane (i.e. $\vec{\mathbf{v}}_{\text{plane-air}}$) is 300 km/h. What speed relative to the ground will the airplane be going?
    a. Less than 250 m/s
    b. 250 – 260
    c. 260 – 270
    d. 270 – 280
    e. 280 – 290
    f. 290 – 300
    g. 300 – 310
    h. More than 310 m/s



$\vec{V}_{plane-ground} = \vec{V}_{plane-air} + \vec{V}_{air-ground}$

Adding vectors:

	x	y
V_{p-a}	$-300\cos\theta$	$300\sin\theta$
V_{a-g}	$+70\cos 45$	$-70\sin 45°$
total		

We want this to be 0, so

$300\cos\theta = 70\cos 45$

$\theta = \cos^{-1}\left(\frac{70\cos 45}{300}\right)$

$= 9.50°$

Then this is our answer:

$V_{pg} = 300\sin(9.5°) - 70\sin 45° = \boxed{246.4\ km/hr}$

3. Sally jumps out of an airplane and reaches "terminal velocity" in approximately 20 seconds. That's the point where she stops accelerating because of air resistance. While she is falling at terminal velocity, which force is largest?
    a. Gravity
    b. Air resistance
    c. Same

if no acceleration, forces are balanced

F_{air}

mg

4. Same situation. After falling at terminal velocity for a while, Sally opens her parachute to slow down before landing. Which force on Sally is largest right after the parachute deploys? (Ignore air resistance on her now.)
    a. Gravity
    b. Parachute
    c. Same

$F_{parachute}$

mg

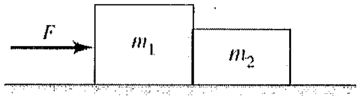
if she's slowing, acceleration is upward, so $F_{parachute} > F_{gravity}$

5. A book lying on a table feels a force of gravity and a normal force. Newton's third law says that forces come in pairs. What is the force that is the Newton's 3rd Law partner of the force of gravity on the book?
    a. The gravitational force of the book pulling up on the earth
    b. The normal force of the table pushing up on the book
    c. The normal force of the book pushing down on the table
    d. More than one of the above

$F_{book-earth}$ is partner to $F_{earth-book}$

6. If I push on an object which is at rest (like a wall), then the force exerted by my hand on the object will be equal to the force exerted by the object on my hand. However, if I push on an object and cause it to accelerate, then the force exerted by my hand on the object will be __________ compared to the force exerted by the object on my hand.
    a. greater than
    b. less than
    c. still equal to

They are N3 partner forces, so still must be equal. Partners are always equal!



7. Two blocks ($m_1 > m_2$) sitting on a frictionless table are pushed from the left by a horizontal force, as shown. They accelerate to the right. What is the magnitude of the force *between* the two blocks?

   a. $\left(\frac{m_1}{m_1+m_2}\right)\mathbf{F}$

   b. $\left(\frac{m_2}{m_1+m_2}\right)\mathbf{F}$

   c. $\left(\frac{m_1+m_2}{m_1}\right)\mathbf{F}$

   d. $\left(\frac{m_1+m_2}{m_2}\right)\mathbf{F}$

   e. $\left(\frac{m_1}{m_1+m_2}\right)^2\mathbf{F}$

   f. $\left(\frac{m_2}{m_1+m_2}\right)^2\mathbf{F}$

   g. $\left(\frac{m_1+m_2}{m_1}\right)^2\mathbf{F}$

   h. $\left(\frac{m_1+m_2}{m_2}\right)^2\mathbf{F}$

Group: $\Sigma F = M_{tot}\, a$

$F = (m_1+m_2)a$

$a = F/(m_1+m_2)$

Mass 2: $\square \rightarrow F_{1-2}$ only force on m_2

$\Sigma F = m_2 a$

$F_{12} = m_2\left(\frac{F}{m_1+m_2}\right)$

8. A 5 kg bucket is accelerated upwards by rope at a rate of 3 m/s^2. What is the tension in the rope?

   a. Less than 50 N
   b. 50 – 55
   c. 55 – 60
   d. 60 – 65
   e. 65 – 70
   f. 70 – 75
   g. 75 – 80
   h. 80 – 85
   i. 85 – 90
   j. More than 90 N

$\Sigma F = ma$

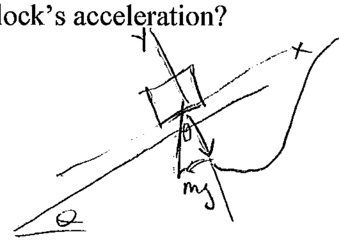
$T - mg = ma$

$T = mg + ma$

$= 5(9.8) + 5(3) = 64\text{N}$

9. A block slides down a ramp with no friction. The ramp is tilted up at an angle of θ, measured relative to the horizontal. What is the block's acceleration?

   a. $g\sin\theta$
   b. $g\cos\theta$
   c. $g\tan\theta$
   d. $g/\sin\theta$
   e. $g/\cos\theta$
   f. $g/\tan\theta$
   g. g

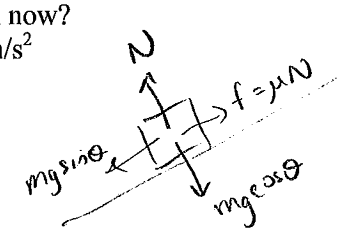


As done many times in class, the component of gravity along the tilted x axis is $mg\sin\theta$.

Therefore accel. is $g\sin\theta$

10. Same situation, but this time there is friction. Let's now use some numbers: $m = 3$ kg, $\theta = 30°$, and $\mu_k = 0.2$. What is the block's acceleration now?

   a. Less than 2.1 m/s^2
   b. 2.1 – 2.3
   c. 2.3 – 2.5
   d. 2.5 – 2.7
   e. 2.7 – 2.9
   f. 2.9 – 3.1
   g. 3.1 – 3.3
   h. More than 3.3 m/s^2



From y: $\Sigma F_y = ma_y = 0$

$N = mg\cos\theta$

From x: $\Sigma F_x = ma_x$

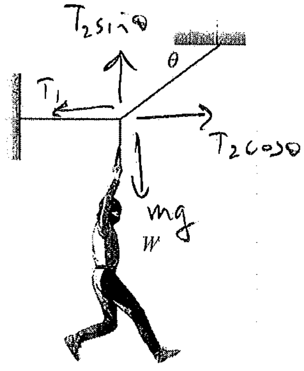
$mg\sin\theta - \mu N = ma_x$

$a_x = \frac{\cancel{m}g\sin\theta - \mu(\cancel{m}g\cos\theta)}{\cancel{m}}$

$a_x = 9.8\sin 30° - .2\cdot 9.8\cdot\cos 30°$

$= 3.20\ \text{m/s}^2$

$\Sigma F_x = 0$ and $\Sigma F_y = 0$



11. A burglar hangs motionless as shown, supported by a cable that goes horizontally to the left and another cable that goes up and to the right. The burglar's mass is 80 kg. The angle θ is 35°. What is the tension in the left cable?
    a. Less than 900 N
    b. 900 – 950
    c. 950 – 1000
    d. 1000 – 1050
    e. 1050 – 1100
    f. 1100 – 1150
    g. 1150 – 1200
    h. 1200 – 1250
    i. More than 1250

$\Sigma F_y = 0 \rightarrow T_2 \sin\theta = mg$

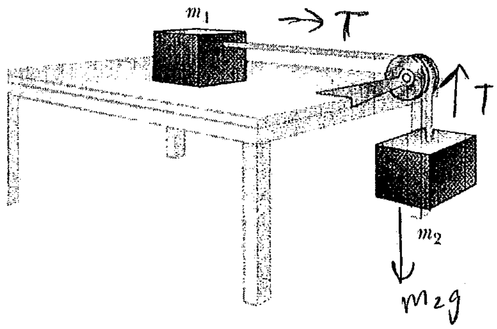
$T_2 = mg/\sin\theta$

$\Sigma F_x = 0 \rightarrow T_1 = T_2 \cos\theta$

$= \left(\frac{mg}{\sin\theta}\right)\cos\theta$

$= \frac{80 \cdot 9.8 \cdot \cos 35^\circ}{\sin 35^\circ}$

$= 1119.7\,N$



12. Two blocks are connected as shown in the figure, on a frictionless table. The block on the table has mass m_1 = 1 kg. The hanging block has mass m_2 = 2 kg. What is the tension in the cable connecting the blocks?
    a. Less than 4.3 N
    b. 4.3 – 4.8
    c. 4.8 – 5.3
    d. 5.3 – 5.8
    e. 5.8 – 6.3
    f. 6.3 – 6.8
    g. 6.8 – 7.3
    h. More than 7.3 N

Group: $\Sigma F = m_{tot}\, a$

$m_2 g = (m_1 + m_2) a$

$a = g \frac{m_2}{m_1 + m_2}$

m_1: $\Sigma F = m_1 a$

$T = m_1 a$

$T = m_1 g \frac{m_2}{m_1 + m_2} = \frac{1 \cdot 9.8 \cdot 2}{3} = \boxed{6.53\,N}$

13. Francis lifts a heavy block 1 meter vertically. Malcolm carries the same block 1 meter horizontally. Both do so with the same constant velocity. Which of the two did more work on the block?
    a. Francis
    b. Malcolm
    c. Same

Malcolm's force is $\perp$ to the displacement. Therefore no work done by Malcolm. ($W = F_{\parallel} \Delta x$)

14. Meg throws three identical balls off a cliff, all with the same speed. She throws ball A downward at an angle. She throws ball B horizontally. She throws ball C upward at an angle. How do the speeds of the balls compare when the balls hit the (flat) ground below?
    a. $v_A < v_B < v_C$
    b. $v_A = v_B = v_C$
    c. $v_A > v_B > v_C$

Same initial KE, same initial PE, therefore same final KE

15. Michael throws two identical balls straight up into the air. He throws ball A twice as fast as ball B. How do the heights reached by the balls compare? (Height measured from the point the balls leave his hand.)
    a. they both reach the same height
    b. ball A goes about 1.41 times as high as ball B
    c. ball A goes about 2 times as high as ball B
    d. ball A goes about 4 times as high as ball B

For each ball: $KE_{bef} = PE_{aft}$

$\frac{1}{2} m v^2 = mgh$

So $h \sim v^2$

if you double v, you quadruple h

16. Mary and Fred have an argument on frictionless ice. Mary shoves Fred, and they both fly off in opposite directions. They were initially at rest, and Fred weighs twice as much as Mary. Which one has the faster velocity as they fly apart?
   a. Mary
   b. Fred
   c. Same
   d. Not enough information to tell

Force is the same, but $m_{Fred} = 2m_{Mary}$

Therefore $a_{Fred} = \frac{1}{2} a_{mary}$ ($F = ma$)

$v_F = \cancel{v_0} + at$

Since t is same, $V_{F\,Fred} = \frac{1}{2} V_{F\,mary}$

17. Same situation. Which one has more kinetic energy as they fly apart?
   a. Mary
   b. Fred
   c. Same
   d. Not enough information to tell

$KE = \frac{1}{2}mv^2 \rightarrow KE_{Fred} = \frac{1}{2} m_{Fred} V_{F\,Fred}^2$

$= \frac{1}{2}(2m_{mary})(\frac{1}{2}V_{F\,mary})^2$

$= \frac{1}{2} \cdot [\frac{1}{2} m_{mary}(V_{F\,mary})^2]$

$= \frac{1}{2} KE_{mary}$

18. Leia, driving in her car, slams on the brakes. The anti-lock brakes properly kick in, preventing the tires from skidding. Which is the proper coefficient of friction (between tires and road) to use when analyzing the situation?
   a. μ_s
   b. μ_k
   c. $(\mu_s + \mu_k)/2$
   d. None of the above

The tires are not skidding, so this is static

19. "Top Fuel" dragsters, i.e. drag racing cars, have extremely impressive specs. A 1055 kg dragster can accelerate from 0 to 100 mph (44.7 m/s) in about 0.84 seconds. Wow! Assuming constant acceleration, how much distance does the car travel in that time? Consider the 1055 kg value to include the driver's mass.

→ Can use kinematics

Hint: First find the acceleration.
Also: Be very careful! The next five problems all depend either on the acceleration, the distance, or both.
Side note: This problem was inspired by this article, in case you want to look it up after you get your exam back: http://www.motortrend.com/features/112_0502_top_fuel_numbers/

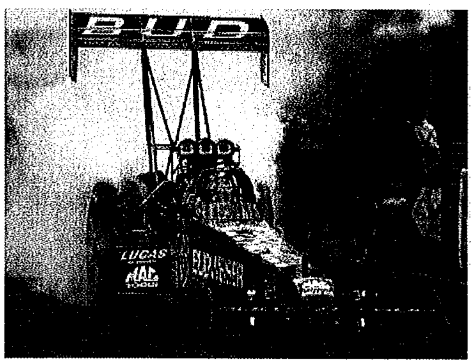


Image credit: kennyspeedsracing.blogspot.com

   a. Less than 6 m
   b. 6 – 8
   c. 8 – 10
   d. 10 – 12
   e. 12 – 14
   f. 14 – 16
   g. 16 – 18
   h. 18 – 20
   i. More than 20 m

$V = v_0 + at$

$44.7 = 0 + a(.84)$

$a = \frac{44.7}{.84} = 53.21\ m/s^2$

$x = \cancel{x_0} + \cancel{v_0 t} + \frac{1}{2}at^2$

$= \frac{1}{2}(53.21)(.84)^2 = \boxed{18.77m}$

20. Same situation. How much net force is required to do that?
   a. Less than 49000 N
   b. 49000 – 50000
   c. 50000 – 51000
   d. 51000 – 52000
   e. 52000 – 53000
   f. 53000 – 54000
   g. 54000 – 55000
   h. More than 55000 N

$F_{net} = ma$

$= (1055)(53.21)$

$= \boxed{56141N}$

21. Same situation. How much work on the car is required to do that?

a. Less than 8.75×10^5 J
b. 8.75 – 9.25
c. 9.25 – 9.75
d. 9.75 – 10.25
e. 10.25 – 10.75
f. 10.75 – 11.25
g. 11.25 – 11.75
h. More than 11.75×10^5 J

$$W = F \cdot d$$
$$= (56141)(18.77)$$
$$= 1053987\ \text{J}$$
$$= 1.05 \cdot 10^6\ \text{J} \quad (= 10.5 \cdot 10^5\ \text{J})$$

22. Same situation. How much power is required to do that? (Conversion factor from W to hp is given on page 1.)

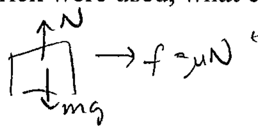
Side note: The actual rated hp of the engine is roughly 4.5× the answer to this question. That's an impressively large number! I believe the difference between the rated hp and the result of this problem is largely due to two factors. First, air resistance undoubtedly becomes significant, and makes the engine work harder than we are predicting. Second, this is the average power, whereas the rated hp is typically the hp obtained at the maximum rpm. To give you a feel for what these engines must do in order to obtain that much power, the article mentioned above says that if the gas pedal were floored for just one minute, the engine would burn through 77 gallons of gas.

a. Less than 1500 hp
b. 1500 – 1550
c. 1550 – 1600
d. 1600 – 1650
e. 1650 – 1700
f. 1700 – 1750
g. 1750 – 1800
h. More than 1800 hp

$$P = \frac{W}{t}$$
$$= \frac{1053987\ \text{J}}{.84\ \text{s}} = 1254746\ \text{W} \times \frac{1\ \text{hp}}{745.7\ \text{W}} = \boxed{1683\ \text{hp}}$$

23. Same situation. The cars use a special trick to increase the friction force between ground and tires (allowing for more acceleration). If no trick were used, what coefficient of friction would be needed to accelerate the car?

a. Less than 4.7
b. 4.7 – 4.9
c. 4.9 – 5.1
d. 5.1 – 5.3
e. 5.3 – 5.5
f. 5.5 – 5.7
g. 5.7 – 5.9
h. More than 5.9



← This is the force accelerating the car, from problem 20

$$\Sigma F_y = 0 \rightarrow N = mg$$
$$f = \mu N$$
$$\mu = \frac{f}{N} = \frac{56141}{(1055)(9.8)} = \boxed{5.43}$$

24. Same situation. The trick is to attach an upside-down wing to the car over the rear drive wheels. You can see it in the picture above. Whereas an airplane wing provides an upwards force on an airplane, this wing provides a *downwards* force on the wheels. That serves to increase the normal force by up to about 53400 N, which in turn increases the friction force. The amount of the wing's downforce depends strongly on the speed, increasing from zero up to that maximum value, so for this problem let's assume it's just a constant force equal to the average value of 26700 N. Given that additional normal force, what does the coefficient of friction *actually* have to be in order to provide the given acceleration?

Side note: The answer turns out to be greater than 1, which is unusual for a coefficient of friction. This would mean that the tire actually partially sticks to the track surface, which I believe may be the case. Or it's possible that my "average force" approximation wasn't quite right. *Another side note*: Because the downwards force from the wing exceeds the car's weight, if the car were flipped over such that the downwards force from the inverted wing became an upwards force from a now rightside-up wing, once the car gets going it could in theory actually drive upside down on a ceiling.

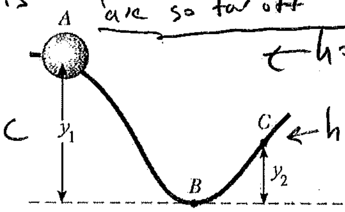
a. Less than 1.1
b. 1.1 – 1.2
c. 1.2 – 1.3
d. 1.3 – 1.4
e. 1.4 – 1.5
f. 1.5 – 1.6
g. 1.6 – 1.7
h. More than 1.7

Like last problem, $\mu = \frac{f}{N}$, but N has been increased by 26700N

$$\mu = \frac{56141}{(1055)(9.8) + 26700}$$
$$\mu = \boxed{1.52}$$

Sorry → This is the one that was originally miskeyed. When I did the problem originally I divided instead of multiplied, which is why the answer choices are so far off

25. A bead slides along a frictionless wire from A to B to C, as shown in the picture. The height of point A is $y_1 = 0.32$ m, and the height of point C is 0.18 m. Point B is at zero height. If the bead starts from rest at point A, how fast is it moving at point C?



← $h = y_1 - y_2$

← $h = 0$

a. Less than 8.4 cm/s
b. 8.4 – 8.6
c. 8.6 – 8.8
d. 8.8 – 9.0
e. 9.0 – 9.2
f. 9.2 – 9.4
g. 9.4 – 9.6
h. More than 9.6 cm/s

I'll take my origin to be at position C

$PE_{bef} = KE_{aft}$

$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$

$v = \sqrt{2gh} = \sqrt{2(9.8)(.32-.18)}$

$= \boxed{1.66\ \text{m/s}} = 166\ \frac{\text{cm}}{\text{s}}$

26. Suppose you are an astronaut in interstellar space and a fellow astronaut throws a 2 kg wrench at you with a speed of 5 m/s. You try to grab the wrench, but can't grab onto the wrench and only manage to apply a stopping force of 30 N over a distance of 0.4 m. What is the final velocity of the wrench? (It doesn't change its direction.)

Side note: I had my daughter proofread this exam. She wanted me to include an ending to the astronaut story, so here you go: Because you failed to stop the wrench, it kept on traveling until being sucked into a wormhole. It traversed the wormhole and popped out at a different point in space and time. Unfortunately, the trajectory after that point happened to coincide with the path of your fellow astronaut, just before he threw the wrench. This prevented him from throwing the wrench, creating a paradox which destroyed the universe. You should really improve your hand-eye coordination next time.

bef — ← 5 m/s
during — F = 30 N →
after — v = ?

a. Less than 3.1 m/s
b. 3.1 – 3.3
c. 3.3 – 3.5
d. 3.5 – 3.7
e. 3.7 – 3.9
f. 3.9 – 4.1
g. 4.1 – 4.3
h. More than 4.3 m/s

$E_{bef} + W = E_{aft}$

$\frac{1}{2}mv^2 - Fd = \frac{1}{2}mv_f^2$

$v_f^2 = v^2 - \frac{2Fd}{m}$

$v_f = \sqrt{v^2 - \frac{2Fd}{m}}$

$= \sqrt{2^2 - \frac{2 \cdot 30 \cdot .4}{2}}$

$= 3.61$ m/s

27. Helen attaches a 0.3 kg weight to a spring ($k = 80$ N/m), and lets it settle to its equilibrium point (i.e. the natural resting point with the weight attached). Then she pulls it farther down a distance d by doing 30 J of work on the weight. Which of the following represents the filled in "blue-print" equation that you could use to determine d? (All numbers are in SI units.)

bef — equilibrium
during — 30 J of work
aft — d
let me call this h = 0

a. $0+30=\frac{1}{2}(80\cdot d^2)$
b. $0+30=-\frac{1}{2}(80\cdot d^2)$
c. $0+30=0.3\cdot 9.8\cdot d$
d. $0+30=-0.3\cdot 9.8\cdot d$
e. $0+30=\frac{1}{2}(80\cdot d^2)+0.3\cdot 9.8\cdot d$
f. $0+30=\frac{1}{2}(80\cdot d^2)-0.3\cdot 9.8\cdot d$
g. $0+30=-\frac{1}{2}(80\cdot d^2)+0.3\cdot 9.8\cdot d$
h. $0+30=-\frac{1}{2}(80\cdot d^2)-0.3\cdot 9.8\cdot d$

$E_{bef} + W = E_{aft}$

$(PE_s + PE_g)_{bef} + W = (PE_s + PE_g)_{aft}$

$0 + 0 + 30 = \frac{1}{2}kd^2 + mg(-d)$

$\boxed{0 + 30 = \frac{1}{2}\cdot 80 \cdot d^2 - .3 \cdot 9.8 \cdot d}$

28. Same situation. Helen then releases the weight from that point, and it starts oscillating. When it returns to the equilibrium point, how much kinetic energy will it possess?

a. Less than 30 J
b. 30 J
c. More than 30 J

Both gravity and spring energy are conservative so the initial energy now (the "after" from the equation above) will be completely transformed into KE. Since the "after" side also = 30 J from the eqn, KE = 30 J

bef — d
after — ↑velocity

100 $\frac{\text{Joules}}{\text{second}}$

29. Suppose I accidentally leave on a 100 W light bulb (can you still get those anywhere?) for an entire week. The 100 W rating means that it consumes electrical energy at a rate of 100 W. How much extra will I have to pay the electricity company because of my foolish mistake? On my latest bill, the cost of electricity was 3.6×10^{-6} cents per joule.
    a. Less than \$1.80
    b. 1.80 – 2.00
    c. 2.00 – 2.20
    d. 2.20 – 2.40
    e. 2.40 – 2.60
    f. 2.60 – 2.80
    g. 2.80 – 3.00
    h. More than \$3.00

$P = \frac{\text{Energy}}{\text{time}} \rightarrow \text{Energy} = P \times \text{time}$

$\text{Energy} = 100\,\frac{J}{s} \times (\#\text{ seconds in a week})$

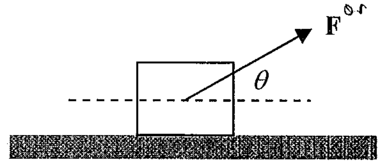
$\hookrightarrow = 7 \times 24 \times 60 \times 60 = 604800\text{ s}$

$\text{Energy} = 60480000\text{ Joules}$

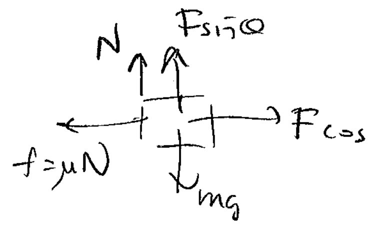
Now just use factor given: $60480000\,J \times \frac{3.6\cdot10^{-6}\text{ cents}}{1\text{ Joule}} = \boxed{217.7\text{ cents}}$

or \$2.17

30. Suppose you are pulling a large block (mass m) across the floor with force **F**, as shown in the figure. There is friction between block and floor, coefficient μ_k. Your want to get the most possible acceleration as you pull it across the floor. This does not necessarily occur when $\theta = 0$, because if you pull up at an angle you will reduce the friction force even though you are also reducing the horizontal component of **F**. Deduce an equation for acceleration as a function of angle θ that you could, for example, use in a spreadsheet with angles from 0 to 90° to figure out which one produces the optimal acceleration. Treat all of the symbols given in the problem as known quantities.



Side note: One can use calculus and the results of this problem to solve for the optimal angle without needing a spreadsheet. When I did so, I was surprised to find that the equation reduces to this extremely simple formula: $\theta_{optimal} = \tan^{-1}(\mu)$. I think that is really cool.



a. $a = \dfrac{F\cos\theta + \mu F\sin\theta + \mu mg}{m}$

b. $a = \dfrac{F\cos\theta + \mu F\sin\theta - \mu mg}{m}$

c. $a = \dfrac{F\cos\theta - \mu F\sin\theta + \mu mg}{m}$

d. $a = \dfrac{F\cos\theta - \mu F\sin\theta - \mu mg}{m}$

e. $a = \dfrac{F\sin\theta + \mu F\cos\theta + \mu mg}{m}$

f. $a = \dfrac{F\sin\theta + \mu F\cos\theta - \mu mg}{m}$

g. $a = \dfrac{F\sin\theta - \mu F\cos\theta + \mu mg}{m}$

h. $a = \dfrac{F\sin\theta - \mu F\cos\theta - \mu mg}{m}$

i. $a = \dfrac{F\tan\theta + \mu F + \mu mg}{m}$

j. $a = \dfrac{F - \mu F\tan\theta - \mu mg}{m}$

$\Sigma F_y = 0 : F\sin\theta + N - mg = 0$

$N = mg - F\sin\theta$

$\Sigma F_x = ma : F\cos\theta - \mu N = ma$

$F\cos\theta - \mu(mg - F\sin\theta) = ma$

$ma = F\cos\theta - \mu mg + \mu F\sin\theta$

$a = \dfrac{F\cos\theta + \mu F\sin\theta - \mu mg}{m}$

Bonus: if you know calculus...
You find the max by taking the derivative, and setting it equal to 0

$0 = \frac{da}{d\theta} = \frac{d}{d\theta}\left(\frac{F}{m}\cos\theta + \frac{\mu F}{m}\sin\theta - \frac{\mu mg}{m}\right)$

$0 = \frac{F}{m}(-\sin\theta) + \frac{\mu F}{m}(\cos\theta) + 0$

$\cancel{\frac{F}{m}}\sin\theta = \mu\cancel{\frac{F}{m}}\cos\theta$

$\tan\theta = \mu$

$\boxed{\theta = \tan^{-1}(\mu)}$ Cool!