first (given)	*last (family)*	**Physics 2211 AB**	Nine-digit Tech ID

Name, *printed* as it appears in Canvas

Spring 2020

Quiz

4A

- **Print** your name and nine-digit Tech ID *very neatly* in the spaces above.
- Free-response problems are numbered I–III. Show all your work clearly, including all steps and logic. Write **darkly**. Blue or black ink is recommended. Do not make any erasures in your free-response work. Cross out anything you do not want evaluated. Box your answer.
- Multiple-choice questions are numbered 1–7. For each, select the answer most nearly correct, circle it on your quiz, and fill the bubble for your answer on this front page.
- Initial the odd pages in the top margin, in case the pages of your quiz get separated.
- The standard formula sheet is on the back of this page, which may be removed from the quiz form if you wish, but it must be submitted.
- If the page for a free-response problem has insufficient space for your work, ask a proctor for an additional sheet. If you wish this work to be evaluated, put your name on the sheet and make a note on the problem page, so graders will know where to look for your work.
- You may use a calculator that cannot store letters, but no other aids or electronic devices.
- Your score will be posted when your quiz has been graded. Quiz grades become final when the next quiz is administered.

Fill in bubbles for your Multiple Choice answers darkly and neatly.

	a	b	c	d	e	f
1	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
2	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
3	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
4	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
5	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
6	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
7	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ	ⓕ
	a	b	c	d	e	f

Quiz and Exam Formulæ & Constants

$$\vec{v} = \frac{d\vec{r}}{dt}$$
$$\vec{\omega} = \frac{d\vec{\theta}}{dt}$$
$$\vec{a} = \frac{d\vec{v}}{dt}$$
$$\vec{\alpha} = \frac{d\vec{\omega}}{dt}$$
$$v_{\mathrm{sf}} = v_{\mathrm{si}} + a_{\mathrm{s}}\,\Delta t$$
$$\omega_{\mathrm{f}} = \omega_{\mathrm{i}} + \alpha\,\Delta t$$
$$s_{\mathrm{f}} = s_{\mathrm{i}} + v_{\mathrm{si}}\,\Delta t + \tfrac{1}{2}a_{\mathrm{s}}\,(\Delta t)^2$$
$$\theta_{\mathrm{f}} = \theta_{\mathrm{i}} + \omega_{\mathrm{si}}\,\Delta t + \tfrac{1}{2}\alpha\,(\Delta t)^2$$
$$s = r\theta$$
$$v = r\omega$$
$$a_{\mathrm{t}} = r\alpha$$

$$\sum \vec{F} = m\vec{a} = \frac{d\vec{p}}{dt}$$
$$\sum \vec{F}_{\mathrm{ext}} = M\vec{a}_{\mathrm{cm}} = \frac{d\vec{P}}{dt}$$
$$\sum \vec{\tau}_{\mathrm{ext}} = I\vec{\alpha} = \frac{d\vec{L}}{dt}$$
$$f_{\mathrm{s,max}} = \mu_{\mathrm{s}} n$$
$$f_{\mathrm{k}} = \mu_{\mathrm{k}} n$$
$$a_{\mathrm{r}} = \frac{v^2}{r}$$
$$\vec{w} = m\vec{g}$$
$$|\vec{F}_{\mathrm{G}}| = \frac{G m_1 m_2}{|\vec{r}|^2}$$
$$D = \tfrac{1}{2}C\rho A v^2$$
$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$W = \int \vec{F} \cdot d\vec{s}$$
$$W_{\mathrm{ext}} = \Delta K + \Delta U + \Delta E_{\mathrm{th}}$$
$$K = \tfrac{1}{2}mv^2$$
$$K = \tfrac{1}{2}I\omega^2$$
$$U_{\mathrm{g}} = mgy$$
$$U_{\mathrm{s}} = \tfrac{1}{2}k\,(\Delta s)^2$$
$$U_{\mathrm{G}} = -\frac{G m_1 m_2}{r}$$
$$P = \frac{dE_{\mathrm{sys}}}{dt}$$
$$P = \vec{F} \cdot \vec{v}$$
$$\vec{J} = \int \vec{F}\,dt = \Delta\vec{p}$$
$$\vec{p} = m\vec{v}$$

$$\vec{r}_{\mathrm{cm}} = \frac{\sum \vec{r}_i m_i}{\sum m_i}$$
$$\vec{r}_{\mathrm{cm}} = \frac{\int \vec{r}\,dm}{\int dm}$$
$$I = \sum m_i r_i^2$$
$$I = \int r^2\,dm$$
$$I = I_{\mathrm{cm}} + Md^2$$
$$\vec{L} = \vec{r} \times \vec{p}$$
$$\vec{L} = I\vec{\omega}$$
$$x = A\cos(\omega t + \phi_0)$$
$$\vec{a}_{\mathrm{x}} = -\omega^2 \vec{x}$$
$$\omega = \sqrt{k/m}$$
$$\omega = 2\pi f = \frac{2\pi}{T}$$

Physical Constants:

Universal Gravitation Constant $G = 6.673 \times 10^{-11}\,\mathrm{N{\cdot}m^2/kg^2}$
Gravitational Acceleration at Earth's Surface $g = 9.81\,\mathrm{m/s^2}$

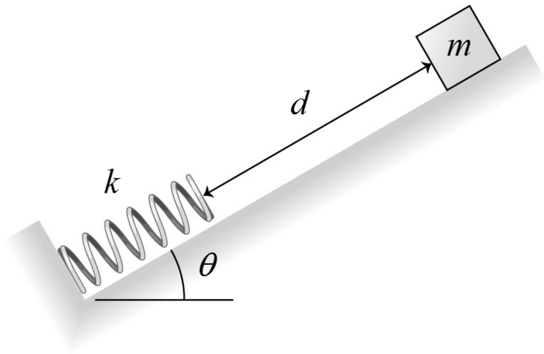
Unless otherwise directed, drag is to be neglected, all problems take place on Earth, use the gravitational definition of weight, and all springs, ropes, and pulleys are ideal. All derivatives and integrals in free-response problems must be evaluated.

You may remove this sheet from your Quiz or Exam, but it must be submitted

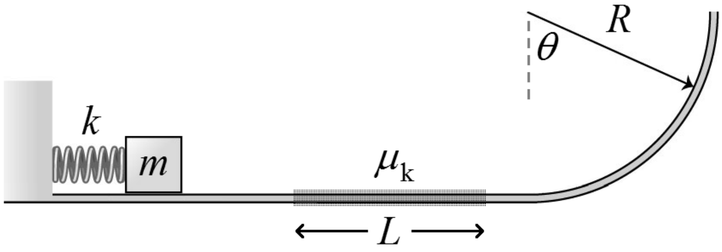
I. (16 points) A block of mass $m = 0.010\,\mathrm{kg}$ is released from rest on a frictionless surface that makes an angle $\theta = 30.0°$ with respect to the horizontal. From what distance d should block be released in order to compress the non-linear spring a maximum distance $x = 2.0\,\mathrm{cm}$? The force exerted by the nonlinear spring depends on compression distance according to

$$F(x) = kx^3$$

where $k = 3.8 \times 10^5\,\mathrm{N/m^3}$. (*On Earth.*)



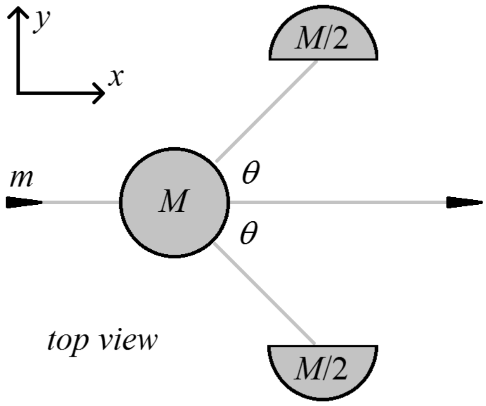
II. (16 points) Using a spring with Hooke's Law Constant $k = 12\,\mathrm{N/m}$ that is compressed a distance $x = 0.20\,\mathrm{m}$, a mass $m = 0.10\,\mathrm{kg}$ is launched along a track that is frictionless except for a rough section of length $L = 0.20\,\mathrm{m}$ and coefficient of kinetic friction $\mu_k = 0.20$. After scraping across the rough section, the mass slides up a circular section of radius $R = 2.0\,\mathrm{m}$, reaching a maximum angle θ with respect to the vertical before sliding back down again. Find the angle θ. You may assume that the mass does make it across the rough section. (*On Earth.*)



1. (6 points) In the problem above, will the block eventually stop and remain motionless? If so, where?
   (a) Yes, it will stop and remain motionless somewhere between the spring and the rough section.
   (b) Yes, it will stop and remain motionless somewhere in the rough section.
   (c) Yes, it will stop and remain motionless somewhere in contact with the spring.
   (d) No, it will not stop and remain motionless.
   (e) Yes, it will stop and remain motionless somewhere to the right of the rough section.

2. (6 points) A wooden cylinder of mass M is at rest on a horizontal frictionless surface, as shown from above. A bullet of mass m is traveling to the in the $+x$ direction with initial speed v_i. It passes through the cylinder, emerging with final speed $v_\mathrm{f} < v_\mathrm{i}$. The cylinder splits in half, with each piece travelling in a direction θ from the bullet's direction. Considering a system consisting of the bullet and the cylinder, what must be conserved in this process?

(a) Both the x and y components of momentum.
(b) Just the y component of momentum.
(c) Both the kinetic energy and the momentum.
(d) Just the x component of momentum.
(e) Just the kinetic energy.



III. (16 points) In the problem above, the wooden cylinder has mass $M = 1.40\,\mathrm{kg}$ and the bullet has mass $m = 0.028\,\mathrm{kg}$. The initial speed of the bullet is $v_\mathrm{i} = 380\,\mathrm{m/s}$ and its final speed is $v_\mathrm{f} = 220\,\mathrm{m/s}$. If the angle θ is $42°$, what is the resulting speed of one half of the cylinder?

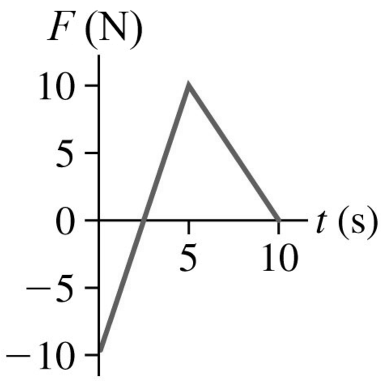
3. (8 points) The force exerted by a frog muscle depends on velocity v of the contracting muscle according to

$$F(v) = F_0\left(v_0^2 - v^2\right)$$

where $v_0 = 2.0\,\mathrm{cm/s}$, and $F_0 = 0.020\,\mathrm{N{\cdot}s^2/cm^2}$. At what contraction speed does this muscle deliver maximum power?

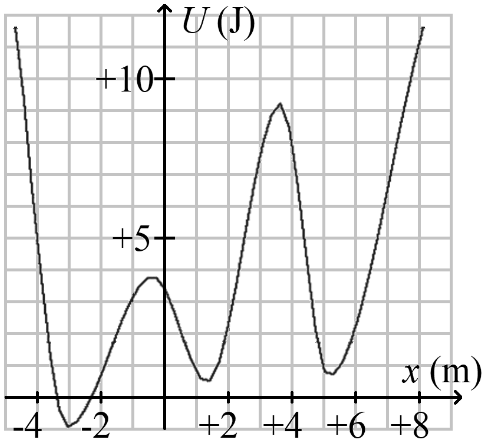
(a) 0.67 cm/s
(b) 1.4 cm/s
(c) 2.0 cm/s
(d) 0.0 cm/s
(e) 1.7 cm/s
(f) 1.2 cm/s

4. (8 points) A 2.0 kg object is travelling with a *speed* of 40 m/s in the $-x$ direction, when it becomes subject to a force that depends on time as shown. What is the *velocity* of the object after 10 s?



(a) +5.0 m/s
(b) +50.5 m/s
(c) -27.5 m/s
(d) 0 m/s
(e) -50.5 m/s

5. (8 points) A system has a potential energy U that depends on the position x of a particle within it, as shown. If the particle has a turning point at $x = -4.0\,\text{m}$, does it have another turning point? If so, where?



(a) Yes, its other turning point is at about +2.5 m.
(b) Yes, its other turning point is at about +3.5 m.
(c) Yes, its other turning point is at about -0.5 m.
(d) Yes, its other turning point is at about -3.0 m.
(e) No, the particle has no other turning point.
(f) Yes, its other turning point is at about +6.7 m.

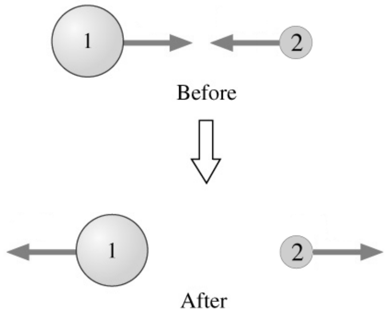
---

6. (8 points) A satellite is in a circular orbit at an altitude $3R_E$ above the Earth's surface, where R_E is the Earth's radius. Its thrusters fire, putting it in a new circular orbit at an altitude $2R_E$ above the Earth's surface (you may assume that the mass of fuel consumed in this process is negligible). Describe the change in the satellite's kinetic energy, and the change in the gravitational potential energy of the Earth-satellite system.

Note: g is *NOT* the same at an altitude of $3R_E$ and an altitude of $2R_E$. Remember that a positive value becoming less positive, and a negative value becoming more negative, are both "decreases", etc.

(a) Potential energy decreases. Kinetic energy remains the same.
(b) Potential energy increases. Kinetic energy remains the same.
(c) Potential energy increases. Kinetic energy decreases.
(d) Potential energy decreases. Kinetic energy increases.
(e) Potential energy increases. Kinetic energy increases.
(f) Potential energy decreases. Kinetic energy decreases.

7. (8 points) Object 1, with mass m_1, is travelling to the right with 60 J of kinetic energy. Object 2, with mass m_2, is travelling to the left with 40 J of kinetic energy. They undergo a perfectly elastic collision, after which object 1 is travelling to the left with 30 J of kinetic energy and object 2 is travelling to the right. If $m_1 > m_2$, what is the kinetic energy of object 2 after the collision?



(a) +20 J
(b) +70 J
(c) -20 J
(d) -50 J
(e) +50 J