UChicago 2020
Machines C Key
January 11, 2020

Total: 130 points

Page 1 (30 points)

Problem 1 [5 pts]. Bus wheel/Car Wheel
Answer: rb/rc = 22/18 = 11/9 = 1.222222

Problem 2 [5 pts]. Screwdriver
Answer: $(2\pi r_{sd} / p) = 2\pi 20 \text{ mm} / 1 \text{ mm} = 40\pi = 125.66$
where r_sd = $d_{sd}/2$ = 10 mm

Problem 3 [5 pts]. See-saw
Answer: $m_1/m_2 = (\cos\theta) / (2-\alpha)$

Problem 4 [5 pts]. Windlass with a ceiling
Answer: 2a/r

Problem 5 [5+5=10 pts]. Differential Windlass
i. *a=b*: The bucket never moves: IMA ~ \infinity
b=0: same as previous question (i.e. IMA 2)
ii. IMA = 2a/(a-b) -- for each full revolution (2πa in), the bucket ascends by π(a-b)

Page 2 (35 points)

Problem 6 [5+5+5=15 pts]. Simple Pulley (aka Double Tackle)
i. 4
ii. ~~1.64 (= 1024/625)~~ 2.316 (=1476/625)
iii. 5

Problem 7 [5 pts]. Pulley System
10

Problem 8 [5+5=10 pts]. Another pulley system
i. 16
ii. 40 N (technically 13.33 N with top ropes)

Problem 9 [5 pts]. Bicycle on a Ramp
Answer: $r_p/r_{gear1} * r_{gear2}/r_w * 1/\sin\theta = 20/14 * 10/60 * 1/\sin(17^o) = 10/7 * 1/6 * 1/0.2924 = 0.814$

Page 3 (30 points)

Problem 10 [2+3+5=10 pts]. Knife as a compound machine
i. Class 3 lever
ii. $1/ (2 \tan(\theta/2)) = 1/\theta = 1/0.01 = 100$
iii. Food is 4+1 = 5 in. from fulcrum; thumb is 1 in. from fulcrum -> lever has IMA 1/5
Overall: 20 (=100/5)

Problem 11 [10 pts]. Balancing the build portion of this event
1/2 (set torques from masses to cancel each other out) [but give 5 points for 1/3]

Problem 12 [2.5 x 4 = 10 pts]. Vinyl Record
i. 24 minutes = 1440 seconds
ii. 2π *6 in * 1s/1.8s = 20.944 in. (= 20π/3)
iii. 2π *2 in * 1s/1.8s = 6.981 in. (=20π/9)
iv. beginning

Page 4 (35 points)

Problem 13 [5+10=15 pts]. Gear system
i. 2
ii. r1/r2 * r3/r4 * r5/r1 * 2*2*2 = 8 * (r3*r5) / (r2 * r4) = 8 * (8*15) / (24*10) = 4

Problem 14 [10+10=20 pts.] Michelson's Harmonic Analyzer
i. 1.5 rpm; 1.5*n* rpm
ii. 3 cm; switching sides performs a phase shift of π without modifying the amplitude.