2004

M

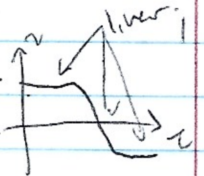
	B	BB	BBR
MC	26	31	35
MCs	33.4	39.9	45
FR	34	41	45
TOT	67.4	80.9	90

E/M

	B	BB	BBR
MC	26	33	35
MCs	33.4	42.4	45
FR	32	41	45
TOT	65.4	83.4	90

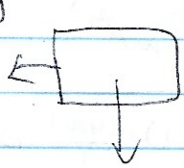
2004 MC M

MCMB $\frac{26}{35}$ MCMB, $\frac{33.4}{45}$

1)  (a) ✓

2) $\Delta x = \cancel{v_0 t} + \frac{1}{2}gt^2 = \frac{1}{2}(10)(36)$
$= 180$. (d) ✓

3)  J ↑ (e) ✓

4)  $F_f = \mu mg \cancel{\cos\theta}$

(c) ✓

5) $F = ma$ $a = \frac{F}{m} = \frac{4N}{3kg}$

(b) ✓

6) $\Delta p = \int F\,dt = 4\ kg \cdot m/s = mv_f$
$p_0 = 0$ $v_f = \frac{4}{3}$ (a) ✓

7) (a) ✓ 8) $mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\frac{v^2}{r^2}$

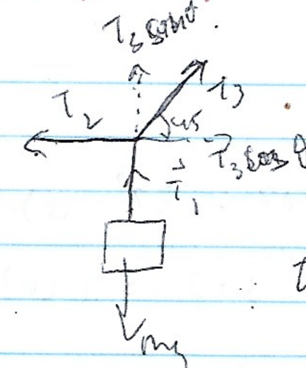
$v^2\left(\frac{1}{2}m + \frac{1}{2}\frac{I}{r^2}\right) = mgh$

~~$v^2 = \frac{2mgh}{I + m}$ $v = \sqrt{\frac{2mgh}{I+m}}$~~

$v^2\left(m + \frac{I}{r^2}\right) = 2mgh$

$v^2\left(\frac{mr^2 + I}{r^2}\right) = 2mgh$

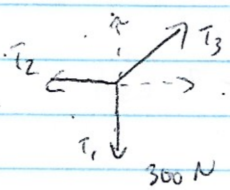
(e) ✓

9) 

$T_1 = mg$

~~$\frac{T_3}{\sqrt{2}} + T_1 = Mg$~~

~~$\frac{T_3}{\sqrt{2}} = T_2$~~



$\frac{T_3}{\sqrt{2}} = 300 = T_2$

$T_3 = 300\sqrt{2}$

(d) ✓

10) (e) ✓ 11) (c) ✓ 12) (c) ✓

13) $\Delta p = \int F\,dt$

$F = \frac{dp}{dt} = 3kt^2$ (a) ✓

14) (e) d ✓ 15) (a) F is ⊥ to $\vec{v}$

16) $v = 4\ m/s$ $\omega = \frac{v}{r} = \frac{4}{0.5} = 8$ (c) ✓

17) (e) ✓ 18) $T = 2\pi\sqrt{\frac{l}{g}} = 2$

$2\pi\sqrt{\frac{l}{10}} = 2$

$\sqrt{\frac{l}{10}} = \frac{1}{\pi}$ $\frac{l}{10} = \frac{1}{\pi^2}$

$l = \frac{10}{\pi^2} = 1$ (d) ✓

19) $A\sin\omega t$ $\omega = \frac{2\pi}{T} = \frac{2\pi}{2} = \pi$

$\theta_{max}\sin\pi t$ (b) ✓

20) (a) e  ?

-0 -2

21) $F = kx^2$

$W = \int F \cdot dx = k\int x^2 dx = \frac{k}{3}x^3$ (e) ✓

22) $\frac{1.5}{2} \cdot 4 + \frac{4}{2} \cdot 1 = 3 + 2 = 5\,J$ (b) ✓

23) $m_1 v_1 + m_2 v_2$

$1.5 \cdot 2 + 4 \cdot 1 = 3 + 4 = 7$ (d) ✓

24) $\frac{dx}{dt} = 6t + 1.5$

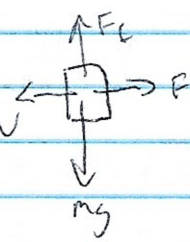
$\frac{dv}{dt} = 6$ (b) ✓

25) moves forward, then backwards (b) ✓

26) $\Sigma \tau = I\alpha = (T_2 - T_1)R$ (d) ✓

27) (e) ✓

28)



$F_f = mg = \mu N = \mu F$

$\mu F = mg \quad F = \frac{mg}{\mu}$ (c) ✓

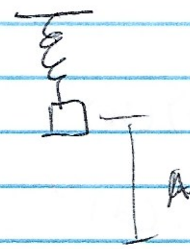
29) $T = 2\pi\sqrt{\frac{m}{k}}$ (e) ✓

30) $\frac{mgh}{t} = P = \frac{W}{t}$

$h = \frac{Pt}{mg} = \frac{100W \cdot (10s)}{10\,\cancel{\text{kg}}(100\,\text{kg})} = 1\,m$ (a)

m_E ✓

31) Max $\cancel{\frac{1}{2}mv^2 = \frac{1}{2}kA^2}$



$mgA + \frac{1}{2}kA^2 = \frac{1}{2}mv^2$

$\cancel{mg(\cos\theta)}$

$2mgA + kA^2 = mv^2$

$v^2 = 2gA + \frac{k}{m}A^2$

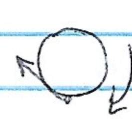
$v = \sqrt{2gA + \frac{k}{m}A^2}$

$= \sqrt{2(10)(0.1) + \frac{(400)}{1}(0.1)^2}$

$= 2.45\,\frac{m}{s}$ (a) ✓

32) (c) d 33) (b) c ?

34)



(c) a

35) (a) $\frac{GMm}{r}$ $2m, r$

b

-4

-3

2004 MC E   MCEB $\frac{24}{35} \rightarrow \frac{33.4}{45}$

36 1) $(2+2+2)^{-1} = \frac{1}{6}$ (e) ✓

37 2) $P = I^2 R = \frac{V^2}{R}$ $I = \frac{V}{R} = 10$

$R = \frac{V^2}{P} = \frac{(120)^2}{1200} = 12\,\Omega$ (d) c

38 3) (a) a

39 4) $V = -\int_0^5 E\,dr = -\frac{1}{2}ax^2 - bx$

$= -\frac{1}{2}(40)(.5)^2 - 6(4)$

$= -7$ (b) ✓

40 5) CCW, $\frac{mv^2}{r} = qvB$

$qBr = mv$ (c) ✓

41 6) $v = \frac{2\pi r}{T}$

$T = \frac{2\pi r}{v} = \frac{2\pi r\, m}{eBr}$

$= \frac{2\pi m}{eB}$ (c) ✓

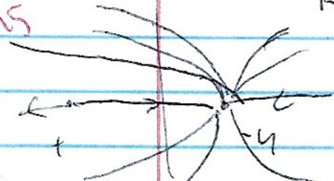
42 7) $U = \frac{1}{2}CV^2 = \frac{1}{2}(20\mu F)(30)^2 = 0.009$

(b) ✓

43 8) $qV = \frac{1}{2}mv^2$ $\sqrt{V}$ (c) ✓

44 9) $\oint B \cdot d\ell = \mu_0 I_{enc}$

$B \cdot 2\pi r = \mu_0 I \cdot \frac{r^2}{R^2}$ (b) ✓

45 10)  $-y, +x$ (e) ✓

46 11) $E = \frac{kQ}{r_1^2}$ $\frac{-k4Q}{r_2^2}$ $r_1 + r_2 = 4$

−2

$\frac{kQ}{r_1^2} + \frac{-4kQ}{r_2^2} = 0$ $r_1 + r_2 = 4$

$r_1 = 4 - r_2$

$\frac{1}{r_1^2} - \frac{4}{r_2^2} = 0$

$\frac{1}{16 - 8r_2 + r_2^2} - \frac{4}{r_2^2} = 0$

$r_2 = 8, \frac{8}{3}$ (a) ✓

47 12) $R_1 = 35\,\Omega$

$R_2 = 30\,\Omega$ inc slightly (b) ✓

48 13) $\frac{\ell_1}{A_1} \cdot \frac{A_2}{\ell_2} = \frac{\ell_1}{r_1^2} \cdot \frac{r_2^2}{\ell_2} = \frac{2\ell}{4r^2} \cdot \frac{r^2}{\ell}$

$= \frac{1}{2}$ (b) ✓

49 14) chg. accum. on outside, Q_{inside} is 0

$E = \frac{dV}{dr}$ $E_{outside} = \frac{kQ}{r^2}$ (c) ✓

$V = \frac{kQ}{r}$ $E = \frac{kQ}{r} \cdot \frac{1}{r}$

50 15) $\frac{F}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi r^{a}}$

51 16) $\mathcal{E} = \frac{d\Phi}{dt} = b\frac{dA}{dt}$

$= \frac{\pi B \cdot R^2}{t} = \frac{\pi b a^2 t^2}{t} = \pi b a^2 t$ (d) a

52 17) $I = \frac{V}{R} = \frac{\mathcal{E}}{R}$ $\mathcal{E} = 3R$ (e)? ✓

53 18) $\vec{E} \perp, \vec{B}_{\parallel}$ (b) ✓

54 19) B decreases, I_{ind} to the wire.

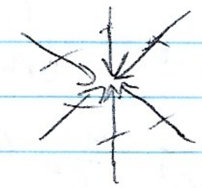
$\Delta B \leftarrow$ I $\rightarrow B$ right

F right?   a, c

(a) ✓   −3

55
20) (C) ✓ 56 21) $35 + (20^{-1} + 60^{-1})^{-1}$
$= 50\ \Omega$ (d) ✓

57
22) ~~$\frac{kQ}{R^2}$~~



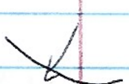
$E_{net} = 0$

(a) ✓

58
23) $U = \frac{kQQ}{r}$ ~~ee~~ $U_T = \frac{6kQ^2}{R}$

$= \frac{6 \cdot \frac{1}{2} Q^2}{2 \cdot 4\pi\varepsilon_0 R}$ (d) ✓

59
24)

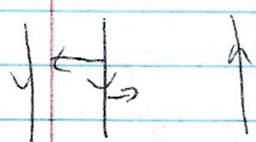


(b) a 60 25) (e) b

61 26) $W = q\Delta V = (-1\mu C)(10V)$
$= -10\mu J$ (b) ✓

62
27) (A) ✓ 63 28) $C = \frac{K\varepsilon_0 A}{d}$ (d) ✓

64
29)



(e) ✓

65
30) (e) ✓ 66 31) $I = \frac{12}{6} = 2A$ (c) ✓

67
32) $\Delta V = \mathcal{E} - L\frac{dI}{dt}$ (c) ? a

68
33) $E_{in} = \frac{kQ}{r^2} \cdot \frac{r^3}{R^3} = \frac{kQr}{R^3}$

$E_{out} = \frac{kQ}{r^2}$ (d) ✓

69
34) I - (-) III - (+) (d) ✓

70
35) ↓ electrons, → photons,

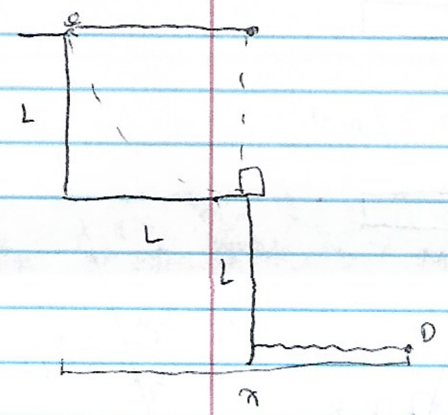
a, b P_2 lower (a) b -4

2004 FRM

FRMB $\frac{34}{45}$

FRMBL+4

1)



a) Since $\vec{T}$ is $\perp$ to $\vec{v}$, the rope does no work on the person.

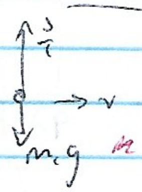
Thus, $\cancel{KE_o} + mgh_o = KE_f + \cancel{mgh_f}$ +1

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

$v^2 = 2gL$

$\boxed{v = \sqrt{2gL}}$ +1

b) $v = \sqrt{2gL}$ ~~the~~



$\Sigma F = T - mg = F_c = \frac{mv^2}{r}$ +1 +1 +1

$T = mg + \frac{m \cdot 2g\cancel{L}}{\cancel{L}} = \boxed{3mg}$ +1

c) $m_1 v_{1_0} + m_2 \cancel{v_{2_0}}^{\,0} = (m_1+m_2)v_f$ +1 +1

$v_f = \frac{m_1}{m_1+m_2} v_{1_0} = \boxed{\frac{m_1}{m_1+m_2}\sqrt{2gL}}$ +1

d) $KE_o = KE_1 = \frac{1}{2} m_1 v_1^2$

$= \frac{1}{2} m_1 \cdot 2gL = m_1 g L$

~~E mgL~~

$KE_f = \frac{1}{2}(m_1+m_2)v_f^2$ +1

$= \frac{1}{2}(m_1+m_2)\cdot\frac{m_1^2}{(m_1+m_2)^2}\cdot 2gL$

$= \frac{m_1^2}{m_1+m_2} gL$

$\frac{KE_o}{KE_f} = \frac{\cancel{m_1 g L}(m_1+m_2)}{m_1^{\cancel{2}}\cancel{gL}} = \boxed{\frac{m_1+m_2}{m_1}}$ +1

e) $v_x = \frac{m_1}{m_1+m_2}\sqrt{2gL}$

$\Delta x = v_x t$ +1

$v_{f_y}^2 = \cancel{v_{0_y}^2} + 2gL$

$v_{f_y} = \sqrt{2gL}$ $\quad v_{f_y} = \cancel{v_{0_y}} + gt$

$t = \frac{v_{f_y}}{g} = \frac{\sqrt{2gL}}{g} = \sqrt{\frac{2L}{g}}$ +1

$\Delta x = \frac{m_1}{m_1+m_2}\sqrt{2\cancel{g}L}\cdot\sqrt{\frac{2L}{\cancel{g}}}$ +1

$= 2L\cdot\frac{m_1}{m_1+m_2}$

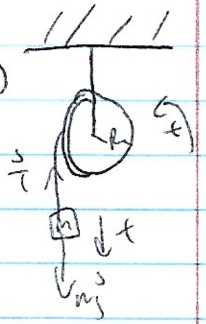
$x = L + 2L\cdot\frac{m_1}{m_1+m_2}$

$= \boxed{L\left(1+\frac{2m_1}{m_1+m_2}\right)}$ +1

$\left(1+\frac{2m_1}{m_1+m_2}\right) = \left(\frac{2m_1+m_1+m_2}{m_1+m_2}\right)$

$= \frac{3m_1+m_2}{m_1+m_2}$

2)



a) $\Sigma F = ma = mg - \vec{T}$

$\Sigma \tau = I\alpha = RT$ +1

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

$\boxed{a = \frac{2D}{t^2}}$ +1

b) (i) $a = \frac{2D}{t^2}$ $\quad D = \frac{1}{2}at^2$

plot D vs. $\frac{1}{2}t^2$, so the graph takes the form $y = mx$, a line with y-intercept 0. The slope gives a. +1 +1

(ii), (iii), see paper

c) $\Sigma F = ma = mg - \vec{T}$ +1 $\quad T = mg - ma$

$\Sigma \tau = I\alpha = R\vec{T}$ +1

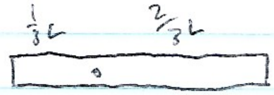
$I\alpha = I\frac{a}{R} = R(mg - ma)$ +1

$\boxed{I = mR^2\left(\frac{g-a}{a}\right)}$ +1

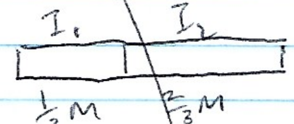
d) There was friction on the pulley's axle, which caused the found acceleration to be lower than expected, which caused the rotational inertia to be less than expected.

-2

3)



a) $I = \int r^2\,dm = \Sigma m r^2$



$I = I_1 + I_2$ $\quad \lambda = \frac{\frac{1}{3}m}{\frac{1}{3}L} = \frac{m}{L}$

$I_1 = \int_0^{\frac{1}{3}m} \left(\frac{1}{3}L\right)^2 dm$

$= \frac{1}{9}\int_0^{\frac{1}{3}m} L^2\,dm$ $\quad \lambda = \frac{m}{L} \quad L = \frac{m}{\lambda}$

$= \frac{1}{9}\int_0^{\frac{1}{3}m} \left(\frac{m}{\lambda}\right)^2 dm$

$= \frac{1}{9\lambda^2}\int_0^{\frac{1}{3}m} m^2\,dm = \frac{1}{9\lambda^2}\left(\frac{1}{3}m^3\right)\Big|_0^{\frac{1}{3}m}$

$= \frac{1}{9\lambda^2}\cdot\left(\frac{1}{3}\cdot\frac{1}{27}m^3\right)$ $\quad \lambda = \frac{m}{L}$

$= \frac{L^2}{9m^2}\left(\frac{1}{81}m^3\right) = \frac{1}{729}mL^2$

$I_2 = \int_0^{\frac{2}{3}m} \left(\frac{2}{3}L\right)^2 dm = \frac{4}{9}\int_0^{\frac{2}{3}m} L^2\,dm$ $\quad \lambda = \frac{m}{L} \quad L = \frac{m}{\lambda}$

$= \frac{4}{9\lambda^2}\int_0^{\frac{2}{3}m} m^2\,dm = \frac{4}{9\lambda^2}\left(\frac{1}{3}m^3\right)\Big|_0^{\frac{2}{3}m}$

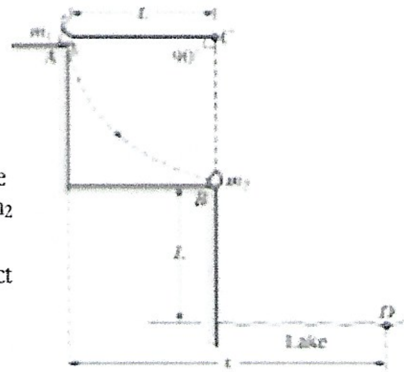
$= \frac{4}{9\lambda^2}\left(\frac{1}{3}\cdot\frac{8}{27}m^3\right) = \frac{4L^2}{9m^2}\left(\frac{8}{81}m^3\right)$

$= \frac{32}{729}mL^2$

$I_{total} = I_1 + I_2 = \boxed{\frac{33}{729}mL^2}$

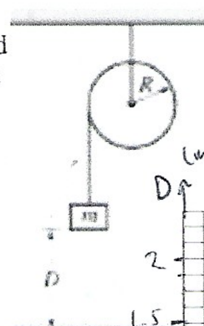
-4

'04 MECHANICS



1. A rope of length L is attached to a support at point C. A person of mass m_1 sits on a ledge at position A holding the other end of the rope so that it is horizontal and taut. The person then drops off the ledge and swings down on the rope toward position B on a lower ledge where an object of mass m_2 is at rest. At position B the person grabs hold of the object and simultaneously lets go of the rope. The person and object then land together in the at point D, which is a vertical distance L below position B. Air resistance and the mass of the rope are negligible. Derive expressions for each of the following in terms of m_1, m_2, L, and g.
   A. The speed of the person just before the collision with the object
   B. The tension in the rope just before the collision with the object.
   C. The speed of the person and object just after the collision
   D. The ratio of the KE of the person-object system before the collision to KE after the collision
   E. The total horizontal displacement x of the person from position A until the person and object land in the water at point D.

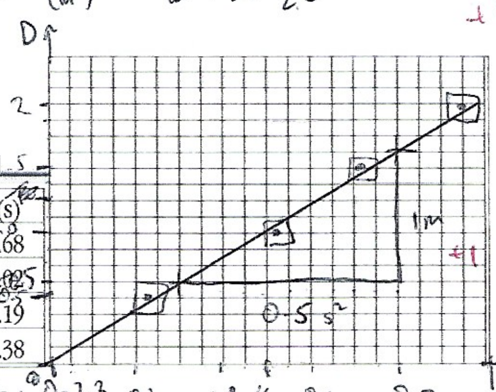
2. A solid disk of unknown mass and known radius R is used as a pulley in a lab experiment. A small block of mass m is attached to a string, the other end of which is attached to the pulley and wrapped around several times. The block of mass m is released from rest and takes time t to fall the distance D to the floor.
   A. Calculate the linear acceleration a of the falling block in terms of the given quantities.
   B. The time t is measured for various heights D and the data are recorded in the table.
      1. What quantities should be graphed in order to best determine the acceleration of the block? Explain your reasoning.
      2. On the grid, plot the quantities determined in (B.1), label the axes, and draw the best-fit line to the data.
      3. Use your graph to calculate the magnitude of the acceleration.
   C. Calculate the rotational inertia of the pulley in terms of m, R, a, and fundamental constants.
   D. The value of acceleration found in (B.3), along with numerical values from the given quantities and your answer to C, can be used to determine the rotational inertia of the pulley. The pulley is removed from its support and its rotational inertia is found to be greater than this value Give one explanation for this discrepancy.



2) B) (ii)

D vs. $\frac{1}{2}t^2$

D(m)	t(s)
0.5	0.68
1	1.025
1.5	1.19
2	1.38



+1 +1 +1

2)B)(iii)

$a = \frac{\Delta y}{\Delta x} = \frac{1m}{0.5 s^2} = \boxed{2 \frac{m}{s^2}}$

+1

+1

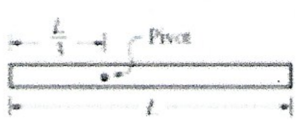
$\frac{1}{2}t^2$: 0.23

0.52

0.71

0.95

3. A uniform rod of mass M and length L is attached to a pivot of negligible friction. The pivot is located at a distance L/3 from the left end of the rod. Express all answers in terms of the given quantities and fundamental constants.
   A. Calculate the rotational inertia of the about the pivot.
   B. The rod is then released from rest from the horizontal position. Calculate the linear speed of the bottom end of the rod when the rod passes through the vertical.
   C. The rod is brought to rest in the vertical position and hangs freely. It is then displaced slightly from this position. Calculate the period of oscillation as it swings



blue points

3) a) I_1 I_2 $\frac{1}{3}$ $\frac{2}{3}$

$I = \int r^2 dm \quad \frac{dm}{dr} = \lambda = \frac{m}{L} \quad \frac{dm}{dr} \cdot dr = dm$ +1

$I = I_1 + I_2$

$I_1 = \int r^2 dm = \int_0^{\frac{1}{3}L} \lambda r^2 dr$

$= \lambda \left(\frac{1}{3} r^3\right)_0^{\frac{1}{3}L}$

$= \lambda\left(\frac{1}{3}\cdot\left(\frac{1}{27}L^3\right)\right) = \frac{M}{L}\left(\frac{1}{81}L^3\right)$ +1

$= \frac{1}{81}ML^2$

$I_2 = \int r^2 dm = \int_0^{\frac{2}{3}L} \lambda r^2 dr$ +1

$= \lambda\left(\frac{1}{3}r^3\right)_0^{\frac{2}{3}L}$

$= \frac{M}{L}\left(\frac{1}{3}\cdot\frac{8}{27}\cdot L^3\right) = \frac{8}{81}ML^2$

$I_{total} = I_1 + I_2 = \boxed{\frac{1}{9}ML^2}$ +1

4BL

b) Mg $\quad \frac{2}{3}L$

$\frac{1}{2} - \frac{1}{3} = \frac{1}{6}$

$\cancel{KE_{t_0}} + \cancel{KE_{r_0}} + PE_g = KE_{r_f} + KE_{t_f} + \cancel{PE_{g_f}}$ +1 +1

$\frac{1}{6} mgL = \frac{1}{2} m v_{cm}^2 + \frac{1}{2} I \frac{v_{cm}^2}{\left(\frac{1}{6}L\right)^2}$ +1 +1 ← includes KE_r

$\frac{1}{6} mgL = \frac{1}{2} m v_{cm}^2 + \frac{1}{2}\cdot\frac{1}{9} mL^2 \cdot \frac{v_{cm}^2 \cdot 36}{L^2}$

$v_{cm}^2\left(\frac{1}{2}m + 2m\right) = \frac{1}{6} mgL$ +2

$v_{cm}^2 = \frac{2}{5m}\cdot\frac{1}{6}mgL$

$= \frac{1}{15} gL \qquad v_{cm} = \sqrt{\frac{gL}{15}}$

$\omega = \frac{v_{cm}}{R} = \frac{v_{cm}}{\frac{1}{6}L}$ $\qquad$ R - distance from pivot

$= \frac{6}{L}\sqrt{\frac{gL}{15}} = \sqrt{\frac{36g}{15L}}$

$= \sqrt{\frac{12g}{5L}}$

$v_{tip} = r\omega = \frac{2}{3}L\sqrt{\frac{12g}{5L}}$

$= \sqrt{\frac{12\cdot 4\, gL}{9\cdot 5}} = \boxed{\sqrt{\frac{16}{15}gL}}$ −1

c) ? −4

$\sum \tau,\ I\alpha = mg\sin\theta = I\frac{d^2\theta}{dt^2}$

$\frac{d^2\theta}{dt^2}\frac{1}{\sin\theta} = \frac{mg}{I}$

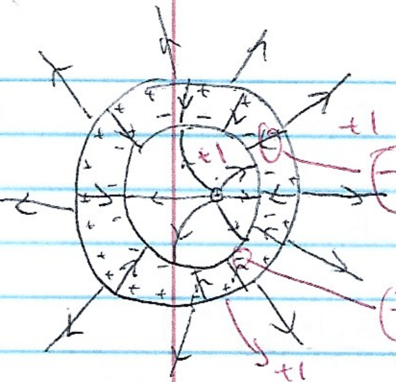
$\frac{mg}{I}dt^2 = \frac{1}{\sin\theta}d\theta$

−5

2004 FR E

FRED $\frac{32}{45}$

1) a)



+1

-1 no field inside

-1 not evenly spaced

+1

b)

3 V_a 5 V_b 4 V_c 1 V_d +1

+1

2 V_e

-1 $V_b = V_e$ -1 V_a has lowest potential

c)

(i) $\int E \cdot dA = \frac{Q_{enc}}{\varepsilon_0}$ $\lambda = \frac{Q}{l}$

$r < r_1$: $Q_{enc} = \lambda dl$ +1

$E \cdot 2\pi r \cancel{dl} = \lambda \cancel{dl}$

+1

$\boxed{E = \frac{\lambda}{2\pi r}}$ $\frac{\lambda}{2\pi\varepsilon_0 r}$

(ii) $\int E \cdot dA = \frac{Q_{enc}}{\varepsilon_0}$ $\rho = \frac{Q}{V} = \frac{Q}{A\,dl}$

$r_1 < r < r_2$ $Q_{enc} = \lambda dl + \rho A dl$ +1

$= dl(\lambda + \rho(\pi r^2 - \pi r_1^2))$

$E \cdot 2\pi r \cancel{dl} = \cancel{dl}(\lambda + \rho\pi(r^2 - r_1^2))$ Substitution +1

$\boxed{E = \frac{\lambda + \rho\pi(r^2 - r_1^2)}{2\pi r \varepsilon_0}}$

-4

(iii) $\int E \cdot dA = \frac{Q_{enc}}{\varepsilon_0}$

$Q_{enc} = \lambda dl + \rho A dl$ +1

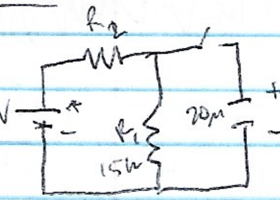
$= \lambda dl + \rho dl(\pi r_2^2 - r_1^2)$

$E \cdot 2\pi r \cancel{dl} = \lambda dl + \rho dl(\pi r_2^2 - r_1^2)$

Substitution +1

$\boxed{E = \frac{\lambda + \rho\pi(r_2^2 - r_1^2)}{2\pi r \varepsilon_0}}$

2) a) $V_c = 0$



$V_2 = \mathcal{E} - V_1$

b) $V_2 = \boxed{8V}$ +1

c) $\Delta V_1 = IR_1$

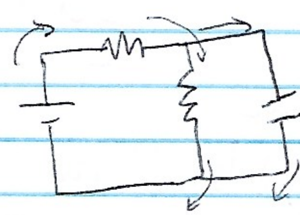
$I = \frac{12V}{15k\Omega} = 8.0\times10^{-4}$ A +1

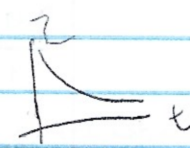
$R = \frac{V}{I} = \frac{8V}{8.0\times10^{-4} A} = \boxed{10\ k\Omega}$ +1 +1

d) $U_c = \frac{1}{2}CV^2 = \frac{1}{2}(20\mu F)(12V)^2$ +1 +1

$= \boxed{1.4\times10^{-3}\ J}$ +1

e) - f), see paper

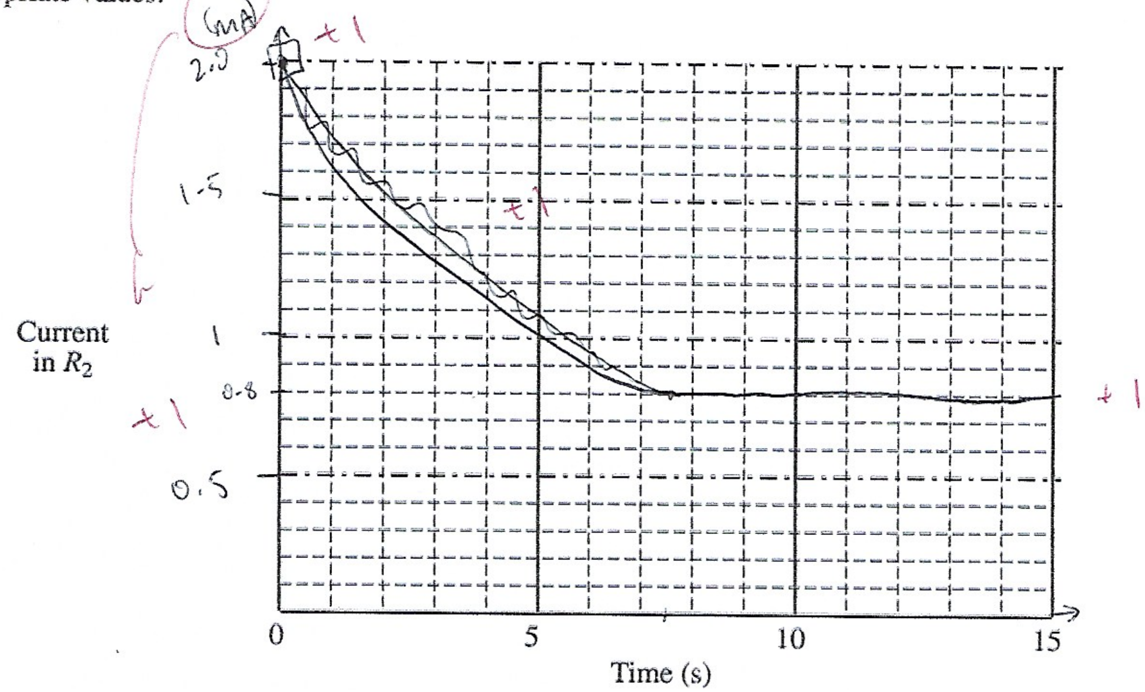




a) $\Delta V_1 = 0$ $\boxed{V_2 = 20V}$ +1

$I = \frac{V}{R} = \frac{20V}{10k\Omega} = 2\ mA$

(e) On the axes below, graph the current in R_2 as a function of time from 0 to 15 s. Label the vertical axis with appropriate values.



Resistor R_2 is removed and replaced with another resistor of lesser resistance. Switch S remains closed for a long time.

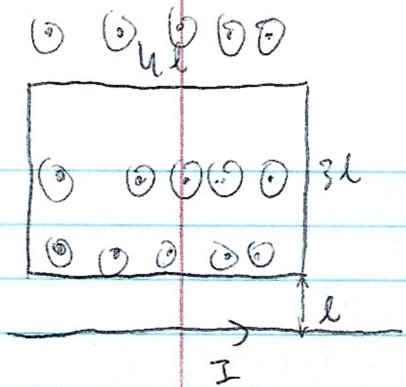
(f) Indicate below whether the energy stored in the capacitor is greater than, less than, or the same as it was with resistor R_2 in the circuit.

X Greater than +1 ____ Less than ____ The same as

Explain your reasoning.

$U_c = \frac{1}{2}CV^2$ less resistance = less voltage drop, which means the capacitor's final voltage is higher, which means it stores more energy. +2

3)



a)

$$\int B \cdot d\ell = \mu_0 I$$

$$dB = \frac{\mu_0}{4\pi} \frac{I\, d\vec{\ell} \times \hat{r}}{r^2}$$

$$B = \frac{\mu_0 I}{4\pi} \int_{\ell}^{4\ell} \frac{dr}{r^2} \qquad r^{-2}$$

$$= \frac{\mu_0 I}{4\pi}\left(-\frac{1}{r}\right)_{\ell}^{4\ell}$$

$$= \frac{\mu_0 I}{4\pi}\left(-\frac{1}{4\ell} + \frac{1}{\ell}\right)$$

$$= \frac{\mu_0 I}{4\pi \ell}\left(\frac{3}{4}\right) = \frac{3\mu_0 I}{16\pi \ell}$$

$$\Phi = BA = \frac{3\mu_0 I}{16\pi \ell} \cdot 12\ell^2$$

$$= \frac{9\mu_0 I \ell}{4\pi}$$

-4

b) B is decreasing over time

Current is ccw +1 since the induced current acts to oppose the change in magnetic field. Since $\frac{dB}{dt}$ is into the page, the induced field is out of the page, thus ccw current.

+2

-4

c) $\underline{\mathcal{E} = \frac{-d\Phi}{dt} = IR}$ +1

$$I(t) = \frac{d\Phi}{dt} R$$

$$= \frac{9}{4} \frac{\mu_0 \ell R}{\pi}\left(I_0 e^{-kt}\right)$$

-3

d) $P = I^2 R = \frac{U}{t}$

+1

integral +1

$$U = I^2 R t$$

$$= R\int_0^{\infty} \left(I_0 e^{-kt}\right)^2 dt$$

$$= R I_0^2 \int_0^{\infty} e^{-2kt}\, dt$$

$$= R I_0^2 \lim_{b\to\infty} \int_0^b e^{-2kt}\, dt$$

$$= R I_0^2 \lim_{b\to\infty}\left(-\frac{1}{2k} e^{-2kt}\right)_0^b$$

-2

$$= R I_0^2 \lim_{b\to\infty}\left(-\frac{1}{2k} e^{-2kb} + \frac{1}{2k}\right)$$

$$= \boxed{\frac{R I_0^2}{2k}}$$

-5

2004 BR

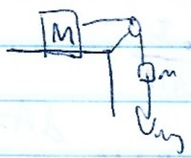
MCM 14, 20, 23, 25, 30, 32, 33, 34, 35

E 2/37, 3/38, 15/50, 16/51, 17/52

24/59, 25/60, 32/67, 35/70

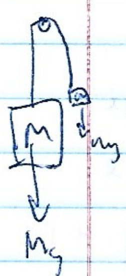
14) (b) d

20)



$\cancel{mg = (M+m)a}$

$\cancel{a = \frac{m}{M+m} g}$



$Mg - mg = (M+m)a$

$a = \frac{M-m}{M+m} g$ (e) +1

23) ρ is constant $3+4=7$ (d) c

25) (b) c

30) $P = \frac{W}{t}$ $W = Pt$

$= 1{,}000\ J$

$mgh = 1{,}000\ J$

$(100\ kg)(10\ m/s^2)\ h = 1000\ J$

$h = 1\ m$ (a) c

32) (d) +1 33) (c) +1 34) centripetal

(a) +1

35) $\frac{GMm}{r} = \frac{1}{2} m v_e^2$

$v_e = \sqrt{\frac{2GM}{r}}$ (b) +1

+5 B, M

2(37) $V = Ir$

$P = I^2 R = \frac{V^2}{R}$

$I = \frac{V}{R}$

$P = \frac{V^2}{R^2} \cdot R = \frac{V^2}{R}$

$R = \frac{V^2}{P} = \frac{120^2}{1200} = 12\ \Omega$

(c) +1

3/38) (a) gauss' law +1

15/50) $\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi r}$ (c) +1

16/51) $\mathcal{E} = B \pi a^2 t^2 \left(\frac{d}{dt}\right)$

$= 2B\pi a^2 t$ (a) +1

17/52) ? (e) c

24/59) (a) high to low V

25/60) (b) +1 32/67) (e) a

35/70) (b) +1

+7 B, E

14) d 23) c 25) c 30) c +4 M, R

17/52) c 25/60) a +2 R, E

FRM

2) d) the effective radius of the pulley was larger than expected b/c the string was wrapped around, and the string also increased the mass. +2

3) a) +4 BL (see orig.)

3) b) $\frac{1}{6} mgL = \frac{1}{2} I \omega^2 = \frac{1}{2} I \cdot \frac{v_{cm}^2}{(\frac{1}{6}L)^2}$

$\frac{1}{6} mgL = \frac{1}{2}\left(\frac{1}{9} ML^2\right) \cdot \frac{36 v_{cm}^2}{L^2}$

$\frac{1}{6} mgl = 2 m v_{cm}^2$

$v_{cm} = \sqrt{\frac{gl}{12}}$

$\omega = \frac{v}{R} = \sqrt{\frac{gl}{12}} \cdot \frac{6}{l}$

$= \boxed{\sqrt{\frac{3g}{l}}}$

$v_{tip} = r\omega = \frac{2}{3}L\sqrt{\frac{3g}{L}} = \boxed{2\sqrt{\frac{gL}{3}}}$ +1

3) c) $\Sigma\tau = I\alpha = mg\sin\theta\cdot\frac{1}{6}L = I\frac{d^2\theta}{dt^2}$

$\theta = \theta_{max}\sin(\omega t)$

$\frac{d\theta}{dt} = \theta_{max}\omega\cos(\omega t)$

$\frac{d^2\theta}{dt^2} = -\theta_{max}\omega^2\sin(\omega t)$

$\frac{1}{6}mgL\sin\theta = -I\theta_{max}\omega^2\sin(\omega t)$

$\theta=0 \quad 0 = -I\theta_{max}\omega^2\sin(\omega t)$?

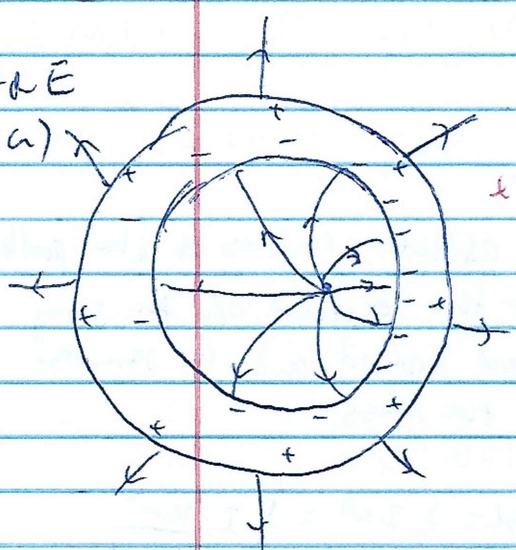
3) c) $T = 2\pi\sqrt{\frac{I}{mgd}}$ +1 $= 2\pi\sqrt{\frac{mL^2/9}{mgL/6}}$ +1

$d = \frac{L}{6}$ +1 $= \boxed{2\pi\sqrt{\frac{2L}{3g}}}$ +1

turn

FRE

1) a)



+2

b) ?

3) a) $\Phi = \int B\cdot dA$

$\oint B\cdot dl = \mu_0 I$

$B\cdot 2\pi r = \mu_0 I$

$B = \frac{\mu_0 I}{2\pi r}$

$\Phi = \int_l^{4l}\frac{\mu_0 I}{2\pi r}\cdot 4l\,dr$ $\quad dA = 4l\,dr$ +1

$= \frac{\mu_0 I}{2\pi}\cdot 4l\int_l^{4l}\frac{dr}{r}$ +1

$= \frac{2\mu_0 Il}{\pi}\left(\ln|r|\right)_l^{4l}$

$= \frac{2\mu_0 Il}{\pi}\ln\left|\frac{4l}{l}\right|$ +1

$= \boxed{\frac{2\mu_0 Il}{\pi}\ln 4}$ +1

c) $\mathcal{E} = \frac{-d\Phi}{dt} = IR$

$I = \frac{\mathcal{E}}{R} = -\frac{1}{R}\frac{d\Phi}{dt}$ +1

$= -\frac{1}{R}\frac{d}{dt}\left(\frac{2\mu_0 l}{\pi}\ln 4\, I_0 e^{-kt}\right)$ +1

$= -\frac{1}{R}\cdot -k\cdot\frac{2\mu_0 l}{\pi}\ln 4\, I_0 e^{-kt}$ +1

$= \boxed{\frac{2\mu_0 kl}{\pi R}I_0 e^{-kt}\ln 4}$

+7

3) d) $U = \int_0^\infty P\,dt \qquad P = I^2 R$

$= R\int_0^\infty \left(\frac{2\mu_0 k l \ln 4}{\pi R}\right)^2 (I_0 e^{-kt})^2\,dt$

$= \frac{4\mu_0^2 k^2 l^2 (\ln 4)^2 I_0^2}{\pi^2 R} \int_0^\infty e^{-2kt}\,dt$

$= \quad " \quad \left(-\frac{1}{k} e^{-kt}\right)_0^\infty$

$= \quad " \quad \left(0 + \frac{1}{k}\right)$ ϕ

$= \boxed{\frac{4\mu_0^2 k l^2 (\ln 4)^2 I_0^2}{\pi^2 R}}$ +9BE

1) b) V_a 4 V_b 3 V_c 2

V_d 1 V_e 3 +2

3) d) $\frac{4\mu_0^2 k^2 l^2 (\ln 4)^2 I_0^2}{\pi^2 R} \int_0^\infty e^{-2kt}\,dt$

$= \quad " \quad \left(-\frac{1}{2k}\right) e^{-2kt}\Big|_0^\infty$

$= \left(\frac{2 l \mu_0 I_0}{\pi} \ln 4\right)^2 \frac{k}{2R}$ +2

+4RE