2009

Mech

	B	BB	BBR
MC	30	33	35
MC_s	38.6	42.4	45
FR	32	43	45
TOT	70.6	85.4	90

E/M

	B	BB	BBR
MC	26	30	35
MC_s	33.4	38.6	45
FR	36	43	45
Tot	69.4	81.6	90

2009 AP C M

$\frac{30}{35}$ B

1) $v_f = v_0 + at = 4 \cdot 5 = 20$ (c) ✓

2) $\Delta x = \cancel{v_0 t} + \frac{1}{2} a t^2 = \frac{1}{2}(4)(25)$
$= 50m$ (e) ✓

3) (e) ✓ 4) $\Sigma F_1 = m_1 a_1$
$= m_2 a_2$ (c) ✓

5) (b) ✓ 6) $v_f^2 = v_0^2 + 2gd$
$v_f = \sqrt{2(10)(0.2)} = 2$ (b) ✓

7) $\Delta P = 0 = Ft = 1kg \cdot 6 m/s$ / s

$F = \frac{dP}{dt} = 6N$ (b) ✓

8) $\Delta\theta = \cancel{\omega_0 t} + \frac{1}{2}\alpha t^2$
$= \frac{1}{2}(3)(4)^2 = 3 \cdot 8 = 24$ (d) ✓

9) $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{2kg}{50 N/m}}$
$= 1.2\dot{6} = 0.4\pi$ (c) ✓

10) U_{min} (e) ✓

11) $F = \frac{Gmm}{r^2}$ I, III (e) ✓

12) I, II (c) ✓

13) (c) e

14) $N = mg\cos\theta$
$\Sigma F = ma = mg\sin\theta$
(d) ✓

15) $\left(\frac{v}{2}\right)^2 \quad \frac{1}{4}v^2$ (d) ✓

16) $\frac{dy}{dx} = \frac{B}{A}$ (c) ✓

17) $\frac{dy}{dx} = \frac{2Bt}{A}$ $\quad \frac{dy}{dx} = \frac{2Bt}{2At}$

$\frac{dy}{dx} = \frac{-2A\omega\sin\omega t}{A\omega\sin\omega t}$ $\quad \frac{dy}{dx} = \frac{A\omega\cos\omega t}{-A\omega\sin\omega t}$ (a) e

-3

18) circular (a) ✓

19) $mg\sin\theta - \mu mg\cos\theta = 0$
$\mu = \tan\theta$ (e) ✓

20) $F\vec{v}\cos\theta = F\vec{v} = ma\vec{v} = P$
$= (2000kg)(3 m/s^2)\left(\frac{20 - 0 m/s}{2}\right)$
$= 60{,}000$ W (e) ✓

21) $x_{cm} = \frac{M_p \frac{L}{2}}{M + M_p}$

Cm shifts to the left

2d (c) ✓

22) $\Sigma F = ma = mg - kv = m\frac{dv}{dt}$

$\frac{m}{dt} = \frac{mg - kv}{dv}$

$\int_0^t \frac{dt}{m} = \int_0^v \frac{dv}{mg - kv}$ (a) ✓

23) $\Sigma F = Mg - T = 0$ (e) ✓

24) $\Sigma F_{hand} = T = Ma$
$a = \frac{T}{M}$ (d) b

25) L conserved b, c, e $\quad \frac{1}{2}I\omega^2$
RKE is conserved (b) c

26) $m_1 v_1 = m_2 v_2 \quad \frac{1}{2}m v_1^2 \neq \frac{1}{2}m_2 v_2^2$

(e) ✓

-2

27) $mv_f = Ft$ $\quad J = F\Delta t = \Delta p$

$v_f = \frac{Ft}{m} = \frac{0.5 \cdot 4}{5kg} = \frac{2}{5} = 0.4 \, m/s$

$mv_f = \int_0^4 0.5t \, dt$

$= \frac{1}{2}\left(\frac{1}{2}t^2\right)_0^4$

$= \frac{1}{2}\left(\frac{1}{2}16\right) = 4$

$v_f = \frac{4}{5}$ (b) ✓

28) $p_x = mv \leftarrow$

$p_y = 0$

4, b, 4, d

(d) ✓

29) $v_{oy} = v_0 \sin\theta$

$\cancel{v_f} = v_0 + gt$

$t_{up} = \frac{-v_0 \sin\theta}{-g} = \frac{v_0 \sin\theta}{g}$

(e) ✓

30) $F_T = \frac{mv^2}{r}$ $\quad \frac{mv^2}{2r} \cdot \frac{1}{4} = \frac{1}{8}$

$\frac{mv^2}{r}$ $\quad v = \frac{2\pi r}{T}$ (e) ✓

$T = \frac{2\pi r}{T}$

$f = \frac{T}{2\pi r}$ $\quad 4T$

31) $mgh = \frac{1}{2}mv_1^2$

$v_1 = \sqrt{2gh}$

$\frac{1}{2}m \cdot 2gh + mgh = \frac{1}{2}mv_2^2$

$2gh = \frac{1}{2}v_2^2$

$v_2^2 = 2(2gh)$

$v_2 = \sqrt{2} \cdot \sqrt{gh}$ (c) ✓

32) $p_y = 0$ $\quad p_x = 0$ (e) ✓

33) $L = rmv$ $\quad \frac{mv^2}{r} = \frac{GMm}{r^2}$

L_1

$v = \sqrt{\frac{GM}{r}}$

v_3 less

$v_2 = \frac{1}{\sqrt{2}} v_0$

(a) ✓

$v_3 = \frac{1}{\sqrt{3}} v_0$

34) (d) ✓ $\quad$ 35) $\uparrow F_f$, $\rightarrow \vec{N} = F_c$, $\downarrow mg$

$v = r\omega$

$\mu \frac{mv^2}{R} = mg$

$\mu m \frac{R^2\omega^2}{R} = mg$

$\mu = \frac{g}{r\omega^2}$ (b) ✓

B 32

2009 EK M

9:36 – 9:44
1:32 – 2:09

1) a) at $x = -0.50\,m$,

$E = U + KE$ +1

$= 4.0(-0.50\,m)^2 + \frac{1}{2}mv^2$

$= 4.0(-0.50\,m)^2 + \frac{1}{2}(3.0\,kg)(2.0\,m/s)^2$

$= 1 + 6\,J = \boxed{7.0\,J}$ +1

b) when $KE = 0$, $U = 7.0\,J$ +1

$4.0x^2 = 7.0$ +1

$x^2 = \frac{7.0}{4.0}$

$x = \pm \frac{\sqrt{7}}{2}\,m$

$= \boxed{1.32\,m,\ -1.32\,m}$ +1

c) at $x = 0.60\,m$, $U = 4.0(0.60\,m)^2$

$= 1.44\,J$

+1

$KE = \frac{1}{2}mv^2 = 7 - 1.44\,J = 5.56\,J$

+1 $v = \sqrt{\frac{2\,KE}{m}} = \sqrt{\frac{2(5.56\,J)}{3.0\,kg}}$

calc. error

$= 1.26\,m/s$ 1.92

$p = mv = (3.0\,kg)(1.26\,m/s) = \boxed{3.78\,kg\cdot m/s}$

+1

5.8 kg·m/s

d) $\Sigma F = \frac{dp}{dt} = ma$

$a = \frac{dp}{dt}\cdot\frac{1}{m}$

$p = mv = \sqrt{2mKE} = \sqrt{2m(7 - 4.0x^2)}$

$a = \frac{dp}{dt}\cdot\frac{1}{m} = \frac{d}{dt}\frac{1}{m}\left(\cancel{\sqrt{14m - 8mx^2}}\right)$

$= \frac{1}{m}\frac{d}{dt}\left(\sqrt{14 - 8x^2}\right)$

d) $p = \sqrt{2m}\sqrt{7 - 4.0x^2}$

$\Sigma F = \frac{dp}{dt} = ma$

$a = \frac{1}{m}\frac{dp}{dt} = \frac{1}{m}\frac{dp}{dx}\cdot\frac{dx}{dt}$

$= \frac{v}{m}\frac{dp}{dx}$

$= \frac{v}{m}\sqrt{2m}\,\frac{d}{dx}\left(\sqrt{7 - 4.0x^2}\right)$

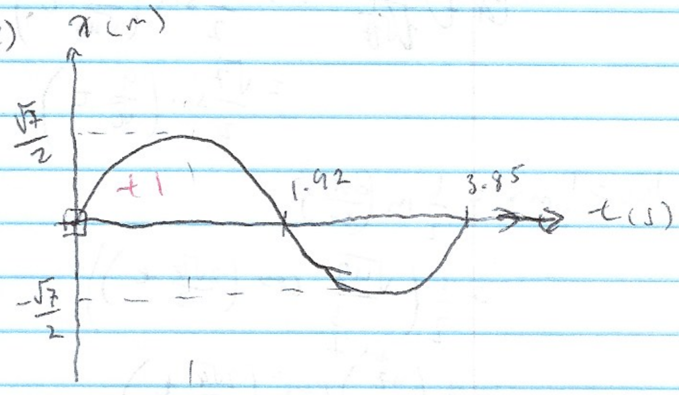
$= \frac{v\sqrt{2}}{\sqrt{m}}\cdot\frac{-4x}{\sqrt{7 - 4.0x^2}}$

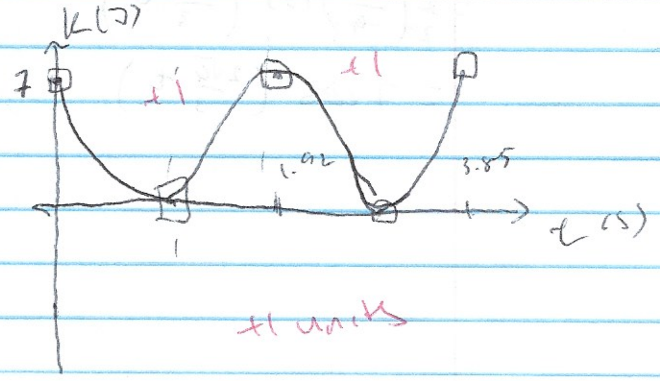
at $x = 0.60\,m$, $v = 1.26\,m/s$

$a = \frac{(1.26\,m/s)\sqrt{2}}{\sqrt{(3.0\,kg)}}\cdot\frac{-4(0.60\,m)}{\sqrt{7 - 4.0(0.60\,m)^2}}$

$|a| = \boxed{1.05\,m/s^2}$ -3

e)





+1 units

$K = 7 - U = 7 - 4x^2$ K vs x

-3

(e) $KE = \frac{1}{2}mv^2 = 7 - U = 7 - 4x^2$

$$7 - 4x^2 = \frac{1}{2}m\left(\frac{dx}{dt}\right)^2 = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{14-8x^2}{m}} = \frac{dx}{dt}$$

$$dt = \frac{dx}{\sqrt{\frac{14-8x^2}{m}}} = \frac{\sqrt{m}\,dx}{\sqrt{14-8x^2}}$$

$$\int_0^t dt = \sqrt{m}\int_0^x \frac{dx}{\sqrt{14-8x^2}}$$

$$t = \frac{\sqrt{2m}}{4}\arcsin\left(\frac{2\sqrt{7}}{7}x\right)$$

$$\arcsin\left(\frac{2\sqrt{7}}{7}x\right) = \frac{4t}{\sqrt{2m}}$$

$$\frac{2\sqrt{7}}{7}x = \sin\left(\frac{4t}{\sqrt{2m}}\right)$$

$$x = \frac{\sqrt{7}}{2}\sin\left(\frac{4}{\sqrt{2m}}t\right) = \frac{\sqrt{7}}{2}\sin\left(\frac{4}{\sqrt{6}}t\right)$$

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{dx}{dt}\right)^2 = \frac{3}{2}\left(\frac{\sqrt{42}}{3}\cos\left(\frac{2\sqrt{6}}{3}t\right)\right)^2$$

+1

$$= \frac{3}{2}\left(\frac{42}{9}\right)\cos^2\left(\frac{2\sqrt{6}}{3}t\right)$$

$$= 7\cos^2\left(\frac{2\sqrt{6}}{3}t\right)$$

2) a)

+1 +1

$$\sum \tau = I_b\alpha = I_b\frac{d^2\theta}{dt^2} = Mgx\sin\theta$$

(i) $\boxed{\frac{d^2\theta}{dt^2} = \frac{Mgx}{I_b}\sin\theta}$ +1

(−1) negative torque

$\sin\theta = \theta$ +1

(ii) $\frac{d^2\theta}{dt^2} \approx \frac{Mgx\theta}{I_b}$ $\theta = k\sin(\omega t)$

$$\theta = \iint \frac{Mgx\sin\omega t}{I_b}\,dt$$

−2 work

$T = 2\pi\sqrt{\frac{I_b}{Mgd}}$ physical pendulums

$$= \boxed{2\pi\sqrt{\frac{I_b}{mgx}}}$$ +1

(b) Set the bar into oscillation at a small amplitude and measure the period with a stopwatch. +1 +1 Use the equation to calculate the I_b. Minimize error by performing multiple trials. +1

(−1) how to find I_b

c) take a thin rail that's elevated off the surface of the lab table. place the bar on the rail and move it until it sits level on the rail, then measure x with a meterstick. Alternatively, have a student balance the bar on their finger.

+2

−4

3) a) $\sum F_{sys} = (M)a = \frac{M}{2}g$ +1

$a = \frac{1}{2}g$ +1

$\cancel{v_h - v_0 \cos} = \frac{1}{2}gt$

$v_h^2 = \cancel{v_0^2} + 2ad$ +1

$v_h = \sqrt{2(\frac{1}{2}g)d}$

$\boxed{v_h = \sqrt{gd}}$ +1

b)

$\lambda = \frac{M}{L}$

$m_y = \lambda y = \frac{M}{L}y$

$\boxed{F_g = \frac{M}{L}yg}$ +2

c) $W = \int F \cdot dy = \int_0^y \frac{M}{L} g y \, dy$ +1 +1

$= \frac{M}{L} g \left(\frac{1}{2}y^2\right)_0^y$

$\boxed{W = \frac{Mg}{2L}y^2}$ +1

d) v_y (-3)

e) v_r greater

b/c the force of gravity changed over time when the force on the block was constant.

(-3)

-6

d) $\cancel{F_g = \frac{M}{L}yg = \left(\frac{M}{L}g\right)a}$

$W_g = \frac{Mg}{2L}y^2$

$E_{total} = M \cdot g \cdot \frac{L}{2} = PE_g + KE$

$W_g = -\Delta PE$

$KE = E_{total} - W_g$

$= \frac{1}{2}MgL - \frac{Mg}{2L}y^2 = \frac{1}{2}m v_r^2$

$= \frac{1}{2}\left(\frac{M}{L} \cdot y\right)v_r^2$

$v_r^2\left(\frac{My}{2L}\right) = \frac{MgL}{2} - \frac{Mgy^2}{2L}$

$v_r^2 = \frac{MgL^2 - Mgy^2}{My}$

$\boxed{v_r = \sqrt{\frac{g}{y}(L^2 - y^2)}}$

+0

2009 M BR

MC B1 3 R 2

FRB 11 R 2

MC) 5, 13, 17, 24, 25

5) (c) ✓ +1

13) (e)? +1

17) (d)? e

24) $\Sigma F = T = ma$

$a = \frac{T}{M}$ (d) b

25) L conserved

(c) +1

17) e

24) b

FR 1) d) $U = 4.0x^2$

$F = \frac{dU}{dx} = 8.0x = ma$ +1 +1

$a = \frac{F}{m} = \frac{8.0x}{m} = \frac{8.0(0.60\,m)}{3.0\,kg}$

$= \boxed{1.6\,\frac{m}{s^2}}$ +1

2)a)(i) $\tau = -Mgx\sin\theta$ +1

(ii) $I_b \frac{d^2\theta}{dt^2} = -Mgx\sin\theta$

$\sin\theta \approx \theta$

$I_b \frac{d^2\theta}{dt^2} + Mgx\,\theta = 0$? +0

2)b) measure T

$T = 2\pi\sqrt{\frac{I_b}{Mgx}}$

$\frac{T}{2\pi} = \sqrt{\frac{I_b}{Mgx}}$

$I_b = \left(\frac{T}{2\pi}\right)^2 Mgx$ +1

+5

3)(d) $W = \Delta KE = \frac{1}{2}mv^2 = \frac{Mg}{2L}y^2$ +1

$\cancel{M}v^2 = \frac{\cancel{M}gy^2}{L}$ +1

$\boxed{v = \sqrt{\frac{gy^2}{L}}}$ +1

(e) v_f is the same, since both systems start with the same mechanical energy, so their final kinetic energies should be the same, which makes the speed the same since the masses are the same. +3

+6

2) a)(ii) $\frac{d^2\theta}{dt^2} + \left(\frac{Mgx}{I_b}\right)\theta = 0$

$\omega^2 = \frac{Mgx}{I_b}$ +2

$T = \frac{2\pi}{\omega}$ $T = 2\pi\sqrt{\frac{I_b}{Mgx}}$

+2

2009 EM MC

MCB $\frac{26}{35} \to \frac{33.4}{45}$

1) (e) 2) $I = \frac{V}{R}$ (a) ✓

3) V/m, N/C (e) ✓

4) (e) ✓ 5) (b) ✓ 6) $C = \frac{k\varepsilon_0 A}{d}$

$\frac{2\varepsilon_0 \pi r^2}{d}$

$\frac{4}{2} \cdot 2 = 8$ (e) ✓

7) (a) ✓ 8) (c) ✓ 9) $B = \mu_0 n I$

$\int B\,dl = \mu_0 I$ (a) ✓

10) $U = \frac{1}{2} C V^2$ (e) ✓

11) (e) ✓ 12) (c) d 13) (b) ✓

14) $V = \frac{kq}{R}$ (e) ✓

15) $W = qV = 4\mu C \cdot 20V$

= (d) e

16) ΔB out of page

II, (b) ✓

17) (d) ✓ 18) $\overleftarrow{B_0}$ (b) ✓

19) $I = \frac{V}{R} = \frac{6}{4}$ (d) e

20) $V = \frac{C}{Q}$ $C = QV$ (b) d

~~BACK~~

21) $KE = qV = \frac{1}{2}mv^2$

$V = Er$ $qV = 3E_0(r)q$

$4E_0 d = 3E_0 r q$

$r = \frac{4}{3}d$ (a) ✓

22) $U_L = \frac{1}{2} L I^2$ (e) a

23) I true, can't do work or change KE

since always ⊥

(a) ✓

24) $R = \frac{\rho L}{A}$ $\frac{4d}{\frac{1}{4}A}$ (e) ✓

25) I, III (d) ✓

26) L (−) R (+)

(d) e

27) (e) ✓ 28) (c) ✓

29) (a) d

30) $\frac{kQq}{\ldots r}$

$3\frac{kQ^2}{L} + 3\frac{kQ^2}{L}$ (e) ✓

31) (c) ✓ 32) $\mathcal{E} = IR = \frac{dB}{dt}A$

$\frac{dB}{dt} = \frac{IR}{A} = \frac{1.0\,mA \cdot 30\,\Omega}{5.0\,m^2}$

$= 0.01$ (d) ✓

33) $C = QV$ $C = \frac{k\varepsilon_0 A}{d}$

$C_x = 5C_y$ $V = \frac{C}{Q}$

$V = \frac{C}{Q}$ $V_x = 5V_y$ Q equal

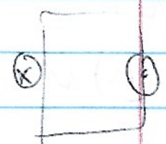
(b) d

−4

−4

34)  $F_e = mg = \frac{kQq}{h^2}$

$h^2 = \frac{kQq}{mg}$ (e) ✓

35)  $F = IlB$

$\tau = \left(IlB\frac{d}{2}\right)2 = IlBd$

(a) b

9) $\oint B\cdot dl = \mu_0 I$ $\cancel{dB = \frac{\mu_0}{4\pi}\cdot\frac{I\,d\vec{l}\times\hat{r}}{r^2}}$

$\cancel{2r \rightarrow \frac{B}{4}}$

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

$\cancel{B = \frac{\mu_0 I}{4\pi^2 r^2}}$ $\frac{\mu_0 I}{2\pi r}$ (a)

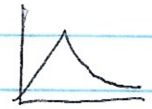
-1

2009 E/M FR

$\frac{36}{45}$ B

9:30-9:44
1:35

1) a) (i) $r < R$ → radially inwards +1



$E = \frac{dV}{dr}$

$= \frac{d}{dr}\left(\frac{Q_0}{4\pi\varepsilon_0 R}\left(-2+3\left(\frac{r^2}{R^2}\right)\right)\right)$ +1

$= \frac{d}{dr}\left(\frac{Q_0}{4\pi\varepsilon_0 R}\left(-2+\frac{3r^2}{R^2}\right)\right)$

$= 6r \cdot \frac{Q_0}{4\pi\varepsilon_0 R} \cdot \frac{1}{R^2}$

$= \boxed{\frac{3Q_0 r}{2\pi\varepsilon_0 R^3}}$ +1

(ii) $r > R$ - radially outward +1

$E = \frac{dV}{dr} = \frac{d}{dr}\left(\frac{Q_0}{4\pi\varepsilon_0 r}\right)$ $\quad r^{-1}$ or $-r^{-2}$

$|E| = \frac{Q_0}{4\pi\varepsilon_0 r^2}$

$= \boxed{\frac{Q_0}{4\pi\varepsilon_0 r^2}}$ +1

b) (i) $\oint E \cdot dA = \frac{Q_{enc}}{\varepsilon_0}$ +1

$E \cdot 4\pi r^2 = \frac{Q_{enc}}{\varepsilon_0} = \frac{3Q_0 r}{2\pi\varepsilon_0 R^3} \cdot 4\pi r^2$ +1

$Q_{enc} = \boxed{6 Q_0 \frac{r^3}{R^3}}$ (-1) negative!

(ii) $Q_{enc} = \boxed{Q_0}$ +1

(-1) explicitly state Gauss' law

-2

c) at $r=R$, the electric field is continuous. Thus,

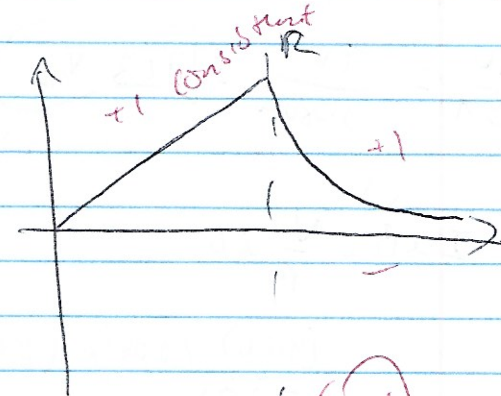
$\frac{Q_0}{4\pi\varepsilon_0 r^2} = \frac{3Q_0 r}{2\pi\varepsilon_0 R^3}$

$\frac{3r}{2R^3} = \frac{1}{2\pi r^2}$

$\frac{4r^3}{R^3}$

at $r=R$, the function for enclosed charge is $6Q_0\frac{r^3}{R^3}$, which should equal Q_0. however, $6Q_0 \neq Q_0$, so there is no charge. (-2)

d)



(-1)

$F = qE$

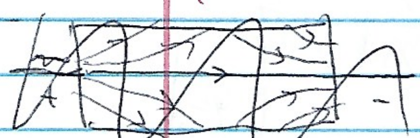
-3

2) a) $R = \rho \frac{l}{A} = \frac{(4.5\times10^{-4}\,\Omega\cdot m)(0.080\,m)}{(5.0\times10^{-6}\,m^2)}$

$= 7.2\,\Omega$ +1

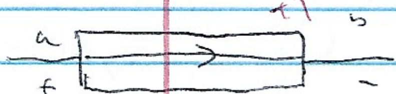
$P = \frac{V^2}{R} = \frac{(9.0V)^2}{7.2\,\Omega} = \boxed{11.3\,W}$ +1

b) +1



~~electric field~~

+1



electric field points from (+) to (−) polarity (−2) potential or current

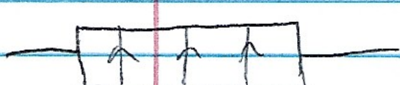
c) $E = \frac{\Delta V}{\Delta x} = \frac{9V}{0.080m} = \boxed{113\ V/m}$ +1 +1

d) $F_m = I l B = \frac{V}{R} l B$ +1

$= \frac{(9.0V)}{(7.2\Omega)}(0.080m)(0.25T)$

$= \boxed{0.025\,N}$ +1

e)

 +1

f) $\Sigma F = ma = 0$

$F_e - F_m = 0$ +1

$F_e = F_m$

$qE = qvB$ +1

$E = vB$

$= (3.5\times10^{-3}\,m/s)(0.25T)$

$= \boxed{8.75\times10^{-4}\,V/m}$ +1

+1 Units

−2

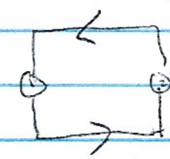
3) a) $\mathcal{E} = \frac{d\Phi}{dt} = L^2\frac{dB}{dt}$ +1

$= L^2 \frac{d}{dt}(at + b)$ +1

$= \boxed{aL^2}$ +1 +1

b) (i) $I = \frac{\mathcal{E}}{R_{eq}} = \boxed{\frac{aL^2}{2R_0}}$ +1 +1

(ii)

 +1

I_{ind}

c) $P = I^2 R = \frac{a^2L^4}{4R_0^2}\cdot R_0$ +1

$= \boxed{\frac{a^2L^4}{4R_0}}$ +1

d) Brighter +1

If the 3rd bulb is added, the overall eq. resistance is lower +1 while the emf remains the same. +1 This means the current thru the 1st bulb increasing, increasing the power output, which makes it brighter. +1

e) dimmer (−2)

the extra wire makes it become two connected loops, where the induced emf is reduced, making the power less and the bulb dimmer.

−2

2009 E/M BR

MC 12, 15, 19, 20, 22, 26, 29, 33, 35

12) (d) ✓ 15) $\frac{W}{t} = \frac{8e^{-5}\,J}{5\,s}$ = (e) ✓

19) $I = \frac{V}{R} = \frac{6}{4}$ = (d) e

20) (d)? ✓ 22) (d)? a

26) (d) e 29) (a) d

33) Q = , V splits

$\tau = QV$ $V = \frac{C}{Q}$ (b) d

35) $F = IlB$

$\tau = IdB\frac{d}{2}$

$\Sigma\tau = Id^2B$ (b) ✓ +4

19) e 22) a 26) e 29) d 33) d

+5

FR

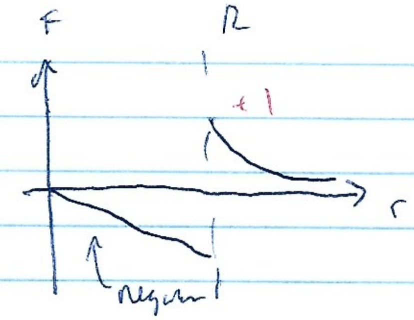
1) b)(i) $Q_{enc} = -6Q_0\frac{r^3}{R^3}$ +1

(ii) $\oint E\,dA = \frac{Q_{enc}}{\varepsilon_0}$ +1

$E \cdot 4\pi r^2 = \frac{Q_{enc}}{\varepsilon_0}$

c) There is charge. Since the E field needs to be continuous, and $-6Q_0\frac{r^3}{R^3} + Q_0$, the charge at the surface needs to cancel this out, so $Q_s = Q_0 + 6Q_0 = 7Q_0$ +2

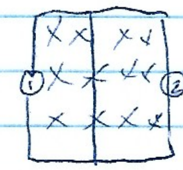
d)



2) b) the conventional current is from a to b, so the electric field is in the same direction of conv. current.

+2

3) e) Brightness remains the same.



why??

+2

3)e) brightness same.

Area cut in 1/2; 1/2 ε, but R is also $\frac{1}{2}R_0$, so P is the same.

+2